Capacity studies on DeLaval's sort gate DSG10

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Institutionen för husdjurens utfodring och vård	**Examensarbete 281**
	30hp E-nivå
Swedish University of Agricultural Sciences	**Uppsala 2009**
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Preface

This Master Thesis in Animal Science was initiated and carried out for Björn Forss Jannes at DeLaval International AB. The overall aim of the thesis was to evaluate the capacity of DeLaval´s sort gate DSG10 and the existing formula for calculating the sort gate capacity. The Thesis was conducted at the Department of Animal Nutrition and Management at the Swedish University of Agricultural Science. Margareta Emanuelson and Gunnar Pettersson acted as supervisors from the Department. The practical part of the study was performed on three farms in USA and one in Sweden. All travel arrangements in relation to the farm studies was taken care of by DeLaval.

Uppsala in April 2009

Johanna Karlsson

Abstract

In the dairy production it is necessary to be able to sort cows. Dairy cows are sorted for many different reasons i.e. regrouping into production strings or for treatments i.e. inseminations, pregnancy and health checks, vaccinations or hoof trimmings. One labour saving way of conducting sorting is by using an automatic sort gate. DeLaval's sort gate DSG10 is a multiple sort gate that can sort cows in up to five different directions when the dairy cows are returning to the barn from the milking parlour. The sort gate capacity is calculated during the planning process with a theoretical formula based on parlour capacity (cows/hour), percentage of cows to be sorted, distances within the sort gate system, walking speed and time for one cow to pass the DSG10. In this study the two constants in the formula, walking speed and time for one cow to pass the DSG10, were evaluated through time studies conducted on four dairy farms in Sweden and the United States of America.

The time studies were conducted by clocking cows when passing through the DSG10 sort gate. To be able to compare the conditions on the different farms these were documented concerning layout in the sorting area, animal environment and management strategies on the farms with photographs, measurements, sketches and interviews with farm staff.

From the collected data it was found that walking speed of cows is about 1 m/s. It takes in median 6 seconds for unsorted cows to pass the sort gate and 17 seconds for sorted cows to pass the DSG10. It was found that lame cows walked slower than other cows. Therefore a percentage was added as an extra parameter to the formula to allow for lame cows. The time for all unsorted cows to pass the sort gate was lowered to 5 seconds and an extra time of 4 seconds for every lame cow was put in. However, when evaluating the different formulas it was concluded that lame cows can still be a tricky figure to use, since it can be difficult to forecast the herds claw health.

On farms with parlour capacities under approximately 350-400 cows per hour it is sufficient with one DSG10, and on farms milking up to about 800-850 cows per hour it would theoretically be enough with two DSG10's working at a time. These approximations will be lowered if distances within the sort gate system, percentage of cows that is to be sorted and percentage of lame cows are high.

Sammanfattning

Inom mjölkproduktionen är det viktigt att kunna sortera kor. Mjölkkor sorteras på grund av gruppbyte eller behandlingar som insemination, dräktighets- och hälsoundersökning, vaccination eller klövverkning. Automatiska sorteringsgrindar är ett arbetsbesparande sätt att sortera mjölkkor på. DeLavals sorteringsgrind DSG10 sorterar kor i upp till fem olika riktningar i anslutning till att korna återvänder till ligghallarna efter mjölkning. Sorteringsgrindens kapacitet beräknas under planeringsprocessen med en teoretisk formel som baseras på mjölkningskapacitet (kor/timme), andel kor som ska sorteras, avstånd i sorteringssystemet, gånghastighet och tid det tar för en ko att passera DSG10. I den här studien uppskattas formelns konstanter (gånghastighet och tid det tar för en ko att passera DSG10) genom tidsstudier utförda på fyra olika gårdar i Sverige och USA.

Tidsstudierna utfördes genom att ta tid på kor när de passerade igenom sorteringsgrinden DSG10. För att kunna jämföra förutsättningarna på de olika gårdarna dokumenterades dessa med avseende på planlösning över sorteringsområdet, djurmiljö och skötselmetoder på gårdarna med hjälp av fotografier, mätningar, skisser samt intervjuer med personal.

Av studien framkom att kornas gånghastighet är ungefär 1 m/s, mediantiden för osorterade kor att passera sorteringsgrinden är 6 sekunder och uppskattningsvis tar det 17 sekunder för sorterade kor att passera genom DSG10. Kor med hälta går långsammare än icke halta kor och därför lades andel halta kor i besättningen till i formeln. Tiden det tar att passera sorteringsgrinden för osorterade kor sattes till 5 sekunder, halta kor fick utöver det ett tillslag på 4 sekunder. Slutsatsen är dock att det ändå kan vara svårt att uppskatta andel halta kor i ett planeringsskede, därför är denna parameter troligen inte så användbar, trots att jag i denna studie har visat att den påverkar resultatet.

På gårdar med mjölkningskapacitet under ca 350-400 kor per timme är det tillräckligt med en DSG10 och på gårdar med mjölkningskapacitet lägre än ungefär 800-850 kor per timme borde det räcka att använda två sorteringsgrindar samtidigt. Dessa uppskattningar kommer att sjunka om avstånden inom sorteringssystemet, andel kor som ska sorteras och andel kor med hälta är höga.

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Introduction

Sorting of cows is a frequently recurring event on dairy farms. One labour saving way of conducting sorting is by using an automatic sort gate. DeLaval sort gate 10 (DSG10) is the name of DeLaval's multiple sort gate that sort cows into three and up to five different lanes. Dairy cows pass through the sort gate when returning to the barn from the milking parlour and can then be sorted for different treatments or regrouping. The sort gate identifies individual cows based on their transponders (identification tags) and sorts the cows one by one to the predefined lane and pen. Cows that are not to be sorted walk straight through the sort gate.

The capacity of the sort gate need to be calculated during the planning process. This is of critical importance especially on very large dairy farms with more than 1000 milking cows where the capacity of the sorting system might be a bottleneck in the cow flow if not the correct number of sort gates is used. The sort gate capacity is calculated with a theoretical model. This model is based on: number of cows to be sorted, total number of cows, walking distance, walking speed of cows and the time it takes to sort one cow. In the theoretical model values for walking speed and time it takes to sort one cow are estimations. It has been found that the DeLaval model needs to be improved with data from field studies to improve the accuracy of the model, this would entail improved estimations of walking speed and the time it takes to sort one cow in the DSG10.

Aim

The aim of this Master's Thesis of Animal Science is to develop an improved capacity calculation model for the DSG10 sort gate, based on DeLaval's existing calculation model and time study results from field trials in consultation with the outcome from a literature study. The hypothesis is that the calculation model used today gives incorrect capacity estimations.

Literature survey

Sorting of cows

The females of the European dairy breeds are considered to be quieter than the females of the beef breeds (Ewbank & Parker, 2007). Dairy cows are raised in groups and are in close contact to humans every day. Therefore they usually have a small flight zone. When moved they are often driven by handlers. Therefore the facilities that are needed to handle this type of cattle are much simpler than the ones needed to handle extensively raised cattle. If sorting and restraining facilities for dairy cows are well designed and constructed the handling is often efficient and not so stressful for the animals, assumed that the handlers are skilled. The best handling situation occurs when animals, facilities and handlers work in harmony. According to Albright (1995) automation of the cattle enterprise can lead to better animal welfare through more time for interaction between animals and humans, this in turn would lead to reduced stress in the handlers who in turn would then treat the animals with more patience.

It is necessary to be able to sort and restrain cows in loose housing systems. Dairy cows can be sorted due to many different reasons like regrouping or treatments i.e. inseminations, pregnancy checks, health checks, vaccinations, hoof trimmings and slaughter. Sorting and treatments can be conducted in many different ways and in different places.

Cornered in home pen

Traditionally sorting of cows have been done by selecting individuals in the group where they stay between milkings and then move them. It can be difficult to find cows and they can be unwilling to be taken out and leave the group (DeLaval, 2008). This system needed a lot of labour and can be dangerous and stressful for both humans as animals (Wagner-Storch & Palmer, 2002). The only positive thing with the system to corner cows in home pen is that it does not have an investment cost.

In milking parlour

Treating cows in the milking parlour is not recommended by either Bickert (1998) or DeLaval (2008) because it can result in cows associating this place with discomfort.

Self-locking head gates along a feeding line

Treating cows along feed tables is not recommended by DeLaval (2008) because cows should not associate this place with discomfort, but it is still a common practice (Forss Jannes, 2009). Self-locking head gates have a mechanism that makes it possible to catch and release all cows along a feeding line (figure 1). One head gate for each cow in the barn is required (Bewley *et al.*, 2001). The most positive thing about the self-locking head gate system is that the cows have access to feed while waiting for treatment (Bickert, 1998; Wagner-Storch & Palmer, 2002). One disadvantage is that if gates adjacent to a locked cow are empty cows move around which is unsafe and make it difficult to work for the veterinarian (Wagner-Storch & Palmer, 2002). Another disadvantage is that it can take some time to find pre-selected cows though as the cows positions themselves randomly along the feeding line (Bickert, 1998). It was found in a survey with 302 Wisconsin herds that the self-locking head gates were experienced to be more labour efficient, easier to use and safer for workers than the treatment rails (Bewley *et al.*, 2001).

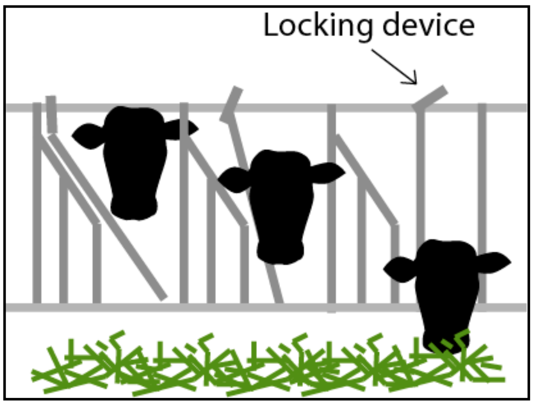

Figure 1 .Example of a self-locking head gate

Treatment rails

A less expensive and simpler alternative to self-locking head gates can be treatment rails, see figure 2 (Bewley *et al.*, 2001). The treatment rail has the advantage that the top bar at the back restrains the cows which makes insemination and palpation easier while making it difficult for the cows to kick the person working behind them (Wagner-Storch & Palmer, 2002). Wagner-Storch & Palmer (2002) also found that the treatment rail had a low investment cost but that it was labour intensive. Normally it took two persons to load the cows into the treatment rail to ensure that the cows placed themselves correctly.

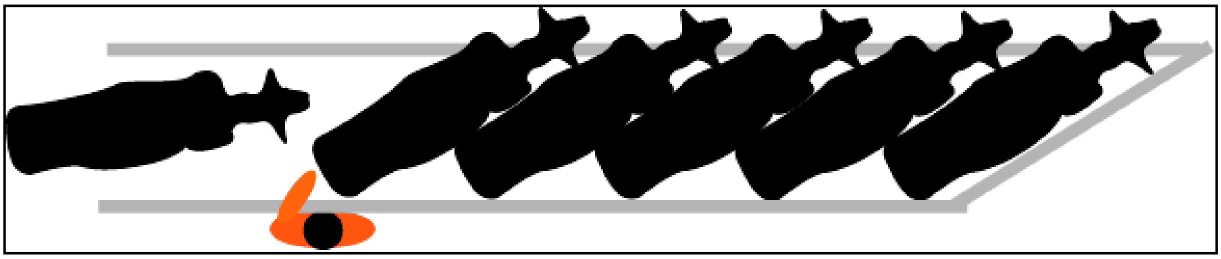

Figure 2. Example of a treatment rail

Sorting gates

Description of DSG10

The DSG10 have been on the market since 2003 and there are approximately 70 DSG10's in use today (Krausbauer, 2009). The DSG10 consists of a cow-ID unit, a saloon gate with a 3-way sort gate and a control unit. Optional to the main assembly another one or two 2-way sort gates can be added to increase to sorting configuration to 5, see figure 3 (DeLaval, 2008). All gates are built mainly in 2" steel bars and moves with a pneumatic cylinder. The gates have rubber bumpers to minimise noise. The control unit that operates the gates executes commands from the herd management computer program ALPRO.

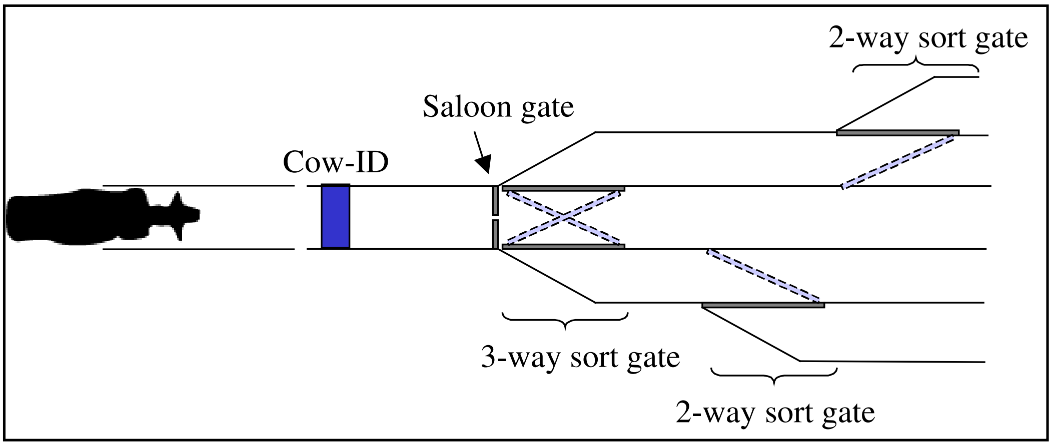

Figure 3. Principal sketch over DSG10.

The ALPRO system can sort one specific cow or all cows that fulfil certain criteria. Cows can be marked for sorting during a milking session from the milking parlour but can also be programmed for sorting at one specific time or for a sequence of days. Cows that fulfil programmed criteria (like being milked in a wrong group, having low milk yield or high activity) can be sorted whenever this occurs. The sort gate can be activated only for certain periods of time if wanted. It is possible to sort manually at the sort gate by pushing buttons on the control unit.

The cow-ID unit, placed close to the saloon gate, identifies cows by their transponder number. When a cow enters the cow-ID unit on the sort gate and is identified, the transponder number is sent to the ALPRO processor. If the cow should be sorted, a message is sent to the control unit, which activates the relevant pneumatic cylinders to move the gates and allow the cow to access to the specific lane. The saloon gate will halt the cow that is to be sorted by closing its gates during the time the 3-way sort gate changes position. The DSG10 only stop cows that is to be sorted and stops the cows walking behind this cow until she has been successfully directed past the 3-way sort gate. Cows that are going to pass straight through (not sorted) will not be stopped unless they walk behind a cow that is sorted.

Photocells are used to detect the movement of the cow through the sort gate, to control the operation of the gates. All gates return to default position when no cow is detected by any photocell for a set period of time (2 seconds as default). As long as the photocell in the first sort gate detects a cow the gates are directed for that cow. When the 3-way sort gate is empty it is possible to let cows into the default lane even if there are cows still walking through other parts of the sorting system.

The system can handle only three cows at a time; one in the system and two that are waiting. If a fourth cow would somehow be identified, maybe because the third cow walks away, the new cow would get the identity of the third cow that has already walked away.

A report list can be attained in ALPRO Windows after each sorting session. The cut report list can show information like: cow number, group number, sort date, sort time (hour and minute), sort area and sort cause.

Other available sort gates

WestfaliaSurge has a multiple sort gate named Auto Select 5000 that sorts cows up to five different sort directions (Westfalia, 2009). This sort gate is working together with a computer controlled management system and cow identification transponders. An ID antenna identifies the animals and cows that are to be sorted are stopped with a saloon gate positioned before the sort gate. The sort gates stays in the same position until a cow with a different sorting decision is identified. Auto Select 5000 sorts both individual cows and groups of cows.

ATL (Agricultural Technology Ltd, 2009) provides a sort gate system called Pegasus that is based on a three-way sort gate that can be combined with a second two-way sort gate if positioned close to each other. The cows are lead through a single file race up to an ID antenna that is positioned just before the sort gate. The ATL sort gate system does not halt cows. The sorting system is operated either directly through a control or via a computer and it sorts cows that are marked in the system.

Milfos have a sorting system that can manage up to 11-way sorting by combining several three-way sort gates for a maximum of 5000 cows. Every 3-way sort gate has a separate ID-unit and a saloon gate that halt cows walking behind sorted cows. This is run together with a herd management program.

DeLaval (2009), Westfalia (2009), ATL (2009) and Milfos (2009) all have more simple sort gate solutions available, the sort gate systems described above are the ones that can handle the maximum number of sorting directions per sorting system with one ID-unit (Milfos use one ID-unit per 3-way gate). Boumatic (2009) has a two-way sort gate called EZ Sort that sort cows that are marked with a sort tag that is put on the rear leg of the cow by a person in the parlour at each milking. This system cannot be managed via a computer.

Location of sort gate

Using automatic sorting can increase efficiency on farms with more than four groups and where milking is conducted for more than four hours (Bickert, 1998). Sort gates can be operated both manually by a person or automatic via a computer. If sorting is conducted in connection to the milking centre using manual or automatic operation, the cow flow is improved the further away from the parlour the sort gate is positioned. However, if sorting is conducted by the persons in the parlour it is not possible to place the sort gate far away from the parlour. To conduct the sorting in connection to the milking centre is recommended also if using a separate handling and treatment facility according to Bickert (1998). It is important to consider the co-ordination of group movement to and from the parlour when using sort gates. Also Wagner-Storch & Palmer (2002) found that the electronic sort gate save time and labour but a problem is that all cows in their study were not correctly identified and the cows that were fast-moving sometimes followed the cow in front of her which resulted in sorting of the wrong cow. Grandin (2007) have made designs for large sorting facilities for range cattle with individual animal identification that can be used with electronic sorting systems.

Several other ways and locations for sorting and treating cattle are used on farms, like restraining dairy cows in return lane from parlour (Wagner-Storch & Palmer, 2002; Bewley *et al.*, 2001). Many of the different ways of sorting and restraining cattle are possible to combine to an even greater variety of choices available to the farms.

Factors affecting sort gate capacity

Walking speed

Cows are considered to be mammals with a low speed of locomotion (Taylor, 1985). The average walking speed of healthy mature cows varies between 1,4 m/s (Chapinal *et al.*, 2009) and 0,65 m/s (Phillips & Morris, 2000). Heifers seem to walk faster than mature cows (Schmid *et al.*, 2008).

Flowers *et al.* (2006) found that cows with healthy hoofs walked about 0,2 m/s faster after milking than before milking (table 1). Chapinal *et al.* (2009) saw no difference in walking speed before and after milking, but the cows got better gait scores after milking when the udder was empty. The same study compared walking speeds of cows 7 to 11 days before calving with walking speed 24 to 72 hours after calving and found that the cows walked faster before calving (table 1). A handler walked behind the cows in this experiment, encouraging them to walk in a way that was consistent.

Table 1. Walking speeds before and after calving and milking

Walk speed (m/s)	Treatment	Reference
1,4	Before calving	Chapinal *et al.*, 2009
1,3	After calving	Chapinal *et al.*, 2009
1,2	Before and after milking	Chapinal *et al.*, 2009
1,08	After milking	Flower *et al.*, 2006
0,89	Before milking	Flower *et al.*, 2006

The floor surface also affects walking speed. Cows walk faster on rubber than on concrete (Jungbluth *et al.,* 2003; Telezhenko & Bergsten, 2005; Flower *et al.*, 2007). Cows prefer to stand and walk on rubber rather than concrete (Telezhenko *et al.*, 2007). Solid floors allow a faster walking pace than slatted floors (Telezhenko & Bergsten, 2005). It is possible to reduce slipping by increasing the friction coefficient (FC) of the floor. The FC is calculated by the force required to move an object over a surface divided by the weight of that object. Cows usually do not slip on floors with a FC above 0,4 (Phillips, 2001). A lower friction coefficients for the floor surface will result in a slower walking speeds (Phillips & Morris, 2000; Phillips & Morris, 2001a). Phillips and Morris (2000) also found that a layer of slurry on the floor drastically decreases the friction coefficient of the floor and subsequently the walking speed of the cows. See table 2 for a short summary of walking speed for dairy cattle on different floor surfaces.

Table 2. Comparisons on walking speeds on different floor surfaces

Walking speed (m/s)	Floor surface	Reference
1,12	Sand	Telezhenko & Bergsten, 2005
1,1	Slatted rubber	Jungbluth *et al.,* 2003
1,08	Solid concrete	Telezhenko & Bergsten, 2005
1,08	Continuous rubber	Telezhenko & Bergsten, 2005
1,06	Slatted rubber	Telezhenko & Bergsten, 2005
0,9-1,1	Pasture	Sommer according to Jungbluth *et al.,* 2003
0,97	Slatted concrete	Telezhenko & Bergsten, 2005
0,81	Dry concrete	Phillips & Morris, 2000
0,8	Slatted concrete	Jungbluth *et al.*, 2003
0,80	Wet concrete	Phillips & Morris, 2000
0,67	5 cm of slurry on concrete	Phillips & Morris, 2000
0,65	12,5 cm of slurry on concrete	Phillips & Morris, 2000

It is known that cows spend more time walking and less time eating and resting when in oestrus (Hunrik *et al.*, 1975). However, no studies have been found where walking speed of cows in oestrus has been examined.

The short time effect of hoof trimming on walking speed of cattle can be seen in table 3. Cooper *et al.* (2008) found no difference before and 2 days after trimming, but two other studies (Aoki *et al.*, 2006; Meyer *et al.*, 2007) got results showing that cattle walk slower after trimming. Other walking parameters like positioning of withers, limb angles (Aoki *et al.*, 2006), positioning of hoofs and weight bearing on the claws (Meyer *et al.,* 2007) are improved after trimming, which in the long run might improve walking speed.

Table 3. Walking speed for dairy cattle before and after claw trimming

Walk speed (m/s)	Animal	Surface	Treatment	Reference
1,4	Heifer	Treadmill	Before trimming	Meyer *et al.*, 2007
1,33	Heifer	Treadmill	1 day after trimming	Meyer *et al.*, 2007
1,13	Cow	-	Before trimming	Aoki *et al.*, 2006
0,87	Cow	-	2 days after trimming	Aoki *et al.*, 2006
0,82	Cow	Concrete	Before and 2 days after trimming	Cooper *et al.*, 2008

Dairy cows with hoof problems walk slower than cows with healthy hoofs (Telezhenko & Bergsten, 2005; Flowers *et al*., 2006; Flower *et al*., 2007). Flowers *et al.* (2006) found that cows with sole ulcers walked almost 0,1 m/s faster after milking than before-milking (table 4). Sole ulcer and other claw lesions are the most common cause of lameness among dairy cattle (Murray *et al*., 1996). In Sweden about 5% (Manske *et al*., 2002) and in Wisconsin approximately 23% of the dairy cows are lame (Cook, 2003).

Table 4. Comparisons of walking speed (m/s) of lame and non-lame cows

Treatment	Non-lame (m/s)	Lame (m/s)	Reference
All floor types	1,11	0,99	Telezhenko & Bergsten, 2005
Rubber	1,26	1,22	Flower *et al*., 2007
Concrete	1,21	1,17	Flower *et al*., 2007
After milking	1,08	0,87	Flower *et al*., 2006
Before milking	0,89	0,80	Flower *et al*., 2006

Manske *et al.* (2002) define lameness as "asymmetric gait, avoiding weight-bearing on one or more limbs". Cook (2003), Telezhenko & Bergsten (2005), Flower *et al.* (2006) and Flower *et al.* (2007) all used locomotion scores based on Sprecher *et al.* (1997) for defining lameness in dairy cattle. Scores 3-5 are considered as lameness. See table 5 for lameness scoring according to Sprecher *et al.* (1997).

Table 5. Lameness scoring system (Sprecher *et al.,* 1997)

Lameness score	Clinical description	Assessment criteria
1	Normal	The cow stands and walks with a level-back posture. Her gait is normal.
2	Mildly lame	The cow stands with a level-back posture but develops an arched-back posture while walking. Her gait remains normal.
3	Moderatly lame	An arched-back posture is evident both while standing and walking. Her gait is affected and is best described as short striding with one or more limbs.
4	Lame	An arched-back posture is always evident and gait is best described as one deliberate step at a time. The cow favours one or more limbs/feet.
5	Severely lame	The cow additionally demonstrates an inability or extreme reluctance to bear weight on one of her limbs/feet.

Environment in sorting facilities

Feed and light affects the walking speed of cattle. In a study seven non lactating British-Friesian cows were taught to select the side in a Y-maze (the cows were first walking in a single file and then given the choice of walking to the right or to the left) that offered the largest amount of molasses. The cows were then tested with 5 cm of slurry on the floor in one of the two sides in the maze, it was found that the cows did not care about the slurry on the floor as long as they got the molasses. Then one side of the maze were lit to a light intensity of 22 lux and the other unlit side had a light intensity of 0,03 lux. The cows clearly avoided the dark passage (0,03 lux), also when there was 400 ml of molasses in the dark passage and no feed reward in the light passage (Phillips & Morris, 2001b).

Phillips *et al.* (2000) found that cows walked faster through a passageway if it was dark than if it was light when walking on a floor with good grip, probably because the cows are trying to spend as little time as possible in the dark (see table 6). But when the floor was slippery on smooth concrete, walking speed was the same whether it was dark (0 lux) or light (approximately 250 lux). Phillips *et al.* (2000) therefore recommend that passageways should be lighted (32-119 lux) at all times to improve the welfare of the cows. Another positive effect of well lightened environments is that it results in cows producing more milk (Peters *et al.,* 1981; Marcek & Swanson, 1984; Stanisiewski *et al.,* 1985; Dahl *et al.,* 2000).

Table 6. Walking speed of cows in different light intensities (from Phillips *et al*., 2000)

Walking speed (m/s)	Floor surface	Light intensity
0,9	Smooth concrete	0 lux and 250 lux
0,7	Grooved concrete	0 lux
0,65	Grooved concrete	119 lux
0,62	Grooved concrete	32 lux

Grandin (1980) observed that cattle will enter races and pens with solid walls with less hesitation compared to gates and fences made of bars. Cattle tend to follow the animal in front, with this in mind, it is better to have some of the gates "see-through". Where cattle in different races move in opposite directions the races should be separated by solid walls, but where they move in the same direction there should be see-through fences. Curved races that prevent the animal from seeing distractions that comes ahead have better animal flow than straight ones as long as the curve is not to sharp. Curves and corners that are too sharp will appear as dead-ends for cattle. An inside radius of 3,5-5 meters for a single-file race or a curve of 15° is recommended. Loud noise should be avoided, both from equipment and handlers. Later studies (Grandin, 1985) concluded also that races with a inter radius of 1,5-2 meters works well for most cattle.

Learning and adaptation in cattle

Learning is defined as the ability to change behaviour to cope better with environmental circumstances (Kratzer, 1971). In a study with twenty-four Holstein heifer calves by Schaeffer and Sikes (1971) it was shown that it took one to five days for the animals to learn in which bucket (black versus white or large versus small bucket) there were feed available to eat.

A study by Kilgour (1981) tested the learning ability of 73 non-milking Jersey cows by looking at how long time and how many times it took for hungry cows to find their way to feed through a square arena where the way to the feed was altered by moving around 2 meter high walls. The cows moved through the same type of wall conformation in the labyrinth (maze) for nine times. Only one cow was in the arena at a time. It was found that wall conformations where the cows had to learn to move to the right just after having moved to the left for several times was the most difficult for the cows to learn. In the beginning of the study four to five cows refused to move into the goal box where feed was kept and instead they backed out, turned and made their way back to the start point. In the labyrinths 16% of the cows took the right way on their first run and by the fourth run as many as 93% took the right way without making any errors. It was found that it took the longest time for the cows to move through the arena the first time they encountered one of the labyrinths (3-0,33 m/s, average of 0,79 m/s), and that they were faster the second time (3-0,6 m/s, average of 1,15 m/s) and that there were less difference between cows the remaining runs (2-0,75 m/s, average of 1,15 m/s). When the cows were moving through the 58 meters long return race back to the start point, after they had completed a labyrinth, they had to be driven by humans the first four or five days. After that they moved through the race on their own and after several more days the cows tried to push past gates that hindered them in the race.

It took between four and five days for heifers to learn to press a panel to open a gate and to get access to feed (Hagen & Broom, 2004). During the trial period the heifers reduced the time it took before they pressed the panel from 3 minutes down to 3 seconds. It took between 4 and 71 seconds (3,75-0,21 m/s) for heifers to move from the gate down to the feed, with a median time of 8 seconds (1,88 m/s).

Kovalcik and Kovalcik (1986) compared learning ability and memory testing for 15-month old heifers, primiparus cows and cows in their second lactation by looking at how long time it took for the animals to learn which one out of two feeders that contained concentrates and how many of the animals that after six weeks remembered where to find the feed. They showed that heifers were better in learning. During the first four runs 92% of the heifers, 23% of the primiparous cows and 54% of the cows in their second lactation took the right feeder. It was also found that cows have better long-time memory than heifers, 77% of the cows and only 46% of the heifers did choose the feeder with feed after the pause of six weeks. Another study looking at memory in cattle (Hagen & Broom, 2003) found that heifers that were trained to associate a specific herd member to a feed reward and another specific herd member with no feed reward had no problem to remember this for 12 days.

To find out if heifers can learn by watching other heifers performing a task Veissier (1993) split a group of animals into an experimental and a control group. The experimental heifers observed another heifer that had been trained to push a panel in a testing room to get feed while the control heifers observed an untrained heifer in the same testing room. The study found that the animals that observed a trained heifer tended to be more active near or at the place were feed were found than the animals that had watched an untrained heifer. Veissier (1993) concluded that watching a trained animal performing a task did not increase the ability of the observing cattle to conduct the task successfully, but might indirectly help learning by increasing the observing cattle's interest in the stimuli involved in the task.

It seems like cows need to practice four to five times in order to learn something new and that they can remember things that they have learned for some weeks. Cows can not learn just by watching others performing a task.

Deprivation of lying, feeding and drinking

Dairy cows that are waiting for treatments like veterinary checks or breeding often have no access to cubicles or feed. In a study made by Cooper *et al.* (2008) it was found that cows deprived for two hours did compensate for the lost feeding time by eating more after the deprivation within 24 hours. This was not the case when cows were deprived for four hours. Cows did not restore their lying time after deprivation of lying, but they also found that neither 2 nor 4 hours of lying and feeding deprivation caused any change in milk yield. It is advisable to offer cows feed and the possibility to lie down while waiting for treatments for longer periods. Bickert (1998) recommends that sorted cows waiting more than a few hours for treatment should be provided with both feed and water.

Loose housed lactating cows drink between 2 and 13 times a day, with a mean of 7 times a day (Andersson, 1987). Dairy cows drink most of their daily water consumption in connection to feeding and milking (Osborne *et al*., 2002; Cardot *et al.*, 2008). Cows that do not get free access to water reduce their milk yield (Little *et al.*, 1980; Senn *et al*., 1996) and feed intake (Senn *et al*., 1996). Therefore it is recommended to provide cows with water if they are waiting for treatment after milking.

Material and method

Material has been collected on four farms, one in Sweden and three farms in the United States of America (US) during January and February 2009. Farms were chosen on the basis that they should have and use the DSG10. DeLaval ran the search of farms and decided which farms were to be visited, mainly based on geographical location.

Farm visits

The time studies were conducted between 07.10 and 11.30 at morning milking and between 14.20 and 17.40 at afternoon milking the same day on farm 1. On farm 2 the time studies were conducted between 15.15 and 16.45 on two consecutive days. Times from farm 3 were collected at one day, from 13.50 to 16.45. Farm 4 was visited on two consecutive days and the first day the time registrations started at 10.30 and ended at 13.40 and on day 2 the time studies took place between 9.50 and 13.00. The farms were documented concerning farm layout, animal environment and management.

Sketches were made of the sorting area and the whole farm layout. The sketches of the sorting area were combined with measurements of the interior so that it would be possible to make drawings of the sorting area. The farms sorting area, milk centre and cow barns were also documented with photographs and notes regarding animal environment such as floor surface, manure system, feeding, drinking water, light, temperature, ventilation and building types.

Management data were collected from ALPRO, which is DeLaval's herd management tool. The remaining documentation was based on questionnaires (appendix) and interviews with farmers, herd managers and/or animal keepers on way of working and thinking regarding sorting, animal health, animal environment, milking routines, treatments and general management.

Farms

Two of the farms in the US were situated in the state of Wisconsin and one was situated in the state of New York. At the time of the farm visits in the US the temperature inside the barns was below freezing point but in the parlours the temperature was above freezing. On the Swedish farm the temperature in the barns was just above freezing.

Farm 1

Cow data

This farm milked 1000 Holstein dairy cows in a 60 milking point parallel rotary. They milked about 200 cows per hour, three times a day, one milking session lasted for about five hours. The average milk yield was 32 kg (70,5 lbs) per day for lactating cows. About 42% of the herd was in first lactation, the cows were on average culled after 2,8 lactations and the culling reason was mainly low fertility or difficult to milk. About 5% of the cows were lame.

Sort gate location

DSG10 sort gate was installed in February 2005 at the same time as the rotary was installed. Before the installation of DSG10, the cows were sorted manually. The sort gate was placed in an old barn reconstructed into a treatment area. The three-way gate lead unsorted cows straight on and had one sort pen on each side. On the left side were a larger and size-adaptable area with ten cubicles and a row with self-locking head gates while the right side was a simple pen of approximately 50 m^2. See figure 4 for a drawing over the sort area.

Sorting principles

The left pen was used every day for insemination. All cows carried activity meters for heat detection. The left pen was also used for hoof trimming, pregnancy checks, dry offs, veterinary checks and regroupings. The right sort pen was used less frequently, had a smaller area and no interior. Most sorting decisions were set for specific cows and occasions, and this information was put in by a person on one of the PC's with ALPRO. A cow stayed in a sorting pen for approximately five hours at most, as this was the time it took for one milking session. All cows passed the sort gate after every milking on their way back to the cow barn. One cow was on average sorted about nine times per year.

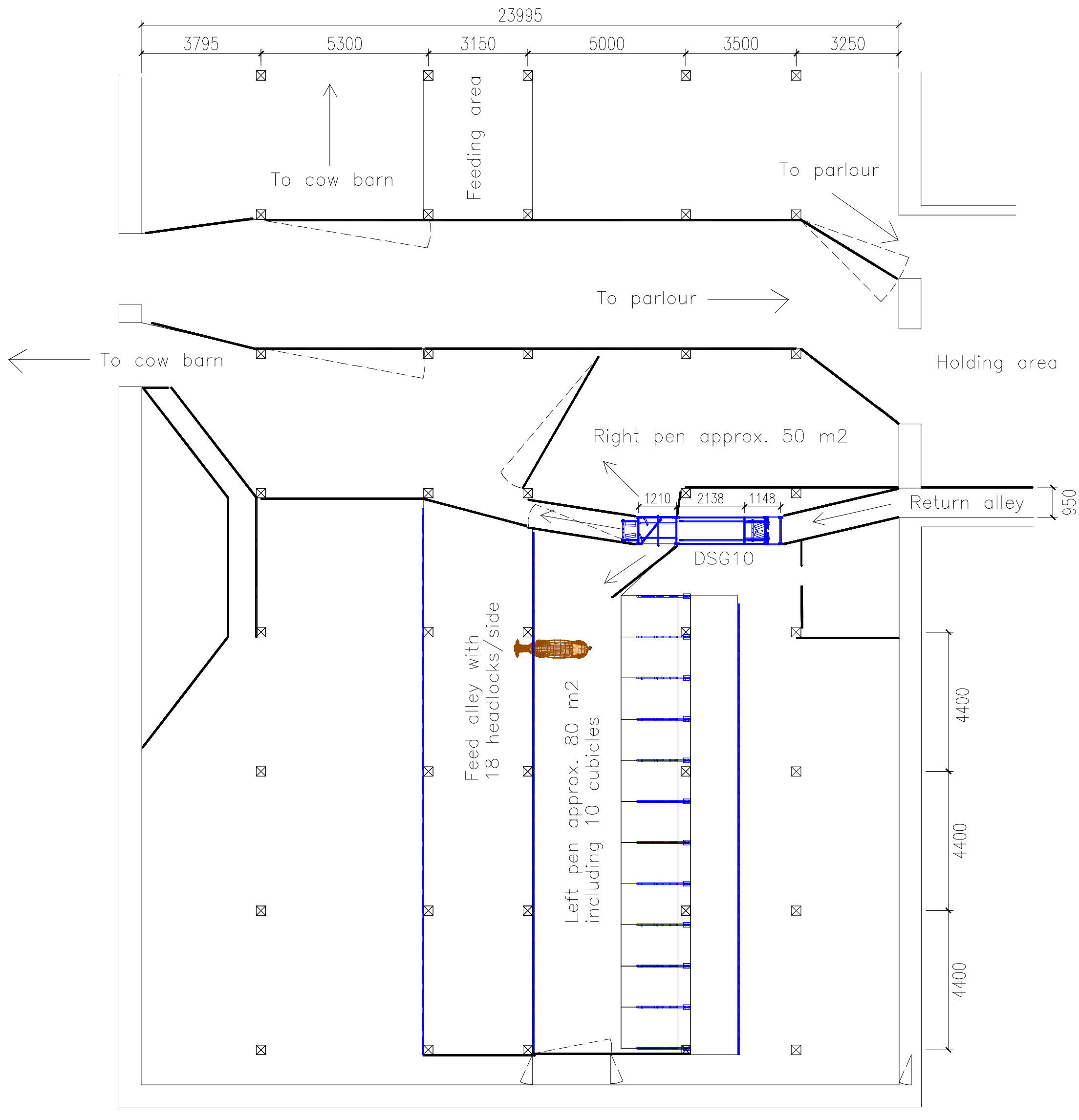

Figure 4. Drawing of sort area at farm 1.

Cow traffic

The cows were moved from the cow barn to the holding area with a crowd gate by an animal keeper. Two milkers stood at the rotary, one for udder preparation while the other attached milk clusters. An alley, about one meter (3 feet and 3 inches) wide and approximately 52 meters (170 feet) long, lead the cows from the rotary to the sort gate. Most times the long alley had enough room, also when a cow was occupying the sort gate for a longer period of time

Flooring
The alley leading cows from the rotary to the sort gate was down hill, had solid walls and concrete slatted floor with rubber attached to it. The floor at the sort gate was mainly grooved concrete, but some parts were slatted concrete. The floors in the cow barns were grooved concrete with scraper on top.

Feeding
The cows were offered fresh feed (total mixed ratios) in the cow barns or in a separate feeding area situated on the way back to the cow barn after milking. Water was available in bowls in the cow barns and feeding area. Neither feed nor water was available in the sort pens.

Farm 2

Cow data
The second farm had 300 Guernsey cows that were milked in a 2x10 herringbone parlour. About 70 cows per hour were milked two times a day, one milking session took about 3,5 hours. The average milk yield was 27 kg (60 lbs) per day for lactating cows. About 36% of the cows in the herd were in first lactation, the cows were on average culled after 4 lactations and the main reason for culling was low fertility. About 5-10% of the cows were lame.

Sort gate location
The DSG10 had been installed in June 2007 at the same time as the loose housing cow barn and parlour was build. Before June 2007 the farm had tie stalls and did not sort cows. The sort gate and sort pens were placed between the holding area and the cow barn which is visualised on the drawing in figure 5. The three-way gate lead unsorted cows to the left, back to the same alley as the cows used to walk from the cow barn to the holding area before milking. Straight on was a treatment rail and to the right was an alley that lead to a sorting pen with a headlock. The sorting pen to the right could be adjusted into four smaller pens if needed.

Sorting principles
Cows were sorted for inseminations, pregnancy checks, dry offs, veterinary checks, vaccinations, hoof trimmings and regroupings. Two times a week, when the temperature was above freezing foot baths were placed in the alley to the right. Most of the sorting decisions were set for specific cows and occasion via the PC, but some were manually controlled as the animal keeper then stood by the sort gate control panel, pushing its buttons and visually sorted the cows. The sorted cows stayed in the sorting area for the maximum time of two hours but most of the time for only half an hour or less. All cows passed the sort gate DSG10 once a day and were sorted on average nine times a year.

Cow traffic
The cows were moved from the cow barn to the holding area with crowd gate by an animal keeper. Two milkers were in the milking parlour at a time. From the parlour there was one alley on each side of the holding area that lead the cows down to the sort area and back to the

cow barn. The alleys were 20 meters (65 feet) and 36 meters (118 feet) long respectively, had rails adjacent to the holding area and was 1 meter (3 feet and 4 inches) wide.

Flooring
The floors were solid rubber in the parlour, holding area, walking alleys between the parlour and the cow barn and the area in front of the water troughs in the cow barn. In the sorting area and in the cow barn the floors were grooved concrete. The floors in the sorting area there were manually cleaned and in the cow barn a tractor was used to scrape the floors.

Feeding
The cows were offered fresh feed (total mixed ratios) in the cow barn after milking. Water was available in troughs in the cow barns but also in the sort pens to the right.

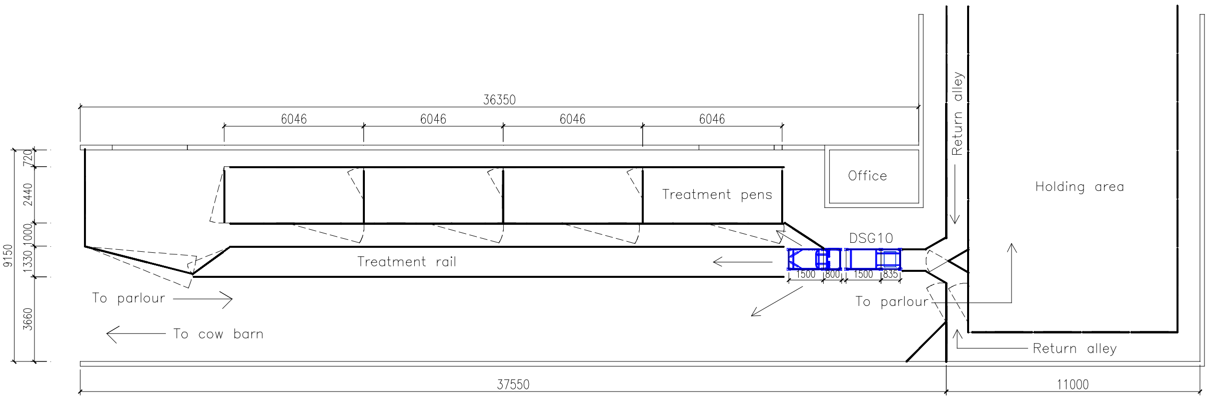

Figure 5. Drawing of sort area at Farm 2.

Farm 3

Cow data
The third farm milked about 1000 Holstein cows in a 2x20 parallel parlour. One milking session lasted for approximately 6,5 hours, the cows were milked three times a day and they milked about 155 cows per hour. The average milk yield was 35 kg (78 lbs) per day for lactating cows. About 45% of the cows were in first lactation, cows were culled mainly because of low milk yield or bad hoof health after an average of 2,4 lactations. The farm said that they had big problems with lame cows, and thought the bad hoof health was caused by the grooved concrete floors and the sand used as bedding material in the cubicles.

Sort gate location

The farm installed the sort gate DSG10 in October 2008 at the same time as the parlour and the farm's largest cow barn was ready after construction. Manual sorting had been practised before the installation of the sort gate. The sort gate was placed opposite the holding area, see figure 6.

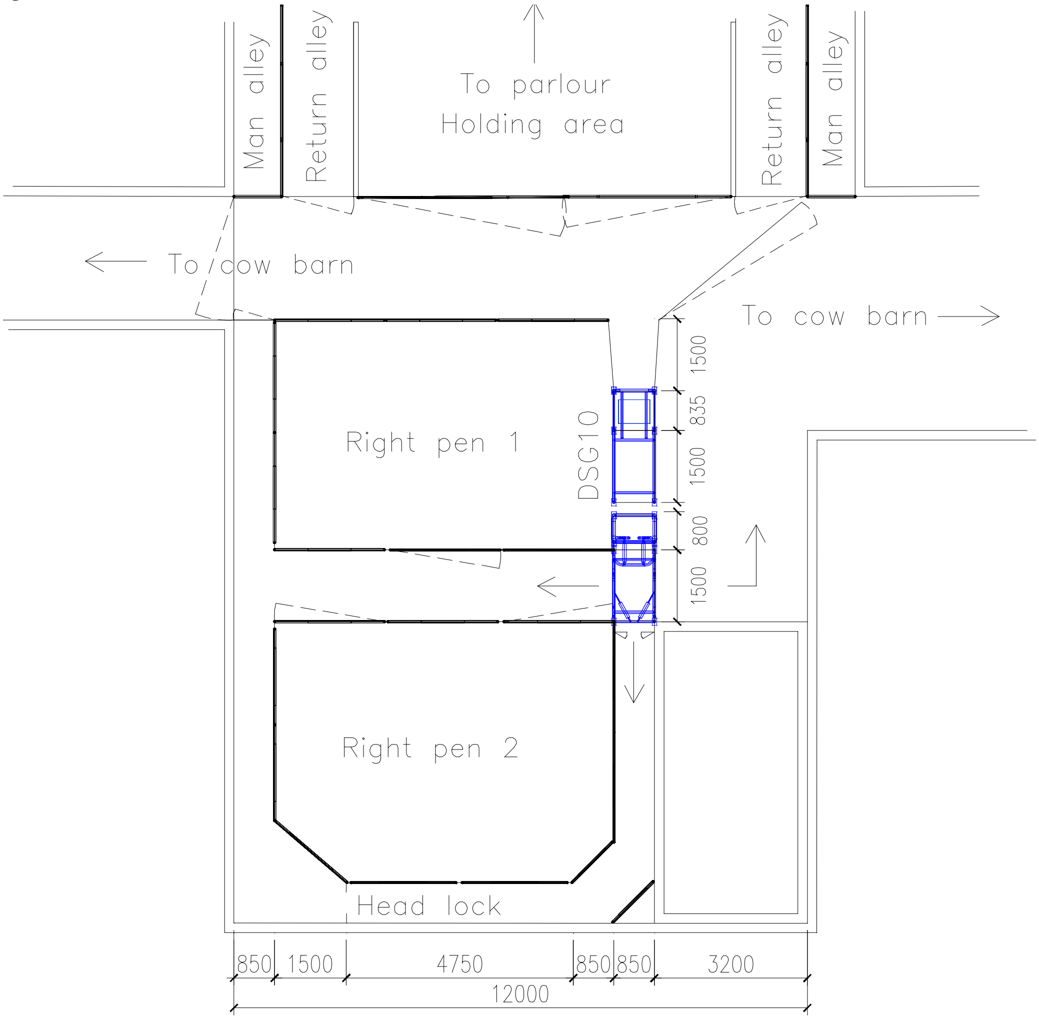

Figure 6. Drawing of sort area at farm 3.

Sorting principles

The three-way sort gate leads the unsorted cows to the left, where the unsorted cows took a 360° turn to return to the cow barn. Sorted cows that was led straight on passed a one-way gate that was situated just after the sort gate before walking straight on for approximately 5 meters before making a 90° turn into a headlock with solid walls. Cows sorted to the right walked into one of two sorting pens or back to a cow barn. The cows were sorted by the sort gate for hoof trimmings and regroupings. About four times a week, when the temperature was above freezing, foot baths with copper sulphate were placed in the alley adjacent to the pens to the right and then all cows were directed to the right in the sort gate. The cow barns have headlocks at the feeding table where other treatments were carried out. Most sorting decisions were set for specific cows and occasions by a person via the PC, but sometimes the sorting decisions comes from the parlour or were manually conducted via the control panel on the sort gate. The cows were sorted about three times a year and walked through the sort gate about four days a week when it was above freezing (for foot baths) and more seldom when it was below freezing.

Cow traffic
The cows were moved from the cow barn to the holding area with crowd gate by an animal keeper. Two milkers worked in the parlour at a time. One return alley on each side of the holding area, about 1,5 meter (5 feet) wide and 35 meters (115 feet) long each, lead the cows from the parlour down to the sort gate. There was a 1,7 (6 feet) meters high solid wall separating the holding area from the return alley.

Flooring
The floors were all grooved concrete. Flushing was used in the holding area and return alleys, manure was manually scraped in the sorting area and in the cow barn scrapes ran.

Feeding
The cows were offered fresh feed (total mixed ratios) in the cow barns after milking. Water was available in troughs in the cow barns. Water and feed was not available in the sorting area.

Farm 4

Cow data
The fourth farm milked approximately three thousand Holstein dairy cows in a 2x52 parallel parlour. The cows were milked three times a day and the number of milkings per hour was around 400. The parlour was in use for 24 hours a day. The average milk yield was 39 kg (86 lbs) per cow in lactation and day. In the herd about 45% of the cows were in first lactation and the cows were on average culled after 3,5 years of age. Approximately 15% of the cows were lame and the cow hoofs were trimmed about three times a year.

Sort gate location
This farm installed their first automatic sort gate in 1993, but had used the DSG10 since August 2008. The farm had two DSG10 but was using one at a time (figure 7). The reason for having two sort gates was that the cow barns were situated on both sides of the parlour and to improve cow flow they had installed one sort gate on each side of the treatment area. This farm combined each 3-way sort gate with two 2-way sort gates into a five-way sort gate. The 3-way sort gates and the two 2-way sort gates had one cow-ID unit each and operated independent from the others. For each five-way sort gate there were four different sort areas; three pens and one race leading up to a headlock.

Sorting principles

Sort pen 1 was used for pregnancy checks and bovine somatotropin (bST)-injections some days a week, but the other days it was used for regrouping. Sort pen 2 and 3 were used for breeding activities like inseminations, injections and heath checks. These two sort pens could be used in combination with the sort race where cows were standing in a queue waiting for treatment. The sort race that normally led up to a headlock could also be redirected to the hoof trimming area. The sorting decisions were set for specific cows and on occasion in advance via the PC, also cows that fulfilled certain criteria i.e. being in the wrong group were programmed to be automatically sorted. Some sorting decisions were made from the parlour and it also occurred that cows were manually sorted by animal keepers at the sort gate control panel down in the treatment area. The sorted cows normally stayed in the sorting area between 20 and 60 minutes. All milking cows passed the DSG10 once a day and were sorted on average ten times per year.

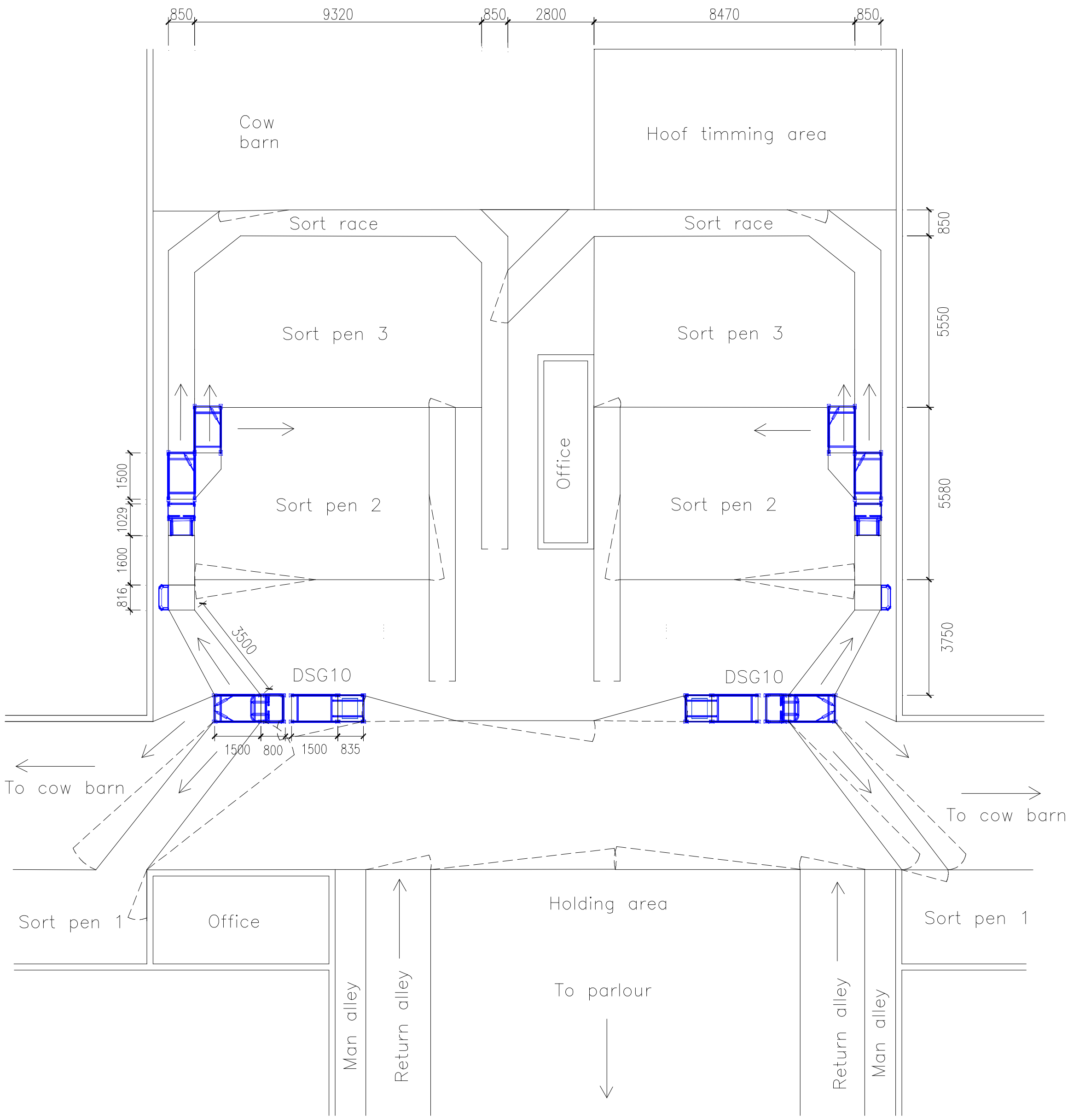

Figure 7. Drawing of sort area at farm 4.

Cow traffic
The cows were moved from the cow barn to the holing area with crowd gate by an animal keeper. Five milkers worked in the parlour at a time. There was one return alley on each side of the holding area which was 2,1 (6 feet and 10 inches) meter wide and 27 (88 feet) meters long each and lead the cows from the parlour to one of the sort gates. There was a rail separating the holding area from the return ally. At the end of the return alleys there were permanent foot baths with formaldehyde that were used every day.

Flooring
In the holding area and in the return alleys the floor was covered with rubber and those areas were flushed. In the areas between the cow barn and the holding area there were slatted floors with rubber on top. In the sorting area the floors were mainly grooved concrete that was cleaned with scrapers running on top. In most of the cow barns there were grooved concrete with scrapes on top, and the areas around the water troughs had rubber on top and were cleaned manually. Some cow barns were scraped with a bobcat when the cows were milked.

Feeding
The cows were offered fresh feed (total mixed ratios) and water in troughs in the cow barns after milking. Neither water nor feed were available in the sorting area.

Method for time studies

On all farms time studies were made with a time logger. One person was standing where it was possible to see the whole DSG10 and this person estimated visually when cows were entering and exiting the sort gate and registered this on the time logger. One cow at a time was observed as she passed through the whole sort gate system. It was not possible to register all cows entering and exiting the sort gate. A cow that was to be sorted was prioritised over cows that were passing straight through.

On three of the farms the time studies were conducted at two different milking sessions and on one farm the time studies were done during one milking session. The goal was to register as many sorting events as practically possible on each farm. On the three smaller farms they added extra sorting events during the milking sessions when the time studies occurred so that the total number of sorting events would increase. Then some of the milked cows were randomly picked out by the herd's manager or herd's person in the computer program ALPRO Windows to be sorted. These cows were sorted to open pens or alleys so that the cows could return to the cow barn after passing the pen or alley, this mean that no build up of cows occurred in those sort pens or alleys. Only the largest farm sorted so many cows that it was not practically possible or necessary to sort even more cows.

The data logger that was used for time registrations is called PASS (Parlour Analysis Simulation System). PASS data logger and the computer program that comes with it are developed for analysing working routines in milking parlours. The equipment was developed by L. Jones from Cornell University, Ithaca, NY, USA (Jakobsson, 2000) and later modified by DeLaval AB. With PASS it is possible to register twelve different *events*, ten different *sides* and optional also nine different *operators*. In this time study only the two events *enter* and *exit* were used in combination with the sides *1* or *2* (table 7). Time was recorded in seconds.

Table 7. Definitions of the different time study events registered on PASS

Event	Side	Definition
Enter	1	Cow that is not to be sorted is registered by cow-ID and cow number is visible on the Sort Gate Control panel.
Exit	1	Cow that is not sorted passed the whole sort gate.
Enter	2	Cow that is to be sorted is registered by cow-ID, cow number is visible and a red lamp flashes on the Sort Gate Control panel.
Exit	2	The sorted cow has passed the sort gate and the saloon gates opens.

Registration of events that occurred during the time studies and that might have affected the cows in connection with sorting was noted.

ALPRO is DeLaval's herd management tool (DeLaval, 2009). After each time registration session on the farms the ALPRO database backup for the current day was collected from a PC with ALPRO Windows software connected to the ALPRO processor. The ALPRO data shows, among other things, data concerning time (in hours and minutes) when sorted cows was registered in the cow-ID on the sort gate, sorting direction and cause of sorting.

Formulas for calculating sort gate capacity

The aim of this thesis was to improve the present calculation model that DeLaval was using to estimate the capacity of the sort gate. The model that is used today is called formula 1 in this paper. See figure 8 for a principle sketch that describes the variables "D" and "Pen 1-4" in the calculation formulas.

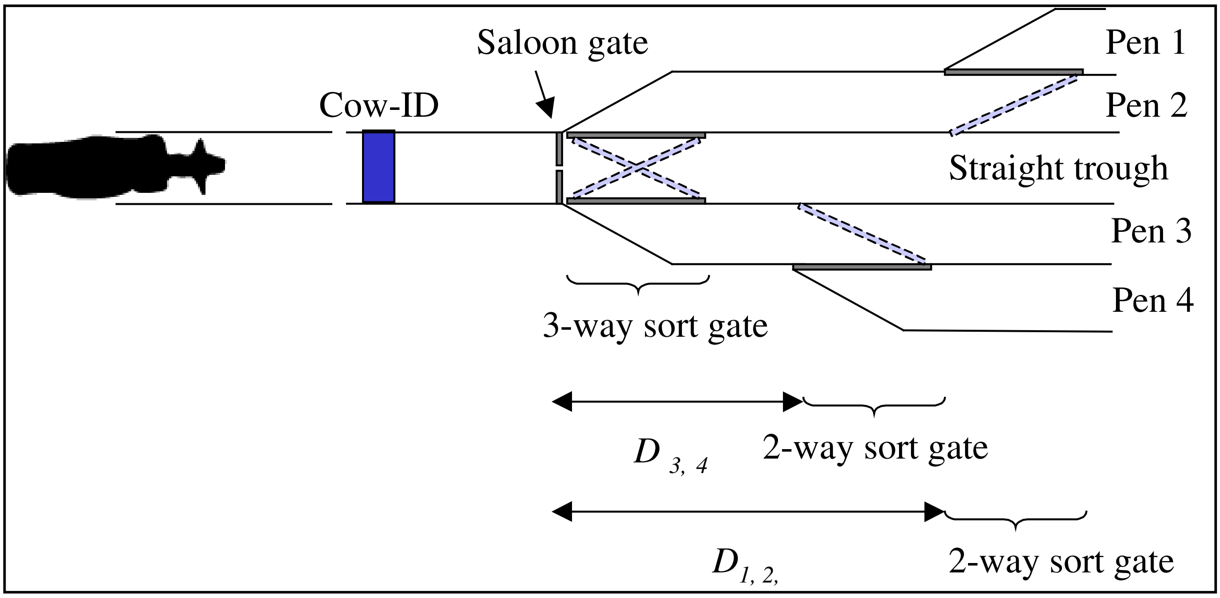

Figure 8. Principal sketch of DSG10 sort gate system.

The milking parlour capacity (milked cows/hour) has to be less than the sort gate capacity (sorted cows/hour) in order to avoid queues in front of the sort gate.

Formula 1

Number of milking cows to sort = Parlour capacity (cows/h) / number of DSG10 used at a time

Unsorted cows per saloon gate and hour = Milk cows sort – N_1 – N_2 – N_3 – N_4

Sort time per gate = (D_1 * W * Pen_1 * Ts * N_1) + (D_2 * W * Pen_2 * Ts * N_2) + (D_3 * W * Pen_3 * Ts * N_3) + (D_4 * W * Pen_4 * Ts * N_4)

D = Distance from Saloon gate to Sort gate (m) 1-4
W = Walking speed of cows (3 s/m) (inverted)
Pen 1-4 (0 if the gate/pen is not in use or 1 if the gate/pen is in use)
Ts = Time for sorted cow to pass sort gate (10 s)
N = Number of cows that is to be sorted to pen 1-4 per hour

Straight time per gate (s) = Number of unsorted cows per saloon gate and hour * Tu

Tu = Time for unsorted cow to pass sort gate (7 s)

Capacity per gate = (Sort time per gate + Straight time per gate)/3600

Capacity per gate is the critical parameter that shows if there is enough sort gates on the planned farm. If "Capacity per gate" is over 1 the capacity is not enough for the planned number of animals and the planned number of sorted animals.

Formula 2 is a combination of an older capacity calculation formula from DeLaval (Forss Jannes, 2009) and formula 1. The parts that differ from the formula 1 is presented below.

Formula 2

Sort time per gate = ((D_1 * W * Pen_1 * N_1) + (Ts * Pen_1 * N_1)) + ((D_2 * W * Pen_2 * N_2) + (Ts * Pen_2 * N_2)) + ((D_3 * W * Pen_3 * N_3) + (Ts * Pen_3 * N_3)) + ((D_4 * W * Pen_4 * N_4) + (Ts * Pen_4 * N_4))

Formula 3 is based on formula 2, but the estimated constants (walking speed of cows, time for sorted cow to pass sort gate and time for unsorted cow to pass sort gate) are exchanged to values obtained from the time study results. The parts that differ from formula 1 and 2 is presented below.

Formula 3

W = Walking speed of cows (inverted)
Ts = Time for sorted cow to pass sort gate
Tu = Time for unsorted cow to pass sort gate

In formula 4 the actual number of lame cows in the herds were included. See table 11 for the approximate percentage of cows in each herd that were lame (since farm 3 had a "big problem" with lameness the approximate percentage of lame cows were set to 40%). The time for unsorted cows to pass the sort gate was lowered at the same time as an extra time for lame cows was added to the formula.

Formula 4

Tu = Time for unsorted cow to pass sort gate
Tl = Extra time for lame cow to pass sort gate

Capacity per gate = ((Sort time per gate + Straight time per gate) +(Number of lame cows * Tl))/3600

Capacity formula 5 is calculated from the data collected during the time registrations and based on formula 3. This formula is thought to give the capacities closes to the "true" capacity on each studied farm. The parts that differ from the formula 3 are presented below.

Formula 5

Parlour capacity = actual number of milked cows during the time of the time registrations (instead of theoretical and average number of milked cows per hour).

D = 0,1 meters on all the studied farms
N = actual number of sorted cows during the time of the time registrations to each pen (instead of estimated number of sorted cows per hour).

Analysis of data

This study was a non-experimental one where data have been collected as time registrations, measurements and interviews without any attempt of trying to alter the conditions for the cows. It is not as easy to determine the cause of differences between groups in a non-experimental study in relation to an experimental one (Olsson *et al.,* 2005).

The data from the time registrations were presented on different levels: all time registrations together, per farm, per time registration occasion and when possible also per group of cows.

All data were presented as mean value (average), median value and average value for the 95% fastest moving cows. The reason for using median values was that the data consisted of some "outliers". Looking at the averages for the 95% fastest moving cows was another way of reducing the effect of "outliers", assuming that the walking speed from the 5% slowest moving cows were occasional divergences. In the calculations for walking speed, in the scatter plots and box plots the median values were used.

Calculations on how the variable time was related to the variables percentage of sorted cows or parlour capacity (cows/hour) was showed in scatter plots. Simple linear regressions were also presented (called linear trend line). The variables were median values per registration occasion.

Effects of different parameters were analysed by dividing cows in groups and presenting the data as box plots. Box plots are a good way of analysing data when making comparisons between several groups (Olsson *et al.*, 2005). In the box plots median value, first and third quartile, minimum value and sometimes also maximum value were shown.

Bar charts have been used to compare the different formulas used to estimate sort gate capacities.

All statistical analyses and calculations were carried out with Microsoft Office Excel 97.

Results

Conditions on farms

The farms differed in size, from 260 to 3000 milking cows, and milking capacities varied from 70 up to 400 cows per hour. Still all farms were using one DSG10 at a time. A summary of the conditions at each farm is given in table 8. Farm 4 had the largest number of cows, the highest milking parlour capacity and was using the sort gate to a large extent. The smallest number of animals and also the lowest capacity in the parlour was found on farm 2. Farm 1 and 3 had about the same number of milking cows and parlour capacity but farm 1 had a rotary which means that the cows were walking from the parlour to the sort gate in an evenly distributed flow. Farm 2, 3 and 4 all had parlours that the cows exits in a more batch-like way. This results in that the cows were entering the area with the sort gate in batches part of the time and other times the sort gate can be empty on cows.

Three of the farms used the sort gate for most treatments and let the cows pass it at least once a day. Farm 3 used its sort gate least frequently of all farms. Farm 1 had used the DSG10 for the longest period of time and had a different configuration of the DSG10 compared to the other farms. This results in the different distance from ID and pass the sort gate (table 8). Farm 4 had the DSG10 installed in 2008 but had been using a different model of sort gate since 1993.

Table 8. Summary of the farms

	Farm 1	Farm 2	Farm 3	Farm 4
No of cows milked (ALPRO)	1005	260	1005	2970
Parlour capacity (cows/h)	200	70	155	400
Parlour	Rotary 60pl	2x10 herringbone	2x20 parallel	2x52 parallel
DSG10 since	2005 Feb	2007 June	2008 Oct	2008 Aug
Approx. no of sortings/cow & year	9	9	3	10
No of times a cow pass sort gate/week	21	7	Max 4	7
Distance from ID to pass the sort gate (m)	6,00	6,33	6,33	6,33
Average % of cows sorted during time registrations	5	30	17	19

Events in connection to sorting

Events that might have affected the cows in connection with sorting were registered during the time studies, like animal keepers interaction with cows. Unusual events like cows backing out of sort gate, cows walking so fast that the sort gate did not manage to stop them for sorting and cows that was standing still for a very long period of time was also noted.

Farm 1

On farm 1 there was the occasional total stop at the sort gate, caused by cows that did not move out of the sort gate. On each occasion it took about ten minutes before the stop was detected by the milkers at the rotary. Then one of the milkers or the person moving cows from barns to the holding area had to go and make the cows move.

On farm 1 and 2 the animal keepers found that it was hard to get a good cow flow when foot baths were placed in the sort gate or in close proximity to the sort gate.

Farm 3

The animal keepers regularly had to encourage some cows to move forward in the sort gate so that they did not back out of it. The noise from both the hydraulic cylinders and the gates in the sort gate was thought to make the cows back out. The animal keepers had also seen that many cows stopped just before the one-way gate (placed just after the sort gate for cows that were to be sorted straight ahead) because they likely did not understand that it was a gate possible to pass. This led to a total stop in the sort gate and someone had to go to the gate and make the cow pass the one-way gate. The animal keepers passed the sort gate frequently, and could then encourage the cows to move, resulting in the milkers not normally noticing the stops at the sort gate.

Farm 4

On the fourth farm there were always two or more animal keepers in the treatment area when sorting. The animal keepers conducted treatments on the sorted cows, but had also an eye on the cow flow at the sort gates and encouraged slow moving cows now and then to move on. According to the herd manager it took about four to five days for the fresh cows in first lactation to get used to the sort gates.

On farm 4 the cows often walked through the sort gate in a “cow-train” kind of way; the cows walked so close to each other that they often rested their head on the back of the cow in front of them. On the farm they experienced that the sort gate missed to sort 6-8% of the cows that were supposed to be sorted. During the time registrations it was observed on a few occasions that, when a cow that was to be sorted walked through the sort gate system the saloon gates closed on the cow’s brisket, and then she was stuck for some seconds before the saloon gate opened and she could continue to walk through. When the cow was stuck in the saloon gate it was not possible for the sort gates to change position and therefore the cow that was supposed to be sorted was not sorted. This occurred when cows was walking fast and close to each other.

Time to pass sort gate

It takes longer time for sorted cows to pass the sort gate than for unsorted cows, as is shown in table 9 and figures 9-10. The saloon gates on farm 2, 3 and 4 halted the sorted cow while the sort gates were getting in position, and on all farms the saloon gates halted the cows behind the sorted cow until the sorted cow had passed the sort gate.

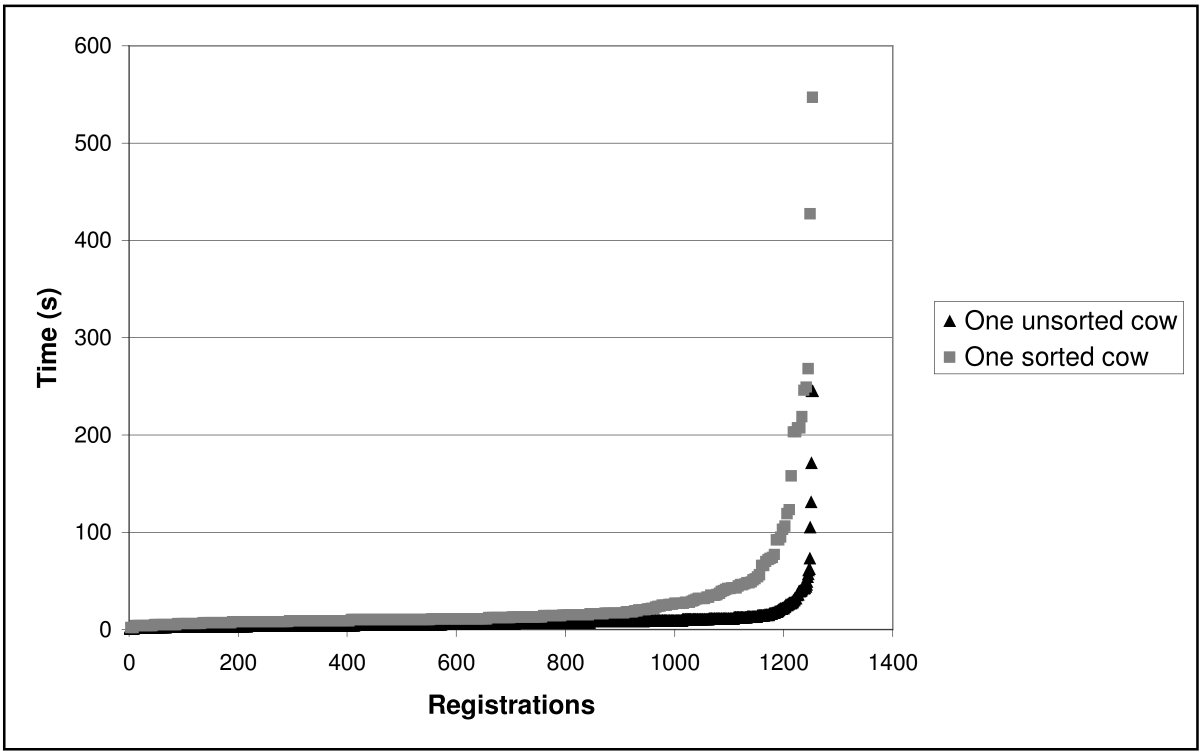

Figure 9. Every dot in the diagram represents a time registration made for one cow on one occasion (on the x-axis) and how long time (s) it took this cow to pass the sort gate (on the y-axis). Data from all four farms are collected here in the same diagram.

Table 9. Time (in seconds) for cows to pass the sort gate per farm and on average

		Farm 1	Farm 2	Farm 3	Farm 4	**All registrations**
Unsorted	Average	8	10	10	8	**8**
	Median	5	6	7	8	**6**
	Average 95%*	5,8	6,2	7,1	7,8	**6,3**
Sorted	Average	32	27	40	15	**26,5**
	Median	10	13	17	10	**11**
	Average 95%*	17,5	18,6	23,8	15,3	**16,6**
Number of time registrations	Unsorted	747	100	143	263	**1253**
	Sorted	77	56	77	113	**323**

** = Average time for the 95% fastest cows.*

Almost four times as many time registrations were collected from unsorted cows than from sorted cows. The number of time registrations for sorted and unsorted cows were not the same as the actual number of sorted and unsorted cows that passed the sort gate. In table 9 the number of time registrations are shown. But when calculating the percentage of sorted cows out of the total number of cows (table 11), data from ALPRO (the actual number of milked cows and actual number of sorted cows during the time when the time registrations were conducted) were used.

A few cows walked very slowly through the sort gate in comparison to the majority of the cows. Therefore the average time for cows to pass the sort gate differs quite substantially from the median time for cows to pass the sort gate, see table 9. When taking the average time for the 95% of the fastest cows to pass the sort gate that time was closer to the median time than to the average time. The 5% of the slowest passing cows can be considered "outliers". All registered times on all farms are visualised in figure 9.

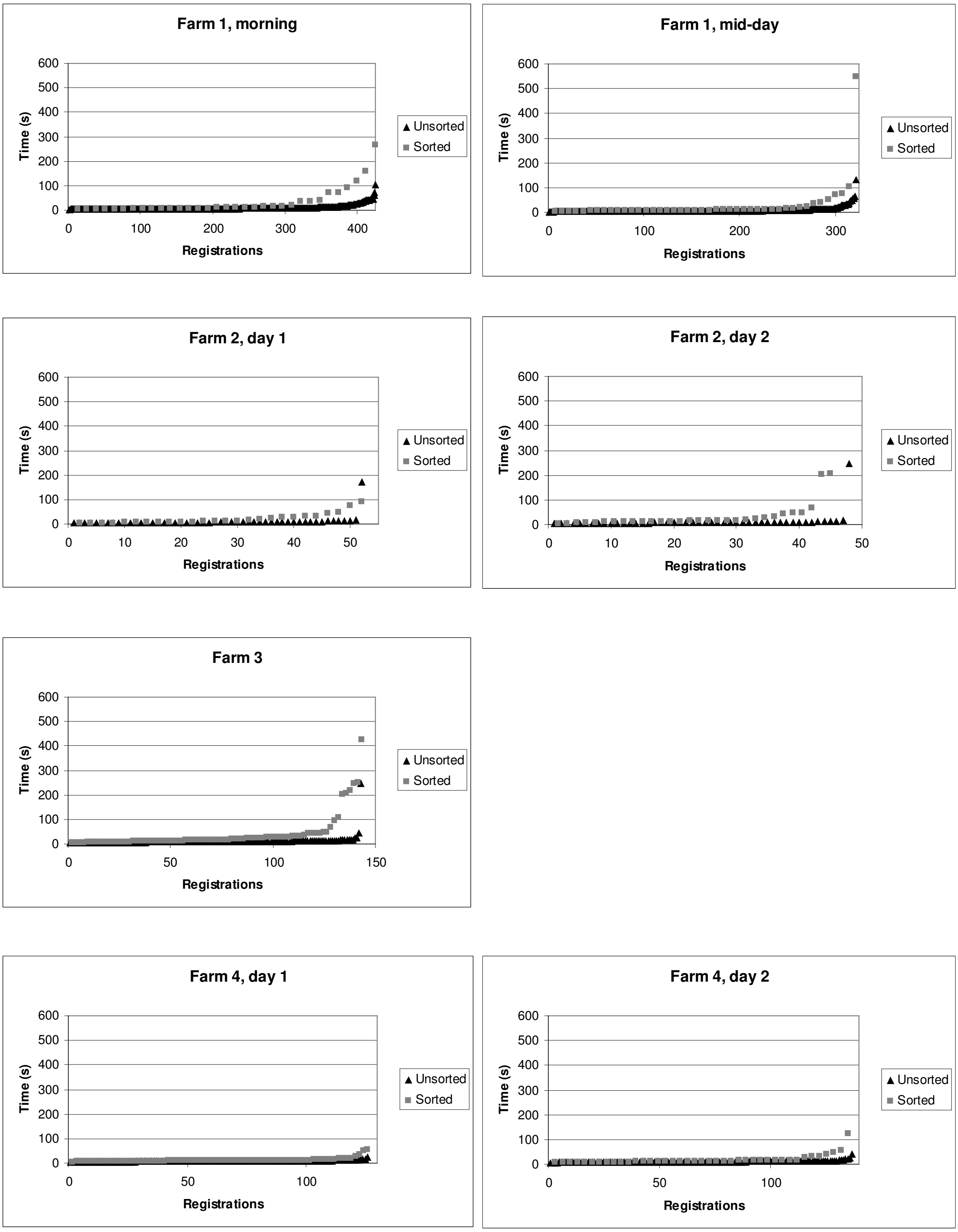

Figure 10. Time registrations per registration occasion.

When comparing the results from different farms in figure 10 it can be seen that farm 4 differs from the other by having very low maximum times. Furthermore the difference between average time, median time and the average time for the 95% of the fastest moving cows were not as big as for the other three farms (table 9). Farm 4 has the smallest difference in times for unsorted and sorted cows. When comparing the times for sorted cows on farm 4 with the other farms, farm 4 have the fastest moving cows.

On farm 1 during mid-day milking one sorted cow had a sorting time that was far longer than the rest. This cow stood still in the sort gate for more than 9 minutes (547 seconds) and did not move until an animal keeper came to the sort gate and opened the sort pen that was full of sorted cows at the time. But even when no sort pen had been filled to capacity with cows it can be seen in figure 10 that some cows were standing still in the sort gate for more than 200 seconds (over 3 minutes) before either being encouraged by an animal keeper to move or before deciding to walk on.

The difference between the three ways of calculating the time it takes for a cow to pass the sort gate were not as big for unsorted as for sorted cows, table 9. For unsorted cows the times varies between 5 and 10 seconds. Sorted cows on the other hand have time estimations ranging from 10 to 40 seconds. Farm 4 had the longest median time for unsorted cows to pass the sort gate (8 seconds) and the longest average time for the 95% fastest cows (7,8 seconds), while both farm 2 and 3 have the longest average time (10 seconds). Farm 1 had the shortest times for all three different ways of estimating time for unsorted cows to pass the sort gate.

The estimated time to sort one cow differs quite a lot between average, median and average for the 95% fastest cows, as can be seen in table 9. Farm 3 had the longest time for sorted cows irrespective of way of calculating and farm 4 have the shortest times. In table 8 it can be seen that farm 3 uses the sort gate the least frequent of the four farms and that farm 4 have the biggest herd and highest milking parlour capacity.

Walking speed of cows

Unsorted cows walked faster than cows that were sorted. The walking speeds in table 11 are based on the distance that a cow walks to pass the sort gate system and the median time it took a cow to pass the sort gate system The sorted cows had a median walking speed of between 0,37 to 0,63 m/s and the unsorted cows were walking with a speed of 0,79 to 1,20 m/s. It should be mentioned that sorted cows on farms 2, 3 and 4 were halted by the saloon gate for some seconds when the sort gate changed position.

Table 11. Walking speed of cows in m/s based on median values and percentage of lame cows

	Farm 1	Farm 2	Farm 3	Farm 4
Unsorted	1,20	1,06	0,90	0,79
Sorted	0,60	0,49	0,37	0,63
Lame cows on farm (%) approximately	5	5-10	”big problem”	15

Farm 1 had the fastest median walking speed for unsorted cows and also the lowest percentage of lame cows in the herd. Farm 2 had the next fastest walking speed for unsorted cows and the next lowest share of lame cows. Farm 4 had the slowest walking speed for unsorted cows and approximately 15% of the cows in that herd were lame. On the other hand, farm 4 had the fastest walking speed for sorted cows. Farm 3 had “big problems” with lame cows and had quite low walking speeds for both sorted and unsorted cows.

Percentage of cows that are sorted

The higher percentage of cows that were sorted, the longer time it seem to take for all cows to pass the sort gate. This is illustrated in figure 11. When making a trend line for sorted and unsorted cows together the line get the function y = 0,084x + 7,4 (R^2 = 0,06). That means that the time for a cow to pass the sort gate when no cows were sorted was about 7,4 seconds, and for every increase in percentage point for sorted cows the time to pass the sort gate for each cow will on average be increased with 0,084 seconds.

When looking at the functions for the separate trend lines for sorted and unsorted cows in figure 11 the line was steeper for the sorted cows than for the unsorted cows, which means that the time for sorted cows to pass the sort gate was more affected by the percentage of cows to be sorted. But the triangle point of 17 seconds to pass DSG10 and with 17% of the cows being sorted might be considered as an outlier. If that point is excluded the trend line for sorted cows will get the function y = 0,121x + 8,6 (R^2 = 0,69), which is an even steeper line than the one in figure 11.

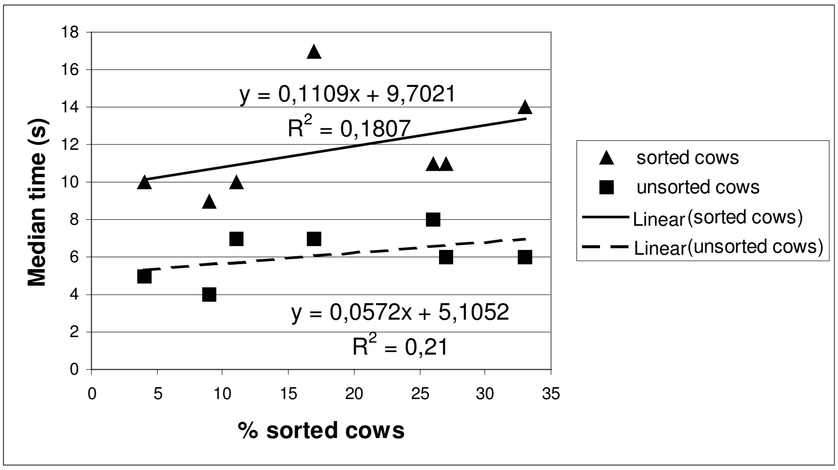

Figure 11. Median times per registration occasion (two occasions for farm 1, 2 and 4; one occasion for farm 3) for cows to pass the sort gate in correlation to the percentage of sorted cows out of the total number of cows passing the sort gate.

Parlour capacity

It seems that the passing time for sorted cows were lowered with increasing milking parlour capacity (milked cows per hour), while the time for unsorted cows to pass were longer the higher the parlour capacity on the farm (figure 12). If the point at 17 seconds median time and parlour capacity of 155 is considered as an outlier the trend line for sorted cows get the function y = -0,005 + 12,0 (R^2 = 0,20). For parlour capacities on each farm see table 8.

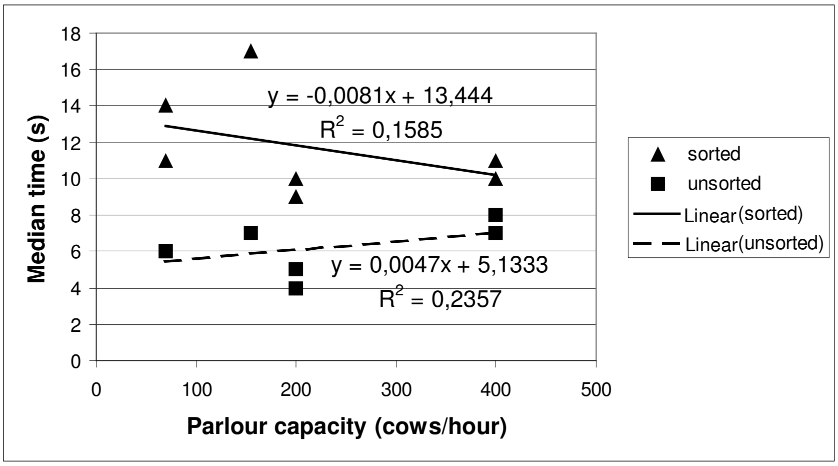

Figure 12. Median times per registration occasion for cows to pass the sort gate in correlation to the milking parlour capacity (cows per hour).

Differences between groups on farm

On farm 1 and 4 it was possible to correlate time registrations with different groups of cows that passed the sort gate. On farm 1 the groups were well defined. The groups on farm 4 were not defined in any distinct way. On farm 2 only one separate group was observed (late lactation group). On farm 3 it was not possible to correlate time registrations with group belonging. Only unsorted cows were compared because there were too few observations of the sorted cows.

Farm 1

On farm 1 it was clear that the lame cow group was walking slower than all the other groups. Only minor differences were also possible to see between the other groups. In figure 13 and 14 the time registrations for different groups observed on farm 1 are shown.

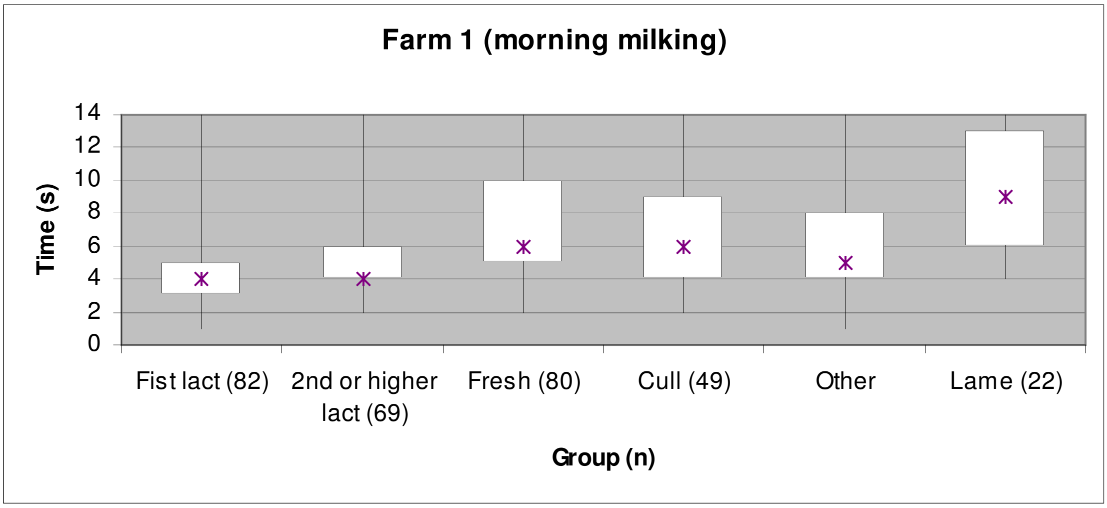

Figure 13. Box plot for the time it took unsorted cows on farm 1 during morning milking to pass the sort gate (maximum values are not visible).

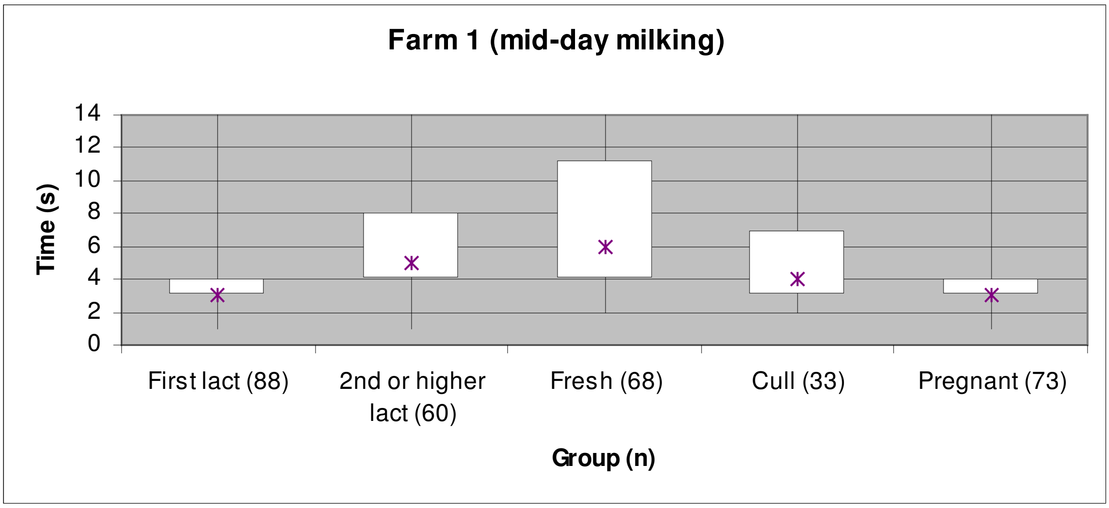

Figure 14. Box plot for the time it took unsorted cows on farm 1 during mid-day milking to pass the sort gate (maximum values are not visible).

For unsorted cows in the lame group it took in median 9 seconds to pass the sort gate (figure 13), and for the all the other groups it took between 3 and 6 seconds to pass the sort gate (average of 5 seconds for all groups together but the lame group).

The group with pregnant cows (on average 134 days in pregnancy, ranging between 56 and 235 days) were only observed during mid-day milking and they had a median time for passing the sort gate of 3 seconds. The fresh cows on farm 1 were between 3 and 80 days in milk (DIM), with an average on approximately 25 DIM. The reasons for allocating cows to the "udder problem" group, i.e. high somatic cell count (SCC) and mastitis, does not seem to affect walking speed.

Farm 4

There were not any clear differences between the groups on farm 4. All groups walk faster during day 1 than during day 2 (figure 15 & 16). A larger proportion of cows were sorted during day 2 (26%) than during day 1 (11%).

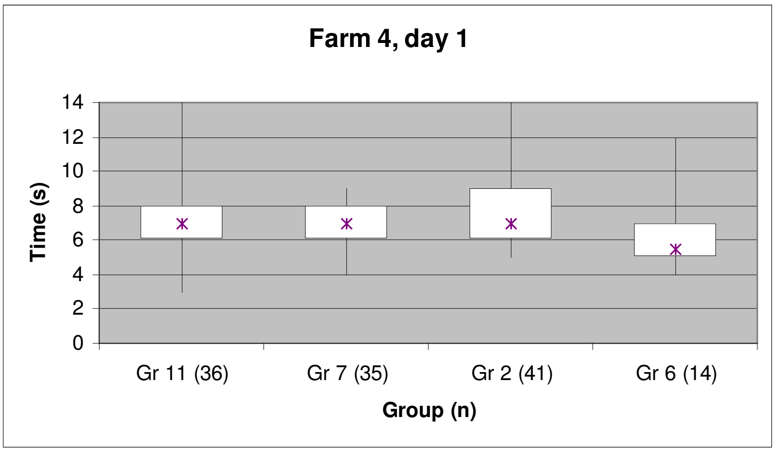

Figure 15. Box plot for the time it took unsorted cows on farm 4, day 1 to pass the sort gate (maximum values are not visible for most groups).

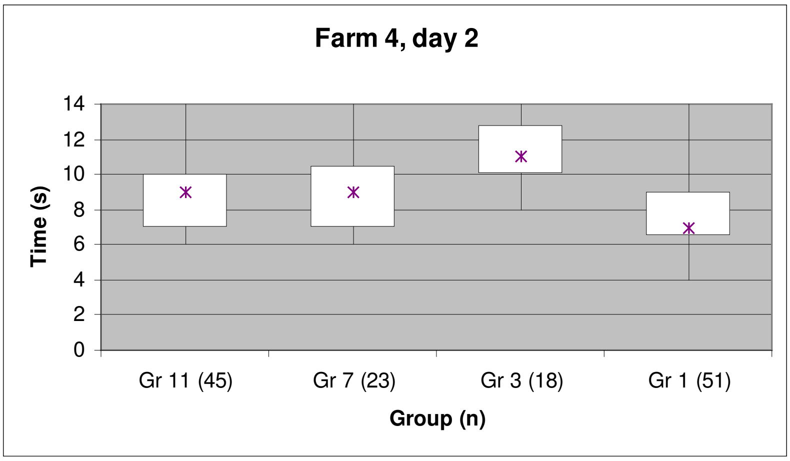

Figure 16. Box plot for the time it took unsorted cows on farm 4, day 2 to pass the sort gate (maximum values are not visible).

Calculating sort gate capacity

Formula 3 and 4 have values obtained from the time study results. The estimated walking speed of cows in formula 1 and 2 of 0,33 m/s (3 s/m) were in formula 3 and 4 replaced with the median walking speed of unsorted cows of about 1 m/s (1 s/m) (table 11). The estimated time for unsorted cows to pass sort gate was exchanged from 7 seconds in formula 1 and 2 to the median time for unsorted cows to pass the sort gate of 6 seconds (table 9) in formula 3. In formula 1 and 2 the estimated time for sorted cows to pass the sort gate was 10 seconds and in formula 3 and 4 the time 17 seconds (average time for the 95% fastest moving cows) from table 9 is used. The values that were used in formula 3 is presented below.

Formula 3

W = Walking speed of cows (inverted) (1 s/m)
Ts = Time for sorted cow to pass sort gate (17 s)
Tu = Time for unsorted cow to pass sort gate (6 s)

When looking at farm 1 during morning-milking the group with lame cows had longer times (median of 9 seconds) to pass the sort gate in comparison to all the other groups (median of 5 seconds). The time for unsorted cows to pass the sort gate was in formula 4 reduced from 6 to 5 seconds and an extra time for every lame cow of 4 seconds (9 - 5 = 4) to pass the sort gate was included. The parts that differ from formula 3 are presented below.

Formula 4

Tu = Time for unsorted cow to pass sort gate (5 s)
Tl = Extra time for lame cow to pass sort gate (4 s)

Comparing different ways of calculating sort gate capacity

The five formulas used for estimating sort gate capacity gave different estimations. A comparison of the different ways of calculating sort gate capacity can be seen in figure 17. It is assumed that the formula 5 way of calculating capacity was closest to the "true" or real capacity on the farms because the observed data was included. From figure 17 it can also be seen that formula 4 gives capacities closest to the ones obtained by formula 5. But on farm 2 formula 2 actually gave the capacity estimation closest to the "true" formula 5. Formula 1, the one that is used today, was the one that gave the most divergent estimation of the capacity from the estimation with collected data.

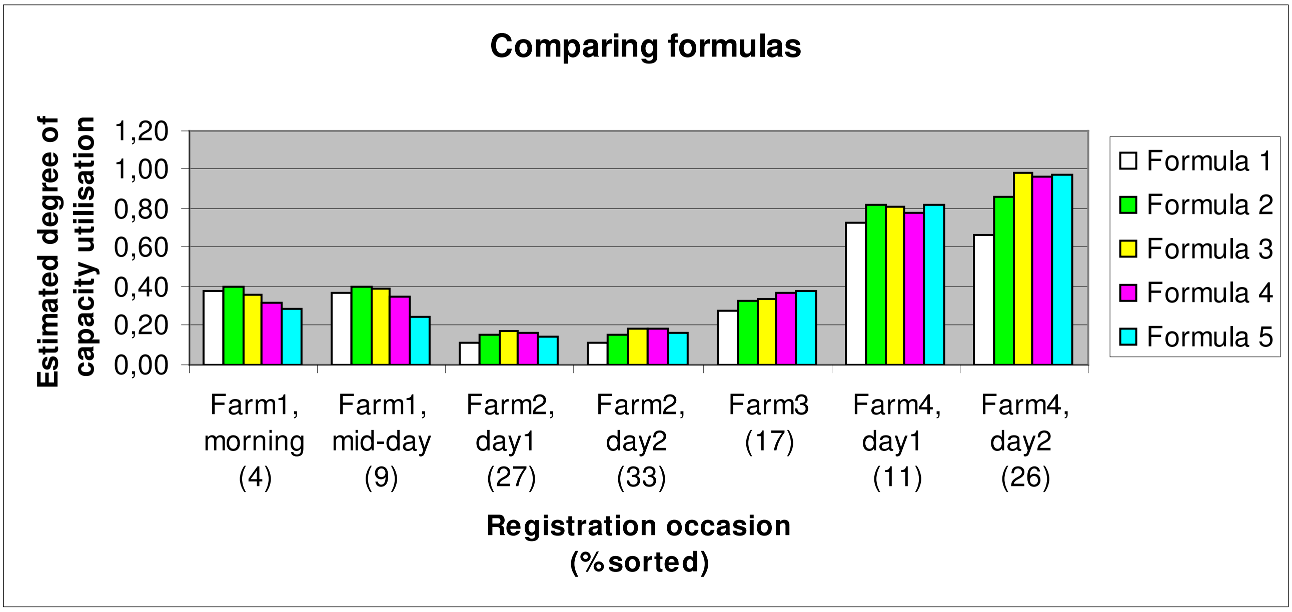

Figure 17. A comparison of the five different ways of calculating estimated degree of sort gate capacity utilisation.

Calculation examples of capacities on larger farms

To see where the limits are for when one, two or three sort gate systems are needed and to compare the different formulas to each other, three calculation examples were made.

Example 1

The first example is for a farm milking 2000 cows three times a day in a 70 milking places parallel rotary, with a parlour capacity of 427 cows per hour. Approximately 10% of the cows are lame. In this example a maximum of 20% of the cows are sorted, distributed as follows; 5% of the cows to pen 1, 10% of the cows to pen 2 and 5% of the cows to pen 3. The distance from the saloon gate to the second sort gate for pen 1 and 2 is 3 meters (see figure 18). In figure 19 the capacities from formula 1-4 are shown. Formula 1 gives much higher values than formula 2-4. Since capacities ranging between 1,01-2,00 need two sort gates and capacities between 2,01-3,00 need three sort gates, formula 2-4 indicates that this farm need two sort gate systems like the one in figure 18, and formula 1 say that this farm need three sort gate systems working at the same time.

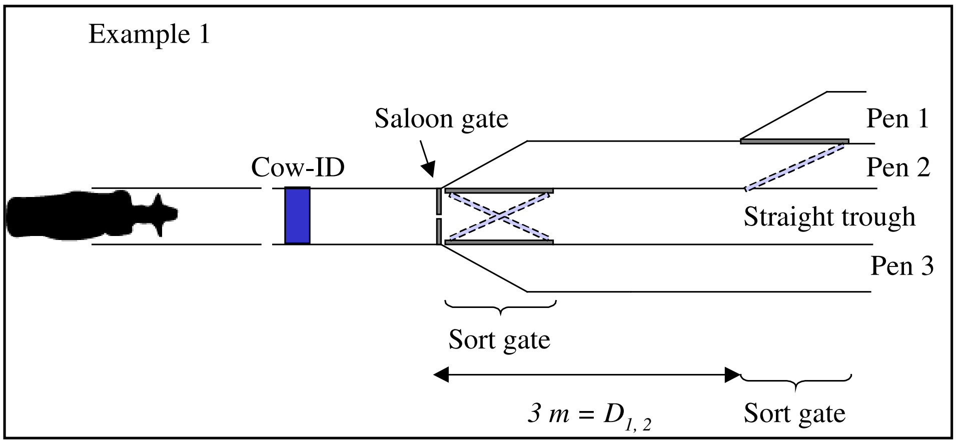

Figure 18. Sketch over the sort gate system in example 1.

Milk cows sort = 427
Number of DSG10 used at a time = 1
D_1 = 3 m D_2 = 3 m D_3 = 0,1 m
Pen_1 = 1 Pen_2 = 1 Pen_3 = 1 Pen_4 = 0 Pen_5 = 0
N_1 = 21 N_2 = 43 N_3 = 21
Number of lame cows = 43

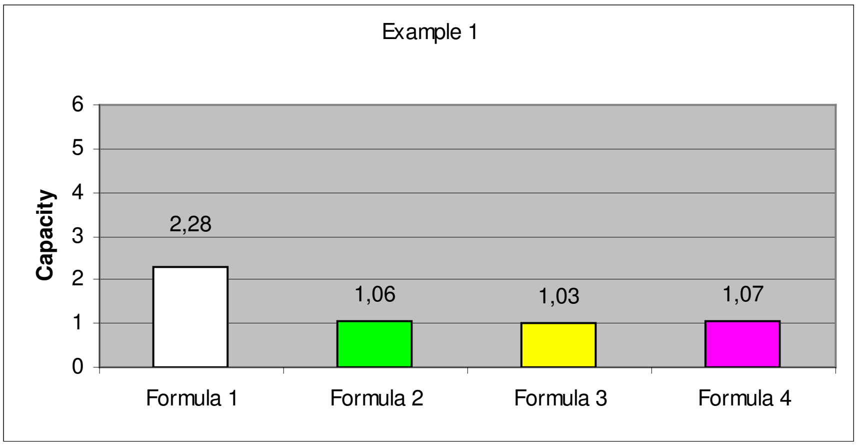

Figure 19. Comparison of the capacity formulas for example 1.

Example 2

This example is based on farm 4, but with only one ID-unit for each 5-way sort gate. Figure 20 gives an illustration over the sort gate system in example 2. In this example the farms sorts maximum 25% of the herd (5% of the cows are sorted to pen 1, 10% to pen 2, 5% to pen 3 and 5% to pen 4). The distance from the saloon gate to the second sort gate is 6,9 meters, and from the saloon gate to the third sort gate the distance is 8,4 meters.

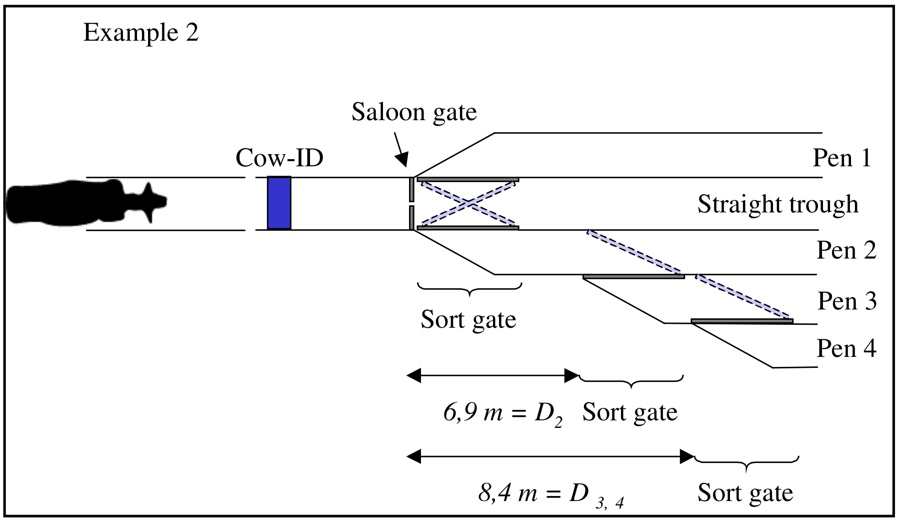

Figure 20. Sketch over the sort gate system in example 2.

Milk cows sort = 400
Number of DSG10 used at a time = 1

D_1 = 0,1 m	D_2 = 6,9 m	D_3 = 8,4 m	D_4 = 8,4 m	
Pen_1 = 1	Pen_2 = 1	Pen_3 = 1	Pen_4 = 0	Pen_5 = 0
N_1 = 20	N_2 = 40	N_3 = 20	N_4 = 20	

Number of lame cows = 60

The calculated capacities are compared in figure 21, and it can be seen that formula 1 give even more divergent values from the other formulas the longer the distances are between saloon gate and sort gates (compare with figure 20 in Example 1). According to formula 2-4 the farm would, in this example need to use two sort gates at a time, but according to formula 1 they would need six sort gate systems like the one in figure 20 working at a time.

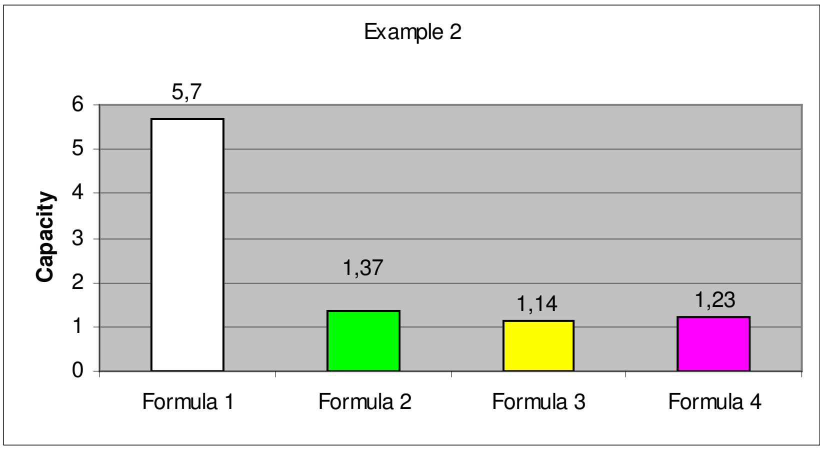

Figure 21. Comparison of the capacity formulas for example 2.

Example 3

This example is based on example 1, with the same layout for the sort gate system (figure 18). The only difference is that the parlour capacity is increased to 855 cows/hour. Formula 2 and 3 indicates that a farm with these conditions need three sort gate systems working at a time, and formula 4 is also close to the break-point of needing three sort gate systems. See figure 22 for the different capacities attained from formulas 1-4.

Milk cows sort = 855
Number of DSG10 used at a time = 1
D_1 = 3 m D_2 = 3 m D_3 = 0,1 m
Pen_1 = 1 Pen_2 = 1 Pen_3 = 1 Pen_4 = 0 Pen_5 = 0
N_1 = 43 N_2 = 85 N_3 = 43
Number of lame cows = 85

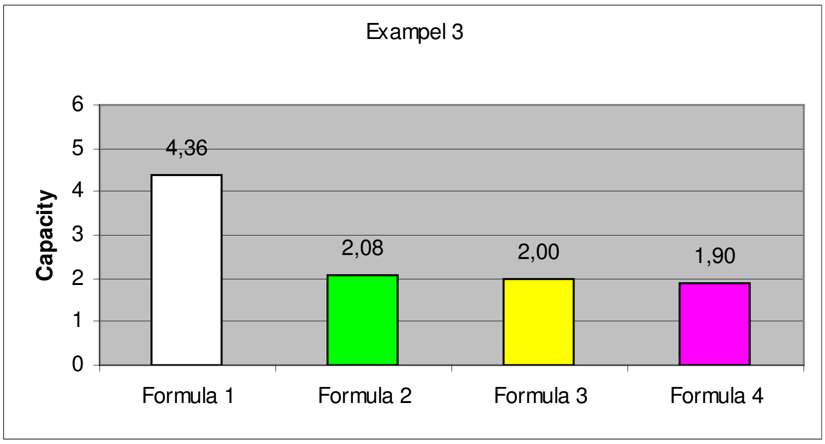

Figure 22. Comparison of the capacity formulas for example 3.

If using a three-way DSG10 sort gate and sorting maximum 20% of the herd the parlour capacity need to exceed about 940 (formula 2), 860 (formula 3) or 875 (formula 4) cows per hour to make it necessary to use three sort gates at a time.

Discussion

Capacity formula

This study has not been able to study all parts of the sort gate capacity formula. For example it was not possible to study farms with distances between saloon gate and a second two-way sort gate with one ID-unit. At farm 4 they did have 5-way sorting, but there they used two separate ID-units which most probably increased the capacity of the total sort gate system. Therefore the part of the formula considering distance between saloon gate and a two-way gate has not been tested here. Neither have a system with more than one DSG10 working at a time been studied. On farm 4 they had two DSG10's, but used only one at a time. Still it can be assumed that the distance part of the formulas and the estimation of number of sort gate systems that needs to be used at a time are in theory correct as walking speed of cows was investigated and because farm 4 was on the limit of needing to use more than one sort gate at a time.

The results from formula 1 differ a lot from the other formulas. This study confirms the hypothesis that formula 1 gave incorrect capacities. The longer the distance inside a sort gate system, the more variable the results from formula 1 in comparison to the other formulas. Probably it was a typing error when taking formula 2 from an Excel-file to a planning program that gave rise to formula 1. The old DeLaval formula (formula 2) with estimated walking speed of 3 m/s and estimated time for sorting of 10 seconds was showing similar results as formula 3 (with walking speed of 1 m/s and time for sorting of 17 seconds). It seems as if the slower walking speed and shorter time for sorting in formula 2 was mostly cancelled out by the faster walking speed and longer time for sorting in formula 3. In formula 4 where the time for unsorted cows to pass the sort gate was a bit lower but extra time for each lame cow was added, the sort gate capacity seem to show similar results to formula 2 and 3 on farms that do not have extremely high numbers of lame cows.

Formula 2, 3 and 4 were all showing similar results to formula 5. Formula 5 is thought to show results as close to the real capacity as possibly from the data available in this study. When comparing the different formulas (figure 17) it can be concluded that formula 1 differs the most from formula 5 on average, and that formula 4 was the one that shows the results closest to formula 5 most of the time. However, formula 4 can sometimes be tricky to use since it can be hard to get correct estimations on the percentage of lame cows in a future herd, as the capacity formula will be used during the planning process of farms. The formula giving the next closest estimations to formula 5 was formula 3.

Approximate numbers on parlour capacities for one, two or three sort gate systems working at a time can be indicated from the results from the studied farms and from the calculation examples. It seems like one sort gate is enough when milking less than 350-400 cows/h and two sort gates would be needed for parlour capacities up to 800-850 cows per hour. Such high parlour capacities of 800 cows/h or more will probably never come into question as that would demand about 150 milking places in a parlour (Forss Jannes, 2009). These approximations are not applicable on farms that sort a very large part of the herd, have very long distances between the first sort gate and other sort gates in the same system (same ID-unit) or that have huge problems like lameness, which decreases the cow's mobility. Then the parlour capacities for the number of sort gate systems will be decreased.

Walking speed

The well defined groups on farm 1 made it possible to compare lame and non-lame cows, young and older cows, and cows before and after calving (figure 13 & 14).

Lameness

Many studies have shown that lame cows walk slower than non-lame cows (table 4). The difference in walking speed between lame and non-lame cows is greater after milking than before (Flower *et al.*, 2006). This agrees with the results from farm 1 where the cows in group "Lame" had a median time to pass the sort gate of 9 seconds, which was about 4 seconds longer than the rest of the groups (figure 13). The claw health differs a lot between farms (Manske *et al.*, 2002; Cook 2003) and therefore it can be useful to have the opportunity to take that into consideration when estimating the number of sort gates required on a farm. The scoring system based on Sprecher *et al.* (1997) is an easy way of defying lameness on farms. Formula 4 takes the percentage of lame cows in the herd into consideration when estimating sort gate capacity and this formula seems to give good estimations of sort gate capacity (figure 17). However, in practice it can be hard to predict the number of lame cows on a farm during the planning process.

Age

Schmid *et al.* (2008) observed that heifers walked faster than mature cows and this is also in agreement with the time studies on farm 1 where the group "1st lact" in median took 3 and 4 seconds to pass the sort gate compared to group "2nd or later lact" with median times of 4 and 5 seconds. However, the number of observations and the differences were too small and needs to be further evaluated before age can be incorporated in the capacity formula.

Calving

On farm 1 the cows in group "Fresh" (3 to 80 DIM) passed the sort gate on a median time of 6 seconds both during morning and mid-day milking (figure 13 & 14). The only group having longer times than the group "Fresh" was the group "Lame". These results indicate that cows in early lactation, after calving, were walking slower than other cows with healthy claws. This agrees with the results from Chapinal *et al.* (2009) showing that cows walk faster before than after calving. The difference in walking speed between cows in early and late lactation was not that big, and the number of cows in early lactation is quite constant on farms with an all year round calving pattern, therefore it was not put into the sort gate capacity formulas. It could be considered to use a somewhat slower walking speed and longer times for passing the sort gate when planning to use sort gates on farms with seasonal calving patterns.

Floor surface

The floor surfaces affects walking speed of cows (Phillips & Morris, 2000; Phillips & Morris, 2001a; Jungbluth *et al.,* 2003; Telezhenko & Bergsten, 2005; Flower *et al*., 2007). Probably all different floor surfaces on a dairy farm sums up for the overall claw health which indirectly affects the walking speed of the cows, and the floor surface in a specific part of the farm affects the walking speed of cows in that area. Farm 3 had grooved concrete in all areas, which provides a good grip but the animal keepers experienced that it caused lameness among many cows on the farm. This can be one of the reasons why this farm had slow walking speeds for both sorted and unsorted cows (table 11). The other farms had some areas covered with rubber which probably gives improved claw health. All farms had grooved or slatted concrete floors in the sorting area.

Time to pass sort gates

In the thesis by Mehlqvist (2003), times to pass a 2-way sort gate in an AMS were on average 11 seconds for high ranked cows and 14 seconds for low ranked cows. The median time to pass the sort gate DSG10 in this study was 11 seconds when looking at all time recordings, and the average time for the 95% fastest cows was 17 seconds (table 9). These time results agree quite well with the ones presented by Mehlqvist (2003). The average time for sorted cows to pass the DSG10 was about twice as long (27 seconds). In formulas 3 and 4 the time to sort one cow was estimated to 17 seconds (from table 9) and that seem to give good sort gate capacity estimations (figure 17).

Cows are herd animals (Albright & Arave, 1997) and they are less stressed when together with their herd mates. The reason that it takes a longer time for the sorted cows to pass the sort gate was partly because the cows (on farm 2, 3 and 4) were stopped by a saloon gate for some time before they can enter the sort gate but probably also because sorted cows have to leave the majority of the herd which can make them hesitate to walk on into the sort area. According to Grandin (1980) animal flow is improved when making use of cattle’s tendency to follow the animals in front.

Maximum times

There were only a few cows that lingered in the sort gate for a long period of time (some minutes) as can be seen in figure 9-10. It was most pronounced on farm 1, which had the longest maximum time to pass the sort gate. On farm 1 animal keepers did not pass by the sort gate that often and did not have the possibility to clearly see what was going on inside the sort gate because of solid walls around the DSG10. Farm 4 had the shortest maximum time for passing the sort gate. Here animal keepers conducted treatments close to the sort gate at all times when the sort gate was in use and they encouraged cows to move through the sort gate if stopping. It would not be possible for all farms and for all treatment strategies to always have animal keepers at the sort gate to get the few cows that stand still in the sort gate to move. But it would most certainly improve the total sort gate capacity to have an animal keeper working close to the sort gate, in order to avoid lingering cows.

Percentage of sorted cows in herd

The larger the proportion of the herd that was to be sorted the longer it took for sorted and unsorted cows to pass through the sort gate (figure 11). This was probably caused by the fact that sorted cows were often stopped by the saloon gates. A higher number of cows to be sorted will cause more cows to be stopped by the saloon gates and every stop will result in a reduced sort gate capacity. An unsorted cow might have to wait behind a cow that is to be sorted and that will reduce the walking speed of the unsorted cow.

Parlour capacity

It seems as if milking parlour capacity affects the time it takes for unsorted and sorted cows to pass through the sort gate (figure 12). The higher the parlour capacity (cows/hour) the longer time it takes for unsorted cows and the shorter time it takes for sorted cows to pass the sort gate. Probably parlour capacity do not affect times for unsorted and sorted cows in the way interpreted in figure 12. There was not enough data in this study to give any clear results concerning parlour capacities effect on walking times.

Habit of being sorted

The more accustomed a cow is to being sorted the easier the sorting process will get. It was very clear from this study that farm 4 that sorted cows most frequently also had the shortest sorting time (table 8 and 9). The higher number of times per week that the cows were just passing through the sort gate, without necessarily being sorted, can also affect the time it takes to sort cows in the DSG10. Farm 3 did not only sort cows the least number of times per year, but they let the cows pass the sort gate for a maximum of only 4 times a week (compared to 7-21 time a week on the other farms) and have the longest times for sorting cows.

Cows are curious animals and a change in their environment will in most cases lead to an investigation of the change by the cows (Albright & Arave, 1997). Cows that experience the sort gate and the area to where they get sorted as a new environment would probably take some extra time to investigate it. The person conducting time recordings on the farms was a new object in the cows' environment and on most farms the cows halted for some seconds before entering the sort gate in order to look at the new person. Therefore the times in this study might be somewhat longer than times would have been on a "normal" day. But few cows stopped to look at the new person when inside the DSG10 (where time recordings took place).

It takes about four to five days for cattle to get accustomed to something new, according to both the literature (Schaeffer & Sikes, 1971; Hagen & Broom, 2004) and staff on the studied farms. Even though most cattle can remember things for at least a few weeks (Kovalcik & Kovalcik, 1986; Hagen & Broom, 2003) it was likely not enough to let cows pass the sort gate for a maximum four times a week and to sort them around three times a year. If a sort gate is present it is probably the best strategy to use it as much as possible and not to combine it with other ways of sorting the cows.

Cows being accustomed to pass through the sort gate might also lead to cows walking faster through the sort gate, but that was not confirmed in this study. All four farms had similar times for passing straight through the sort gate (table 9) irrespective of number of times per week that the herd was using the sort gate or number of times per year that a cow was sorted (table 8).

Kilgour (1981) saw that cows had difficulties in learning to move to the right in a maze after having moved to the left several times. Futcher (2009) had an idea that cows may move faster trough the sort gate when letting the unsorted cows walk straight ahead. Farm 1 and 4 let the unsorted cows walk straight ahead in the sort gate (most of the time on farm 4). On farm 2 all unsorted cows walked to the left in the sort gate and on farm 3 unsorted cows either walked to the left or to the right depending on which cow barn they were heading for. When studying the walking speeds in table 11 it was hard to either confirm or dismiss the theory that sort gate capacity was improved when letting unsorted cows walk straight ahead.

Environment in sorting facilities

Cows do not seem to avoid areas with slurry on the floor (Phillips & Morris, 2001b), but for the sake of their claw health and walking speed (Phillips & Morris, 2000) it is better to have clean flooring. Something that cattle seem to avoid is dark areas (Phillips *et al.*, 2000; Phillips & Morris, 2001b). Stookey and Watts (2007) saw that cattle very strongly prefer to move through facilities that were lit compared to dark. Grandin (1980) recommends that shadows and bright light should be avoided because cattle often refuse or hesitate to cross shadows and bright light can dazzle the animals. It would therefore be advisable to ensure that the sort gate system is well lit when in use, both for the sake of animal welfare and for good cow flow.

Placing foot baths in the sort gate is not recommended by DeLaval (2008). Farm 1 and 2 that had foot baths placed in the sort gate experienced an impaired cow flow through the sort gate during the periods when the foot baths were used.

Walls should be solid in sorting facilities so that cattle do not see distractions like other cattle or people (Grandin, 1980). On farm 1 the walls in the sort gate were solid, with some smaller gaps between gates and walls. The cows could also look under the walls since they did not go all the way down to the floor. Nevertheless the solid walls can be one of the reasons why the walking speed was high on farm 1 (table 11).

On farm 3 the unsorted cows going to the left in the sort gate were making a rather sharp (360°) turn which can result in impaired cow flow according to Grandin (1980). The cows sorted straight ahead on farm 3 were making a 90° turn before entering a head lock with solid walls. The fence in the turn was made from bars and was see-through, therefore the cows might experience that turn as a dead end (figure 23) and hesitate to move forward. This might not have an impact on the recorded walking speeds on farm 3 since the 90° turn was placed several meters after the end of the sort gate. But walking speed on farm 3 was low (table 11) and one reason can be the layout in the sorting area, even if habit of being sorted (table 8) and hoof health (table 11) were two more likely reasons.

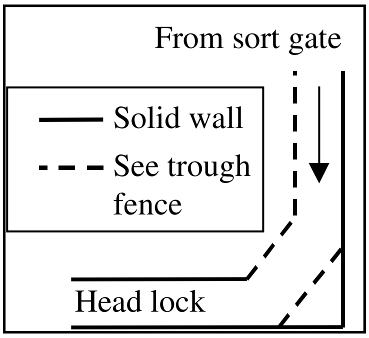

Figure 23. Sketch over 90° turn after sorting on farm 3.

Deprivation of feeding and drinking

The cows probably know that they will get feed on returning to the cow barn, and if sorted it is unclear if they expect to get feed. If the sorted cows do not expect to get feed in the sort area this could make them unwilling to be sorted. None of the farms in this study offered feed in the sort area. Bickert (1998) recommends that sorted cows waiting for more than a few hours should have access to both feed and water. Cows deprived of feed for four hours or more are not able to compensate for this within 41 hours (Cooper *et al.*, 2008). It was only on farm 1 that the cows normally stayed in the sorting area for more than 2 hours (for maximum 5 hours) and therefore this farm probably could gain the most by starting to offer feed in the sort area.

Only farm 2 offered water in the sort area and on farm 1 water bowls was installed but not in use at the time. Cows drink only a few times per day (Andersson, 1987) but since cows prefer to drink just after milking (Osborne *et al.,* 2002; Cardot *et al.*, 2008) when sorting is conducted, providing water in the sort area would most likely improve the wellbeing of the cows and reduce the risk of lowered milk yield due from lack of water.

Wrongly sorted cows

Automatic sort gates saves time and labour but can sometimes result in that the wrong cow is being sorted (Wagner-Storch & Palmer, 2002). The primary purpose of this study was not to investigate when and why the sort gate sorted wrong cows, nevertheless, wrongly sorted cows were observed on farm 4 on a few occasions during the time recordings. Farm 4 mentioned that 6-8% of the cows that were to be sorted were missed by the sort gate. Wagner-Storch & Palmer (2002) saw that sorting of the wrong cow was caused by incorrect identification by the ID-unit or by fast-moving cows following the cow in front of her. The sort gate keeps record of the cows in the sort gate system with photocells and if the cows walk "on" each other, the system might have difficulties to distinguish the cows from one another. Therefore it is likely that the number of wrongly sorted or missed cows increase the closer to the break-point of using two instead of one sort gate system, because then the cows would follow one another closer. Kilgour (1981) observed that cows that were very confident and used to move through a race sometimes tried to push past gates in the race. Maybe that can be the case and if so also a reason for wrongly sorted cows, when sorting cows frequently in the sort gate.

Comparison of different sort gates

When comparing DSG10 with other types of sort gates available on the market it was probably WestfaliaSurge that have the sort gate that works most similar to DSG10. Both can sort up to five directions, have a saloon gate that halts cows when the sort gate is changing position and works together with transponders and computer based management systems (DeLaval, 2009; Westfalia, 2009). The ATL sort gate Pegasus was the only one that did not halt cows (Agricultural Technology Ltd, 2009), which probably improves the capacity of the gate but might also lead to sorting of the wrong cows to a larger extent. Milfos (2009) sort gate system can handle a large number of cows and a large number of sorting directions, but that system uses one ID-unit per 3-way sort gate.

Future improvements and ideas

In the future it could be possible to adapt today's system so that the cow-ID unit connected to sort gate sends information to PC concerning time when cows are entering cow-ID and time when cows have passed the last photocell in the sorting system (Alagok & Umegård, 2009). Then it would be possible to get "real" information about sort gate capacity on each farm and each sort gate at all times. This information could then be used for an even more correct estimation of general sort gate capacities. This solution would also make it possible to study the time it takes for cows to pass the sort gate without the disturbance from the person conducting time recordings.

Other information like walking speed of cow (which would be possible to collect if registration of time for passing ID-unit and time for passing last photocell and then measuring the distance between them) could be used for detecting lameness in cows (Futcher, 2009). Flowers *et al.* (2006) concludes that it is better to look for lameness after milking than before milking because then the difference between cows with and without claw problems are most evident. Therefore conducting measurements of walking speed for the purpose of detecting lame cows in the sort gate would be a good idea. Lame cows stand and walk less than cows with healthy hoofs (Walker *et al.,* 2008) and maybe data from activity meters can be combined with data concerning walking speed to detect lameness among dairy cows.

Conclusion

The formula used to calculate sort gate capacities today (formula 1) was showing incorrect results when there were longer walking distances inside the sort gate system. Formula 2-4 were showing results that did not differ much from each other, but formula 4 was giving results closest to the reality of the four studied farms.

One sort gate is needed on farms with milking parlour capacities up to about 350-400 cows per hour. On farms milking up to approximately 800-850 cows per hour it would be sufficient to use two DSG10 sort gates at a time.

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Appendix – Questionnaire

- Name of farm ....
- Name of owner ....
- Address...............
- E-mail address..............
- Phone number..............

General

- The farm has been in milk production since the year.........

- What are your production goals for the milk production?......

- Other production at farm besides milk production?........

- The farms number of hectares (acres) for:
    - o Grazing.........
    - o Roughage........
    - o Cereals.........
    - o Forest..........
    - o Other...........

- Number of animal keepers on farm.........

Cows

- Breed of dairy cows?...........

- How do you experience the temperament of the dairy cows?

¤ Calm
¤ Normal
¤ Excited

- Calving season is

¤ Evenly distributed over the year
¤ Concentrated around..........

- Are the heifers kept together with the cows before calving (to get used of parlour etc)?

¤ Yes For about how long.......
¤ No

Sorting

- When was the sort gate installed?…………….

- How did you sort cows before installing sort gate? …………………

- How is the sort gate used?

¤ Planned sorting decision
¤ Automatic sorting decision
¤ Sorting decision from parlour
¤ Other......

- What are the different reasons for sorting cows?
¤ Insemination
¤ Pregnancy checks
¤ To maternity barn
¤ Veterinary checks
¤ Vaccinations
¤ Hoof trimming
¤ To be transported away from farm (sold/slaughter)
¤ Regrouping
¤ Other............

How often are cows sorted?……………………………………………………………………

- Do you experience that there is enough room in the area before the sort gate for all cows that may be waiting for a slow-moving cow?
¤ Yes
¤ No. Comment…………………………………………………………………………………

- Do you experience that there is enough room in the pens that the sorted cows are directed to?
¤ Yes
¤ No. Comment…………………………………………………………………………………

- About for how long time are the cows separated from the rest of their group when sorted out?.............……………………………………………………………………………………...

- Reason for dividing the cows in to the different groups?
¤ Feed ratio
¤ Milk yield
¤ Stage in lactation
¤ Other..........

- Approximate number of regroupings for one cow during one year?………………..

Health

- Average number of lactations (or age) at culling?....

- Recruitment level (% of heifers in herd).......

- How is heat detection carried out?
¤ Activity meters on cows
¤ Visual detection of behaviour
¤ Hormones for synchronisation
¤ Other.........

- What would you say are the health problems that need most attention in your herd?
¤ Infertility
¤ Udder health
¤ Hoof health
¤ Leg health
¤ Metabolic disorders
¤ Calving
¤ Other...........

- Where is foot baths placed?........………………………………………………………

- What products are used in the foot baths?.......…………………………………………...

- How often is foot baths used?........……………………………………………………….

- Number of hoof trimmings per cow and year?.....…………………………………………..

- Approximate proportion of cows that are lame?....…………………………………………

Floors

- How do you experience the floor surface in

Parlour	Area before sorting	Alleys of sorting	Sorting pens	Cow barn?
¤ Good grip ¤ Slightly slippery ¤ Very slippery	¤ Good grip ¤ Slightly slippery ¤ Very slippery	¤ Good grip ¤ Slightly slippery ¤ Very slippery	¤ Good grip ¤ Slightly slippery ¤ Very slippery	¤ Good grip ¤ Slightly slippery ¤ Very slippery
¤ Clean ¤ Dirty	¤ Clean ¤ Dirty	¤ Clean ¤ Dirty	¤ Clean ¤ Dirty	¤ Clean ¤ Dirty
¤ Plane surface ¤ Uneven surface	¤ Plane surface ¤ Uneven surface	¤ Plane surface ¤ Uneven surface	¤ Plane surface ¤ Uneven surface	¤ Plane surface ¤ Uneven surface

Milking parlour

- Number of milkings per hour?............

- Number of milkings per day and cow?...........

- Number of cows that are milked per day?......

Feed

- Is fresh feed offered after milking?
¤ Yes. Where............
¤ No

- Where are the dairy cows offered feed?
¤ In milking parlour. Kind of feed.... and amount of feed....
¤ In the sorting pen. Kind of feed.... and amount of feed....
¤ In the cow barn
¤ Other............

- What type of feed are the dairy cows fed?
¤ Total mixed rations/complete diets
¤ Forage and concentrate separated

- What feed stuffs are the main ingredients in the feed?
Forage...........
Cereals..........
Protein concentrates............

- Approximately % of roughage in feed...........

- Ratios are:
¤ Individual
¤ Per group

- About how much feed are the dairy cows offered per day ?.........

- Number of feeding per day................ When…………

- Do the dairy cows graze?
¤ No
¤ Yes. Period on year..... Hours per day.......

Animal environment

- Approximately max and min temperatures in the buildings over the year........................

- Do you experience any problems with existing ventilation (humidity, temperature, dust, ammonium (NH_3), carbon dioxide (CO_2), draught)?
¤ Yes
¤ No
What?.......................

- Are you happy with the sound environment in:

Parlour	Sorting area	Cow barn
¤ Yes	¤ Yes	¤ Yes
¤ No	¤ No	¤ No
Why?......................	Why?......................	Why?......................

Buildings

- Building year of:
Parlour…………….
Sorting area………….
Cow barns…………..

Nr	Titel och författare	År
270	A Comparison between Forage Digestibility in the Icelandic and the Standardbred horse Sarah Hamilton	2008
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274	The effect of a high energy forage only diet on exercising Standard-bred trotters Helena Gidlund	2009
275	Riskfaktorer för *Staphylococcus aureus* i mjölk och på has hos mjölkkor Risk factors for *Staphylococcus aureus* in milk and on hocks of dairy cows Karin Andersson	2009
276	Smältbarhet på ensilage och hö hos hästar i träning Digestibility of silage and hay for horses in training Sara Gunnarsson	2009
277	Buffalo Production in North Vietnam Wiveca Sveen	2009
278	Optimal group size for calves fed in transponder-controlled milk feeders Optimal gruppstorlek för kalvar som utfodras I transponderstyrda kalvammor Ida Eriksson	2009
279	Böklåda med torv på rastgårdsytan i ekologisk slaktsvinsproduktion - Effekter på beteende och emission av kväve (NH3 och N2O) 30 hp E-nivå Emma Selberg Nygren	2009
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