Robotic Milking Systems: Are They the Way of the Future?

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Take Home Messages

- Robotic milking systems are the “way of the future” because these systems decrease labour requirements on all sizes of farms. Labour costs will go up, availability of farm labour will decline, and the technology will become both cheaper and better over time.
- For freestall dairy herds in the 60 to 240 cow range in need of new milking equipment robotic milking is also the “way of the present” because it is economically competitive with parlor milking and it effectively addresses many of the labour issues that are unique to this herd size.
- Robotic milking permits the family dairy farm to grow into the 120 to 180 cow range without hiring non family labour. In this way it is an excellent fit on most Canadian dairy farms.
- In addition to labour saving farmers choose robots to gain a more flexible lifestyle, to be innovative, to improve cow comfort and because it is economically advantageous to do so.
- With good management, expect production 3 to 5% higher than 2 x parlor milking, and 6 to 9% lower than 3x.
- Free cow traffic, favoured by the majority of Canadian owners to date, is preferred if cow comfort and productivity are the priority while forced cow traffic with pre-selection reduces fetching significantly and should be selected if labour saving is the priority.
- Rations balanced to focus on digestible fibre instead of grain and starch, hard dust free pellets in the robotic feeder, and frequent feeding at the bunk improve cow traffic in robot barns.
- Although any freestall or loafing barn suitable for parlor milking can work with robotic milking, housing factors described can increase ease of cow handling and improve cow traffic. Automated manure removal, highly visible robot placement, space in front of the robot, and layouts that allow

for cow handling at a central point all improve cow traffic and decrease operator labour.

▪ Introduction

Commercial robotic milking was first introduced to North America on an Ontario dairy farm in 1999, and while not every installation in the last 9 years has been successful, there are about 350 single box robotic milking systems operating on an estimated 180 farms throughout North America today. Many of these farms are achieving impressive results in labour saving and in cow comfort and productivity. A year ago, close to 90% of robotic farms were in Ontario and Quebec. As new dealers are given access to the technology, there have been numerous new installations in Western Canada and some in the Maritimes in the past year, so that today nearly 30% of robot farms are located in these regions. This is one technology where US adoption is slower than in Canada. Although one of the largest North American robotic milking herds, Mason Dixon farms, with 10 milking stalls is located in Pennsylvania, only about 12 % of North American robotic farms are in the USA. But in the US market, recent indications that low cost Hispanic labour may become less available has prompted a surge of interest.

Two manufacturers, Lely and DeLaval are responsible for approximately two thirds and one third of the North American installations respectively, and are also the clear market leaders world wide. While the level of experience in Ontario is barely sufficient for formal research, 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. Since 1999, the Ontario Ministry of Agriculture and Food has conducted a number of field trials, surveys and demonstration projects, and has also hosted an international conference on robotic milking in 2002. (Lang 2002). The Ministry has a strong interest in dairy robotics and precision management because there is an expectation that such technology may counteract some of the pressures for economies of scale driven by more traditional mechanization by increasing the labour efficiency of smaller, family run dairies.

▪ Early Adoption 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 70 cows, often housed in tie stalls. Many producers are either working in their first freestall barn or planning to build for 100 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 underutilized or spending too many hours milking with low cost but inefficient equipment. An economic analysis using costs typical for the Midwestern US (Reinemann 2000) estimated the labor and equipment cost for parlor milking 70 to 140 cows at US $4.88 to $8.29 per Hectoliter, three times as much as for a 400 cow herd. The same study estimated milking costs with robots at $2.95 to $4.54 per hectoliter. Robotic milking has the potential to permit a "family farm" to expand to 100 to 150 cows without hiring outside labor. Dairy farm labour surveys of Ontario producers in 2004 and 2007 have demonstrated that labour costs are increasing and with unemployement in Canada at a 33 year low, and with declining costs for robotic milking technology this and other precision dairy management technologies may make a moderate sized robotic milking farm with 120 to 240 cows 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.

Two field surveys, one in 2002 (Rodenburg and Wheeler 2002) and a second in 2006 (Rodenburg and House 2007) involved interviews with robot owners concerning their goals when purchasing robotic milking and their experiences with the technology. Among 43 herds interviewed in 2006 the primary reason for choosing robotic milking was the potential for saving labour, mentioned by 27 owners and defined by 18 as specifically "avoiding or reducing the need for non-family help". Other reasons and the frequency they were mentioned included: flexibility and lifestyle (19), a desire to be innovative (9), lower building costs or lower total investment than a parlor (8), increased milking frequency (7), greater cow comfort (5) and minimizing physical work, in some cases to relieve operator health concerns (4). These reasons are similar to the 2002 survey of the first 15 herds. With an average herd size of 94 cows, these robot owners felt that hired labor is difficult to schedule, requires multi-skilled employees and would demand new skills in people management and employee training. Robotic milking allows them to milk more cows while continuing to work with family labor only. It is noteworthy that "more frequent milking" is cited less often as a benefit of robotic milking today, perhaps because both experience and research (DeKoning 2004) suggest the production and udder health benefits of more frequent milking are much smaller when it is irregular and voluntary as illustrated in Fig. 1, than with 3x parlor milking. Table 1 illustrates how variation in milking intervals impacts on milk production outcomes. The average number of milkings across these 4 cows is 2.65 a value one might assume approaches 65% of the benefit of 3x milking. But due to variation between cows the actual response is far less than the 12% production increase expected from 3x. Field experience is showing that it takes an average of 2.3 milkings per cow per day to match 2x production from 12 hour intervals. Most herds achieve the 2.6 to 2.7 milkings illustrated in Table 1 and experience a production increase of 3 to 5 %, but 3x herds switching to robotic milking need to be prepared for a drop in production of 6 to 9%.

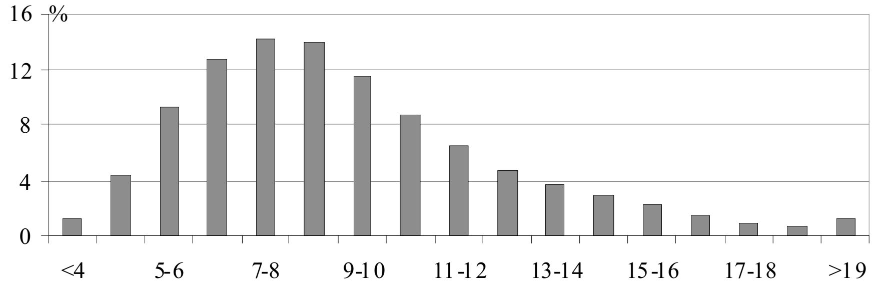

Figure 1: Typical distribution of milking intervals (hours) in a robotic milking herd

Table 1: Production parameters for a typical mix of robotic milking cows.

Cow	Milking Intervals (hours)	Milkings per day	Production vs. 2x
A	5-6-6-7	4.0	+18%
B	12-7-5	3.0	+6%
C	15-9	2.0	-2%
D	15-15	1.6	-6%
Average	9.3	2.65	+4%

Other benefits of more frequent milking such as lower SCC, lower incidence of clinical mastitis and reduced stress on udders will also be realized but to a lesser extent than in 3x parlor milking.

Lower building costs and lower overall investment or operating costs were mentioned by 8 and 4 herd owners in the surveys. They felt that when the cost of building space was included, capital cost of robots at their 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.

■ Economics of Robotic Milking

In the figures below, single box robotic milking systems with a capacity of 60 cows per box are compared to double 8 and double 12 rapid exit parallel parlors and to a low cost 10 stalls per side swing parlor. Labor costs are calculated at $16.03 per hour, the average per hour cost of an “arm’s length” milker in a 2007 Ontario dairy farm labour survey (Rodenburg 2008). The amount of labor required for 2X parlor milking is estimated to be the throughput from the same survey, (81 and 56 cows per hour respectively) plus set up and clean up time of 50 minutes for the double 12 and 40 minutes for the double 8. The robot data assumes 1 hour of labor per box per day made up of clean up, filter changes, and managing the cows that don’t attend voluntarily. The cost of ownership is calculated as repayment of the capital investment at 6% per year over 15 years, or $101 per year for each $1,000 invested. Costs of the equipment are shown in the inset and are based on prices quoted by Ontario suppliers. One of the differences with robotic milking is that these systems take much less space in the barn. The construction cost of building space for each milking system is included at an estimated building cost of $30 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 less palatable.

The Parlors Compared:

2 x 12 - a double 12 rapid exit parallel with full automation, cow I.D., yield, conductivity and activity monitoring, valued at $300,000, in a building space of 43 x 80 ft., for the parlor and holding area. Estimated throughput of 81 cows per man hour and 50 minutes per milking for wash up and set up.

2 x 8 - the same parlor as the double 12, with fewer stalls, valued at $230,000 in a building 43 x 60 ft. estimated throughput of 56 cows per man hour and 40 minutes per milking for wash up and set up.

Robotic milking – One single box robot per 60 cows, valued at $250,000 for one, $430,000 for two, $760,000 for four, and $1,400,000 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 $40,000. Building space is renovated old barn space valued at $15 per sq. ft. with no holding area (vs. $30 for new construction above). Estimated throughput of 50 cows per hour. 40 minutes clean up and set up.

As illustrated in Fig. 2 robotic milking saves labor regardless of herd size. Since set up and clean up for small herds with big parlors is proportionally greater than in large herds, the saving is bigger in small herds. Where labor has a cost, herds of all sizes can justify investing more in robotic milking than in parlors and if labor costs increase the economics of robotic milking will get better.

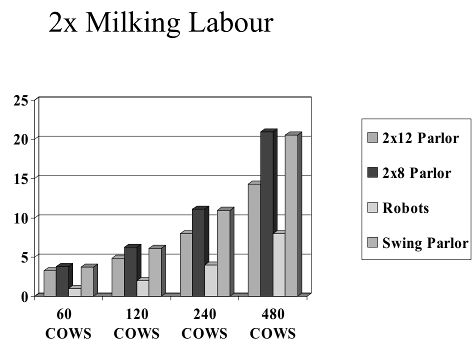

Figure 2: Estimated hours of set up, milking and clean up per day in robot systems and three parlor types, for herds of 60, 120, 240, or 480 cows.

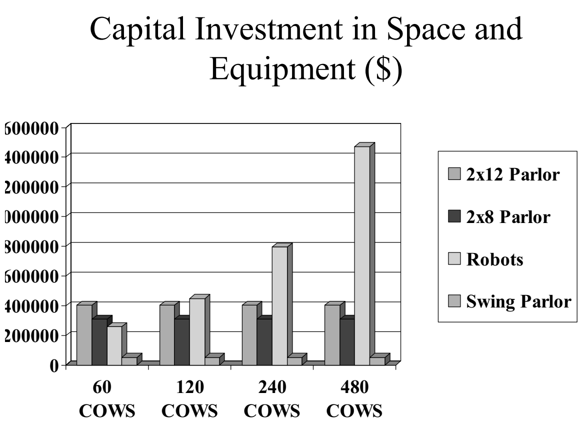

Figure 3: Estimated capital investment in parlours and robotic milking systems at various herd sizes.

The factor that makes herd size so important in the economics of robots compared to parlors is illustrated in Fig. 3. For small herds of 60 to 120 cows, milking parlors that make good use of labor, such as the 2 x12 parallel, cost as much as robot technology, especially when the added building space for a big parlor and holding area is included. Capital investment in robots on small farms will be no greater than in milking parlors. On large farms the same parlor can accommodate more cows with a greater number of hours of use, but the number of robots needed increases with each 60 additional cows.

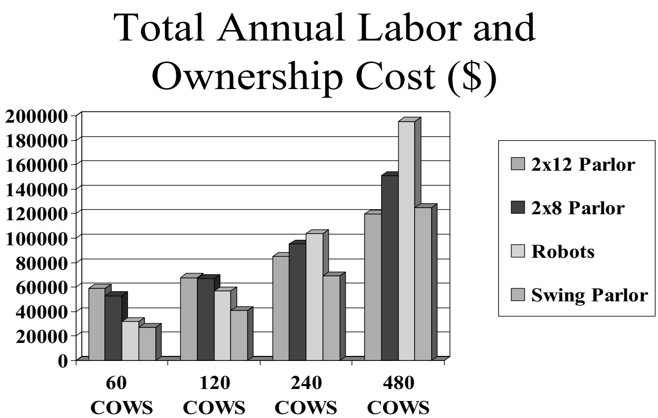

Figure 4: Estimated annual cost of labour and ownership of milking parlours and robotic systems

In Fig. 4, 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, involving more than 4 robotic milking stalls, do 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 cows and will require additional management to be applied by other means.

It should also be kept in mind that the economic evaluation above is a snap shot using current prices for equipment and values for labour. In assessing the real cost of these options the anticipated change in labour costs over the life of the technology should be included in the calculation. According to

Employment Canada, average wages in Alberta today are $23 per hour. Fig. 5 includes the same data as Fig 4 but with labour at $23 instead of $16. Note that robotic milking now looks more promising at larger herd sizes as well. Using these assumptions robotic milking would be preferred at the 480 cow herd size when labour costs exceed $28 per hour. It is not inconceivable that this may happen over the 15 to 20 year lifespan of this equipment.

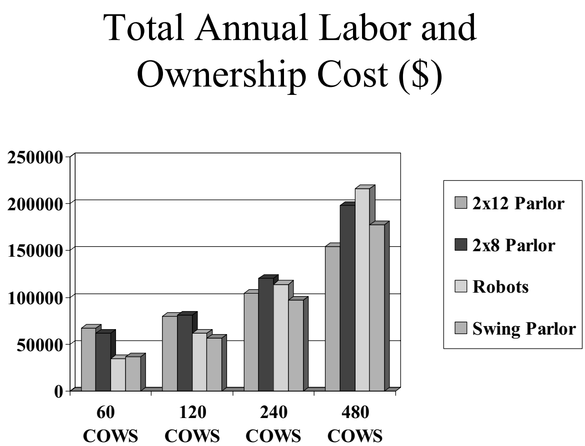

Figure 5: Estimated annual cost of labour and ownership of milking parlors and robotic systems with labour costs at $23 per hour.

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 $7,000 to $9,000 per stall per year for maintenance contracts. Though there is little information available on what parlor owners spend, I suspect it is 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 comparison made here compares robotic systems which typically result in an average milking frequency of 2.4 to 2.7 times per day to 2X parlor milking. If the labour of a third milking were included, parlor milking costs would be higher, making robots more attractive. In terms of milk production, experience with robots in Europe and in Canada indicates production from robotic milking is probably 4 to 6% higher than from 2X milking but lower than 3X.

Another factor which has seen varied interpretations is depreciation. 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. 6 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. 7 illustrates 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.

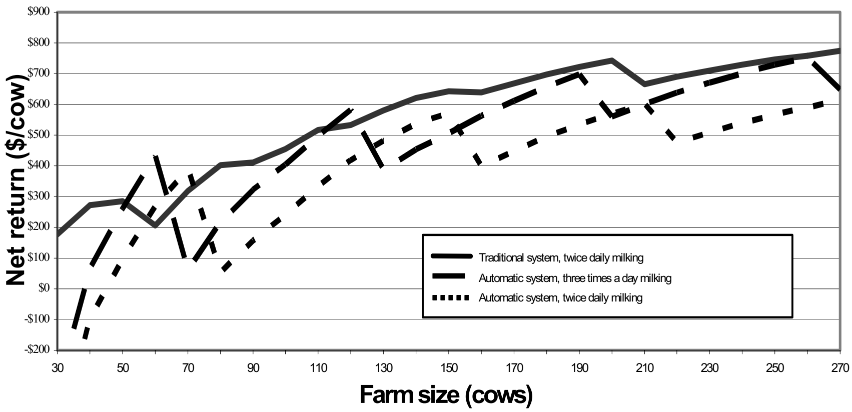

Figure 6. Net return per cow with average milk yields and robotic or parlor milking at various herd sizes (Rotz 2002).

In more than 9 years of robotic milking in Ontario, improvements have involved software and chips that have often been provided free of charge by the manufacturers. Although there have also been at least three model changes, robots sold in 1999 and 2000 are still supported and definitely not worn out. In the broader sense, the introduction of new and different milking technology results in a greater likelihood that today's purchase will be obsolete sooner than expected. But if new and improved robots speed depreciation of present models they will make today's parlors equally dated as well.

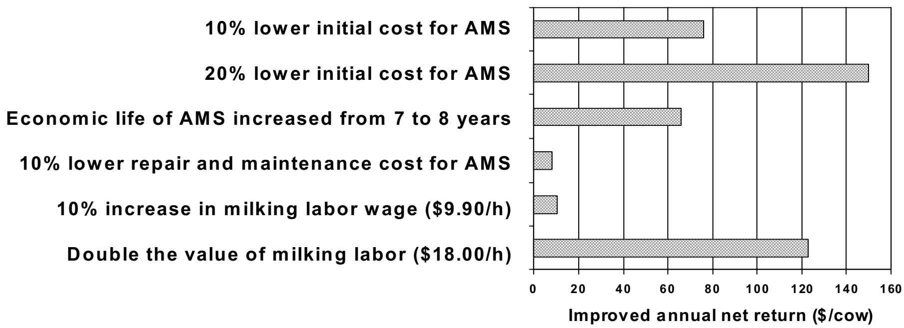

Figure 7. Variable input changes and net return per cow using robotic milking (Rotz 2002).

Robotic milking is clearly competitive now for farms with up to 240 cows. Herds in this size range investing in new milking equipment should consider robotic milking, especially if labour 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.

To summarize, the plusses of robotic milking are substantial. They include much lower labour requirements, greater flexibility in when the work is done; therefore a better lifestyle, competitive total milking costs at the herd size common in Ontario, and a chance to gain experience with a new and rapidly developing technology. Cows also enjoy the predictability of their environment and are clearly more relaxed and less stressed in robotic barns. But the technology does require some change in management and offers new challenges in some aspects of management, nutrition, health care, and ideal barn layouts.

■ Fetching Cows and Free Versus Forced Cow Traffic

In 2001, Canadian owners reported 10 to 15% of the herd did not attend for milking voluntarily and in a subsequent formal study (Rodenburg 2002), 19.2 $\pm$ 12.5 % of cows were "fetched" by the operator. Owners report the effort required to fetch cows is minimal and normally involves identifying them from milking interval data in the computer, followed by a process of chasing these cows from the freestalls and heading them in the right direction so that they end up in the holding area. Fetching cows is usually combined with cleaning freestalls. Barn layouts and gating that define a route for stall cleaning and fetching make the actual additional time required for fetching very small.

Table 2. Reported reasons for fetching cows for milking in 43 survey herds

Reason	% of fetched cows	% of all cows
Fresh or inexperienced cow (less than 14 days experience)	11.0	1.6 ± 1.8
Milked manually due to teat placement	4.5	0.7 ± 1.2
Milked manually for other reasons	2.3	0.3 ± 1.0
Cow is visibly lame	19.0	2.8 ± 9.0
Cow has clinical mastitis or teat injury	5.7	0.8 ± 1.7
No identifiable reason for no-attendance – "lazy cow"	57.6	8.5 ± 9.9
Total fetched cows	100	14.6 ± 10.3

Nevertheless, the need to fetch cows remains one of the main concerns owners have about robotic milking systems. In the 2006 survey, producers reported fetching 14.6 ± 10.3 % of cows either once or twice daily. Variation in number of cows fetched was very large. The five best herds averaged 2.5% of cows, while the 5 worst averaged 41.6%. The differences between herds that fetch 2% and those that fetch 40% may involve lameness or other cow related factors but there is little doubt that the biggest influence is usually the manager him or herself. Experience is proving that good robotic milking managers consistently ensure cows are adequately trained on first exposure, but they also have the ability to not "over manage". Many robot owners report that traffic increases on days when they are not in the barn, and that fetching, except as a last resort, is counter productive and teaches cows bad habits. Good robotic milking management can best be described as keen observation and awareness with minimal but strategic intervention. The reasons for fetching cows are listed in table 2. Fetched cows include lame cows, cows with mastitis, and injured animals. When cows first appear on the fetch list, this can assist with early diagnoses of health problems, especially in free traffic herds. As shown, training new heifers and cows is also an ongoing need that must be addressed in barn design.

Herds were defined as having "free cow traffic if cows could move freely between the freestalls and the manger area at one or more points in the barn, or as "forced cow traffic" if cows had to pass through the milking stall or a selection gate in one direction and a one way gate in the other, between these two areas of the barn. Cows fetched in the 35 herds with some form of free cow traffic was 16.2 ± 10.8% and this was much higher than the 8.52 ± 5.9 % in the 8 forced cow traffic herds. The merits of free and forced traffic have been reviewed (Rodenburg 2004). Both free cow traffic and forced traffic with pre-selection appear to give reasonably satisfactory results. Where high feed intake and productivity per cow is desired, free cow traffic should be the preferred cow routing system despite the fact this results in the need to fetch a larger number of cows. In circumstances where minimizing the labour of fetching cows is highly valued, the continual use of forced cow traffic with pre-selection gates, preferably at remote crossing points, is recommended. Despite greater fetching labor, the majority of robot owners in this survey chose free cow traffic. The main reasons given for this were improved cow welfare and the expectation of higher production. Practical designs for free cow traffic barns should encourage the maximum number of cows to attend voluntarily, while making fetching and training convenient when it is required.

Consideration should be given to the fact that herd dynamics changes over time. For example, field data (Rodenburg 2002) suggests that with experience, the number of fetched cows is likely to decrease and the frequency of voluntary milking increases. As animals selected for their willingness to attend voluntarily begin to populate the herds over time, the labor of fetching decreases. This may make larger groups of cows accessing multiple robots more practical. Forced traffic barns will increasingly be populated by cows eligible to pass through selection gates at will. Since many of these barns are currently built with 4 rows of freestalls accessing one manger area, manger space is restricted to 1 foot per cow. This works today because only half the cows are eligible to pass through selection gates, but in the future, limited manger space will result in crowding and competition at the manger when fresh feed is delivered to the barn. While forced cow traffic with pre-selection may be a preferred management system to minimize labour today, barns should be designed with a reasonable amount of manger space for all cows.

▪ Feeding Management, TMR Rations and Robotic Milking

European studies with robotic milking generally report higher voluntary attendance (Harms 2002, Munksgaard 2002) than the Canadian experience. The use of total mixed rations (TMR) and high grain diets is a possible reason for lower voluntary attendance (Rodenburg 2001).

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 3 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.

Table 3. Voluntary attendance in a case study herd switching from low to high quality pelleted concentrate.

	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

The aspect of the feeding program that shows the strongest association with voluntary attendance was the level of energy and grain in the TMR. 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 (Van Lenteren, 2002). It is well known that high grain diets are associated with laminitis (Manson 1988). 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 that influence rumen acidosis and laminitis.

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.

▪ Housing Facilities and Robotic Milking

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. 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 (Wolters 2000). 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. 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 cows have milking intervals up to 15 hours, sorting must begin more than 15 hours before the cows are being handled and access to feed, water, a resting area and milking must be provided. Locate the milking stall to minimize turns and steps, especially in the immediate entry and exit areas.

Since there are still many unanswered questions about ideal design for robotic milking flexibility in how the barn can be used is an important attribute for robotic milking barns. Figure 8 is presented as an example of an expandable facility for 120 cows incorporating the flexibility to work with a number of different grouping strategies. This plan was developed using the experiences of advisors working with robotic milking herds in Europe as well as North America. The contributions of Dairylogix (www.dairylogix.com) and Vetvice (www.vetvice.nl) robotic milking specialists are specifically acknowledged here.

The plan includes 120 freestalls in 6 rows with drive through feed alleys on the outsides of the barn. This layout allows the cows in the main freestall area to be handled as one group with no gates or as two groups with gates at both ends of the center double row of stalls. Both robots face the same way, a major advantage since a significant percentage of cows trained to turn one way upon entry will not make use of a milking stall oriented the opposite way. Ontario field experience suggests a large open area in front of the milking stalls enhances cow movement in the barn. This open area also makes it easier for cows to negotiate an exit route to either resting or feeding areas regardless of the orientation of the milking stall.

With 4 foot wide freestalls, a 12 foot crossover at the end of the barn and a 20 foot open area in front of the milking stalls, the plan provides 2 feet of manger space per cow for 56 cows per side along the drive through feed alleys at A. Since ideal handling methods for these barns are poorly defined and since headlocks may well play a role in future management schemes, it is tempting to widen the crossover an additional 4 to 8 ft to provide space for one headlock per freestall. Feeding from two drive through alleys on the outside of the barn is more work than a center drive through but makes it possible to handle the herd as one group and makes cow movement between groups and work among the cows more convenient. The outside drive alleys also keep rain and sun out of the cow area. Narrow cross alleys (B) at the ends of the barn permit workers and small equipment to travel around the perimeter of the cow area to push up feed. If alley scrapers are used, manure drops at the end farthest from the milking stalls and a place to "park" scrapers out of the traffic area can be incorporated under this alley. If slatted floors are used, the 24 foot post spacing is compatible with under the barn manure storage.

Gates at C and D can be used to divide the herd into two 60 cow groups. To fetch cows into holding area E, close gates C and F and clean the freestalls in a counter clockwise direction, keeping fetched cows ahead of you. Close gate D when you come to it and complete cleaning stalls in this half of the barn. Repeat this in the other half of the barn, by closing gate G and opening D as you pass it. Once the fetched cows are in the holding area, all gates can be opened. Since the holding areas E and H are only used to house fetched cows, access to the milking boxes for other cows via the "split entry" is unrestricted. High ranking cows from the main milking groups are kept out of the holding areas reducing stress for the usually more timid fetched cows. Note there is a gate in the holding area behind each milking stall which can be used to direct and "squeeze" an inexperienced cow into the milking stall.

A bedding pack for fresh and lame cows at I has access to the milking stall beside it through holding area F. With a post milking sort gate, these cows are returned to the pack. Far off dry cows housed in the freestalls in the center area J have manger access beside the cows in the bedding pack. A movable gate in the interior alley at K separates far off dry cows from close up cows in area L, which eat at the manger behind the other milking stall. The close up cows have free access to the milking stall beside them for lead feeding and training purposes, and a post milking selection gate will return them to their pen area. At calving, close up cows can be easily moved into one of three bedded pens in area M.

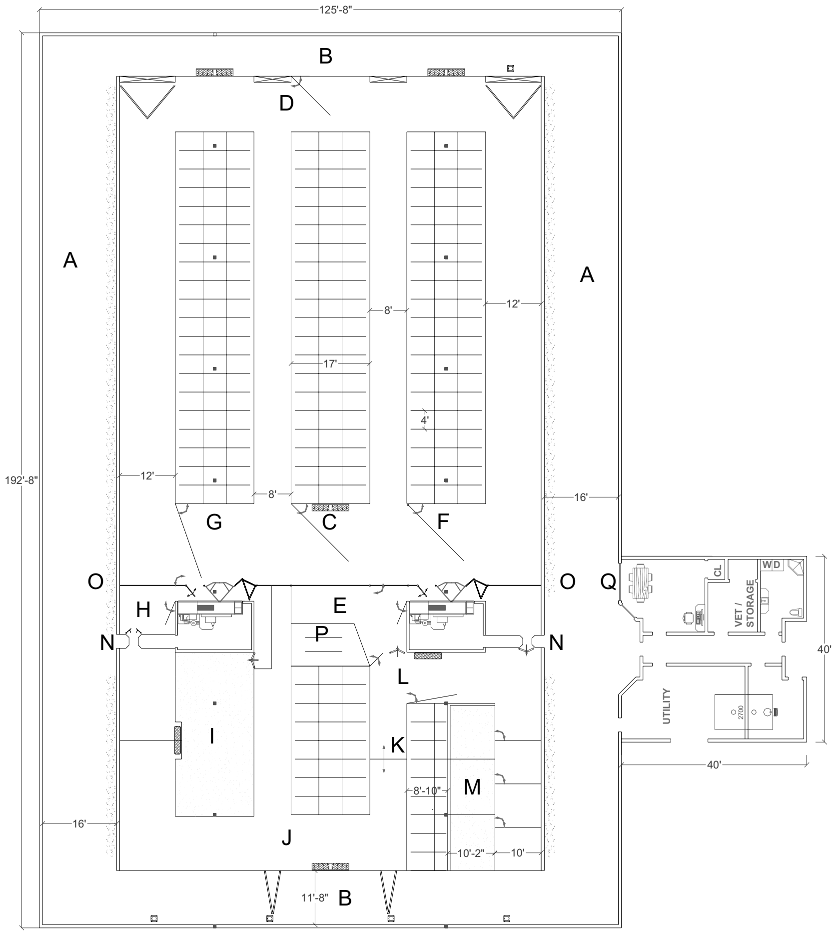

Figure 8 Flexible Robotic Milking Barn for 2 milking stalls, and milking and dry cows. Both milking stalls exit in the same direction.

Clean access to the milking stalls is via a bridge with a 36 inch gap at N .To segregate and restrain a cow for individual handling, she can be fetched into the holding area, and post selected through the milking stall. If the bridge at L is gated, the segregated cow can be restrained in a headlock at O, treated and released back to the main barn. Handling and especially hoof trimming could also be incorporated at P, a spot that is readily accessible to all cow groups. Cows can be easily moved from group to group through a lactation cycle, and all feeding is along the two mangers on the sides of the barn. The bedding pack and calving pens are accessible from the end of the barn for clean out. The office is located to give a good view of both the area in front of the robots and the calving area. With a sliding window at Q and a turntable for the computer screen and keyboard, clean and dirty access to the computer can be provided. Adding a sort gate in the return lane to the bedding pack, and directing cows across to freestall area L could allow use of area L as a separation pen from both robots.

The principles demonstrated in these plans can also be applied to larger herds. To double the herd size, three options are suggested. It is possible to mirror image the barn on the end used for dry cows and create a barn with 4 robot rooms located at the corners of a central handling area. Moving far off dry cows to another facility would keep the central handling facility more compact. This option leaves all the grouping possibilities intact, but it does require clean out of the bedded areas from the side of the barn. Back to back milking stalls with no separation and handling facilities, combined with another barn with at least one milking stall set up for training and handling is a second option. If the choice is made to work with a minimum group size of two milking stalls and 120 cow groups, Fig 9 provides a configuration combining two same sided milking stalls. In Fig. 10 this configuration is used to double the length of each end of the barn, and add a single robot room with two back to back milking stalls.

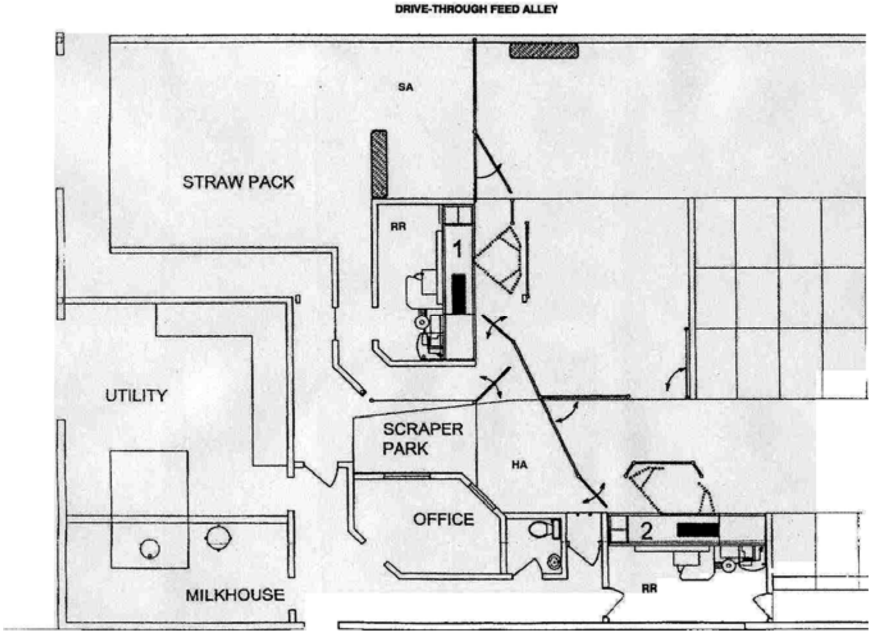

Figure 9 An ideal layout for two milking stalls in a single group of cows.

Fetched cows collected in holding area HA are milked in milking stall 1. Separation cows milked in stall 1 are sorted into Separation area SA, and can access the holding area and milking stall via a lane behind the robot room. Cows separated in milking stall 2 sort into the holding area, are subsequently refused in milking stall 1 and directed into SA.

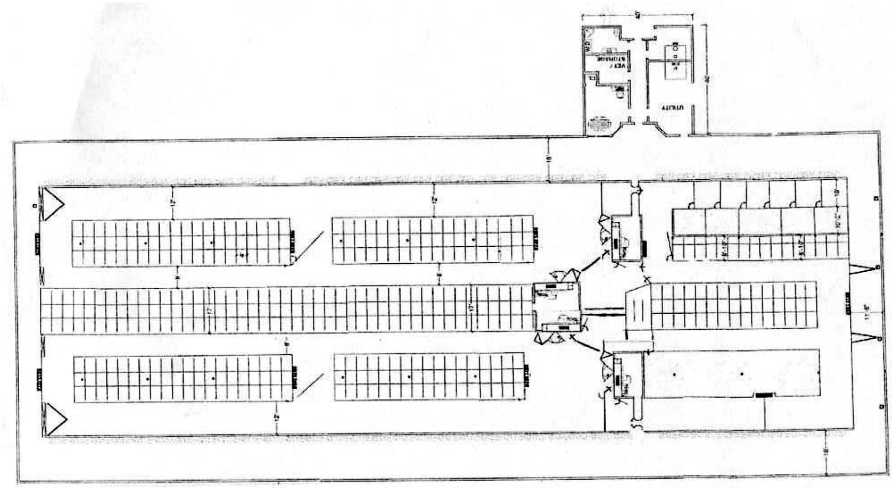

Figure 10 An expansion of the barn in Fig. 8 to include 2 groups of cows each accessing two milking stalls

A forced traffic version of the layout in Fig. 8 would also be possible by eliminating the outside rows of freestalls on each side and lengthening the barn to accommodate 120 stalls.

▪ Summary

Robotic milking offers the opportunity for dairy herds under 250 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 99% of udders. Since parlor technology is expensive and underutilized 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, adjusting management styles and barn layouts to heterogeneous groups of 60 cows, and adapting the technology to larger herds.

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