Dairy Cow Housing
Report prepared for Arla, Morrisons and DairyCo

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1.0 INTRODUCTION TO DOCUMENT

The report should provide you with sufficient information to decide on suitable housing systems for current and future milk production requirements. It gives information on the implementation of new buildings and the adaptation of existing.

Most farmers provide housing for their cows for part, if not all, of the year. Such housing might be required to provide animals with protection from climatic conditions, to confine animals when grazing is not possible, or may simply allow easier control and management of the herd.

Many housing systems were installed in the 1970's and 1980's before the influence of the Holstein cow was felt on the UK dairy herd. The modern dairy cow is considerably larger in stature and in many cases the animals have simply outgrown the housing system.
There are many farms where cows are housed for a significant period of the lactation and consequently, shortcomings in housing systems become more noticeable. This can create significant adverse effects on animal health, welfare and production.

It is worth noting that whether the housing takes the form of straw yards or cubicles, the fundamental requirements remain the same. Although the majority of UK dairy herds are housed on cubicles, there are considerable local variations with the choice of housing system. In the east of England, the decision to house cows on straw yards is heavily influenced by the availability of locally produced straw.

During the course of preparing this report, while we have discovered a wealth of research that provides excellent data on straw yards, cubicles, floor surfaces and feed areas etc, it has become very apparent that very few studies have succeeded in attributing a financial value to their results.

2.0 EXECUTIVE SUMMARY

The original DairyCo publication 'Housing the 21st Century Cow' was published in 2005. This document relied on the latest knowledge available at that time relating to dairy cow accommodation. Milk producers and other industry participants took advantage of the information the document contained when designing new systems and adapting existing housing facilities. This proved particularly helpful when used in combination with the DairyCo Housing Wizard.

However, in the seven years since publication new evidence based information has been published allowing us to better understand the interaction between the cow and her environment and how she reacts in the herd situation. Not only has this provided an opportunity to update the original publication but has provided an opportunity to broaden and add a number of topic areas to ensure the document is suitable for today but also embraces the future needs of the UK dairy farming industry. Chapters on cattle handling and waste management are now included and other areas (based on feedback from the industry) have been expanded. This publication, therefore, better focuses on the areas that impinge on cow comfort, her well being and therefore overall production and herd profitability.

This document has been produced with the cooperation and input of a wide range of industry experts who have all contributed to areas within their specific field of expertise.

As with the original publication there is a wealth of detailed information provided, with a number of technical references included to allow further reading on specific areas for those who are interested. Importantly, the area on ventilation requirements has been expanded as it continues, even with new cattle housing, to be a limiting factor to good health and productivity of the dairy cow. Information on regulatory requirements are included in each section, as necessary, to aid management of the complex areas that can impact on the successful management of the dairy farm business.

This booklet has not been designed as a blueprint for all herd situations, but rather as a thought provoking instrument to allow for the design of the best-fit situation for individual farms taking into account existing waste management systems, type and availability of bedding materials in the area, cow and herd size and the potential for future changes. However, ventilation requirements in particular need urgent consideration in all cattle buildings due to the direct and immediate impact on cow comfort and health, feed intake, cow cleanliness and overall production.

Not all improvements to dairy cow accommodation will involve great expense, adapting and making small changes such as to ventilation can have a significant impact. If planning herd expansion and more major structural improvements or new builds are proposed then use all the information provided to plan your buildings for now but allow flexibility in design and build for the future. Mistakes do prove very costly. Above all, look at the facilities from the perspective of the cow.

3.0 REQUIREMENTS FOR HOUSING

If a housing system is to be successful, it must provide for the spatial and behavioural needs of the cow. To achieve this, it is important to understand how an animal behaves when performing routine activities such as drinking, feeding, lying, rising and walking.

The design of the system and the level of management applied to the system, can affect the health and welfare of the cows. The cleanliness of the housing and animals can have an impact on both lameness and mastitis.

Irrespective of the production system selected, to maximise performance of the herd, the accommodation must fully provide the cow's needs. At a minimum, it must provide a comfortable, well drained lying area, shelter from adverse weather and space to allow the animal to move freely around without undue risk of injury. The cows also need access to wholesome food and water.

Apart from the immediate requirement that any investment in new facilities or improvement of existing facilities must be financially justified, it is critical that the system fully complies with the relevant animal welfare legislation and recommendations (1, 2) and the requirements of the Red Tractor Farm Assurance Dairy Scheme (Red Tractor Scheme) (3).

4.0 LEGISLATION

Much of the legislation covering animal welfare in Great Britain has been devolved to the constituent countries, although in practical terms the various Acts and Regulations are broadly similar.

The Animal Welfare Act of 2006 (4) places the onus on all owners and keepers of animals to ensure that the welfare needs of the animals are met, and broadly reflects the Five Freedoms. The welfare of farmed animals in England is additionally protected by The Welfare of Farmed Animals (England) Regulations (2007) (1) (and those published by the devolved countries of Scotland and Wales) and states that owners and keepers of animals shall take all reasonable steps to ensure the welfare of the animals under their care. They must ensure that the animals are not caused any unnecessary pain, suffering or injury.

These Regulations must be complied with when considering the design of a dairy cow housing system, and such legislation underpins the Red Tractor Farm Assurance Dairy Scheme (3) and the various milk buyer assurance schemes. The same applies to the RSPCA welfare standards for Dairy Cattle (Freedom Foods) (5), which emphasises the need to monitor welfare outcomes as well as providing a number of minimum specifications.

In addition to potential prosecution for offences under The Animal Welfare Act and The Welfare of Farmed Animals Regulations, failure to comply may adversely affect payment of the single farm payment under cross compliance requirements.

To assist in compliance with the Regulations, the Code of Recommendations for the Welfare of Livestock: Cattle (The Cattle Code) (2) provide practical interpretation of the Regulations.

The Welfare Act and the Welfare of Farmed Animals Regulations provide over-arching principles with regards to dairy cattle housing. More specific guidance when considering new or adapting existing dairy cattle housing is provided in the British Standard for Agricultural Buildings and Structures, BS 5502-40:2005 (6). The technical information contained within this standard was heavily influenced by the 1994 CIGR Report on the Design of Dairy Cow Housing (7).

The Dairy Products (Hygiene) Regulations 1996 (8) provides guidance on the design and management of housing systems and stresses that the most effective test of the suitability of a housing system is the cleanliness, health and comfort of the cows.

It is important that planning permission, where required, is applied for at an early stage when developing a housing design and that the design satisfies the Town and Country Planning requirements. These are described in The Town and Country Planning Order 1995 (9).

When building a new facility, it is important that the system complies with the Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations 1991 (10), as amended in 1997 and the publication Protecting our Water, Soil and Air: A Code of Good Agricultural Practice for farmers, growers and land managers (the 'CoGAP') (11).

While any building project is being undertaken it is essential that the relevant Health and Safety regulations are observed. The HSE Construction (Design and Management) Regulations 2007 (CDM) (12), describe steps which must be carried out during the design and building of any new facility. The CDM regulations are particularly important for the dairy farmer. Unless the role of CDM manager is officially passed to a third party (building contractor or project manager), in the event of an accident, the farmer is likely to be considered to carry the entire responsibility.

5.0 WELFARE AND COW COMFORT

5.1 Definitions of welfare

The term animal welfare refers to the state of physical and mental health and well-being of the animal. Welfare has been defined as the state of the animal with respect to its ability to cope with its environment (13). An animal that is in good health and has what it wants is considered to have good welfare (14). These concepts describe welfare in a general sense, but do not define how to provide for good welfare for the individual dairy cow.

The welfare of cattle should be assessed in the context of a framework described in the 1997 Farm Animal Welfare Council Report – Report on the Welfare of Dairy Cattle (15). The guidelines are described as the Five Freedoms. The Five Freedoms form a logical basis for assessing animal welfare within a husbandry system.

- Freedom from hunger and thirst – by ready access to fresh water and a diet to maintain full health and vigour.

- Freedom from discomfort – by providing an appropriate environment including shelter and a comfortable resting area.

- Freedom from pain, injury and disease – by prevention or rapid diagnosis and treatment.

- Freedom to express normal behaviour – by providing sufficient space, proper facilities and the company of other animals.

- Freedom from fear and distress – by ensuring conditions and treatment which avoid suffering.

However, while the Five Freedoms allow for the provision of basic physical needs and lack of harm for the animal, but they do not promote positive experiences as something that are important for animals.

In the final report of FAWC (16) in March 2011, the council reiterated its belief (17) that the minimum standard of farm animal welfare should move beyond the Five Freedoms and that the quality of an animal's life is important with emphasis on whether an animal, from its point of view, has "a life worth living".

The concept of a life worth living is more intuitive, in that it allows there to be a balance between positive and negative experiences, and it gives weight to positive aspects of the animals' life. Therefore, both the negative and positive experiences of an animal contribute, both in the present and in the future, to whether it has 'a life worth living', a 'life not worth living' or a 'good life'. A 'life not worth living' is clearly one in which the animal is experiencing pain or suffering that cannot be alleviated by appropriate veterinary or other treatment. A "life worth living" is one where the balance of positive experiences outweighs the negatives over the animal's lifetime, while a "good life" is one in which this balance is further towards the positive experiences, and the standard of welfare is substantially higher than legal minimums.

However, on a day to day basis, or when designing new housing or altering existing facilities, a more concrete approach is needed, with more detailed and targeted information. And this concept should be acknowledged in the design, construction, maintenance and management of all buildings and housing systems.

5.2 Effects of housing facilities on welfare

There are clearly many aspects of the cow's housing and management systems that can affect her welfare.

Lactating dairy cows expend a lot of energy producing milk, so providing them with a comfortable place to rest is vital to production and welfare.

Straw yards containing clean, dry straw at an appropriate stocking density for all cows to lie, fulfils many of the cow's requirements. In cubicle houses, the design of the cubicle and the type of bedding contribute to cow comfort. There has been a great deal of work put into designing cubicles, but essentially, the base of the cubicle needs to be long enough to allow the cow to lie in the cubicle without her rear-end overhanging the edge.

The cubicle divisions should be wide enough to allow the cow to lie down easily, and should not be positioned so that the cow rubs her legs or neck against them when resting or when moving from standing to lying or vice versa.

The brisket board and head rail should not obstruct the cow when she moves from standing to lying, whilst positioning the cow correctly within the cubicle. There should be sufficient space in front of the brisket board to allow the cow to move her body weight forward over her knees when lying down. Mats and mattresses cushion the cow from the concrete cubicle base while lying and should be deep and resilient enough to support the cow's weight when she drops to her knees when lying down. Knee swellings may result from poor cushioning.

Increased depth of bedding in tie-stalls (cowsheds) has been shown to increase cushioning, comfort and lying time (18), and this concept is likely to be highly relevant with cubicles. Bedding is also essential for cow cleanliness. Studies have shown that clean sawdust or shavings are good for cow comfort but must be managed and renewed regularly to prevent build-up of bacteria that threaten udder health. Sand is used more and more in the United Kingdom, as it provides good cow comfort and when correctly managed does not promote bacterial growth. However, it requires an appropriate slurry management system as sand is abrasive for both machinery and flooring.

There are a number of signs that inform the observer the cubicles are not comfortable. Cows will stand with their front feet in the cubicle only, or stand ruminating in the passageways rather than lying down. As herd animals, cows prefer to synchronise their behaviour and lie down at the same time. For this reason it is important to have at least as many cubicles as cows, with ideally 5% more per management group.

Plate 1 - Cows standing with front feet only in cubicle

The length of time that cows spend lying has often been used as a measure of cow comfort. On average cows lie down for around 12 hours each day, much of it during the night (19). However, there is a great deal of variation between farms. In a large Canadian study, cows were recorded as lying between 4 and 19 hours each day (20). Lameness and management factors such as frequency of milking and access to cubicles may contribute to this variation between farms and individual cows. Some studies found that lameness reduces lying time and some that lying time is increased (21, 22). Lying time is a useful rule of thumb in assessing cow comfort, but other behaviours, such as standing fully in the cubicle or with the front feet only in the cubicle may also help to gauge cubicle comfort (23).

5.3 Cow behaviour

Ignoring cows' natural behaviour and the reaction to their environment will jeopardise both herd welfare and productivity. Several cow behaviour variables, indicative of fear of humans, often correlate with milk yield and composition. Observations from a number of studies indicate that where restlessness was high, productivity was low.

Providing adequate space for cows to socialise will allow subordinate cows to distance themselves from the dominant cows.

Cows are socially gregarious and establish a strong social hierarchy. The social hierarchy consists of a number of dominant animals and a number of subordinate animals. Dominance is often related to body weight. When a dominant animal meets an animal who has no established position in the herd hierarchy, there will initially be some aggressive interaction. One animal will emerge as the dominant animal. When the subordinate animal next meets the dominant animal, she will move away from any potential conflict.

It is known that the establishment of a social hierarchy within a group can take anywhere from 3 to 7 days which can prove stressful especially to heifers. Mixing of groups will also interrupt the establishment of the social hierarchy. There is some evidence that the time taken to establish the hierarchy is extended significantly when group sizes exceed 80 cows.

Stocking densities at the feeding area should allow all cows to feed at the same time thereby reducing aggressive competition and ensuring subordinate cows have access to feed.

Competition at the feeding area can be minimised by using a feed face with individual feeding spaces separated by barriers.

While there is currently a lack of financial evidence to support a firm recommendation, and until further evidence is provided, it is sensible to limit group size to 100 cows and minimise mixing of groups unless necessary for management purposes. However, space allowances, especially at the feed barrier, should be optimised.

5.4 Time Budgets

A suitable design for cow housing needs, as a base line, a good understanding of cow behaviour, if the system is to meet the aspirations of the Five Freedoms. All those involved with designing and building cattle buildings, and those managing cows, have to understand that the cow is a herd animal and behaves accordingly. To ignore cows' natural behaviour and the reaction to their environment will jeopardise both herd welfare and productivity.

The knowledge of how the cow reacts has increased substantially over recent years. To understand her behaviour, knowledge of how she spends her time in her natural surroundings – her time budget is essential in providing her with an environment that allows her to best match it.

The cow's time budget can be simplified into 6 elements and is illustrated in Table 1 24):

Table 1. Typical daily time budget for lactating dairy cow.

Activity	Total time spent per day (hours)
Eating	3 – 5

	(9 – 14 meals per day)
Lying/resting	12 - 14
Social interaction	2 - 3
Ruminating	7 – 10
Drinking	0.5
Non-housing time (milking, travel time)	2.5 – 3.5

A study in the USA (24), noted that high yielding cows rested for 14 hours per day, compared to the usually quoted figure of 12 hours. Therefore as yield levels increase in a herd, provision must be made to allow longer lying times – by an improved environment and by minimising waiting time in collection yards for milking.

While researchers in the USA (21) found similar lying times between sand and rubber crumb filled mattresses, they recorded that the length of lying bouts was longer in sand cubicles – suggesting cows were more comfortable. Cows stood for longer on the mattresses, an outcome that was explained by lame cows being less likely to lie down or stand up on surfaces which are less forgiving compared to sand. Whereas lame cows on the mattresses modified their time budget, those on sand did not.

Although the time budgets show that cows lie down for up to 14 hours each day, the challenge is to provide an environment for that to be achieved. The remaining 10 – 12 hours each day is spent by cows on their feet. Therefore the surface they stand on must also be appropriate. It is suggested in a Canadian review (25) that cows will often stand in cubicles as the underfoot conditions are kinder for the animal – however, this often leads to dirtier cubicles with the inherent risk to milk quality and udder health.

Therefore, due consideration must be given to the quality of the dunging, feeding and loafing passages if cows are to meet their natural behaviour and social interaction.

Irrespective of the housing system chosen, the housing must provide a comfortable place for the cow to lie. Measurement of cow comfort is subjective and therefore, a recognised method of assessing cow comfort is to measure lying times.

A study looking at lying times of dairy cows at pasture (26) suggested that when unhindered, a cow would choose to spend between 10.9 – 11.5 hours each day lying down. Work from Liverpool University (27) indicated that 10.0 hours of lying time each day was considered adequate for cattle housed on straw yards.

The cow will choose to lie down 10 – 15 times per day with each lying bout usually of around 60 minutes. A cow will not lie down for too long in a single bout, as she becomes uncomfortable. Her body weight causes high pressures on those points of her body in direct contact with the ground.

As dairy cows are considered socially gregarious, synchronisation is important to their behaviour. To avoid competition in communal lying areas there should be enough space for all cows to lie down together.

If the intention is to design a dairy housing system which provides an environment as comfortable as when the cow is at pasture, the objective must be to provide a facility which encourages the cow to lie down for at least 12.0 hours each day.

A cow which spends less time lying down will inevitably spend more time standing in passageways, loafing areas or at a feed stance. This cow may be more likely to develop foot related problems. In addition, when a cow is lying down, the blood flow to her udder is increased by 28%, which may be related to increased milk production (28).

A study in Ireland (29) noted that decreased lying times and increased periods of standing, either half in and half out of a cubicle or in passageways, was associated with a more restrictive cubicle partition and a firmer stall surface.

The majority of work which has been undertaken internationally, examining cow comfort in differing housing systems, has focussed on cubicle systems.

This reflects the fact that the majority of research carried out in the subject area is commissioned in North America where the predominant method of housing dairy cows is the free stall (cubicle).

It is assumed that as long as the basic design criteria are met and adequate space is provided, a cow housed on a covered loose yard will be comfortable. It is less easy to make that assumption when cows are housed in cubicles and a greater number of areas need to be considered.

5.5 Cow Hygiene

The lying surface of a housing system can influence udder health. The rate of new mastitis infection increases with the number of bacteria at the teat end (30). Associations between clean housing, clean cows and lower levels of mastitis have been made in a number of studies (31, 32, and 33).

Cleaning of dirty cows, particularly before milking, is both time-consuming and relatively ineffective. Many new dairy facilities with high performance milking systems, fail to achieve their potential as excessive time is required to prepare dirty teats and udders before cluster attachment. Although there are potential welfare issues with cows that are heavily soiled with manure, with regards to mastitis it is the cleanliness of the udder and lower leg that are important (34).

It is therefore imperative to ensure that whatever the housing system selected, the system is designed in such a way that correct account can be taken of the need for cow hygiene. A 700kg dairy cow will produce in excess of 60 litres of slurry each day. To ensure lying surfaces remain hygienic, cubicles must be correctly designed and adequately sized. Straw yards must be stocked at the appropriate rate with adequate loafing areas away from the bedded surface.

Access passages, loafing areas and feed areas should be kept clean and dry since slurry picked up on the hoof will be deposited on the lying area. This will in turn lead to the cow becoming soiled. In addition when a cow lays down, her udder is often in contact with part of her lower leg, increasing risks of soiled udders and increased teat end challenge. When a cow’s foot is in contact with a build up of slurry with a depth greater than around 25mm, the horn will become soft and the foot is more vulnerable to disease (35).

Plate 2 –Clean cows feet

Digital dermatitis is now considered to be on the majority of UK dairy herds. It has been estimated that 20% of all lameness can be attributed to digital dermatitis (36). In a survey carried out in the USA (37), it was estimated that 90% of herds in Wisconsin are affected by digital dermatitis. The disease is often associated with prolonged contact with slurry containing the bacteria *Fusiformis nodosus*. However, the latest studies indicate that digital dermatitis is in fact associated with spirochetes belonging to the genus Treponema (38).

Keeping the cows foot clean and dry, combined with regular foot bathing, has been shown to be effective in controlling the infection. Indications are that spirochetes do not survive in slurry, although circumstantial evidence is that herds kept in housing using automatic scrapers tend to have higher rates of digital dermatitis – initially thought to be due to the accumulation of slurry in front of the scraper spreading the problem from cow to cow.

As the stocking rate within any housing system increases towards the theoretical maximum, the amount of slurry deposited per m^2 increases. This has a direct effect on the cleanliness of the cow's feet, legs and flanks.

The consistency of the slurry has a marked effect on the cleanliness and hygiene within a housing system. This is particularly noticeable in straw yards (39). As the consistency of the dung increases, there are fewer tendencies for the dung to spread and it is easier for animals to remain clean.

When animals are housed on straw yards, management of animals showing signs of oestrus is important. Two or three animals exhibiting oestrus on a covered yard can rapidly turn a previously clean, dry bedded surface into a quagmire.

Most footbaths are located in the exit passages to milking parlours. Increasingly, footbaths are designed with two distinct sections. The first section should contain clean water to remove any slurry from the foot and after a short period walking on a section of raised concrete, the second section should contain a solution with the active ingredient. However some veterinary surgeons are of the opinion that footbaths should be wide and only of one section, as the action of walking through the first footbath creates stress with cows dunging in the next section containing the treatment. This reduces effectiveness of the product being used.

With a two part footbath each section should be at least 2.5m long, separated by a raised strip of around 2.0m. The level of liquid should be around 0.2m. The footbaths should be designed so that they can be easily cleaned with large outlet drains.

5.6 Minimum welfare requirements for dairy cattle

The minimum requirements for dairy cattle welfare are laid out in the 'Code of Recommendations for the Welfare of Livestock: Cattle' published by Defra (2) and The Scottish and Welsh governments.

There are a number of statements within the regulations that relate to the accommodation for animals. They are extracted from The Welfare of Farmed Animals (England) Regulations 2007 (S.I. 2007 no 2078) Schedule 1 (1). These are set out below:

- Materials used for the construction of accommodation, and, in particular for the construction of pens, cages, stalls and equipment with which animals may come into contact, shall not be harmful to them and shall be capable of being thoroughly cleaned and disinfected.

- Accommodation and fittings for securing animals shall be constructed and maintained so that there are no sharp edges or protrusions likely to cause injury to them.

- Where any animals are kept in a building they shall be kept on, or have access at all times to, a lying area which either has well-maintained dry bedding or is well-drained.

- The freedom of movement of animals, having regard to their species and in accordance with established experience and scientific knowledge, shall not be restricted in such a way as to cause them unnecessary suffering or injury.

- Where animals are continuously or regularly tethered or confined they shall be given space appropriate to their physiological and ethological needs in accordance with established experience and scientific knowledge.

There are a number of further recommendations made in the Regulations which can be interpreted as the following:

5.61 Space allowances

- The more you limit the space that cattle have in the housing system you provide, the less choice the animal has to avoid unfavourable conditions. Housed cattle need constant care and attention from staff that are well trained in the nutritional and environmental needs of cattle.

- Irrespective of duration of housing, the accommodation should provide shelter and enough room to move around and interact with each other. The accommodation should provide enough space for a subordinate animal to move away from a dominant one. It is important to provide as comfortable an area as possible, so that the animals can lie down for as long as they want and have enough space to stand up again. The floor should not slope too steeply – no more than about 10% - as steeper slopes can cause leg problems, slipping and falling.

- All concrete yards and passageways should be kept in good condition. They should not be too rough as this can graze or even cut the soles of the animals' feet. On the other hand, the yards and passageways must not be worn smooth, as the animals are then likely to slip and possibly cause leg and other damage. Slurry should not build up on concrete floors and passageways, as this will also make the floor slippery.

- Where slatted floors are used, particular attention must be paid to the type of slats, to avoid slipperiness. The gaps between the slats should not be wide enough to cause foot injuries (for example, when claws get trapped). Slatted pens should only be used for the size of animal that they were designed for.

- Fully-slatted concrete floors should not be used for breeding cows or replacement heifers. Where there are slats, part of the accommodation should be a solid-floor area with straw or some other suitable bedding material, so that animals will be comfortable and less likely to injure themselves – particularly their udders.

- The space allowance for cattle housed in groups should be calculated taking account of:
    - the whole environment;
    - the age, sex, liveweight and behavioural needs of the stock;
    - the size of the group; and
    - whether any of the animals have horns.

5.62 Straw yards

- Straw yards should be completely cleaned out every three weeks. This improves cow cleanliness and should reduce the risk of mastitis from bacteria in the bedding (i.e. environmental mastitis). Straw yards should be bedded daily with clean, dry straw, stored under cover to keep it dry. There should be enough space for all the animals to lie in comfort at the same time and to stand up and move freely.

- Where feed and water troughs are accessible from the bedded area. Measures should be put in place to reduce fouling. Where feed and water troughs are provided in the adjacent loafing area, the access areas should be sufficiently wide to permit free movement of animals and prevent routes becoming wet, fouled and slippery.

- Where a loafing area is used, ideally it should be partly covered.

- Cows exhibiting oestrus should be removed from the main herd temporarily, so that the risk of teat injuries is reduced and the straw yard will not become soiled.

5.63 Cubicles

- The size, shape and weight of the animals to be housed must be considered when cubicles are considered. Cubicle passageways should be wide enough for cows to pass one another easily.

- Cubicles should be designed to encourage cows to lie down and stand up easily without injuring themselves. The lying surface of a cubicle needs to have enough bedding to:

- Keep the cows comfortable
- Prevent them from getting contact or pressure sores (from always lying in the same or cramped positions)
- Keep the cows' teats, udders and flanks clean.

5.64 Ventilation

- All new buildings should be designed with the animals' comfort in mind, and with the aim of preventing respiratory diseases. The buildings should provide sufficient ventilation throughout the year for the type, size and number of stock to be housed. Where appropriate, roofs should be insulated to reduce solar penetration.

- Where the ventilation in existing buildings is not good enough, buildings can be improved by improving air inlets and outlets, or by using mechanical equipment (such as a fan).

- Underground slurry stores can be dangerous and care must be taken to avoid fouling the air with dangerous gases (such as methane), which can kill both humans and animals. Ideally, underground slurry stores should be emptied when the building is not in use. Where it becomes necessary to remove slurry when cattle are housed, all stock should be taken out of the building. Buildings should be well ventilated during this procedure.

5.65 Lighting

- During daylight hours, indoor lighting – whether it is natural or artificial – should be bright enough to clearly illuminate all the housed cattle and for the cattle to feed and behave normally.

5.7 Grooming Aids

Grooming brushes can positively contribute to the welfare of housed cows, and may relieve boredom. Cows normally groom or scratch themselves on walls, fences or protruding metalwork. In a study which provided cows with a mechanical brush, the brush was used extensively (40), and cows appeared to be cleaner. Brushes can be fixed, with no moving parts, or automatic or mechanical which switch on to rotate a brush. Brushes are normally fixed in passageways to allow access from both sides. However, as cows are highly motivated to use brushes, they should not be fitted in high traffic areas or cow flow will be impeded.

Plate 3 – Grooming brush

5.8 Loafing areas

A loafing area is an area which cows can use for behaviours other than feeding or lying. Building recommendations, based on British Standards (5502) (6), indicate that the total loafing area (exclusive of cubicles) must provide a space allowance of 3.0m^2 per cow. This will typically equate to a loafing area representing 120% of the cubicle area, depending on the design of the building. In many cases it defines the passageways that are not immediately adjacent to feeding areas. However, in reality all non-lying areas (in straw yards or cubicles) have tended to form part of the loafing area in many cow housing designs.

Although it is acknowledged that some farmers provide outdoor loafing, the weather has a large influence on the utilisation of such areas. Throughout the year, utilisation of outdoor loafing areas can be high unless it is particularly wet. Animals will also use the loafing area when humidity is high within a building (41). When the weather is particularly hot, cows will usually choose to return to the housing. This is particularly noticeable with modern, well designed facilities. Open loafing areas provide the space for animals to interact and to show oestrus behaviour without fear of collision with cubicle partitions or walls. Social bonding in cattle is reinforced by grooming each other which is more often seen in open loafing areas.

In many more traditional systems, where passage widths are limiting, additional loafing area can be provided by allowing cows' access to concrete areas outside the building.

Plate 4 - Cows using a loafing area

5.9 Measuring and assessing dairy cow welfare

Although legislation underpins all aspects of animal welfare, in recent years, assessment schemes for assessing dairy cow welfare have become more prominent in the dairy industry. They may be part of an overall farm assessment scheme that includes assessment of the hygiene, management and environment (e.g. Red Tractor Scheme (3)) or they may be stand-alone assessments purely looking at animal welfare (e.g. RSPCA's Freedom Foods protocol (5)). The schemes may be run by specific milk buyers, supermarkets or by specific certification bodies.

Welfare assessment protocols were first developed in the 1980's in Austria (42). In these early schemes, it was mainly the quality of the housing, rather than the health and welfare of the animals themselves that was assessed. At that stage, few measures of welfare that could be taken directly from observations of animals had been developed and properly validated. However, there is not always a direct relationship between the animal's welfare and the quality of the housing. Good stockmanship and animal care can insulate the cow from poor housing facilities, while poor stockmanship and animal care may lead to poor welfare in spite of good housing conditions.

More recently, with the development of assessment techniques such as condition, mobility and cleanliness scoring, welfare assessment schemes have moved towards directly assessing the animals. Further methods for assessing welfare directly from animal behaviour and their physical appearance are being developed.

In 2004, the University of Bristol Veterinary School developed a welfare Assessment protocol (Bristol Welfare Assessment Protocol) for dairy cows. A version of this was used in the RSPCA's Freedom Foods welfare assessment protocol for dairy cows (43). A European-wide initiative on the development of welfare assessment protocols known as Welfare Quality® (44) has arrived at a welfare assessment protocol that considers four principles of animal welfare: good housing; good feeding; good health and appropriate behaviour. Within these four principles, twelve animal welfare criteria were identified.

Welfare assessment need not only be carried as part of an official visit by an assessment officer. Many farmers already undertake their own welfare assessments by taking time to observe their cows. Mobility scoring is something that can be done on a regular basis. If animals identified as lame are treated, this can make a major contribution to reduction of lameness and improvement of welfare. Similarly, looking at the cleanliness of the cows, the state of the hocks and knees and the level of butting and pushing at feed troughs and feed faces can alert the farmer to problems. The Dutch 'Cow Signals' initiative encourages farmers and advisors to take a step back and look objectively at the housing and the cows to see where action should be taken to improve health and welfare.

It is clear that there is a significant amount of legislation and farm quality assurance protocols within the UK which needs to be considered when constructing, or even adapting, new dairy cow housing. It is therefore recommended that advice be sought from suitably experienced and qualified sources to ensure compliance with all relevant legislation and codes of practice.

6.0 HOUSING SYSTEMS FOR GREAT BRITAIN

Historically the vast majority of dairy farms kept their cows out at grass from early spring to late autumn, housing the animals for the remainder of the year. Traditionally, cows grazing pasture year round would have been defined as extensive, whereas cows housed for a large part of, if not all, the year would be categorised as intensive.

6.1 Management systems

A number of different management systems have evolved in Great Britain, each with their own advocates. These can be categorised into:

Continuous housing – the dairy herd is housed throughout the whole year, including dry cows, although heifer replacements are likely to be grazed at least during their first year. Cows may have access to an outside loafing area.

Seasonal housing – this is the more traditional (and still the most common) system where cows are housed during the autumn and winter (usually when ground conditions dictate), and cows graze from spring until autumn. Where grazed grass cannot meet the nutrient needs of the cows, the herd or herd groups, will be buffer fed.

Zero grazing – grass is harvested and fed to the cows at a feed trough (normally at the housing). This may be in the spring when grazing by cows could lead to extensive poaching or due to distance of grass fields from the homestead. Zero grazing may involve the cows being housed year round, but cut grass being fed fresh (twice daily) rather than first ensiled.

Full grazing (extensive pastoral) – cows graze grass (or other forages grown specifically for the purpose) year round, perhaps with access to housing (for shelter in inclement weather).

However, many of the defined classifications do merge, with many individual farm systems being a mix of two or more. For example, Total Mixed Ration (TMR), the principle of which is that each bite taken by the cow is the same nutritionally. Although some herds practice TMR year round, many use it as a system of feeding during the housing period, reverting to some or complete grazing during the remainder of the year.

There are certain areas of the UK where the relatively mild climate has led to the emergence of management systems which extend the grazing season and maximise the use of grazed grass. The majority of these systems will still provide covered accommodation for a part of the winter.

The Cattle Code states that the accommodation should provide shelter for the cattle and that they should have access at all times to a lying area which has either well maintained dry bedding or is well drained. The Red Tractor Scheme requires that all cattle housing must be constructed to provide a safe, hygienic and comfortable environment for stock and must be maintained to avoid injury and distress. While there are some dairy farm systems in the UK where no accommodation is provided, these are likely to remain the minority.

The DEFRA climate change study (45) suggested that rainfall in the UK may increase by 10% by 2050 which would make these systems even harder to manage.

6.2 Housing Options

In the UK there are three main options available for housing dairy cattle.

- Cubicles
- Straw (loose) yards
- Cowsheds or tie stalls

In a study carried out in 1982 (??), ADAS suggested that less than 9% of herds are housed in cowsheds. This figure is now significantly less than 9%. Although the housing of cows in cowsheds is still permitted within the welfare legislation and the Red Tractor Scheme, the implementation of this particular system is now so limited that it has not been covered within this report.

This leaves the option of housing dairy cattle in either a straw yard or a cubicle / kennel based system. An MDC funded study (46) in 1997 (97/R2/36) reported that 22% of the farmers who responded to their questionnaire, housed their lactating cows on straw yards.

Data from The Dairy Group MCi (47), The Dairy Group Management System, shows that in 2011 only 5% of the monitored herds are housed in straw yards.

There are advantages and disadvantages with both housing systems and it is therefore impossible to state categorically, which is the best suited for a modern dairy cow. Both systems can work equally well with regards to cow welfare and productivity, with much of the variation due to management decisions and actions.

A brief comparison of cubicles and straw yards is illustrated in Table 2.

Table 2 – Comparison of cubicles and straw yards

Cubicles	Cubicles
Possible advantages	**Possible disadvantages**
Less bedding required	Passageways contaminated with slurry
Flexibility with bedding materials	Increased risk of lameness / leg damage
Lower risk of environmental mastitis	
Higher stocking rate	

Straw Yards	Straw Yards
Possible advantages	**Possible disadvantages**
Lower risk of lameness	Lower stocking rate
Lower risk of damage to knees and hocks	More bedding required
	Increased risk of environmental mastitis
	Loafing areas contaminated with slurry

6.3 Cubicles and straw-yard housing

The behaviour of cow groups in straw housing tends to be more synchronous (i.e. they tend to do the same thing at the same time), but this may be because the group size is generally smaller in straw housing systems. A number of studies have shown that lameness is lower in straw-yards than in cubicle systems (48, 49). Additionally, hock and knee injuries are more prevalent in cows housed in cubicles. This is presumably because of the impact on the cows' joints from standing and lying on concrete floors. Research into the use of rubber-covered flooring has shown some success. Cows prefer to stand on rubber-covered floors, and there is some indication that it may reduce lameness (50, 51).

The choice of housing system will, in part, depend on how much weight the individual producer attributes to each parameter. However, economics and availability of bedding materials plays a large part in the decision, e.g. availability of sufficient clean, dry straw is very poor in many parts of the UK and is arguably the main reason why the proportion of herds kept in straw yards has fallen in the past few years. However, EFSA (52) in a review of factors affecting dairy cattle welfare suggest that if leg disorders are a problem in cubicles then alternatives such as straw yards should be considered, or improvements made to the cubicle house design. In this same report they ranked the main hazards to animal welfare in loose yard systems as ventilation, temperature and humidity and the main housing hazard in cubicle housing was poor cubicle design.

Researchers in a MDC funded study (46) concluded that the incidence of clinical mastitis increased when lactating cows were housed on straw yards compared to cubicles. In a study of low cell count herds, they indicated a ratio of 1.15 cases of mastitis in straw yard cows for every case in cubicles. The incidence of mastitis (and lameness) is also higher in herds where there is less than one cubicle place per cow (52) attributed to reduced lying time and aggression with associated poor welfare.

The higher incidence of mastitis in straw yards compared with herds housed in cubicles is supported by the report prepared for an MDC study in 1999 (39). However, EFSA (53) concluded that the risk of suffering udder problems is independent of the housing system.

The EFSA report (52) also refers to there being a higher risk of metabolic and reproductive disorders in transition cows fed a TMR while housed in cubicles rather than straw yards. This also was attributed to cows eating the bedding straw in the loose yard systems.

A MDC commissioned study carried out at ADAS Bridgets (54) compared cows on a straw yard with cows housed in cubicles. The cubicle cows were tested on either a mat or a mattress, both with a covering of sawdust. The study concluded that there were no production or welfare differences between straw yards and cubicles when both were well managed. There was a slight financial benefit from keeping cows on straw yards when the data from 1997 was considered. This was primarily as a result of a small but consistent difference in feed intake (due to some substitution of straw for TMR) and the relatively low cost of straw at the time.

The study noted lesions of the white line and sole were less severe in cows kept on straw yards but heel erosion was greater. After six months the project concluded that there were no significant differences in the housing systems for milk yield, milk composition, somatic cell count, feed intake, live-weight or locomotion (lameness) score.

In a paper published in 1994 (55), the researchers concluded that cows housed on straw yards spent longer lying down and feeding than cows housed in cubicles. Despite this, there was no difference noted in either milk production or composition although the straw yard cows lost more weight after calving (due to some substitution of straw for silage). The cows on cubicles exhibited a reduction in heel depth which is a predisposing factor to lameness.

When dairy cattle are kept in cubicles, both foot and leg disorders are much greater than they are in straw yards (52).

In the reviews conducted by the ESFA (52), they concluded that, given the choice, cows would choose more individual space than is usually available in most dairy cow buildings. More lying and loafing area decreases the incidence of lameness and the number of injuries to cows and heifers due to less aggressive behaviour.

A study in the Republic of Ireland (56), found that cows housed in cubicles had more limb lesions compared to those on covered woodchip pads, and worse mobility scores post calving. However, 12 weeks post-partum, cows on woodchip pads that were not covered had higher sole lesions scores than on covered pads – considered to be due to the horn being softer from exposure to moisture level in the open woodchip.

Two studies from Wye College (57, 58) concluded that there was a significant effect of stocking rate on cow hygiene and cow interaction but that there was no difference in milk production between the two systems.

A UK study in 1997 (59) reported a significant reduction in both the incidence and prevalence of lameness in a three-herd study after changing from cubicle housing to straw yards.

An observational study looking at 49 herds in Holland (60) concluded that 82% of cows housed on cubicles had one or more claw disorders compared with 58% of cows housed on straw yards. Weaver (61) concluded that disorders of the claw account for around 90% of all lameness incidents. Lameness is clearly of considerable concern due to the impact on both welfare and profitability. A study published in 2002 (62) concluded that the reduction in milk yield for every case of clinical lameness was 360 kg.

Although reporting more lameness in cubicles than would be normally seen in straw yards is a recurrent feature, some studies have concluded (25) that deep bedded cubicles work well for cow comfort but that one of the problems with cubicle buildings was the comfort of the standing areas. However, comfortable the lying areas, cows still stand for around 12 hours per day. If underfoot conditions cause discomfort, cows will stand on the cubicle bases, leading to poorer cubicle hygiene and inherent udder health problems.

These studies confirm that cows housed in a cubicle system will generally get less environmental mastitis although they may well suffer a greater incidence of foot related problems. Conversely a cow housed in a straw yard is likely to suffer from an elevated incidence of environmental mastitis but less foot related problems.

When the literature is reviewed, there appears to be some discrepancy between sources as to the correct space allowance required for a 750kg dairy cow to lie down and loaf. The different dimensions are shown in Table 3.

Table 3 – Space allowances in straw yards for a 750kg dairy cow

Source	Bedded area (m^2 /cow)	Loafing area (m^2 /cow)	Total (m^2 /cow)
BS5502 (6)	7.5	3.0	10.5
CIGR (7)	6.3	3.2	9.5
ADAS (63)	6.5	2.5	9.0
The Red Tractor (3) (based on 700 kg cow)	5.75	3.0	8.75
MDC (39)	6.5	-	-
RSPCA (5)	7.0	3.0	10.0
DMCP (64)	9.4	3.0	12.4

The DairyCo Mastitis Control Plan (64) concludes that space allowances would be more appropriately based on the milk production of a cow. The suggestion is a bedded lying area of 1.25m^2/cow per 1000 litres. With average milk yields at around 7,500 litres/cow/annum, this equates to 9.4m^2/cow, i.e. a 25% increase in area above BS5502 (6). The recommended loafing area is 3.0m^2/cow.

The studies undertaken at Wye College (57, 58) indicated that when the total space allowance per cow increased from 6.7 m^2 /cow to 13.5 m^2 /cow, cows remained cleaner, although they could demonstrate no production advantage at the higher space allowance. A University of Minnesota study (34) found a relationship between cow cleanliness and somatic cell count (SCC). A one unit increase in hygiene score lead to an increase of 40 – 50,000 cells/ml in the SCC. A relationship between cow cleanliness and SCC, (but not Bactocans or clinical mastitis) was seen in a UK study reported in 2007 (65).

In reviewing the association between cow cleanliness in cubicles and milk quality, a study from Wisconsin (33) reported a relationship between cow cleanliness and udder health. Therefore, the more space, and better bedding, an animal has the more likely it is to stay cleaner and therefore have improved udder health.

Published space allowances would appear to be based on subjective assessment. Based on the apparent relationship between bedded lying area and SCC plus reports that the incidence of mastitis are higher in cows with soiled udders (33) it would appear prudent to be calculating stocking rates assuming a bedded area of at least 7.5 m^2 /cow, where the design of the straw yard is optimal. This should be increased to around 9.5 m^2 /cow if the yard design is slightly compromised, (e.g. narrow access, poorly located water trough, excessive bedded area width) or there are concerns about availability of clean, dry straw.

The lying area associated with an adequately sized cubicle will be around 2.8m^2/cow. Both the Red Tractor Scheme (3) and BS5502 (6), recommend a further loafing area of a minimum 3.0 m^2 /cow. However in practice with a 2 row cubicle system, each cow shares 50% of the dunging passage (2.07m^2) plus her space at the feed stance (3.22m^2). This therefore equates to a total space allowance per cow of around 8.05m^2 /cow when housed in cubicles.

This compares with the range of total space allowance in straw yards, highlighted in Table 3, from 8.75 – 12.4 m^2 /cow.

If the objective is to house the maximum number of animals comfortably with a building of fixed dimensions, the cubicle option will provide accommodation for significantly more animals. However, EFSA (52) advise that a total space allowance of less than 8.6 m² in cubicle houses negatively affects welfare.

The selection of a particular housing system may be driven by the availability and costs of bedding materials and how these materials can be handled in an existing waste system.

With any housing system, use of bedding will show great variation between operators and any quoted figure needs to be considered as an average. Table 4 gives an indication of the volume of bedding which may be required in differing housing situations with cow comfort and cow cleanliness as the underlying parameters.

Table 4 – Bedding use in housing systems

	Daily use kg/cow/day	**Total use(180 day winter) kg/cow/winter**
Straw (bedded yard)	20	3600
Straw (chopped) mat	2.5	450
Sawdust – kiln dried	1.0	180
Sawdust - fresh	2.2	396
Sand	16	2880
Recycled paper based material	2.2	396
Lime ash	1.0	180
Gypsum	0.5	90

The labour component of any housing system also needs to be examined. Straw yards require a daily application of straw which has to be brought to the farm, handled and stored (preferably under cover) and then dispensed onto the yard. The straw yard requires cleaning out every 3 weeks, and the waste material stored for subsequent dispersal at a later date.

At the other extreme, sand based cubicles would normally have the surface of the bed raked and conditioned at every milking with fresh sand applied twice a week.

Many buildings were originally designed to house cows on straw yards, then subsequently converted to cubicles due to costs of bedding and time and management considerations.

Often the plan in a new building is to install cubicles at a later date. With this scenario it is important that the widths, access points and location of feed stances are built for cubicles but an earth or chalk base is laid for the straw pad.

Regardless of what type of housing is constructed, the majority of studies stress the need for the system to be well designed, maintained and managed.

When selecting a system, it is important to consider the initial construction costs, on-going management and maintenance costs as well as the animal health and welfare implications. There is also the added consideration of environmental factors, land and nutrient management.

7.0 BUILDING CONSTRUCTION

BS5502 (6) provides recommendations and principles for buildings which are to be used for housing dairy cattle. The basic building structure used in the UK, whether for housing cattle in straw yards or cubicles has remained relatively un-changed for a number of years.

This standard allows certain farm buildings to be designed to a reduced standard compared with other buildings in terms of snow loading due to their limited human occupation and consequent reduced risk to life. The 2010 Edition of the Scottish Technical Handbooks (66) states: "*BS 5502: Part 22: 2003 provides an alternative approach to the design of buildings to be constructed solely for the purposes of agriculture. Designers using this approach must be satisfied that the reduced loads permitted by this Standard are appropriate for the location of the building and for the intended use*."

However following recent heavy snowfalls, when repairing or replacing damaged buildings the Scottish Government have issued additional guidance to farmers recommending that advice be sought from a structural engineer and to consider applying a more demanding snow loading, to buildings sited in exposed locations more than 200m above sea level.

Most common would be a metal span building with sidewalls constructed of blocks, wood or concrete. The sidewalls are completed with some form of ventilation, most commonly space boarding or Yorkshire boarding. Space boarding is illustrated in Plate 5.

Plate 5 – space board for side ventilation.

In Holland, Germany and some states of the USA, buildings are commonly constructed entirely from laminated wood. A wooden framed building from Germany is illustrated in Plate 6.

Plate 6 – Wooden framed barn in Germany

The degree of complexity of the building will ultimately depend on the end use. If a building is to be utilised solely for dairy cow housing for 12 months of the year, it is easier to justify a specialist building. If the building is to house cattle for two or three months and will then fulfil other roles, the design is likely to be more general purpose. However, often this involves compromise, especially to the ventilation of the building, which can have adverse impacts on cow health and welfare.

If the decision is taken to provide shelter at minimal cost then a simple pole barn, utilising straw yards and large bales of straw for walls may have an attraction.

For example, using figures from the 2010 SAC Farm Buildings cost guide (67), the difference in costs of different building types can be assessed. This is illustrated in Table 5.

Table 5 Building costs £ per m^2

Building Type	Cost £ / m^2
General purpose building	185
Timber pole barn	46
Straw bedded yard building	194
Straw bedded yard building (drive through feed passage)	219
Cubicle house	271
Kennel Building	100

The cost of wooden frame buildings compare favourably with a metal frame building although they tend to have a greater on-going maintenance requirement. In addition, some farmers do not like kennel buildings with cubicle partitions with rear legs, which may make cleaning the back of the cubicle bed more difficult and will restrict the type of cubicle base fitted, i.e. no mattresses.

Plate 7 – Wooden kennel building.

The previous generation of kennel buildings had narrow feed and scrape passages but modern kennel buildings are now available with dimensions more suited to the modern dairy cow.

At Wageningen in Holland, a plastic coated building has been constructed from an aluminium framework. The framework forms a series of domes over which tensioned plastic has been fitted. The environment within the building is extremely light and airy although they have had significant problems with ingress of solar radiation and rising summer temperatures.

The sides of the building consist of lifting tarpaulin curtains which can be lifted and dropped depending on external weather conditions. The building cost around 70% of the cost of a conventional span building.

Plate 8 – Plastic covered dome at Wageningen in Holland.

Some farmers have erected more basic shelter for their animals in structures such as round houses. An example is illustrated in Plate 9.

Plate 9 – Roundhouse accommodation

8.0 BASIC DESIGN CRITERIA

Modern housing systems have been designed to make management of the dairy herd easier and less labour intensive, but not always taking full account of the welfare needs of the cow. To ensure cow housing systems do not compromise animal welfare or production, a number of basic design criteria must be considered.

These criteria are often irrespective of housing system selected.

8.1 Group size

Modern housing systems have become more intensive with time. Numerous studies have demonstrated that aggression increases and the synchrony of behaviour is disrupted when cows are housed at a higher density (68). When the reduced space is combined with constant re-grouping, there is a marked increase in aggression, partly as cows have to compete for feed and resting space.

Under these conditions, some animals will compete more successfully (dominant animals) while others will compete less successfully (subordinate animals).

When aggressive behaviour was compared (69) i.e. pushes, threats, butts and avoidance, in housed cows with grazing cows, the animals at grass exhibited less aggressive behaviour. When studied, cows at grass recorded 1.1 aggressive interactions per hour compared with 9.5 aggressive interactions per hour when housed.

All groups of dairy cows will consist of a mixture of dominant and subordinate animals. Dominance is often related to body weight. Mixing of groups will interrupt the establishment of the social hierarchy within a group, which can take between 3 – 7 days to become re-established (70). There is some evidence (68) that the time taken to establish the hierarchy is extended significantly when group sizes exceed 80 cows. However, a further paper from the USA (71) suggests that there is little problem with group sizes of up to 200 cows as long as adequate manger space is available.

Space at the feed stance is also a feature of studies at the University of British Columbia (25) who reported that subordinate cows in particular were displaced more at the feed barrier when stocking rates increased and feed barrier space was reduced. More space meant less aggression.

While there is a lack of financial evidence to support a firm recommendation, until further evidence is provided, it would seem prudent to limit group size to 100 cows and minimise mixing of groups unless necessary for management purposes. However, space allowances, especially at the feed manger, should be optimised.

In many cases, group sizes can be influenced by the size of the milking parlour. To improve efficiency, a parlour should always operate with the standings full. If the parlour has 20 animals per side, group sizes in multiples of 20 will be most effective.

8.2 Example Layout Options

While it is impossible to provide an outline layout for every conceivable scenario, there are a number of basic design fundamentals which can be used to prepare example layouts. The example layouts which follow in subsequent sections describe cubicle layouts for adult lactating cattle and youngstock whilst the straw yard layouts describe examples for lactating cattle and youngstock.

These layouts should be considered as examples and should not be used for detailed designs, working drawings or construction. To standardise building dimensions, layouts are prepared to accommodate typical herd sizes of between 150 – 240 cows.

The dimensions used in the various example layouts are above the minimum dimensions described by some of the standards but would be considered to be best practise.

Larger scale versions of each layout are included at Appendix 1.

9.0 STRAW YARDS

9.1 Shape of the yard

One of the first considerations with a straw yard is to determine the shape of the yard. While the shape of a successful yard can vary to some extent, the shape will affect the space available for the cows. Since cows prefer to lie down along the peripheral walls of straw yards, a rectangular yard is considered a better shape than a square yard.

The distance from the bedded yard to the feed area should be as short and direct as possible. The distance from the feeding passage to the back wall of a straw yard should not exceed 10.0m. This minimises the risk of animals treading on each other as they exit the yard.

Example layouts of straw yard designs are illustrated as Figure 1 and 2.

Figure 1 – Straw Yard and central feed passage

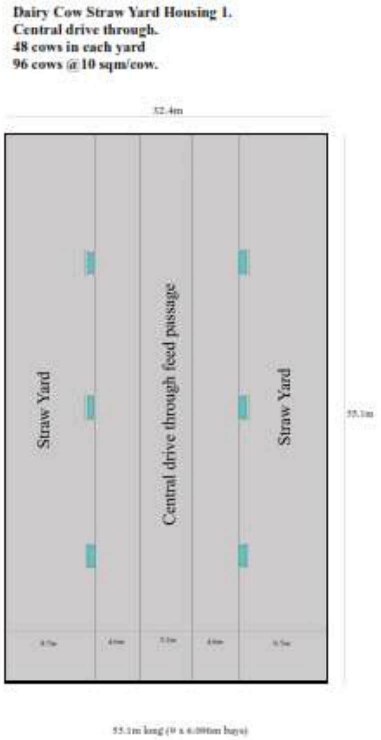
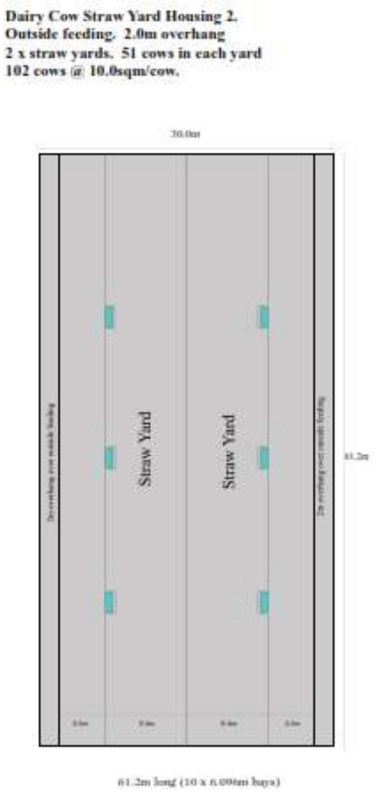


Figure 2 – Example straw yard with perimeter feeding



9.2 Bedded area space allowances

The space allowance required for each cow will determine the stocking rate of the yard. The range of space allowances offered to the UK dairy farmer is presented in Table 3.

Where the design of a straw yard is optimal (rectangular in shape with more than 3.0 m^2 /cow loafing and feeding area and not more that 10.0m in depth), a lying area of at least 7.5 m^2 /cow is recommended. If the bed is deeper than 10.0m or the design of the yards is compromised with poor access or ventilation, the lying area should be increased to at least 9.5m^2/cow. The example layouts use a bedded area of 10.0 m^2 /cow.

9.3 Feed stance / loafing area

Any housing system based on straw yards must provide a concrete area for loafing and feeding. This helps promote some hoof wear and will prevent feet becoming over-grown.

The loafing area should be at least 3.0 m^2 /cow and it is important to ensure that there is ready access to the loafing area from the straw yard through multiple exits or, preferably, un-hindered access. If the loafing area also serves as a feeding passage, the minimum width of the feed passage should be 4.6m. This allows cows uninterrupted feeding at the manger, while animals are moving around behind them. The loafing area should be scraped at least twice each day to reduce faecal soiling of the feet.

The floor surface on the feed stance and loafing area should be well drained, easy to clean and non-slip. Floor surfaces will be covered later in the report.

9.4 Access from the straw yards

There should be un-hindered access from the straw yard to the feeding and loafing area to prevent the development of soiled areas. If access is restricted, these localised areas around gateways become very dirty and wet, reducing the available bedding area for cows to lie and increasing the risk of mastitis.

A step should be provided between the feeding and loafing area and the straw beds. This will help retain the bedding and prevent the ingress of faeces and urine into the beds which can lead to contamination and soiling. A solid barrier also provides a straight edge to scrape against when cleaning out the loafing area. The height of the barrier will depend on the frequency in which the beds are cleaned out but it is likely to be around 0.2m.

It is important to be able to close off the bedded area to keep the cows on their feet after milking, for a minimum of 30 minutes, to reduce the opportunity for new mastitis pathogens to enter the open teat canal (46, 72). This can be achieved by the use of an electric fence, tensioned wire or sections of fixed barriers and gates.

9.5 Location of water troughs

Water troughs should be located so that it is impossible for cows to drink when they are standing on the bedded area. This will either mean locating the trough in the feed fence (which can create problems with feed contaminating the trough during delivery) or on the edge of the bedded yard but protected by a block wall, or similar, so cows can only drink from the feed stance.

10.0 CUBICLES

10.1 Cubicle design and cubicle bedding

There are a number of features of cubicles that can affect welfare. Ideally, a cubicle will allow an animal to lie down and rest without colliding or rubbing against any divisions. Cubicles that are too short for the cow or divisions with back legs may cause rubbing and swelling on the hocks. Brisket boards that allow the cow to lunge forward when she kneels down to reach a lying position will facilitate the easy movement to lying which may prevent awkward twisting of the neck, back and front legs.

An appropriate cubicle length will prevent soiling of the bedding. A good depth and cleanliness of cubicle bedding will create cubicle comfort, and also prevent knee swelling and hock injury.

Cubicles must provide a clean comfortable lying space for cows. The cow must be able to enter and leave the cubicle easily and lie down and rise without interference or injury. Poorly designed and managed cubicles can lead to poor occupancy, wet and soiled cubicle beds, increased risks of udder disease and lameness and physical damage to the cows.

Plate 10 – Well occupied cubicles

The cubicle must be long enough to allow the cow to rest comfortably on the floor without injury, yet short enough to ensure that urine and faecal material fall into the scraping passage and not onto the cubicle bed.

The cubicle must be wide enough for the cow to lie comfortably, but narrow enough to prevent her turning around. The cubicle also needs to accommodate the natural rising behaviour of the cow. The cow should not come into contact with the cubicle partition in such a way that could cause injury. This is particularly important when the cow is lying down, since the last stage in this movement is uncontrolled.

When a cow rises from a lying position, she lunges forward to transfer the weight from her hindquarters onto her front legs. She will then raise her hindquarters before raising her front. To accommodate this transfer of weight, the cow thrusts her head forward as she lunges. Observations have shown that a cow requires between 0.7 and 1.0m of space in front of her to rise easily. If the forward lunging space is restricted, she will have difficulty in rising. She also throws one foot forward when rising, and any barrier to this normal activity may compromise the way she raises and lead to lameness and reduced occupancy.

Figure 3 - Illustration of cow rising

There are a number of factors to consider when reviewing cubicle-housing systems.

10.2 Number of cubicles

The Red Tractor Scheme (3) and the FAWC Report (15) requires that a cubicle housing system has a minimum of one cubicle per cow. The DEFRA Cattle Code (2), BS5502 (6) and the DairyCo booklet on making cows more comfortable(73) recommends that there are 5% more cubicles than cows.

Overstocking buildings in the USA has been a common response to increasing cow numbers without increasing investment on the facility. Researchers in Virginia in 1997 (74) suggested that a cubicle shed could be overstocked by 30% without any adverse effect on production or behaviour.

However, a paper published in 2001 (75), looking at 244 expanding Wisconsin dairies suggested that concerns over cow comfort, reduced dry matter intakes and lower milk production were discouraging many producers from the practise of overstocking. Further reviews (52) indicate that when there is not a cubicle for every cow in a cubicle house, reduced lying time and aggression, with associated poor welfare, is more likely to occur. It may also lead to increased lameness and mastitis. EFSA therefore advise that in cubicle houses there should be at least as many cubicles as there are cows in the house. Researchers at the University of British Columbia (25) suggest that what looks to us as 1:1 cow to-stall stocking density may seem considerably worse to the cows if some stalls are less attractive, implying there needs to be more than one cubicle per cow.

A paper published in the USA (76) reported that for every 10% increase in stocking rate above 80%, there is reduction of 0.73kg milk per cow per day.

The adverse effects of overstocking (more cows than cubicles) can be viewed from two angles. Firstly, within any given cubicle building, the addition of every extra animal introduces at least another 60 litres of slurry each day. This extra slurry is distributed on the same surface area, which can lead to an increase in hoof and cubicle bed soiling. Secondly, overstocking has been shown to impact negatively on lying times and increase the risk of laminitis if continued over a period of time (77, 78).

When a cubicle system is designed and built, the feed face per cow and available water troughs should be calculated on a known number of cows. Increasing stocking rate above this threshold can have a negative impact on dry matter intake and water consumption.

A study in the USA (68) suggested that animals which were lower in the social hierarchy spent more that 45% of their day standing in alleys. This compares with a more typical figure of around 10%. These cows suffered significantly more sole, interdigital and heel lesions. Providing additional cow places in the cubicle system will allow these cows to lie without risk of aggressive interactions. Researchers (25), have demonstrated that not all cubicles are occupied to the same degree, with some being preferred to others. This can result in subordinate cows standing for longer periods of time.

A number of other studies have reinforced the argument that overcrowding will decrease lying times in cubicles (77, 78). Significantly, many of these researchers have pointed out that, even at high stocking rates, it takes several months for lameness to develop, suggesting that many studies on the effect of over-stocking are of insufficient length to consider longer-term implications to cow health.

There is also considerable debate regarding the location of the cubicle within a building and how this can affect occupancy. Some work in Canada (79), suggested that cubicles closest to a feed passage, were occupied for 68% of the day, compared with only 48% occupancy for cubicles which were further from the feed area. In addition, cubicles at the end of rows were occupied 25% less than cubicles located in the centre of the building.

A study from the USA (80) confirmed that stalls on the periphery of a building were used less than stalls in the centre of a row. This suggests that certain stalls, particularly those furthest from the feed stance or at the ends of rows are less desirable to cows.

This may be because the cows have to walk further to the food or have to navigate certain physical barriers (e.g. narrow passages) or social obstacles (e.g. dominant cows) on their way to the more distant stalls. Work carried out in Cambridge in 1990 indicated that the movement and resting of subordinate animals is heavily influenced by the location of dominant animals (69).

There would appear to be a number of convincing arguments to support the justification that there should always be more cubicles than cows and that the 5% figure quoted is relevant.

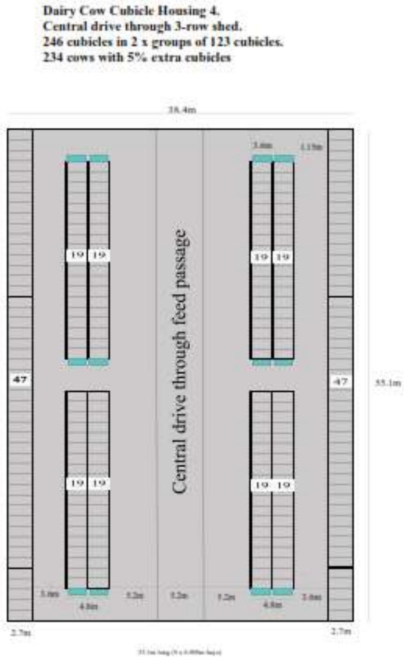
10.3 Number of rows of cubicles

When considering a cubicle housing system with a central feed passage, the system is likely to be either a two-row system (two rows of cubicles accessing one section of feed stance) or a three-row system (three rows of cubicles accessing one section of feed stance). The three-row design has been favoured by many farmers and designers as the space requirement per cow and therefore cost per cow is less (i.e. cows are housed at a higher stocking rate).

Plate 11 – Three row cubicle system

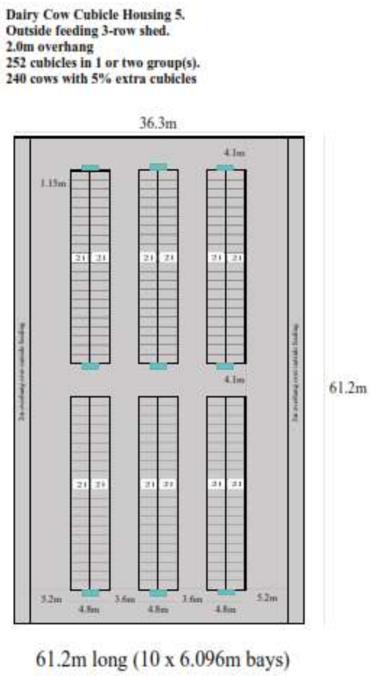
An example layout of a three row system is shown in Figure 4 utilising a central feed passage.

Figure 4



In Figure 5, a three row cubicle system utilises perimeter feeding.

Figure 5



Typically, a three-row system has a 25% reduction in passage dimensions when compared with a two-row system. It should be noted that the loafing area in a three-row system will be reduced in size, although there may be sufficient loafing space to comply with the varying standards and codes of practice, there will be other considerations such as cow behaviour, aggression and feed intake.

Plate 12- Two row cubicle system

Clearly each animal will generate a similar amount of slurry in a 24-hour period and having 20% more surface area to distribute the slurry in a two-row system will reduce the depth of the accumulated waste.

A critical component of any environmental mastitis programme is the requirement to keep cows standing on clean concrete for 30 minutes after milking, to allow sufficient time for the teat orifice to close (46,72). Although this can be achieved with a three-row system, it requires the use of electric fences or other moveable barrier to prevent cows accessing the first row of cubicles which are adjacent to the feed stance. This may impact on occupancy of such cubicles if an animal has previously had a negative experience around these beds.

Two row systems utilising perimeter feeding and two sets of head to head cubicles (Figure 7) have the same issue keeping cows off the cubicle beds after milking.

Example layouts for a two row system are illustrated in Figures 6 and 7.

Figure 6 – Two row system with central feed passage

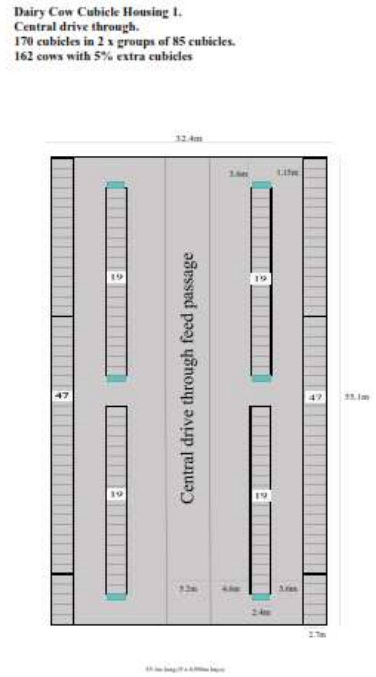
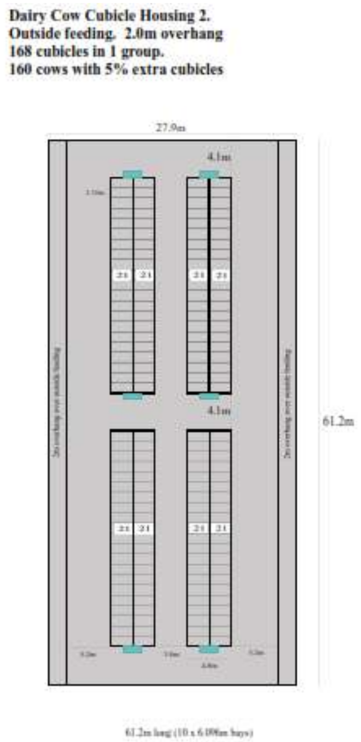


Figure 7 – Two row system with perimeter feeding



10.4 Passage widths and layout

The purpose of a passage within a cubicle building is to facilitate cow movement, allow the animals to loaf and exhibit normal behaviour and to allow the removal of slurry. Passages and cross passages should be designed to ensure that there are no dead ends where a dominant animal can interact aggressively with an animal of lower social ranking.

BS5502 (6) and Red Tractor Dairy Scheme (3) both require a total loafing area of 3.0 m^2 / cow (excluding cubicles). To achieve this figure within the confines of a feed / sleep building, the width of the scrape passage between rows of cubicles should be a minimum of 3.0m, although 3.6m would appear more appropriate as we gain a better understanding of cow behaviour.

Where a three-row system is built, with one row of cows backing out of cubicles onto the feed stance, the passage width should be at least 5.2m. When a two-row system is built, the feed stance width can be reduced to 4.6m.

Wide passages increase loafing area and can improve social interaction between cows. In hot weather, wide passages can be difficult to scrape as slurry is spread over a wider area and can dry out more quickly.

Plate 13 – 5.2m wide feed passage

Cross passages should be installed at the end of every row of cubicles to remove dead ends. A cross passage should also be located at approximately every 20 cubicle places, depending on building layout and size. It is recommended that there should be no more than 25 cubicles without a cross passage. The cross passages should be constructed to the same height as the surrounding cubicle beds to ease cleaning. To provide un-interrupted cow flow, an intermediate cross passage should be at least 2.4m wide (assuming that no water trough is installed).

When a drinking trough is installed in the cross passage, the width should be increased to a minimum of 3.6m to allow cows to pass behind other animals who are drinking.

Plate 14 – Cross passage with drinking trough

Passages also have to facilitate vehicle movement. In particular, farms that rely on forage boxes / complete diet feeders, need to ensure that the machine can enter the building and work easily once inside. As the capacity of these trailed feed dispensers increases, the dimensions also increase and consideration should be given to possible future requirements.

It is also important to take account of the driving skills of the operator. Minimising all building dimensions to reduce costs may appear prudent. However, if these tight dimensions are marginal, not only will the time taken for the tasks to be carried out increase, but damage could occur to staff, cows or the machine.

10.5 Cubicle dimensions

The dimensions of a cubicle are dependent on the size of the cow. Previously this has been best-estimated using body weight, although division design can affect this.

The body weight of an animal can be estimated by measuring the chest girth and the diagonal body length (81). This is demonstrated in Table 5.

Table 5 – Relationship between chest girth, diagonal body length and weight.

Cow body weight (kg)	Chest girth (m)	Diagonal body length (m)
375	1.68	1.36
425	1.75	1.41
475	1.81	1.46
525	1.87	1.50
575	1.93	1.54
625	1.98	1.58
675	2.04	1.62
725	2.09	1.65
775	2.14	1.68
825	2.18	1.72

Research has concluded that cubicle usage increases with increased cubicle size. However, the dimensions required for a cubicle will depend on the cubicle location (e.g. against an outside wall, open fronted facing a feed passage or head to head facing another cow). It is important to try and weigh the value of the expected increased milk production and lower health costs against the extra costs incurred by increasing the cubicle dimensions.

10.6 Cubicle Length

The total length of the cubicle should provide body space, headspace and lunging space.

Cubicles which are open fronted (either facing a feed passage or head to head) allow a cow to extend past the cubicle perimeter when rising, either by placing her head in the adjacent stall in a head to head arrangement or by utilising the extra space available in the feed passage.

Plate 15 – Open fronted cubicles

Cubicles which are closed at the front have some type of barrier which prevents the cow from lunging outside the perimeter of the cubicle. These are often the outside cubicles facing a wall.

When rising naturally, a cow will choose to lunge forward. If a closed front cubicle is too short, the cow may respond by lunging to the side or rising dog/horse fashion. Selecting a cubicle partition which allows this lunging action can be helpful, although this can encourage cows to lie diagonally, resulting in dirtier cows (82,83, 84).

When a cow can lunge forward, she will lie straighter in the cubicle. Cows which are forced, by inadequate cubicle length, to lunge to the side will often lie at an angle in the cubicle.

A study in Canada (85) examined the rising pattern of cows and reported that when cows were housed in a cubicle bed with a closed front which was 2.4m long, they lunged diagonally 68% of the time. When the fronts were removed to allow straight lunging, the percentage of cows lunging diagonally fell to 44%.

In a UK survey reported in 1996 (84), the researchers concluded that a Fresian / Holstein cow at pasture required a lying space approximately 2.4m long and 1.2m wide. They suggested that a cow required an additional 0.6m length to facilitate lunging. When they considered these parameters, they reported that 87% of cubicles in the study were too short and 50% either too wide or to narrow. However, cow size has increased in the intervening period and such dimensions would now be considered too small.

A paper presented at the Fifth International Dairy Housing Conference (87) concluded that to optimise cubicle occupancy, it was critical that the length of cubicle bed was correct. The paper acknowledged the significant difference in bed length required when cows have either an open or closed front cubicle and the results are demonstrated in Table 6.

Table 6 – Guidelines on cubicle length

Weight of cow (kg)	Total length of bed (m) (open front)	Total length of bed (m) (closed front)	Total length of bed (m) (Head to head)
550	2.10	2.40	4.20
700	2.30	2.55	4.60
800	2.40	2.70	4.80

As the length of the bed increases, it is important that the length of the partition increases. There should be around 0.35m from the back of the partition to the cubicle kerb. If this distance is greater, cows may walk along the back of the cubicle or try and reverse into the bed.

A number of recent studies into cubicle dimensions for the modern cow have been undertaken in Wisconsin. The current recommendation by these workers would be for a cubicle length of 3.05m when against a solid wall, reducing to 2.6m when head to head (106). This shows a situation where recommendations change as cow size changes. Although, the assertion has been that with head to head cubicles the length of each stall can be somewhat reduced due to the potential of cows sharing the common lunging space, studies by the University of Wisconsin (82) and others have shown that this leads to bobbing action by both cows, causing the cow opposite to rise as well.

One cubicle size does not fit all cows and therefore a compromise has to be reached where cow groups include animals of various size and parity.

10.7 Cubicle width

It is important that a cubicle is wide enough to allow the cow to recline and rise easily. If the cubicle width is excessive, cows will tend to lie at an angle in the stall or some smaller cows may lie backwards in the cubicle. Both will lead to an increase in faecal soiling at the rear of the bed. However, Cook (82) concludes that the main issue with cows lying at an angle with wide cubicle dimensions is insufficient cubicle length. If the cubicle length is correct then cows will lay straight.

The width of the cubicle will be determined in part by the choice of cubicle partition. If the partition fitted has a rear support leg, the partition should be installed with a clear distance between partitions of 1.2m (73). However, in their summary report EFSA state that cubicle width should be at least 1.8 times cow hip width, (measured across the hook bones) (52).

With divisions which are space sharing, the distance between partitions can be reduced. In a relatively recent study (88), space sharing partitions were placed at 1.05m centres, 1.150m centres and 1.2m centres. When total lying time, length of lying bouts, occupancy and bed hygiene were measured, the 1.15m cubicle width was considered superior. However, 1.22m centres were found to increase resting time. A study in 2009 (24) reported an association between resting time and milk yield, although studies by at Wisconsin did not found this association (82). However, in a review Cook suggests that the cubicle width between divisions should be 1.2 m for heifers, 1.27m for mature cows and 1.37m for pre-fresh cows (89). This work was based on 800kg cows.

10.8 Partition design

There are numerous types of cubicle partition currently available on the market. The overall requirement of any partition is to provide the cow with maximum comfort, while ensuring that she is correctly positioned. The partition also needs to impart a degree of protection to prevent injury from neighbouring animals but not cause any discomfort or injury to her.

Many of the traditional partition designs have sections of the partition impinging on the area the cow may choose to spread. Lower rails (often installed 400mm above the bed surface) could lead to cows becoming trapped and many partitions with a rear support leg caused damage to cows hock's and pelvis.

Suspended partitions with very little restrictions to interfere with the cow at rest continue to be very popular.

A study undertaken in 1991, looking at occupancy rates of different partition designs (summarised in Table 7), confirmed that the Super Dutch Comfort cubicle partition is favoured by the cow (73). The suspended Cantilever partition is generally considered to have superseded the Super Dutch Comfort partition.

Unfortunately, although variations of suspended cantilever divisions remain a popular choice, there is little evidence to compare their performance with other partitions. Manufacturers make small design changes, but in essence there is little independent evidence based science to support these adaptations.

Plate 16 – Suspended cantilever partition

Table 7 – Occupancy rates for a range of partition designs.

Partition Design	% Occupancy / cubicle (lying)	% Occupancy / cubicle (lying and standing)
Newton Rigg	30	43
Dorsdun	31	46
Dutch Comfort	33	50
Dutch Cantilever	39	64
Super Dutch Comfort	51	71

Studies, particularly in the US, have looked at different cubicle partition concepts, but there do not appear to be any significant advantages over the suspended cantilever, with many leading to dirtier cows.

A recent development has seen the emergence of a simple division design incorporating a flexible pole. This is illustrated in Plate 17.

Plate 17 – Flexible pole cubicle division

A Norwegian study suggested the individual flexible pole offered an advantage over cantilever divisions (90) in respect of cow preference, but lying, standing and stall cleanliness parameters remained unchanged. Further studies are needed, especially to their use with head to head situations. One of the advantages of several designs of the cantilever type of partition is that both height and width can be adjusted, allowing small changes to be made with significant changes in, for example, cubicle occupancy, cleanliness and standing position.

Farmers who have installed the flexible pole division report animals walking along the front of the beds and the manufacturer has subsequently released an updated version of this partition which includes a horizontal rail from the partition to the front of the bed.

10.9 Brisket Board and Head Rail

The purpose of the brisket board is to position the cow correctly when she is lying down. When the board is correctly located, it will prevent the cow lying too far forward which can lead to soiling on the cubicle bed. If the cow lies too far forward, it can also cause her difficulty when she rises.

The brisket board should not be more than 0.1m in height. The height of the board is important as the cow will often swing her leg forward before rising (82, 84, 85, 91). It is felt that 0.1m is the maximum height the leg can be swung without risk of impact.

The board should be angled towards the front of the cubicle to allow for the natural shape of the cows neck. There is general agreement that the distance from the rear edge of the brisket board to the rear kerb should be 1.6 – 1.8m, with indications that the greater figure is more suitable (84, 91).

The purpose of the head rail is to position the cow when she enters the cubicle, before she reclines. The position of the head rail needs to be correct both horizontally and vertically. If it is too far forward on the partition, when the cow is standing with four feet on the cubicle, she can soil the back of the bed. If it is too close to the kerb, it will limit the occupancy of the cubicle and lead to cows perching (two feet on the cubicle and two feet in the passage).

If the head rail is mounted too low, it can cause injury to the cow when she reclines and rises. Restrictive head rail position prevents cows standing in cubicles but helps keep the base clean (92).

A study, reported in 2004, looking at cubicle occupancy, left all other parameters unchanged but raised the height of the head rail from 1.125m to 1.250m (93). The occupancy percentage increased from 40.0% to 51.4%. However, the size of UK dairy cow is increasing, and the height of the head rail should now be placed between 1.22 and 1.32 m above the base of the cubicle bed for cows weighing 636 to 818 kg (91).

As with head rail height, as cows become larger the horizontal distance from the head rail to the rear kerb needs to take this into account. Therefore the horizontal distance may vary between 1.6 and 1.8m, but up to 1.9m for herds with larger cows.

Another guideline is for the diagonal measurement from the head rail to the kerb to be between 2.1 and 2.2 m.

10.10 Slope

Cows prefer to lie facing uphill so cubicle beds should be installed with a slight fall from the front to the rear. The fall will also help drain any liquids (e.g. milk and urine), where the cubicle base has an impermeable finish, which could otherwise contaminate the bed.

A consistent fall of 2 – 3% across the length of the cubicle bed is satisfactory. Where the slope is greater than 3%, there can be problems retaining the bedding material on the surface of the bed.

10.11 Kerbstone

The height of the kerbstone should be between 0.15 – 0.2m. The final height of the kerb will be dictated by the method of slurry removal, although cow comfort should always be the main consideration. Although concerns have been raised about excessive kerb height, with adverse affects on foot health with cows perching, this concern is minimised if overall dimensions are correct and cows stand four feet on the cubicle.

Long scrape passages may require a slightly higher kerb to prevent faecal soiling of the beds while slatted passages will allow the kerb to be reduced in height. The kerb height should not be reduced below 0.15m, as this can encourage some cows to lie partly in and partly out of the cubicle.

If mats or mattresses are fitted, their height should be considered in the kerb depth calculation.

10.12 Cubicle Lying Surface

The surface of the cubicle has many roles to fill. It must be comfortable to the cow and encourage high occupancy, it must be easy to keep clean and be durable and it must be cost effective to initially install.

If the bedding surface is comfortable, in combination with the correct cubicle dimensions, the cows will be encouraged to spend increased time lying which will have a direct bearing on the condition of their feet and the incidence of lameness.

As well as providing a comfortable bed, the bedding surface must prevent hock damage and other injuries.

There are numerous types of cubicle surface available. It is regrettable that in many cases the choice of cubicle bedding surface is dictated not by the requirements of the cow but by the requirements of the farm's existing slurry handling system.

The consistent finding from all the research is that the softer the bedded surface, the more acceptable the cubicle will be to the cow.

Constructing a cubicle bed from concrete is a common practise. The concrete is then covered with a surface layer of straw (chopped or long straw), sawdust or shavings or wood ash to improve comfort. Numerous studies have demonstrated that when concrete cubicle beds are compared with softer alternatives, the cow will show a preference for the softer alternative.

When researchers in Sweden (94) compared concrete cubicle beds covered with straw with a mattress covered in straw, the cows spent significantly more time occupying the cubicle with the mattress.

When researchers in Ireland (95) examined the options of concrete and sawdust, concrete and paper, mattresses and sawdust and mattresses and paper, cows were more likely to occupy the beds with mattresses and least likely to occupy the concrete beds.

Swiss researchers (96) compared cows housed in cubicles bedded with straw and cows bedded with a mat, and were unable to identify any difference in cow behaviour between the two systems although they concluded that there was more hock damage with the soft lying mat. This study somewhat contradicts the conclusion of other studies considering cow comfort and concrete.

An MDC funded study in 1997 (97) examined cow comfort on cubicle beds, compared the impact absorbing properties of a rubber crumb mattress (to simulate the last uncontrolled movement of a cow when she reclines) with an EVA mat.

The study concluded that a new rubber crumb mattress provided a softer bed than a new EVA mat. However, after four years the EVA mat had maintained its original softness while the rubber crumb mattress had become harder.

An MDC funded study in 1996, compared mats and mattresses at two Agricultural Colleges (98). The objective of the study was to determine if the more expensive mattress cubicle bed resulted in a better housing environment for the cows. The study considered a number of parameters including, lying time, hock and knee injury, udder cleanliness and milk production.

Although the study concluded that the cows housed on mattresses spent longer lying down and more time eating than cows on mats, they were unable to identify any difference in either milk yield or milk composition. Mattress cows had fewer hock and knee injuries.

An alternative to the geotextile mattress is a waterbed. The initial cost of the waterbed is greater than a more traditional mattress. There appears to have been limited work undertaken comparing the waterbed with other mats or mattresses. A US study (99) however found that cows preferred mattresses over water beds and that cow lying times were superior in deep bedded sand cubicles.

Cubicles with either mats or mattresses require a small amount of some type of absorbent bedding applied to them to help keep the beds dry and the cows clean and help prevent abrasions. A Canadian study in 2004 (100) demonstrated that as sawdust usage increased from zero to 7.5kg, there was a marked increase in lying times. In the UK, it would be typical to use in the region of 1.0kg of kiln dried sawdust each day on a mattress.

Sand bedded cubicles have become very popular in the UK. The practise has been widespread in the USA for a number of years. US based consultants frequently state the only choice of bedding in a new cubicle system is sand or a geo-textile mattress (101).

Experience from the USA and recently the UK suggests that the initial cost of a mattress is around £55 – 70 / cow and they have a life expectancy of between 6 – 10 years. Although the initial investment with sand based cubicles is low, the labour associated with filling and maintaining the beds and the adverse effects that sand can have on waste handling systems needs to be considered.

The study of Wisconsin dairy farms (75) that increased herd size by 40% between 1994 and 1998 showed no significant difference in milk production or somatic cell counts between those farms using sand bedding and those farms using mattresses. The study concluded that producers using sand were more satisfied with cow comfort but less satisfied with waste management. Although the differences in culling rate were not significantly different between the systems, there was a numeric advantage in favour of sand bedded cubicles (34% culling rate with mattresses vs 32% culling rate with sand).

A more recent study (21) in Wisconsin studied differences in behaviour on cows housed on sand and geotextile mattresses. The study was not able to demonstrate a significant difference between bedding surfaces for milk production. Although not statistically significant, there was a reduction in culling rate for the herds bedded on sand (36% culling rate on mattresses compared with a culling rate of 29% on sand).

The average prevalence of lameness was significantly higher in the herds using the mattress than in the herds using sand. The rate of clinical lameness was 24% on farms using mattresses compared with only 11% on herds using sand.

Researchers at the University of Wisconsin Arlington Farm looked at cow preference for different stall bases over a three-year period (102). They compared sixteen different surfaces including concrete with chopped straw, sand, waterbeds, rubber filled mattresses and rubber mats.

When occupancy was observed, sand and rubber filled mattresses consistently showed the highest occupancy while concrete and rubber mats consistently showed the lowest occupancy. The results can be seen in Table 8.

Table 8 – Cow preference for different stall bases

Stall base	% stalls occupied
Rubber filled mattress	89
Sand	79
Mat	65
Concrete	39

One of the mattresses consistently ranked higher for occupancy than the other mattresses tested. This suggests that not all mattresses are equally attractive to cows and that general statements about ‘mattress’ performance may be misleading.

Producers who opt for sand bedded cubicles accept that there is an ongoing labour requirement to keep the beds raked clean and populated with sand. When the depth of sand begins to decline, occupancy also declines. A study published in 2005 looked at the effect of sand depth on cubicle occupancy (103). The study concluded that there was a reduction in lying times of 1.15hours / day when the sand depth, measured at its deepest point, dropped from 6.2cm to 3.5cm. When the sand beds became pitted (defined as a drop below the kerb height of 13cm) the lying times declined by 2.33 hours/ day.

When the research is considered, there is little evidence to support the use of concrete cubicles without the use of some kind of cushioning. This may be provided by a mat, mattress or sand. There is clearly a role for sand cubicles, but these need to be considered in the context of the whole farm system.

Although a considerable amount of work has been done looking at the features of different lying surfaces, by and large researchers have failed to demonstrate a financial benefit from investing in one technology to another. However, the majority of the researchers have demonstrated improvements in cow comfort and lying times and a reduction in physical damage which will indirectly influence cow longevity and welfare and may be the driving force from milk buyers and consumers for such investments.

11.0 COW FLOW

11.1 Cow behaviour

A basic understanding of animal behaviour is important when designing dairy cow housing. Cattle remember painful and frightening experiences and cattle with previous experience of quiet, gentle handling and movement will be less excitable in the future.

Cattle have well developed senses and rely heavily on visual stimulation. While they have a wide field of vision, they are poor judges of detail and distance. They also have poor depth perception which explains why they are reluctant to enter dark or shadowy areas.

Cows have a tendency to move towards light but are sensitive to harsh contrasts of light and dark within housing facilities. Consistency of lighting throughout a building is as important as level of illumination.

Cattle are less sure footed on downward slopes and prefer to move up gradual inclines rather than steep slopes.

When a housing system is designed, it is important to understand the social hierarchy within a dairy herd (71). There will be a number of dominant animals and a number of subordinate animals. The majority of animals fall between these two camps. When a dominant animal meets an animal who has no established position in the herd hierarchy, there will initially be some aggressive interaction. One animal will emerge as the dominant animal. When the subordinate animal next meets the dominant animal, she will move away from any potential conflict.

The system has to be designed to allow subordinate animals to move away from dominant animals without conflict. Cubicle passageways which end in dead ends mean that to escape a dominant animal, a subordinate animal must walk past her. All passageways must provide a subordinate animal with an option to avoid aggressive interaction.

The use of backing gates in collection yards of milking parlours is a useful tool if used correctly to improve cow flow. This can speed up the time spent milking, which not only releases time for other husbandry tasks and maintenance, but minimises the time that cattle have to involuntarily stand.

However, they must be used sensitively and electrified backing gates are strongly discouraged. Cows are very sensitive to electrical current and standing on concrete on often wet floors aggravates the problem. In addition the animals getting the shock are not usually those the herdsman is requiring to move. This increases stress, will often lead to cows scrambling around and slipping and certainly increases the incidence of lameness.

12.0 Floors

When cows move around a building, they must have confidence that they can move without risk of slipping, particularly when the floor is covered by a layer of slurry. This can be achieved using a combination of slope and floor surface.

Previous advice has been to install floors on areas which require scraping with no fall (7). This was to prevent the separation of the faeces and urine to facilitate easier scraping.

All concrete surfaces which cows walk on should be easily cleaned and provide adequate traction without being excessively abrasive. The floor should provide sufficient slip resistance when covered in slurry, at all times of the year, to prevent injuries from slips and falls. Poorly designed and maintained concrete floors can cause considerable sole and hoof wall injury. Excessively abrasive floors, such as new concrete, may also cause sole injury.

The CIGR document (7) suggests that solid floors should be laid with a slope of 2.5% where drainage is required for urine or wash water. The document then suggests that floors should be laid level in scraped areas to prevent the separation of dung and urine and ease cleaning. However, there is considerable evidence that scrape passages in which floors are laid flat can lead to slurry ponding which increases the risk of foot related problems.

Plate 18 – Scrape passage laid with no fall.

However, there is now considerable evidence that installing scraped floors with a slight fall will prevent slurry ponding which has a marked effect on lameness (30). Wet floors can reduce hoof hardness and increases the susceptibility to wear and damage. The DairyCo publication 2008 (104) also advises the importance of preventing pooling of slurry for lameness, cow cleanliness and udder health. The floor should be installed with a fall of between 1.5% (1:66) and 3% (1:33) to assist drainage.

Where floors have been laid flat and pooling is occurring, there is little option other than to break up the existing concrete and relay with a fall. This must be done taking due account of kerbstone height.

Research in Canada (105) demonstrated the chances of a cow slipping on various floor surfaces. These results are shown in Table 9. The value for dry un-grooved concrete is the reference value (100%)

Table 9 – Estimates of cows slipping on different floor surfaces

Floor surface	Probability of slipping
Dry un-grooved concrete	100
Un-grooved concrete and slurry	350
Grooved concrete and slurry	60

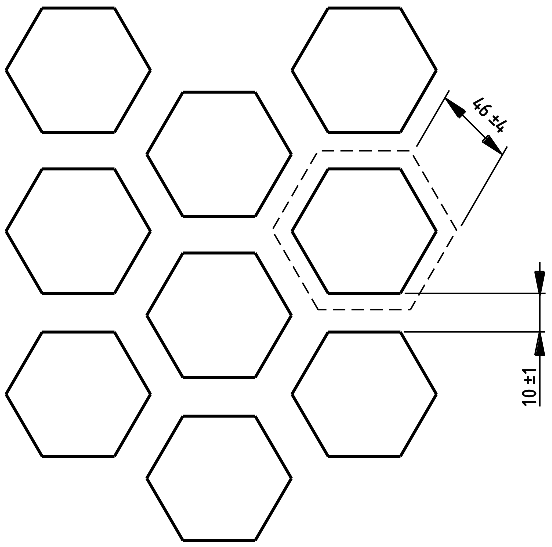
12.1 Improving traction on floor surfaces

There are many options available for improving traction and reducing slippage on concrete surfaces.

BS5502 (6) and the CIGR document (7) suggest that to provide skid resistance for cattle walking in all directions and to eliminate the adverse effects of high pressures on the hoof, a hexagonal pattern should be formed in newly laid concrete. The hexagon should have sides of 46mm and the groove should be 10mm wide and 6 – 10mm deep.

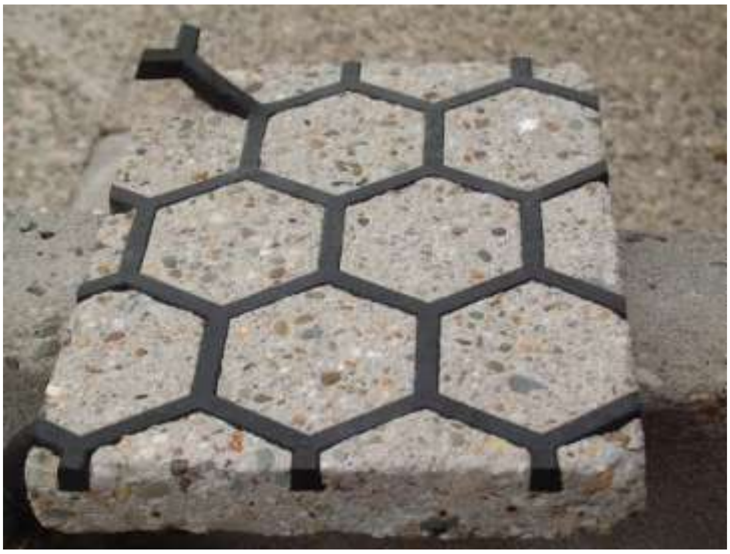
The hexagonal pattern should consist of regular hexagons with 46 ± 4 mm sides separated by grooves 10 ± 1 mm wide and a minimum 6 mm deep as shown in Figure 8.

Figure 8 —Concrete floor with hexagonal pattern



In Holland, the hexagonal pattern is created by tamping a pre-formed rubber template into the floor and removing the template as the concrete cures.

Plate 19 – Hexagonal rubber floor template

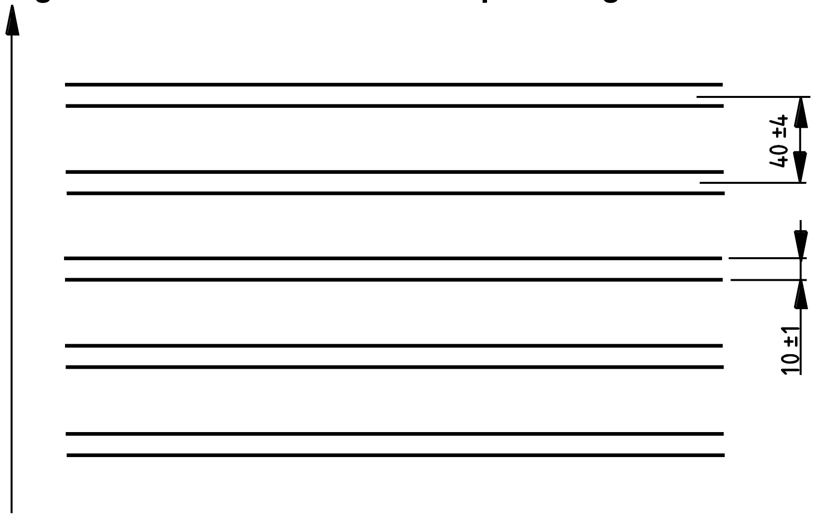


In the UK, many farmers create a hexagonal pattern using a roller on the surface of the concrete just as it starts to cure.

If the direction of cow flow is known and not random, i.e. on access passages, parallel grooves can be formed in the concrete. The grooves should be placed at right angles to the movement of the cattle.

The grooves should be placed 40mm between centres and the groove should be around 10mm wide to prevent slurry accumulation. The grooves should be a minimum of 6mm deep but more usually 10mm.

Figure 9 — Concrete floor with parallel grooves



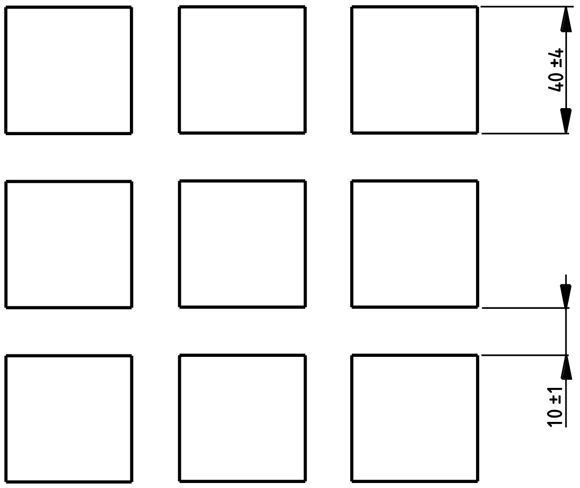
Key
↑Direction of cattle movement

If an existing floor is to be improved, it is normal to adopt either the parallel grooves or if the direction of movement is more random, a pattern of regular squares or diamonds. Parallel grooves are preferable, as squares and diamonds have been found to provide an increase in the number of pressure points on the cow's foot, without any benefit in slip resistance.

If squares or diamonds are to be used, the pattern should be regular with 40mm sides separated by 10mm wide grooves. Again the grooves should be 6 – 10mm deep. From practical experience, most grooving is of insufficient depth and width and too close together. This type of grooving provides poor cow traction when manure is dry – due to diet or ambient temperature.

If improving existing concrete, diamond cutters are preferred to flail cutters to avoid aggregate becoming exposed and risking damage to cow's feet.

Figure 10 — Concrete floor with square pattern



Where dairy cows are housed in cubicles using sand bedding, there are reports that the sand provides an initial improvement in grip on the passage floors. However, over time, the sand will polish the floor surface, which can lead to a slippery surface unless some grooving is carried out.

12.2 Slatted floors

Slatted floors are often seen in passages. It is important that the slats are well constructed with no rough edges or abrasions. The width of the slat and their spacing is a compromise between the provision of adequate support for the cow's foot and effective self-cleaning. For a mature dairy cow, the width of the slat is likely to be around 140 – 160mm and the spacing between slats between 35 – 40mm.

Plate 20 – Slatted floors

12.3 Automatic scrapers

Many modern cubicle housing systems are constructed with automatic slurry scrapers. These scrapers, run frequently, will remove waste material from the passages within the building. The scrapers either deposit the slurry outside the building on a hard standing for collection by a tractor scraper or scrape directly into a slurry lagoon or slurry channel.

Practical experience suggests that irrespective of the frequency of operation, unless scraped runs are kept below 25m, there is likely to be a build up of slurry in front of the scraper blade. This accumulation of slurry does not appear to concern the cows, who will wait until the blade is nearly in contact with their feet, before stepping over the blade and continuing their activity. However, this soiling of the foot and lower limb can have a negative impact on foot health.

Plate 21 – Cow walking over automatic scraper.

The installation of a slatted cross passage every 25m will significantly reduce the pooling of slurry in front of the scraper blade.

Research undertaken in Holland (60), looked at the prevalence of claw disorders in Dutch Dairy cows on different flooring systems. The study concluded that the lowest levels of digital dermatitis were recorded when passages were slatted with automatic scrapers. The installation of slats reduces slurry accumulation during passage scraping and improves foot cleanliness. Although the causative agent for digital dermatitis has not been found in slurry (38), the wealth of anecdotal evidence suggests that this disease is worse in dairy units using automatic scrapers and has been blamed on the accumulation of slurry in front of the scraper blade.

12.4 Rubber on flooring

There has been a recent trend to install rubber mats on scrape passages and feed stances to improve underfoot conditions for the cows. These textured mats, which are designed for cattle housing, allow the foot to penetrate into the mat to provide grip. The mats interlock to prevent movement during use.

A study in the USA compared rubber mats in the scrape passages with grooved concrete flooring (106). This study was unable to demonstrate any significant difference in several indices of lameness between the two floor surfaces.

A Canadian study (105) compared an un-grooved concrete surface with a textured rubber mat and found that 70% of cows slipped at least once on a concrete floor compared with only 20% of cows who slipped on a textured rubber mat.

Unfortunately, they did not compare a grooved concrete floor with a textured rubber mat.

When researchers in Germany looked at rubber mats on scrape passages, they compared a standard slatted scrape passage (40mm slots) with a rubber coated slatted scrape passage (107). They demonstrated that bruising on the sole of the hoof was reduced on the rubber coated floor and there was a significant reduction in lesions of the hoof wall caused by slippage.

Cows on the rubber floor showed a significant change in behaviour by exhibiting twice as much caudal licking. Caudal licking is a specific grooming behaviour when a cow lifts her rear leg and licks it. It is considered an excellent method to monitor floor quality as it requires the cow to lift her rear leg which increases the risk of her opposite front foot slipping.

Plate 22 – Rubber mats on slatted floors.

However, they were unable to demonstrate any difference in milk yield or clinical cases of lameness. It should be noted the study only ran for six months and, as stated previously, there is some evidence that this period is of insufficient duration for clinical lameness to develop.

Rubber mats are also placed on the feed stance in front of feed mangers. A Canadian study (108) compared a 1.85m strip of rubber mat in front of the feed fence with a grooved concrete floor. The researchers concluded that the rubber mat did not affect the time that the cows spent eating or the volume of milk which they produced.

A further Canadian paper (105) considered two studies which compared a textured rubber mat in front of the feed fence with a grooved concrete floor. In both studies, they report an increase in time spent at the feeders when the rubber mat was installed. This paper suggests that cows ate 0.8kg more of the fresh TMR when they were able to stand on the rubber mat.

However, not all types of rubber mat are equivalent (108). This study looked at installing rubber conveyor belting in front of the feed barrier. This material is commonly used in quarries and needs to be durable. The study demonstrated a reduction in time spent at the feed barrier suggesting that the cows found the product less acceptable than concrete. The researchers suggested this could have been as a result of a combination of hardness and slippiness.

Both surface friction and a forgiving surface have been found to improve cow mobility, walking speed with less slipping (109), but more information is still required as to the type of floor surface required for improved mobility and reduced lameness. In addition, although studies at the University of California (110) found that interlocking rubber mat was better for foot health than concrete, they also suggested that further long term studies were needed during lactation to determine the long-term effect of different flooring surfaces on claw health.

Recent studies and reviews have re-iterated the importance of underfoot conditions for cows, not only in terms of lameness but also udder health and production. Cows standing on a dry comfortable standing area have less lameness (25).

13.0 HANDLING FACILITIES

Every farm that handles cattle should have proper handling facilities which are well designed, maintained and in good working order. This is not only important for the welfare of the animals which are due to be handled but also for the safety of everybody associated with the task.

Regardless of the type they need to have non slip surfaces, be sited to avoid tight turns, be in well lit areas and without any projections on gates, hurdles, etc, on which animals (and operator) could injure themselves. The location should be in close proximity to the cattle’s visual route to and from the milking parlour. Although the crush and race are only used intermittently it will then become a familiar sight.

The facilities must make the most of existing features and be flexible in use. The design should take into account the numbers and type of animals to be handled and the type of treatments to be carried out. Sometimes a portable system will be most appropriate, particularly when cattle are out grazing far away from the farm, or where there are a number of buildings. However, more often permanent cattle handling facilities will be necessary and should be planned carefully in terms of location, space allowance and construction.

There are a number of key requirements for any cattle handling facility. It must take into account the numbers and type of animals which are due to be handled and be flexible enough to accommodate the wide range of tasks required on a modern dairy farm.

The handling facility must;

- Be well lit
- Have non-slip surfaces
- Avoid tight turns
- Avoid projections such as posts and hinges which could damage stock or staff

Generally a handling facility will consist of a holding pen, a forcing area, a race, crush and a dispersal pen. Additionally on dairy farms, insemination facilities are often required.

13.1 Design Principles

A basic understanding of animal behaviour is important for all stockpersons and it is particularly important when designing and operating any cattle handling facility.

In addition to this, animals that have had previous experience of bad or un-safe handling are likely to behave in a less predictable manner which has safety implication for all staff involved in the activity.

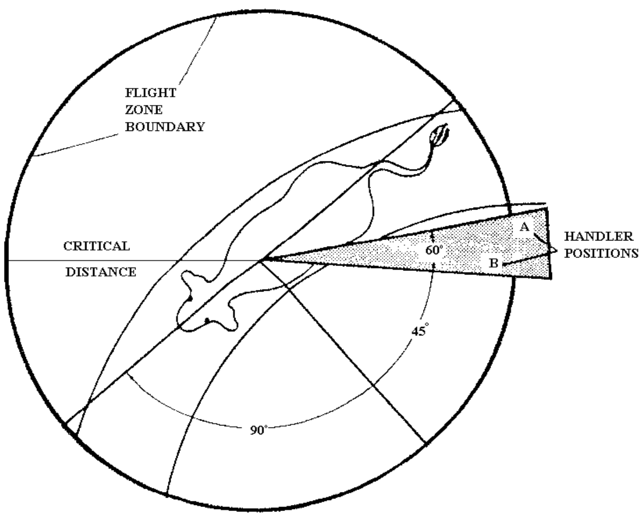
Cows have a tendency to move towards light but are sensitive to harsh contrasts of light and dark within handling facilities. Consistency of lighting is important. Cattle are less sure footed on downward slopes and prefer to move up gradual inclines rather than steep slopes. Handling facilities should either be sited on the flat or on a slight incline with the predominant direction of cattle flow uphill.

One of the greatest fears of cattle is the fear of slipping. As a minimum, the floor of the forcing pen and race must be non slip either with a tamped concrete finish or grooving of sufficient depth and width to provide confidence when moving around the pen, or preferably finished with the hexagon pattern. Bearing in mind that cow movement in the forcing pen can often be in a random direction it is essential that floor surfaces are kept clean to reduce the risk of slippage.

13.2 The Flight Zone

All animals have an imaginary area or comfort zone around them. This is called the flight zone and is illustrated in Figure 11. This zone can be used to control an animal's movements. The shaded area is the best place to be in order to control animal movement.

Figure 11 – The Flight Zone



To stop an animal from moving the best place for the handler to position themselves is point A (just outside the flight zone).

To get an animal to move forward the handler should step forward and position themselves at point B (just inside the flight zone).

When the handler penetrates this zone the animal will want to move away. This flight zone can be used to control the movement of cattle.

The size of the flight zone will vary between individual animals; young inexperienced cattle will have a large flight zone often in excess of 50 - 100 metres. Older animals which have become accustomed to human contact may have a flight zone of between 2 - 10 metres. Extremely quiet cattle, used to regular handling, are often very difficult to move because they no longer have a flight zone.

The size of the flight zone is also affected by previous experience; cattle with previous experience of gentle handling will have smaller flight zones than cattle which have been handled roughly.

13.3 The facility

Observing cows moving within a handling facility will often allow problems to be identified and resolved. Symptoms such as animals avoiding corners, reluctant to enter particular areas or backing away from obstructions will all indicate a problem with the design or layout of a handling facility.

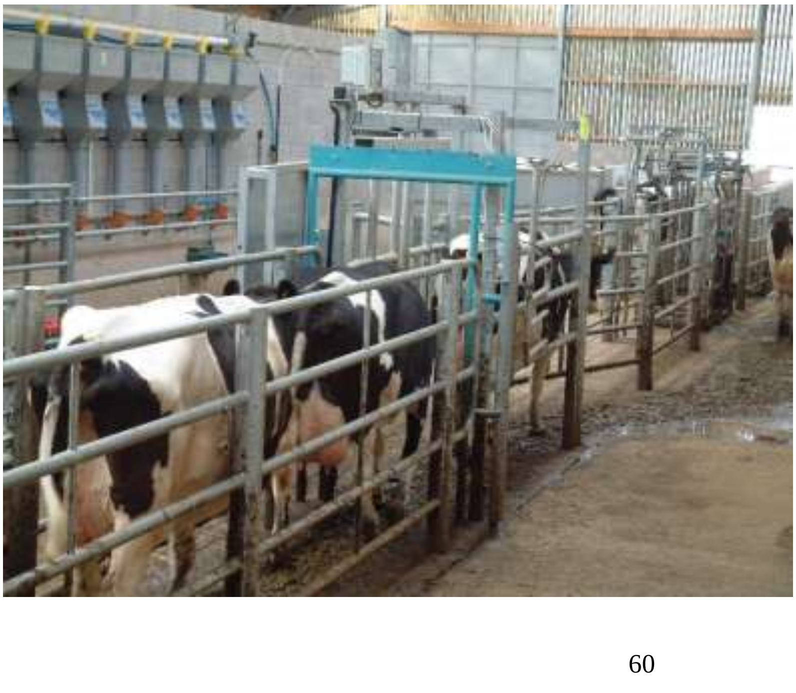
On a dairy farm, the majority of cattle handling is done after milking. This involves either manually shedding cows into a holding pen or relying on automatic shedding systems to identify a cow and separate her into a holding pen.

When shedding automatically, it is important that cows are moving consistently, with adequate separation between cows to allow the gate to operate freely. When cows are reluctant to enter a separation system or bunch into groups, the effectiveness of the system is reduced.

Automatic shedding requires the animals to be in a single file. This can be achieved in a number of ways described below. It is important the animal is familiar with the system and must go through the shedding system at every milking, irrespective of whether they are to be shed or not. Finally, having the default or normal direction to the side and the separated route straight ahead ensures that when the animal requires shedding, there is no physical barrier to her progress.

This is illustrated in Plate 2.

Plate 23 – Autoshedding system with default direction to the right.



Manual Separation systems are common on many farms and still require the animals to be in single file. These systems tend to be either entirely manual, requiring the operator to physically hold back the cow, open a gate and separate the required cow or semi-manual where a cow is separated by an operator using a remote vacuum or weight operated gate. Both systems can be very effective although they can be quite disruptive to the milking routine.

13.4 The Holding pen

The handling facility must be large enough to hold the largest group of animals required for handling as a batch and lead directly into the forcing pen and race.

Each cow requires around 1.8m^2 of space within the holding pen. It is important to recognize that some areas of the holding pen will not be as well utilized as other areas and so calculating stocking rates needs to reflect this. If the cows to be handled are originating from separate groups, it may be necessary to have the ability to sub-divide the holding pen.

The holding pen needs to lead into the race. Animals should be encouraged to leave the holding pen using angled splays, avoiding corners which restrict cow flow. The flow of animals should naturally lead to a race.

13.5 The race

The race should hold the animals in single file and should be around 680 -760mm internal width, depending on the size of the largest animals in the herd. The sides of the race should be around 1.5m high. To provide access to one side of the race for treatment, the top section can be hinged or alternatively a raised walk way provided as illustrated in plate 24.

Plate 24 – Raised walkway on race

Solid sided races are best for cow flow. Animals are less distracted, rather like blinkers on a race horse, and their inquisitive nature will help keep them moving forward.

A curved race prevents the animals seeing too far in front and takes advantage of the animal’s natural tendency to circle the handler and keep them in sight at all times.

Races should avoid tight corners and if animals need a change of direction, this should be achieved with swept bends rather than straight corners. The width of the radius of the curve should not be less than 5.2m. A swept bend with solid sides can be seen in Plate 25.

Plate 25 – A swept race

The flow of animals is improved when the race is evenly lit with no areas of shadow.

13.6 The crush

A simple crush can be formed by fitting a head yoke to the exit gate of the race and installing a tail bar. It is important when using a restraint of this nature to ensure adequate squeeze gaps for personnel to enter and leave the race quickly and quietly, often when carrying equipment.

If an operator is going to work behind a cow in the race, a gate must be fitted to prevent the next animal crushing the operator.

A purpose built crush should be available on all dairy farms.

13.7 Artificial insemination

As an ancillary to the main herd handling facilities, stalls to enable small numbers of dairy cows to be held for AI and other routine day-to-day treatments are useful. For good AI results it is essential that cows are held quietly and calmly while awaiting treatment and during insemination.

If there is likely to be any delay between separation and insemination, consideration should be given to provision of feed and water.

Stall design must control the animal, whilst giving ease of access to the inseminator.

- Stalls arranged side-by-side have a calming effect on the animals.
- Stalls should be under cover, with access from the milking parlour exit
- Milking parlours and cattle crushes are unsuitable for AI.

- All stalls should be fitted with rear chains, to stop cows moving during AI or other treatment.

- Short term confinement stalls are usually 0.7metres wide x 1.75 metres long with 1.1 metre high partitions which give good control.

- A minimum of 2 stalls or approximately 5 stalls per 100 cows should be provided.

Typical AI stalls are illustrated in Plate 26

Plate 26 – Typical AI stalls

13.8 Herringbone treatment races

Increasingly, larger herds are relying on herringbone treatment races for routine handling of cattle. These are used for insemination, dosing and vaccinating, routine veterinary work and TB testing.

These races vary in length and hold the cows at around 50 degrees. In many herds it would be prudent to ensure that the race can accommodate one side of the cows from the parlour at a time to facilitate herd testing or vaccination. Providing a walkway in front of and behind the race provides operator flexibility. Installing a herringbone treatment race with adjustment on the height of the rump rail and breast rail as well as the clear distance between the two rails will provide flexibility for dealing with mature dairy cows as well as young stock. A typical treatment race can be seen in Plate 27.

Plate 27 – Herringbone treatment race

13.9 Footbaths

The footbath should be sited on the exit route from the parlour (but not so close as to impinge on free cow flow). Double footbaths are usually considered better because they allow dirt etc., to be washed off prior to treatment. The first bath also tends to activate the dunging reflex which means that the second (treatment) bath remains active for longer. A solid platforms between the baths of 3.0m will help shed off some of the wash solution prior to the treatment solution.

Permanent footbaths which do not involve setting up temporary gates and more likely to be used on a regular basis.

Emptying and filling footbaths must be quick and easy. Drains in baths should not be less than 100mm internal diameter while 150mm is considered ideal.

Cows should take 3 – 4 steps in the bath and walking through the bath calmly should take between 6 – 9 seconds. To achieve this, the footbath needs to be 3.0 – 4.0m long. If cows are walking briskly, only around 60% of cows will achieve four steps in a 3.0m long bath.

Footbathing before milking can also work well although the design will be different as cows are being treated in a larger group. Irrespective of whether cows are treated before or after milking, it is important that there is a clean dry concrete area provided immediately after treatment to allow the product to penetrate.

13.10 Calving boxes/pens

It is vitally important that the calving box/pen is free draining, well ventilated but free of draughts. The flooring, although it will be bedded, needs to provide good traction for the worst case scenario. Most pens will have a concrete floor and it is recommended that the concrete be finished with the octagon pattern (see above). A layer of sand with straw or other material can then be used to provide cleanliness and comfort. Alternatively, rubber flooring can be laid over concrete which will reduce the amount of bedding required.

Plate 28 – Rubber floor calving box

The pen should be at least 3.9m square and ideally 4.5m square, with provision for feeding and a permanent water supply. A hook should be located in one wall/side at a height of around 1.5 m in order to tether the animal if required. The walls/sides must be free of projections.

The calving box needs to be easily accessible, including by machinery. It is advisable that a full width gate be provided on one side as this will allow for lifting cradles to be operated or fallen livestock to be readily removed.

Siting calving boxes/pens close to the milking facility minimises the distance the cow has to be taken for her first milking and returned to the calf.

13.11 Isolation box

To practise good biosecurity, it is essential to provide at least one isolation box per 100 cows. It should be located away from other livestock, ie. no physical contact or within the same air space. The box should be as per calving boxes/pens and ideally with a separate drainage system. As with the calving facilities, the isolation box must be capable of being readily cleaned and disinfected.

14.0 FEEDING ARRANGEMENTS

The influence of different systems of feeding dairy cows is fundamental to the overall design of the housing system. Most feeding systems aim to maximise the intake of good quality forage while balancing the nutritional requirements of the stock with concentrates or other feeds. A reduction in feed intake leads to an increased risk of disease for the cow (25), and therefore good design and upgrading should be given due attention. Far too often cow housing and parlours are upgraded due to an increase in the size of cows in the herd, but the feed area is neglected. Any missing hair or worse callouses or ulceration, on the back of the neck due to incorrect positioning of the feed rail leads to a reduced intake and poorer productivity.

There are a number of feeding systems, although they often merge into a mix of the various categories:

- Self-feed

- Easy-feed

• TMR

On any one farm the way in which the feed is made available to the animals will also often be based on a variety of methods;

- Feed trough – usually at or within a building:

- Ring Feeders – within a loafing area, a straw bedded area or field:

- Feed lots – often a feed trough in a large loafing area, usually of sand or earth and only suitable for low rainfall areas

- Stand-off pads – similar to feed lots but are constructed using geotextile membranes over which stone, sand and finally a 100 – 150mm layer of woodchip is provided. Cows can have access from grazing, e.g. buffer feeding without poaching and cow hygiene deteriorating, or can be used as an outside lying and feed area. Often ring feeders will be used as a low cost option but with the flexibility of moving them around so that one area does not become foul. Good drainage and dirty water collection facilities are likely to be essential.

With stand-off pads, the area around each feeding place is a location where aggressive behaviour can occur (52). Therefore, the feeding area should be designed in such a way and with sufficient space that all cows can feed with minimal aggression or other interference, and as such the underfoot conditions are especially important at the feed barrier,

14.1 Self feed silage

A self-feed system normally provides the cows with an un-limited access to the forage where it is stored. Any additional feed is either fed through the milking parlour or through out of parlour feeders. For this system to be effective, it is important that cow flow and access are well designed.

Clamp height should be no greater than the reach of the cows who are feeding at the face. A mature Holstein dairy cow can reach around 1.8m from floor level. To maximise clamp capacity, it is common to fill clamps above 1.8m. This means that the top of the silage face must be removed or cut down to avoid wastage or injury to cows.

The clamp width should be based on the total number of stock required to feed at any one time. If animals have free access to the feed face, previously it would have been recommended that 0.3m / cow is adequate. With the need to optimise forage intake and because eating from a consolidated clamp requires more effort and time to eat sufficient dry matter then each cow should have access to at least 0.7m., i.e. the same space as when concentrate is fed at the feed face, in the form of a mid-day feed. In practise, providing 0.7m/cow is usually impractical and highlights the potential barrier to intakes which can occur with self feed systems.

To prevent wastage, a self-feed system requires some form of feed barrier. The position of the barrier affects the cow’s ability to feed. The barrier should be easy to move as it will require moving at least once each day.

In the simplest form, the barrier can be a tensioned electric wire. For this barrier to be successful and prevent excessive contact with the wire, the wire should be moved frequently during the day. Failure to move the wire regularly will depress feed intakes with depressive effects on milk yield.

Plate 29 – Self feed silage system.

The barrier should be located 0.75 – 0.8m above the floor and around 0.6m from the feed face.

The self-feed clamp should be located as close as possible to the accommodation and ideally be covered. As well as reducing dirty water volumes, a dry feeding environment will encourage intakes and reduce wastage.

14.2 Easy-feed and TMR

These systems are fundamentally similar in that feed is taken from the store and fed to the cows behind a barrier (e.g. ring feeders, trough or a feed passage). Cows fed on an easy-feed system are likely to have additional concentrate fed either through out of parlour feeders or in the milking parlour.

Cows fed a TMR receive all their feed through the diet feeder.

There are a number of advantages of easy-feed / TMR systems above a self-feed system.

- Increased dry matter intake.
- Flexibility to feed a range of supplementary feeds.

14.3 Out of Parlour Feeders (OPF)

These are individual concentrate feed stations which are either located in the loafing areas or within the cubicles. Cows wear an identification device, either on their foot, neck or ear. When they enter the feed station, they are identified and fed a pre-determined amount of concentrate. It is not uncommon for the system to be set to provide the daily concentrate allowance in four or five feeds. Many OPF now allow a number of different concentrates to be fed, depending on the individual feed requirements of the cows.

The OPF must be located in easily accessible areas to which cows have access 24 hours each day. Each feed station is around 2.4m long and 0.7m wide which ensures they can be fitted into runs of cubicles relatively easily.

If OPF are installed, instead of parlour feeding, in a self-feed situation, there can be an issue of access to the OPF when the cows are grazing.

If out of parlour feeders are to be installed, an allowance of 25 cows per feed station should be made.

14.4 Feed System design

Irrespective of feed systems employed, feed will either be dispensed onto a feed passage or into a trough.

One advantage of a feed passage, when the stanchions are flush with the brisket board, is that surplus feed can be easily and quickly removed. One disadvantage of a feed passage is that cows will constantly nose through the feed. This results in some food being pushed beyond their reach. The feed needs to be regularly pushed back within the comfortable reach of the cow.

Although there is no requirement for frequent pushing up of food when feed is dispensed into a trough, the trough will require frequent manual cleaning.

Feed troughs where cows can access from both sides should be designed so that cows push food from one side to the other. This will reduce wastage. However, double-sided feed troughs, particularly when formed as part of a central feed passage; rely on the feed being dispensed when cows are not present. The double-sided feed trough is typically 1.8m wide.

There are numerous designs of feed system available but for comparison, the report will focus of four main feed systems. The main features of each system are described.

14.41 Drive though central feed passage.

A drive through feed passage, which should be a minimum of 4.6m wide, can add significantly to the overall size and cost of a building. However, the drive through passage allows animals to be fed when it is most convenient for farm staff, rather than limiting feeding to milking times when the feed stance is clear.

When labour levels are reducing on dairy farms, it appears economically prudent to design facilities which even out labour requirements rather than creating peaks of demand.

14.42 Central feed trough.

Feed is dispensed into the feed trough from a machine driving down the feed stance. This limits the times when animals can be fed as the standing needs to be clear before entry.

A double-sided feed trough will be around 1.8m wide compared with a central feed passage of 5.2m width. This difference in width on a 40m long building equates to a reduction in floor space of 136m^2. The building to house a central feed trough will be less costly than a building with a central feed passage although there will be a greater on-going labour requirement.

A major disadvantage of the central feed trough is that the tractor and feeder drive through manure. This gets taken across clean yard areas, with a potential pollution issue, but also that contaminants are taken back to the feed bunkers with the prospect of contaminated feed and reduced intake by the cows.

14.42 Perimeter feeding.

A perimeter feed building combines the advantages of a reduction in building size with flexibility of feeding. If the building is in a sheltered location, the feed stance is moved to the outside of the building and cows feed through the sidewalls either onto a raised feed table or into a trough.

Feed can be added when it is convenient for farm staff. An additional advantage of perimeter feeding is that the sides of a building can be left open to encourage airflow. To prevent feed wastage, the overhang of the roof is extended beyond the eaves of the building and the first row of cubicles is moved into the building to ensure rain cannot spoil the beds.

However, this system increases the risk of contamination of the feed by wildlife such as birds and badgers, with the potential for disease. With regards to badgers, fencing can be erected, but at a cost.

14.43 Open feed yard with troughs.

The drawback of any feeding system which requires animals to leave the protection of their housing is that during periods of inclement weather, they will be reluctant to go and feed. This is likely to reduce dry matter intakes.

In addition, the open yard will contain slurry and the subsequent run-off from this area after rainfall will need to be contained. Unless the troughs are covered, wastage and contamination will be a significant factor.

Satisfactory design of the feeding system and surrounding area is important to maximise feed intakes. Correct design of the barriers and mangers should provide access to a large volume of feed; prevent bullying and feed wastage while ensuring a safe, non-injurious environment for the cows.

It is also important to realise that although many TMR fed herds have access to feed 24 hrs each day, there are peak periods for feeding during the day. These are generally considered to be immediately after the fresh feed is dispensed and following a milking. If there is competition for feed space during this period, subordinate cows will give way to dominant animals and modify their feeding behaviour.

When cows are being fed from a feed fence, the dimensions of the feed stance are critical to ensure that animals can pass behind feeding animals without disturbing them. In a two-row cubicle system when the animals in the second row can lunge into the feed passage, a width of 4.6m is preferred. When a three-row system is considered, with animals backing out of cubicles into the feed stance, the width should be increased to 5.2m.

To provide maximum reach for the cow and reduce wastage, the feed table (where feed is dispensed) should be raised above the cow standings by 100mm. This also reduces weight transfer onto the front feet. The feed table should be smooth to encourage intakes and ease cleaning. This can be achieved using highly floated concrete, plastic lining, ceramic tiles or gel-coat finishes. The low pH of silage can etch the surface of the feed table and expose the cows tongue and mouth to rough edges.

Plate 30 – Smooth feed table surface

14.45 Feed face per cow

The amount of feed face per animal will depend on the weight of the animal and the competition for food. If all animals are expected to eat simultaneously, the feed face required per cow, as described by BS5502:2005 (6), is shown in Table 10.

Table 10 – Feed face required for cattle eating simultaneously.

Mass of animal (Kg)	Width of feed face (m)
200	0.40
300	0.50
400	0.55
500	0.60
600	0.67
700	0.70
>800	0.75

BS5502 suggests that when feed is available 24hrs per day, the feed face allowance per cow can be reduced by 75%.

The Red Tractor Scheme (3) stipulates the feed face required per cow for simultaneous and ad-lib feeding. This is demonstrated in Table 11.

Table 11- Feed face requirements

Mass of cow (kg)	Simultaneous feeding (m)	Ad-lib feeding (m)
350	0.55	0.15
400	0.55	0.17
450	0.55	0.19
500	0.55	0.22
550	0.55	0.24
600	0.60	0.26
650	0.65	0.28
700	0.70	0.30
750	0.75	0.32

Both BS5502 and The Red Tractor Scheme concur closely on the feed face required per cow when all animals are feeding simultaneously. When *ad-lib* feeding is considered, The Red Tractor Scheme is slightly more generous in feed face requirement.

A UK study in 1980 (111) compared cows fed simultaneously who were offered 1.05m / cow and 0.15m /cow feed face. This study was not able to demonstrate any adverse effect of the reduced feed face when they examined time spent feeding, feed intake, milk yield or aggressive behaviour. However, cow size and feed demand were much lower than for the modern dairy cow.

When researchers compared a feed face of 0.5m with a feed face of 1.0m (67), they reported a reduction in aggressive behaviour of 57% with the increased feed face. They also reported an increase in feeding behaviour by a quarter, particularly in the 90 minutes after providing fresh feed, with the main beneficiaries being subordinate cows. However, this was not associated with an overall increase in milk yield. The reduction in the number of aggressive incidences will reduce the risk to lameness in particular.

A paper written in 2003, (112 concurs with BS5502 and The Red Tractor Scheme that for simultaneous feeding a modern adult dairy cow, 0.7 –0.75m per cow is required.

This paper suggests that there is some data to indicate feed face per cow in an *ad-lib* system can be reduced as low as 0.15m per cow without any detrimental effect on feed intakes and yield. However, the authors suggest that the increase in aggressive interactions between cows seen at 0.15m, lead them to recommend a minimum of 0.3m / cow. This contradicts the findings of a Canadian study reported in 2006 (113) who found that feeding time was increased, and therefore presumably feed intake, with an increase in feed barrier space from 0.21 to 0.81 m/cow and standing time and aggression were reduced. These researchers have demonstrated that a barrier between cows, such as a yoke, provides some physical separation between adjacent cows, which further reduces competition at the feed barrier, with the main winners being the subordinate cows. There will be added health benefits.

A consequence of a feed-face that does not allow all animals to eat at once is that there may be more aggressive pushing and butting at peak feeding times. With time, cows low in the dominance rank will learn to wait until the animals that are higher in rank have finished eating before approaching the feeder. However, this means that low-ranking animals have different meal patterns, and will feed at night and at other times of the day. Where there is not too much feeding pressure, cows can adapt to these conditions and overall daily intake is not compromised. However, if pressure on access to feed is higher, low ranking cows will be forced to eat in a few large meals, and to eat very fast. This can be problematic, as high intakes of concentrates is one of the causes of rumen dysfunction such as acidosis (114).

14.6 Feed barrier design

Studies in the USA have shown that cattle produce more saliva when they eat in a more natural position with their heads down, making feed consumption easier. Cattle fed in elevated troughs also wasted more food by tossing and sorting it. The surface of the trough should be smooth as roughened surfaces can damage the mouths and tongues of cows (115).

The type of feed barrier will affect the amount of pushing and butting seen at the feed trough. Aggression is higher at strap-feeders than where yokes or other forms of divider or head-bale are present. The type of diet will also affect the cow’s hunger and consequently the motivation to get to feed. Cattle on lower concentrate diets show more aggression and will queue for access to feeders compared to cattle with a higher level of concentrate in the diet (113, 116).

Plate 31 - Strap feed barrier

When the type of feed barrier is being considered, the method of forage delivery should be taken into account. There is considerable variation in delivery height between forage boxes and an easy feed system using a bucket or shear grab requires a certain turning circle to be effective.

It is impossible to be prescriptive when describing dimensions for any feed barrier, as there will always be some variation in stature between herds when cow weight is considered.

The most popular barrier type is a post and rail barrier. It is relatively inexpensive to construct but provides no restriction to sideways movement and therefore can encourage bullying when feed face per cow is restricted (113). The post and rail also permits some adjustment in dimensions to suit individual herd circumstances.

Plate 32 – Post and rail feed barrier

The brisket board, which retains the feed on the feed table, should be around 500mm above the feed stance. The brisket board should be rounded to avoid rough edges, which may injure the animal.

The rail should be positioned around 700mm above the top of the brisket board although this should be mounted to allow some adjustment. The top of the cow's neck should only just touch the rail when she reaches forward to feed. The rail should be mounted on the feed side of the stanchion to allow the cow maximum reach with minimum contact with the rail. This is normally around 75mm from the brisket board.

Plate 33 – Adjustable neck rail

As the height of the feed table increases above the cow standing, the reach of the cow increases. This is shown in Table 12.

Table 12. Average reach of Dairy Cows

Feed Table height above standings (m)	Average reach of cow (m)
0	0.6
0.1	0.9
0.2	1.2

An alternative to the simple post and rail fence are self-locking yolks. These are very popular in Europe where they are used as an alternative to a handling facility. They provide an opportunity to keep cows on their feet after milking and reduce bullying when cows are feeding. The locking yolks are also very popular in the USA where they are used with large herds to undertake routine tasks such as PD and AI. Users of self locking yolks, report there is a significant period of training and familiarisation required before yolks are successful.

Plate 34 – Self Locking yolks

A number of manufactures of locking yolks now supply yolks which are angled away from the cow. This allows the cow better access to the feed without undue pressure on her shoulders and neck.

A study undertaken in 1997 (117) compared cows restrained for four hours each day in self locking yolks with cows un-restrained and fed with a post and rail fence. They were not able to demonstrate any production penalty from restraining cows for four hours each day although they did report an increase in aggressive behaviour immediately on release. It appears that as long as the restraint is limited to a maximum of four hours each day, self-locking yolks may be a valuable management tool on some farms. However, keeping cows on their feet may be detrimental to good cow welfare.

15.0 WATER REQUIREMENTS

Water use varies greatly between dairy farms, and typically cow drinking accounts for 50 – 75% of all water use on a dairy farm (119). Besides cow drinking, other main uses of water on the dairy unit are plate cooling (around 25%), plant cleaning and collection yard and parlour washings. Although plate cooling water should be re-used, such as for wash down water, or piped to drinking troughs, much of the water used will eventually have to be disposed as dirty water. DairyCo (119) have estimated that the cost of disposal can be at least as much as the cost of purchasing water.

Various regulations apply to premises with a mains water supply, including the Water Supply (Water fittings) Regulations 1999. The main requirement of this regulation is that back siphoning of potentially contaminated water must not be allowed to enter a mains supply network. Air gaps are needed between mains supply and non-potable water.

15.1 Drinking water

Adequate provision of water is essential in any dairy housing system. Any restriction in water supply will have an immediate effect on milk yield. Good quality water supplied through adequate, reliable and readily accessible drinking facilities must be provided. Allowing cows to drink from streams and other water courses is discouraged due to disease risks from contaminated water and can lead to water pollution, erosion of banks and habitat damage (118).

The water requirement of a cow will depend on a variety of factors, including milk yield, dry matter content of the feed, stage of lactation and ambient temperature (119). High yielding cows can require up to 5 litres of water for every litre of milk they produce. This is demonstrated in Table 13.

Table 13 – Daily drinking water requirements

Daily Milk Yield		20 litres			30 litres	
Temperature	<16^{0}C	16 - 20^{0}C	>20^{0}C	<16^{0}C	16 - 20^{0}C	>20^{0}C
Ration DM%						
30	50	57	65	71	82	94
40	54	62	71	76	87	100
50	57	66	76	79	91	105
60	62	71	82	84	96	110
70	64	74	85	87	100	115

Surveys suggest an average cow will drink 61 litres of water per day. However, basing water requirements on an average figure will ensure that high yielding cows will suffer from a restricted water intake, which is not acceptable. DairyCo data (118) suggests that a dairy cow will drink 3 to 4 times her milk yield, i.e. a cow giving 30 litres per day will require between 90 and 120 litres of water.

Cows prefer to drink from a trough than from natural water sources, such as streams. Cows housed indoors can visit the water troughs up to seven times a day, and any building design must take this into account with regards access and cow flow. As with feeding, lame animals may be less motivated to walk to water to drink (120, 121), and such animals need to be kept in housing where access to water is readily available.

Peak drinking water demands coincide with the completion of milking and around sunset. Up to 50% of the cows daily requirement can be consumed during these times. As cows can drink at the rate of 15 – 20 litres/min, it is important to recognise these peak periods and provide adequate trough capacity, bearing in mind the flow rate of the water supply. The objective should be to provide a flow rate to the trough of a minimum 10 litres/minute.

Because dairy cows are sociable in their behaviour, it is important that there is adequate trough space to allow 10% of the herd to drink at anytime. The DairyCo Mastitis Control Plan (64) recommends a minimum of 100 mm/cow.

Water troughs should be placed in areas that allow easy access, and not in a dead end. They should be checked daily and cleaned regularly. Cows can become more aggressive around a water trough. It is necessary to have more than one trough available to the cow group to allow for social rank differences within the herd.

Trough size is important (120, 121). Studies have shown that cows prefer to drink out of larger troughs when given the choice between two trough sizes ($1.32m^2$ vs. $0.86m^2$ surface area). As a rule of thumb, the surface area of the trough should be at least 1.0 m^2 for every 60 cows in the group.

The water trough should be located at the correct height for the cow. The edge of the trough should be 850mm from the floor the cow stands on. The water level should be 50 – 100mm below the edge of the trough to minimise splashing. In a recent study, cows were given the choice between troughs that were placed 600mm from the ground and troughs placed at 300mm. The cows preferred and drank more water from the high trough than the low trough (120).

The provision of fresh, clean water is important to maximise intakes (112). A high turnover of water through a trough will improve water quality. Smaller troughs which see a greater number of water changes are preferable to large troughs where water movement is slow (122). Tipping troughs or installation of large bore drain holes (50 – 75mm) all ease the task of keeping water clean.

Plate 35 – Tipping water trough

Research from Holland (??) suggests that there are improvements in water quality when cows are drinking from on demand water bowls. However, it should be noted that this work was done on small groups of cows where there was little competition for water at any one time. In a large herd situation, when up to 10% of the herd may want to drink simultaneously, water could become limiting.

Water flow rates must therefore be capable of supplying the peaks of demand. Where water pressure is low, booster pumps or extra covered storage tanks (that can fill during low water demand times) should be considered. Where water pressure is adequate poor flow rates may be improved by using a larger supply pipe. Doubling the diameter of this pipe can increase the flow to the trough by up to 6 times.

Many troughs are fitted with the wrong pattern of ball valve and these should be replaced where necessary. Ball valves conforming to British Standards have interchangeable orifices and floats and it is important to use the right combination of these for each trough.

The orifice should be selected to pass the required flow at the working head available on the ball valve and then a float of suitable diameter chosen to close the valve against the maximum static pressure on the trough. Table 14 shows how the orifice size affects the flow through the valve under a working head of 3m.

Table 14 – Relationship between orifice size and water flow rate

Diameter of orifice (mm)	Flow (litres/minute)
3.1750	1.8
4.7625	3.6
6.3500	6.0
9.525	14.4

Troughs should be located so that cows on bedded yards can only drink when they are standing on the feed / loafing yard. In a cubicle-based system, the drinking troughs should be sited on the walk through passages between rows of cows. The passage should be at least 3.6m wide to allow two cows to pass behind a group of animals drinking. It would be normal to remove three cubicle places to provide a walk through passage with a drinking trough.

16.0 SLURRY AND WASTE MANAGEMENT

16.1 Slurry removal

Slurry will be removed from a housing system either by manual tractor scraping or by some form of automatic system. The automatic systems will either involve automatic scrapers or alternatively a flush wash system.

Removal of slurry with a tractor-mounted scraper is time consuming and will place a practical limit on the number of times each day that slurry will be removed. The operation can only be done when the cows are away from the housing.

On long cubicle runs, a number of 'bites' must be taken to avoid the wave of slurry contaminating the rear of the cubicle beds.

The installation of automatic scrapers has been linked to an increase in levels of digital dermatitis on many farms (36?, 37?), although the causal agent has not yet been isolated from slurry (38). This is assumed to be associated with the bow wave of slurry, which precedes the scraper blade. When the cow is familiar with the scraping system, she will wait until the blade is nearly on her foot before stepping over, leading to soiling of her foot and lower leg.

This effect is noted, apparently irrespective of the number of times the scraper operates.

Installing slatted floors or slatted cross passages, where slurry is deposited during the run, is beneficial. This avoids the accumulation of slurry and helps keep feet in good condition.

Automatic scrapers tend to be either hydraulic, where the scraper blade sits on a saddle which moves around 1m every time the track is pushed forward by the ram. This system requires a track to be mounted on the scrape passage which can be problematic if manual scraping is required. The hydraulic scrapers also require the track to be kept clean in the summer to prevent a build up of slurry. The slurry layer on the track will cause the saddle to disengage from the track. The track is also not particularly kind to cow's feet.

Other scraper designs rely on chains, ropes or plastic coated wires. While these systems are kinder to cow's feet, particularly if the chain or rope is recessed into the floor, they require maintenance. Chains and ropes can stretch and break over time.

Plate 36 – Recessed chain for automatic scraper

Slatted areas are particularly important where runs are longer than 25m (123).

Keeping dairy cows on a totally slatted floor, with underground slurry storage below is an option and is favoured in several other European countries. The type and shape of slats has an important bearing on cow comfort, cleanliness and foot health (158). Slats must have solid, smooth edges and they must be close enough to allow the cow to walk comfortably and easily over them while at the same time have a large enough gap to allow slurry to fall through into the store below. Recommendations from the DairyCo Healthy Feet programme are for the slat width to be 140-160mm with a spacing of 35-40mm.

In some cases a build of slurry in non-slatted areas, such as around water troughs, cross passages etc. has been noted. It is important that these areas are scraped regularly to avoid a build up of slurry and pathogens which thrive in the slurry.

16.2 Flood washing

The uptake of flood washing in the UK has been limited. There has been an interest with this system with large collection yards, due to the difficulties of tractor scraping and the time and cost of manual hosing down.

The quoted benefits for flood washing include

- Labour saving compared to tractor scraping
- More frequent cleaning of passages compared to tractor scraping, often using an automatic timer to flush every 2 hours.

- Passageways keep cleaner with improved foot health

There are however a number of concerns where flood washing is proposed. These concerns include,

- If the system is operated when cows are present, floodwater will splash onto the legs and udders of some cows and often into the cubicle beds.
- Wash water is recycled dirty water, providing a risk to udder health, foot disease and an unpleasant aroma.
- An alternative system is required during breakdowns.
- The need for additional “fresh” water from time to time.

Plate 37 – Flood water splashing on cows legs during operation

The slope of the scraper passage is critical to maintain the momentum of the floodwater. A slope of 2 – 4% will maintain the momentum with a minimum volume of water (124). The success of the system depends on creating a wave of water around 20m in length, 75mm in depth moving at a velocity of 2m/sec. This will generally allow the water to be in contact with the slurry for 10 seconds.

The wave of water can be seen in Plate 38.

Plate 38 – Flood washing wave

Feedback from farms in the UK who have installed flood wash systems is mixed. The most significant problem appears to be the volumes of water required and the need to constantly change the water to reduce odour problems

Once a passage has been flood washed, the water is stored and re-used. The more often the water is re-used, the more contaminated it becomes with slurry and the thicker it becomes. The smell of the flood wash liquid will also increase significantly with use (124). It is recommended that to minimise the problems of odours and keep the liquid manageable, 20% of the volume of the stored water should be changed each day.

The management issues with storing and handling large volumes of foul water along with environmental concerns of disposal of foul water and smell are likely to limit the uptake of this technology in the UK. If future legislation limits emission of ammonia, as is the case in the Netherlands, then this system is likely to become un-sustainable.

16.3 Slurry Storage

There are several types of slurry store used on farms, they all have own pros and cons and there is a wide range in costs.

There are a number of options available and demonstrated in Table 15.

Table 15 – Slurry storage options and costs

Type of store There are many options, with the following typical	**Typical cost per cu m.** [including safety fencing, pumps, agitators etc]	**Typical cost per cow.** [based on 22 weeks storage at 15 cu m per cow]	**Pro's**	**Con's**	**Comments**
Clay lined lagoon	£7	£75	Relatively low cost, especially if an ideal site in a low-rainfall area. Can be	Sloping sides hence large surface area, with a freeboard	Decision to build depends on location, levels, availability of suitable clay,

			designed with a ramp for vehicle access.	requirement of 750mm. Mixing and emptying can be difficult.	and necessary consents.
HDPE lined lagoon	£17	£255	An option where clay is not available or not approved.	Large surface area as above, needs to be carefully laid on well prepared surface, since liner only 2 to 3mm thick.	Need a professional approach with careful consideration of mixing and access to remove slurry, possibly with concrete flooring.
Slurry bag	£29	£435	Compact with slurry completely contained, with surface area regarded as clean water and no freeboard requirement.	Still relatively new membrane technology, but widely used in Holland for over 20 years.	There may not be the cost advantages of scale with this system, and slurry spreading needs to be fully integrated.
Steel tower	£34	£510	Compact with the ability to go high on a circular base, hence efficient with only 300mm freeboard.	Relatively expensive compared with very low cost lagoons. Frequent mixing required to avoid crusting.	A very common, proven system in high rainfall areas, Can be linked very effectively to an umbilical spreading system.
Concrete store	£39	£585	Versatile in shape to suit and can be indoors and slatted if required. Long life and robust in use.	Relatively expensive compared with low cost lagoons but compact and efficient with a 300mm freeboard requirement.	Concrete stores must be professionally designed and built to the required standards.

All costs are taken from the DairyCo Dairy Wizard booklet.

When choosing a slurry storage system, the bedding material must be taken into account. For example, if cows are housed on sand cubicles then systems such as a slurry bag and steel tower may not be suitable.

Irrespective of the storage system chosen, it is essential that the dangers of storing slurry are fully understood. Underground slurry stores can be particularly dangerous as the mixing of the slurry associated with agitation prior to emptying can lead the production of hydrogen sulphide gas. Hydrogen sulphide is colourless although it has a pungent, rotten egg odour, and can quickly lead to suffocation in poorly ventilated areas.

Adding silage effluent to slurry increases the risk of hydrogen sulphide production as the nutrients in the silage effluent feed the bacteria in slurry that are responsible for gas production.

The increased use of gypsum as a bedding material also increases the risk of the production of hydrogen sulphide. Gypsum or calcium sulphate contains sulphur which encourages the bacteria to produce even greater amounts of hydrogen sulphide.

Clay for lining lagoons must be tested in a laboratory to ensure it has the correct properties to create an effective seal. This should be done before it is used. If the clay fails the tests then a HDPE liner may be required.

When planning slurry system it is always advisable to speak to your local Environment Agency office before any groundwork is carried out.

It is important to make sure that all inputs to a slurry system are fully taken into account when working out the required size of the system. For example parlour washings, yard run off and roof water must be taken account if they enter the slurry store. To calculate individual farm requirements DairyCo has produced a booklet and CD entitled ‘DairyCo Dairy Wizard’ the ‘Slurry Wizard’ part of the software allows you to work out the size of store required.

16.4 Slurry Separation

The use of mechanical slurry separators has become more widespread, partly due to increasing herd size and modernisation of dairy units and partly in response to the NVZ regulations.

There are several types on slurry separator on the market, the main two types are:

Rotating screen separator - slurry is smeared over a mesh screen, the more liquid fraction passes through the screen and the solid components are directed out of the separator where they can then be stored separately.

Screw press separator – slurry is squeezed by a large screw shaped plunger, the liquid portion is squeezed out and the solids are directed into a separate, solid manure store.

Both types are manufactured by a range of companies and by removing the solid portion a 15-20% reduction in slurry volume is expected. When considering which system is most suitable, annual service, maintenance and running costs should be considered.

There is a limited amount of nutrient partitioning. There will be more available nitrogen and potash (as they are water soluble) in the liquid fraction and more organic (slow release) nitrogen and phosphate in the solid component. This effect can be increased by the addition of polymers but is not currently available commercially (125).

The liquid portion is a lower dry matter than raw slurry and so it leaves less contamination on the sward when it is applied to land.

16.5 Farm Manure Management Legislation

Red Tractor Scheme

Most milk buyers require assurance under this scheme which requires a series of environmental standards to be met. The farm must have access to, awareness of and be able to observe the Code of Good Agricultural Practice, which provides advice on protecting the environment.

The farm must ensure that potential pollutants are appropriately stored to avoid the risk of polluting groundwater and watercourses. Any slurry stores must not be leaking or overflowing. Slurry pits of lagoons must be fenced for animal and human safety.

Manures and fertilisers must be applied to land in ways that prevent pollution, contamination and spread of disease. The farm must have and implement a written manure management plan.

Cross Compliance

Cross compliance (126) requires a farm to demonstrate it is keeping the land in Good Agricultural and Environmental Condition (GAEC) and complying with a number of Statutory Management Requirements (SMRs) in order to receive single farm payment. The GAEC covering waterlogged soil requires that all operations, including spreading manure and slurry, must not be carried out on areas of waterlogged soil. In extreme weather events derogations can be given by the Secretary of Sate to allow spreading.

The GAEC for the protection of hedgerows and watercourses states that 'you must not apply manures to land within 2m of a hedgerow, watercourse or field ditch.'

The GAEC controlling no spread zones requires organic manures to not be spread within 10m of surface water and that organic manures are not applied within 50m of a spring, borehole or well. All farms claiming single payment must have a map of the farm showing all surface waters and land within 10m of them. The map must also show all springs, wells and boreholes and land within 50m of them. The map must be updated within 3 months of any changes.

Further details on these and other cross compliance requirements can be found in the cross compliance handbooks for England and devolved authorities (126).

Nitrate Vulnerable Zone Regulations (NVZs)

NVZs are part of cross compliance (SMR 4) and are also law in their own right. Therefore they apply to farmers within the zones whether or not they claim single farm payment.

- Whole Farm N Loading – this is based on a stocking rate calculation and the limits are set at 170kg N/ha/year or 250 kg N/ha/year for grassland fields (including undersown arable crops) on farms with the NVZ grassland derogation.
- The Field Manure Application Limit – the maximum amount of manure nitrogen that can be applied in any 12 month period is 250kg N/ha. This is equivalent to approx 40 t/ha of cattle farmyard manure or 83 m^3/ha of dairy slurry (not including manure deposited on the field by grazing livestock).
- The following closed spreading periods apply to land within the NVZ zone:

	Grassland	Tillage land
Sandy or shallow soils	1 September to 31 December	1 August to 31 December
Soils that are not sandy or shallow	15 October to 15 January	1 October to 15 January

- N Max – There are limits of nitrogen use on some crops including grassland, maize and wheat. These limits include artificial nitrogen and a percentage of total manure nitrogen. The applications are averaged over each crop type across the whole farm.
- Spreading controls – The use of high trajectory slurry spreaders is now banned. Manures must not be spread on frozen, snow covered or waterlogged land.
- Slurry Storage - All dairy farms within NVZ zones must have 22 weeks of slurry storage.
- Record Keeping - There is a requirement to keep records including livestock numbers on the farm, manures imported or exported, cropping details, fertiliser and manure applications on a field by field basis.
- Derogation – The NVZ grassland derogation can be granted by the Environment Agency on a farm by farm basis as requested by farmers. This allows more livestock to be kept and has its own, more detailed record keeping requirements.

Silage, Slurry and Agricultural Fuel Oils Regulation – SSAFO (10)

These regulations set the minimum standards of design and construction for slurry stores in England and Wales. Slurry includes yard and parlour washings and other dirty water. Runoff from solid manure stores also counts as slurry for the purposes of the regulations. The Environment Agency enforce the regulations and must be notified in writing at least 14 days before a new or substantially altered installation is brought into use.

The general requirements of the regulations are that it must:

- Be constructed to last for 20yrs with proper maintenance
- Meet performance standards
- Not be constructed within 10m of watercourses (inc. land drains)

Further essential guidance is provided in The Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations 1991, as amended.

Code of Good Agricultural Practice (11)

The Code of Good Agricultural Practice (COGAP) is a practical interpretation of legislation and good practice which provides an important point of reference to help farmers and land managers understand their environmental responsibility. The code is not a legislative requirement in its own right.

The new COGAP, has replaced the previous 3 Codes of Good Agricultural Practice for the protection of Water, Soil and Air. The new revised code is a single consolidated document which focuses on high level, integrated messages on environmental protection based around the main operations that farmers might undertake. More details can be found in the Code of Good Agricultural Practice (11) covering the protection of water, soil and air quality.

Environmental Schemes

The Environmental Stewardship Schemes promote improved environmental practice by providing financial incentives for a range of environmental measures including buffer strips in both grass and arable land. More information is available from Natural England, Welsh and Scottish Governments.

Future Outlook

The consultation documents have been released by Defra in advance of the planned 2013 NVZ update. The consultation documents concentrate on 3 main themes:

- a review of the NVZ action programme measures
- whether discrete NVZ boundaries should continue to be used or whether to designate the whole of England as an NVZ area.
- A rationalisation of the SSAFO regulations.

It is impossible to say at this stage what the outcome of the consultation will be. Some other European countries have restrictions on phosphate applications and ammonia emissions from livestock and/or slurry stores and it is possible that these types of restrictions may be on the horizon for the UK.

17.0 VENTILATION

17.1 Natural Ventilation

Correct building design is critical to ensure adequate ventilation. This is extremely important to maintain air quality. To ensure adequate ventilation, it is important that the building is designed to,

- Remove excess heat
- Remove excess water vapour
- Remove microorganisms, dust and gases
- Provide a uniform distribution of air
- Provide correct air speed for stock

Natural ventilation is the least troublesome, most efficient and least expensive system for providing an optimum environment within a building. The aim of the ventilation system must be to provide a continuous stream of fresh air to every housed animal at all times of the day or night. Buildings will naturally ventilate best when they are sited at right angles to the prevailing wind direction.

In the UK, wind speed is above 1m/sec for more than 95% of the time. This means that for the majority of time, there is sufficient generating force to provide the necessary air changes within a building by natural ventilation. For the remaining time, the building relies on the stack effect to replace foul air with fresh air.

Plate 39 – Stale air requires removal.

Heat produced by the livestock naturally rises. If it is unable to exhaust from the building at the highest point (at the ridge), it will condense and remain within the building. This will raise the humidity within the building. As the air cools, it will fall back onto the bedding, increasing the moisture content and creating a suitable environment for bacteria to flourish.

If the warm air is able to exhaust from the ridge of the building, this draws fresh air into the building through the side inlets. This air change ensures the stack effect is maintained. However, if there are insufficient air inlets warm air cannot escape from the building as a vacuum cannot be created.

17.2 Outlet ventilation

There are a number of methods to achieve adequate outlet ventilation which includes various ridge designs or a slotted roof. These are illustrated in Figures 12, 13 and 14 and Plate 40.

It is essential that there are adequate outlets in the ridge of the building. An open ridge is generally between 0.3 – 0.4m wide and should be un-restricted. As a useful rule of thumb (7), there should be 5cm of ridge opening for every 3.0m of building width. A typical two row cubicle feed / sleep building of 23 m width will require an open ridge at least 0.385m wide.

Figure 12 – Open ridge

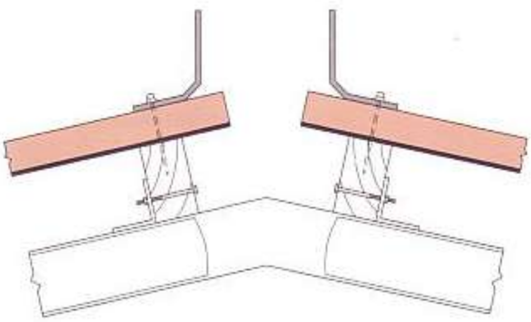


Figure 13 – Covered open ridge

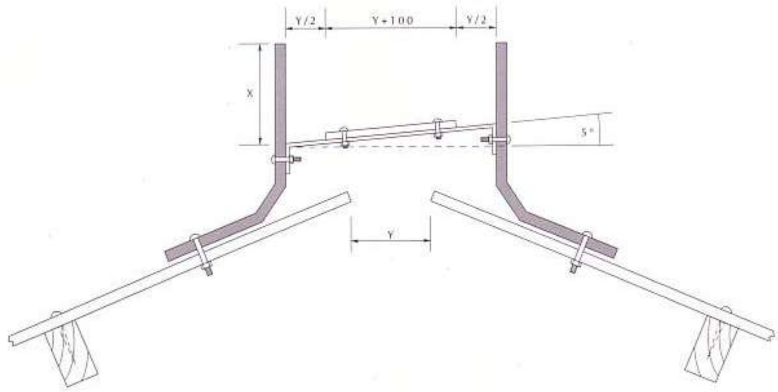


Figure 14 – Light ridge

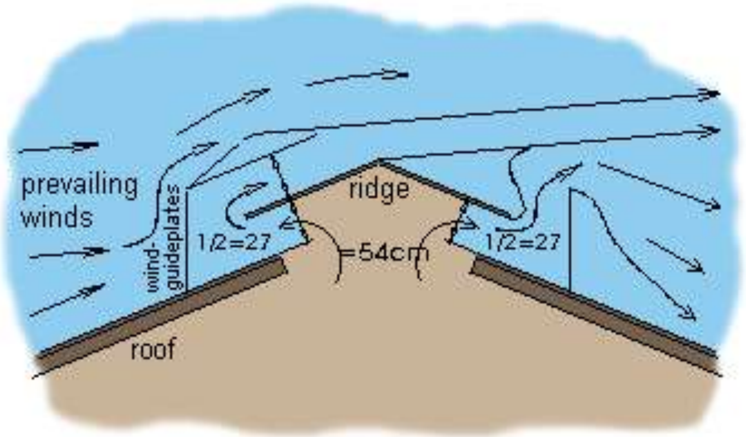


Plate 40 – Slotted roof

Slotted roofs (where the roof sheets are inverted and fitted with a space of around 10 mm between each adjacent side sheet) can be very useful, particularly if summer housing is being considered. With the emergence of multi-span dairy units, spaced roofs become a necessity. It should be remembered that a spaced roof will reduce the flexibility of the building, if it was to be used without animals.

Cranked open ridges are not suitable as they only offer around 20% of the required outlet, although are still commonly fitted.

17.3 Inlet ventilation

The inlet area, ideally split evenly across the two sidewalls, is an absolute minimum of twice the outlet area and better at 4 times the outlet area. The aim of the inlets is to not restrict airflow but to reduce airspeed at animal height. Un-controlled air speed at animal height is only likely to be beneficial in the UK during the warm, summer months.

It is generally accepted in the USA (127), that the inlet ventilation should be a minimum of 50% of the surface area down the length of the building.

The aim should be, where possible, to ventilate the building from the sides. Inlets areas in the gable ends are only recommended where the building is excessively wide (>25m), or where there are restrictions in the inlet areas along one or both sides of the building.

A cladding material with many small openings is suitable for inlets in UK winter housing. The design requirement is to match the available materials with:

- the calculated optimum area of inlet for each sidewall (a)
- the available area in the sidewall for cladding (b)
- the degree of exposure to the weather of the sidewall (c)

The example building requires an optimum of 9.4m^2 of inlet area in each sidewall (a).

If there is 2m height between the top of a solid concrete/block wall and the eaves, in a building 27m long, the available area for cladding is 54m^2 (b). Therefore approximately 20% of the cladding area must be void. The inlet area can be greater than the calculated opening as long as due consideration is given to air speed at animal height.

The required inlet area for the example building could be covered with:

- A horizontal slot 370mm deep, below the eaves, the full length of the building
- Space board (4 inch board, 1 inch gap) the full length of the building
- Yorkshire boarding (6 inch board, 1.5inch gap) the full length of the building
- Plastic or woven cladding with at least 20% void.
- Perforated metal sheeting with at least 20% void.

The first example needs to be further protected from wind penetration (such as overhanging eaves). Space boarding should not be used with a gap larger than 1 inch, otherwise wind, rain and snow can be expected to penetrate the cladding. Yorkshire boarding can be used on exposed sides of buildings; the two rows of boards are placed either side of the purlins opposite the vertical gaps between the boards.

Plate 41 – Space Boarding

The pitch of the roof can influence how well the stack effect is established but selecting the pitch of a roof, particularly with a span building, will always be a compromise between ventilation and overall ridge height. Roofs are normally pitched around 12.5% although examples can be seen with roof pitches of 22.5%. The building height will be significantly greater with a 22.5% pitch, which may create issues with the planning authorities.

There are many farms installing curtain sides to the cubicle building which allows the amount of air admitted through the inlets to be varied according to prevailing weather conditions. These curtains can be lifted and raised manually or automatically and provide greater environmental control.

Plate 42 – Lifting side inlet ventilation

Consideration needs to be given to the prevailing wind direction when considering inlet ventilation. If there is insufficient weather protection, rain will drive into the building and result in wet cubicle beds. In addition, wind velocity can blow bedding off of the beds and lead to lower cubicle occupancy in some cubicles due to the "draft", increasing the stocking rate in the rest of the building.

17.4 Protection from wind speed.

The horticulture industry has long understood the cost of wind speed, and uses windbreaks to protect crops and reduce costs of production. For cattle, the impact of wind speed can vary from very little, to reduced feed conversion ratio, to immune suppression and increased severity of disease. The principle mechanism from air speed that impacts on animal health and performance is energy loss.

Energy loss will double when wind speed rises from 0 to 6.8m/s (15mph).

The basic rules of using wind breaks

- The purpose of a wind break is to reduce air speed.
- A badly located or poorly finished wind break is often worse than no wind break.
- The optimum porosity/permeability of a windbreak is 50%.
- The minimum ratio of length to height of a windbreak is 12:1 to minimise the effect of the increased windspeed coming around the ends of the windbreak.
- Windspeed will be reduced downwind of a permeable windbreak for up to 30 times the barrier height.
- Support structures for windbreaks should be at approximately 3m intervals.

Plate 43- Windbreak material

As can be seen the design of a successful natural ventilation system is complex and requires account to be taken of the span of the building, the location of the building relative to other buildings, wind breaks, the pitch of the roof and the stocking rate.

17.5 Ventilation calculations

The area of outlet that is required in the roof to allow heat and moisture from the livestock to leave the building by natural convection is calculated first. The inlet area required in the side walls to support the natural ventilation is defined after the area of outlet is calculated.

A ventilation calculation is shown for an example building below.

Building length = **27.43m (A)**
Building width = **18.29m (B)**
Area = (B) x (A) = **502m^2(C)**

Stocking density = 50 cows at 600kgs **(D)**
Area per animal = 502m^2(C) ÷ 50 (D) = **10m^2/animal (E)**

Refer to figure 15 (upper graph). A floor area of 10m^2/animal (**D**) at an average live weight of 600kgs requires an outlet area per animal of **0.149m^2 (F)**

The outlet area in the roof per animal **(F)** needs to be modified by the influence of the pitch of the roof; in effect the difference in height between the eaves height and the ridge height.

To calculate the height difference between the eaves and the ridge of a building, either measure or extract the measurement from building plans, or estimate by counting reference points in the gable ends, such as rows of blocks. An alternative is to estimate the slope of the roof and use Table 16.

Table 16
Height difference **(G)** = roof slope multiplier x **half** the building width (B)

Roof slope	Multiplier
10 degree	0.176
12 degree	0.213
15 degree	0.268
17 degree	0.306
20 degree	0.364
22 degree	0.404

For a 15^o roof slope the height difference **(G)** is:

0.268 x (0.5 x 18.29 **(B)**) = 2.45m

With a 15^o pitch the eaves to ridge height difference of the example building is therefore **2.45m(G)**

Referring to Figure 16 (lower graph), a height difference of 2.45m corresponds to a height factor for the example building of **0.63 (H)**

The actual outlet area required for this example building is:

Outlet area per animal **(F)** x height factor **(H)** x number of animals **(D)**

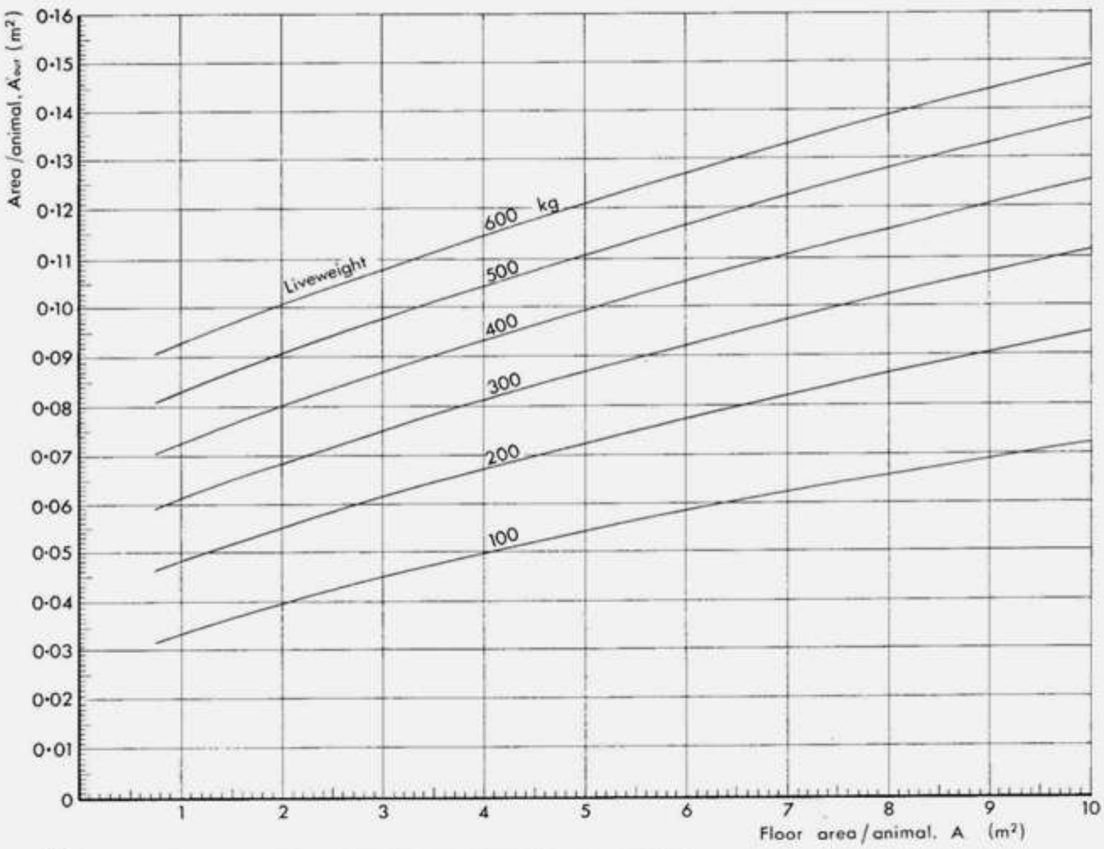
Outlet area required is 0.149(F) x 0.63**(H)** x 50**(D)** = **4.69m^2** **(I)**

The outlet area required is a defined value; how this area is achieved in the ridge is flexible. A common solution is to provide a continuous gap along the ridge, in which case the required gap width is the outlet area required **(I)** divided by the building length **(A).** In this case the required gap is 4.69m^2 **(I)** ÷ 27.43 **(A)** = 171mm. This is a precise minimum gap size; in reality it would be practical to provide a gap of 180 or 200mm.

The inlet area, ideally split evenly across the two sidewalls is an absolute minimum of twice the outlet area and better at 4 times the outlet area.

Figure 15 – Ventilation areas for Cattle Buildings

VENTILATION AREAS FOR CATTLE BUILDINGS



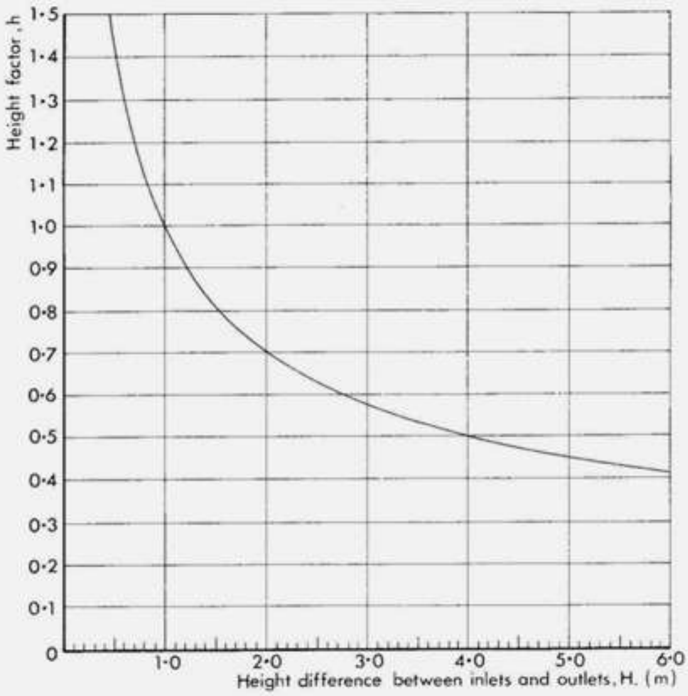


Fig 1 (above) Outlet area for height differences of 1 m This gives values for A'_{out} for total building area per animal at various live-weights: eg for A = 3 m²/head and W = 400 kg, A'_{out} = 0.087 m³/head. Where a range of animal weight occurs, use an average weight. Where there are suckler cows and calves, again use an average weight but consider the calves at their heaviest. To determine the actual outlet area A_{out} use **Fig 2 (left) Height factor.** Multiply A'_{out} by h: eg for a height of 2.5 m h is found to be 0.63 so that $A_{out} = A'_{out} \times h$ = 0.087 x 0.63 = 0.055 m²/head (0.59 ft²/head). Where there are distributed openings, such as in a perforated roof, the average height should be taken. Inlet areas are assumed to be twice the outlets.

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17.6 Mechanical Ventilation

In the UK there is growing interest in the installation of fans to move volumes of air within cattle buildings. These are often described as mechanical ventilation systems. However, in fact all they are doing is recirculating existing air within a building.

There are a number of systems available for assisting the ventilation of cattle buildings. These are:

- Ventilation fans should be drawing fresh air from outside the building, and blowing the fresh air down a duct with numerous small outlets along the length. The aim is to distribute clean fresh air along the length of the building, acting as a substitute for an inlet in the sidewall. It is essential that a well distributed outlet is provided in the ridge; otherwise a fan system can act as a mechanism to distribute any airborne infections throughout a building.

- Extractor fans are only effective in small volume spaces, or in modern fully-controlled environment houses. In the former situation they can be used to extract moist exhaust air from the ceiling area of old cart sheds and similar spaces that are useful for housing a low number of stock but have no roof outlets.

- Cooling fans increase the rate of air flow across cattle and assist the uptake and removal of heat and moisture from a surface. The cooling fans reduce the accumulation of heat and moisture within a building with a subsequent positive impact on animal comfort and disease risk.

Cooling fans are located in or near to the gable end of a building dependant on the degree of weather protection provided. The cooling fans typically hang vertically from roof trusses and project air up to 60ft (<20m). In longer buildings fans should be located every 60ft within the building airspace so that a column of horizontal airflow is moved along and out of the building.

Cooling fans are not a fresh air distribution system. As the air flow is forced along a building through the cattle and above the bedding and cubicle surfaces it will accumulate heat, moisture and biological aerosols.

The HVLS fans are large fans (between 4.8 – 7.5m in diameter) which revolve slowly and move large columns of air at a relatively low velocity (2.0 km/hr). A 6.0m fan will typically move around 3500m^3 / min of air.

A HS fan is more compact (less than 1.0m diameter) and operates at a higher speed. Each HS fan can typically move around 600m^3 / min of air. To move the same volume of air as a HVLS fan, six HS fans are required. Most HVLS fans are operated by a 0.75kW motor and research at the University of Kentucky has suggested that when HVLS fans are compared with HS fans, the same volume of air can be moved for around 30% of the energy cost.

Plate 44 – High speed fans.

A HVLS fan will cost around £2700 while a HS fan can be purchased for around £200. However, six HS fans are required to move the same volume of air as a HVLS fan.

The HVLS fans have been tested at Lelystad in Holland and although they have no published data to confirm their observations, the research team reports that the HVLS fans produce a more even air movement throughout the barn. The HS fans produce higher velocities of air in the area directly surrounding the fan, leaving large areas of still air. The HVLS fans can be located 20m apart and are often located above the cubicle area.

There are relatively few buildings which cannot be made to ventilate naturally if they are designed carefully or remedial works undertaken. The decision to resort to assisted ventilation, with the resulting running costs and maintenance should not be taken lightly.

The installation of fans should be seen as a response to an issue of heat stress rather than failing ventilation.

17.7 Heat Stress

Dairy cows are homeothermic animals and need to maintain a constant body temperature of 38.8ºC +/- 0.5ºC. They are sensitive to factors which influence their thermal exchange with the environment. These factors are air temperature, radiant temperature, air velocity and relative humidity.

When an animal becomes heat stressed, her feed intake will decline and so will her milk yield. There will be a reduction in fertility and an increase in embryonic loss. There is often an increase in cases of clinical mastitis in heat stressed animals (128)

Air temperature and radiant temperature directly influences the heat exchange ability of the animal. Air velocity increases the amount of heat transfer from the surface of the cow. Air movement can also improve evaporation, which assists in heat loss.

Relative humidity can be a problem in either the summer or the winter. In winter, it can make the animals coats wet which reduce their insulating properties. In summer, it reduces evaporation and limits heat loss.

A number of papers (128, 129) have suggested that for a lactating dairy cow, there is a band of temperature at which she is most comfortable. This comfort zone or Thermoneutral zone falls between 5ºC and 25^0C. The objective of any dairy housing system must be to maintain this comfort zone, irrespective of season.

The temperature of 5^0C is called the Lower Critical Temperature (LCT) and 25^0C is the Upper Critical Temperature (UCT). At temperatures below the LCT the cow will increase her dry matter intake to keep warm or convert feed to heat rather than produce milk. At temperatures above the UCT, cows will sweat in an attempt to dispel the excess heat and the cow will become heat stressed. When the relative humidity increases, the UCT will fall and animals will become heat stressed more quickly.

When a cow becomes heat stressed, she will eat less feed and produce significantly less milk. As the ambient temperature increases above the UCT, milk yields can fall by as much as 20% (130). There is evidence that heat stress is most marked when it comes in short periods with no time for the cow to adapt to the rising temperatures.

The effects of heat stress and the mechanics of heat exchange were extensively studied in Missouri, USA in the 1950's. The research concluded that at ambient temperatures above 21^0C, heat loss from the cow was primarily due to moisture evaporation from the lungs. As temperatures exceeded 32^0C, over 85% of total heat dissipation was due to vaporisation of water from the body surfaces. This is the basis for the recommendation to wet cows during periods of high ambient temperatures.

It is clear that when ambient temperatures exceed 25^0C, the cow begins to become heat stressed. When the effect of humidity is considered, the ambient temperature at which she becomes stressed falls.

One study in the USA (131) examined the impact of increasing air temperature and relative humidity on milk yield. A summary of the findings are highlighted in Table 17. The milk yield reductions are shown as a % of the control.

Table 17 – Effects of Ambient Temperature and Relative Humidity (RH) on Milk Yield.

Control (22^{0}C and 40% RH)	**29^{0}C and 40% RH**	**29^{0}C and 90% RH**
100%	97%	67%

This clearly shows the significant role played by humidity in heat stress.

The Temperature – humidity index (THI) was developed by the University of Arizona and indicates the degree of stress on dairy cows (132). This is demonstrated in Table 18.

Table 18 – THI Index

Temperature Humidity Index (THI) Relative Humidity %									
C	20	30	40	50	60	70	80	90	100
22	66	66	67	68	69	69	70	71	72
24	68	69	70	70	71	72	73	74	75
26	70	71	72	73	74	75	77	78	79
28	72	73	74	76	77	78	80	81	82
30	74	75	77	78	80	81	83	84	86
32	76	77	79	81	83	84	86	88	90
34	78	80	82	84	85	87	89	91	93
36	80	82	84	86	88	90	93	95	97
38	82	84	86	89	91	93	96	98	100
40	84	86	89	91	94	96	99	101	104

No heat stress
Moderate heat stress
Severe heat stress
Dead cows

When the THI index exceeds 72, high producing dairy cows become affected by heat stress. This level is breached and the cow can become stressed with temperatures as low as 22^{0}C when the relative humidity is high (90%). As the humidity falls, the temperature at which the cow becomes stressed rises. When humidity is 10%, the ambient temperature needs to be 29.4^{0}C before the cow becomes stressed.

When the THI exceeds 80, the cow is considered to be severely stressed. When the THI exceeds 100, animals will die.

Increasing airflow over a cow has a dramatic effect on evaporative heat loss from the skin. The results of research from the USA (133) suggest that airflows as low as 10 km/hr can reduce respiration rates in heat stressed animals by as much as 50%.

The installation of fans, combined with spraying water onto cows can dramatically reduce the effects of heat stress (133). There is conflicting advice on the most effective use of water to wet the skin of the cow. One paper (??) suggested that cows should be wet in the feed stance with 1.5 litres of water over a period of 60 seconds followed by 4 minutes of drying with a 10km/hr airflow.

Another paper (70) suggested that when the temperature exceeds 21^{o}C, a spray cycle should include the application of 3.5 litres per cow over a period of 3 minutes followed by 12 minutes with no water application.

A study is the USA (132) suggested that when ambient temperatures reached 27^{0}C, the addition of fans and sprinklers in the collecting yard reduced the cow body temperatures by 1.7^0 C. This increased milk yields by 0.79kg/day over cows with no fans or sprinklers.

Application of water to cows around the bedded area has implications for the dryness of the beds and ultimately mastitis levels. Water can be applied more easily within the collecting yard while cows wait for milking.

There is evidence of considerable benefit from providing spray cooling and assisted airflow in the tight confines of the collecting and dispersal yards. When cows are closely confined in the collecting yard, ambient temperatures can rise rapidly.

The application of water in the feed area has proved very popular in the USA but research concludes that the benefits are reduced unless the wetting is combined with fans to increase airflow and therefore evaporative losses.

17.8 Insulated roof

There is concern about the transfer of radiant energy through metal roof in cow accommodation. When the roof is constructed from tin sheets, research in the USA has suggested that there can be a typical temperature difference of 10^0 C, measured on the underside of the roof, between an insulated and an un-insulated roof.

On one study in the USA, a temperature difference between an insulated and a conventional roof was 20^0 C.

In the UK, most roofs are constructed from a fibre cement product. The heat transfer properties of these sheets are less well tested.

In the USA, the cost and practicality of insulating roofs has limited the uptake. The insulating material was fixed to the underside of the sheets and damage from birds limited the product lifespan.

Some work carried out in 1993 (134 looked at the use of reflective coatings in enclosed poultry houses with no ventilation. They reported a reduction of 2 - 3^0 C when the reflective coating was used. However, when the same coating was used on well-ventilated dairy housing, no temperature effect was noted. The authors noted that the cost and reduced reflectiveness over time led them to the conclusion that reflective coatings are of little benefit to well ventilated dairy buildings.

Observations from the research staff at Lelystad in Holland confirm that during the summer months the temperature under the roof of their high technology farm (with an insulated roof) can reach 40^0 C. This is compared to a temperature of 60^0 C under the roof of their non-insulated shed. However, this appeared to have relatively little effect on the ambient temperature within the building.

The exterior roof colouring of the building should be considered. Light colours have reflective advantages over dark colours. Although light colours will reduce the solar heat gain within the building, they may raise the temperature of the local planning authority.

17.9 Roof lights

The heat at ground level of sun shining through a roof light can be around 850W/m^2. This can cause considerable stress to cows if they cannot move away, such as in a collection yard. Depending on the aspect of the collection yard roof, there may be advantages of providing shade during the summer months by painting out the roof lights. It may also be advisable to limit the amount of roof lights on south facing roofs in housing areas, while increasing the number of roof lights on the north facing roof.

18.0 LIGHT

Good lighting is a fundamental requirement of the efficient operation of a dairy farm. It is required for both the stock and stockmen. Research on the performance of dairy stock indicates that enhanced lighting levels can improve lactation and growth. For the stockman, it supports visual acuity, performance and safety both through higher lighting levels and better colour rendering. But lighting is also costly to provide and run, so choosing the most suitable fitting layout and control equipment is important.

18.1 The requirement for light

There are minimum light levels required for both general inspection and welfare, respectively. Enhanced lighting levels may be required for stimulation of milk yield for the cows, or for more visually demanding tasks for the stockmen. In such cases higher lighting levels may have to be provided in some areas for a specific time.

18.2 Properties of light

There are a few important characteristics of light which are worth considering when a lighting system is being designed.

- **Lighting level** - this is measured in lux. Lux is not a 'linear scale' so a doubled lux level does not appear as twice the brightness to the eye. In fact, you have to increase lux levels by four to double the perceived light level or by 16 to double it again. This is demonstrated in Table 19.

Table 19 – Lux Levels

Condition	Light level (lux)
Bright sunlight	80,000
Overcast day	5,000
Bad light stops play	1,000
Modern office	500
Twilight	10
Road lighting	5
Full moon	0.2
Starlight	0.02

Typical lighting levels (135)

- **Lighting colour rendering** – the degree to which light from different sources accurately renders colour is know as the colour rendering index (Ra) with a maximum level of Ra 100. Best rendering is from natural daylight and tungsten light. At the other end of the scale is low pressure sodium light (the yellow light used for street lighting) which has an index of just Ra 20. Colour rendering is important when it is necessary to discern one colour from the next - for veterinary tasks for instance.

- **Uniformity** – is generally not a critical thing for most dairy buildings other than in the milking parlour itself. Usually using a larger number of small lamps as opposed to fewer large ones will give best uniformity.

- ***Shadows*** – are not desirable for visually critical tasks. Shadows are most defined when light sources are small (like a tungsten halogen lamp) and where a small number of high powered lamps are used. Shadows can be minimised by using lamps with a large emitting area – like long fluorescent lamps and by employing a larger number of smaller wattage lamps.

The performance of a lighting system is often a compromise between the installation of a large array of the most desirable lamps and cost. Fewer larger lamps will always tend to be cheaper to install, both in terms of wiring and capital equipment, but uniformity and the production of shadows will be worse.

Poor light distribution is shown in Figure 16

Figure 16 – Poor light distribution

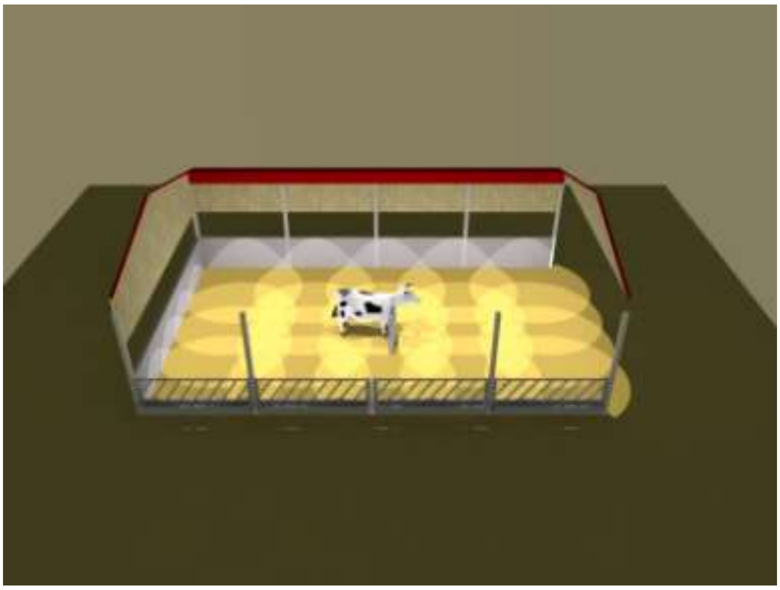
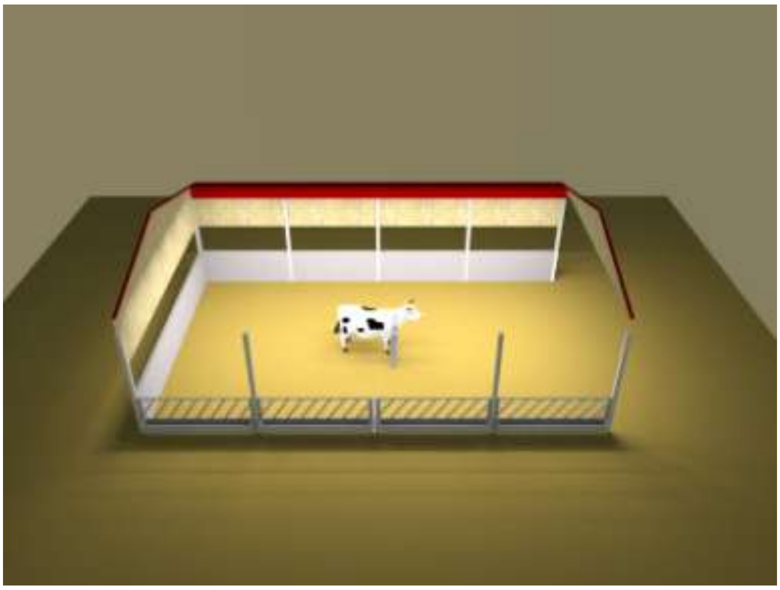


Figure 17 illustrates the effect of lighting type and luminaire numbers on lighting uniformity.

Figure 17 – Good light uniformity



18.3 Animal performance

The effect of lighting periods on milk yield has been the subject of a number of studies in Europe, United States and Canada in the last 30 years. A consensus seems to show that milk output and feed intake of lactating cows is highest with light periods of 16–18 hours per day and with a lighting level of at least 160–200 lux.

Long day length would appear to alter the secretion of a number of hormones. Such hormonal shifts are not unique to cows and drive the commonly observed changes in reproductive activity in other species too. Long days reduce the duration of elevated melatonin and produce higher secretion of the hormone insulin-like growth factor-I (IGF-I; 6). Higher IGF-I, in turn, is thought to increase milk yield.

On average it is expected that cows on long days will produce an average of two litres more than control animals on natural photoperiod.

It is important to balance extended daylight with period of darkness. However, light levels should be maintained around 30 lux to provide the cows sufficient light to move around the building and exhibit normal behaviour with confidence.

In addition to the long day effect on lactating cows, there is now substantial evidence that dry cows exposed to a reduced photoperiod (8L:16D) produce more milk in the subsequent lactation than contemporaries exposed to long days or even natural light conditions. An increase in prolactin receptor (PRL-r) mRNA leads to greater mammary growth during the dry period and improvements in immune function, both of which are likely to contribute to the higher milk yield in the subsequent lactation.

18.4 Tasks and lighting requirement

The following table gives some guidance on lighting levels and desirable light properties for different areas of a dairy enterprise. There are no definitive standards in this area, but Table 20 contains figures derived from practical experience and from similar practical references.

Table 20 – Lighting Applications

Applications	Lux level required	Colour rendering	Uniformity	Control	Comments
Cubicle and feeding area	170–200 lux for photoperiod yield effect, 50 lux for general	Low to medium	Medium	Timed, with light level sensing. Fluorescents can use light level driven dimming	High pressure sodium, metal halide lights or multiple fluorescent fittings
Milking area	500 lux for pit	Good	Very good	Timed with manual override	Fluorescent lights will punch light through the mass of pipes and fittings and give even shadow less light
Collection yard	50 lux	Low to medium	Medium	Timed with manual override	High pressure sodium or metal halide lights
Bulk tank area	200 lux	Good	Medium	Proximity	Fluorescent lights are most commonly used
Outside areas	20 lux	Low to medium	Low	Timed/light level	High pressure sodium or metal halide lights are the best compromise between cost and performance
Office	300 - 500 lux	Good	Good	Proximity	Fluorescent lights are most commonly used

18.5 Provision of Light

Light can be provided naturally or artificially.

- **Natural lighting** – can make a very big contribution to dairy buildings, both in cubicle housing and for parlours and other areas.

Providing 10–15% roof light area will be enough to provide between 100–500 lux through natural lighting, depending on the time of day and year. The key to sustaining this is to maintain the cleanliness of the roof lights. Transparent wall sections are also effective. Naturally lit buildings need to be well ventilated to counteract the effects of heat build up from solar gain, and the proportion of roof lights fitted should be higher on north rather than south facing roofs..

Plate 45 – High percentage of roof lights

- **Artificial lighting** – even with the best natural lighting resource, artificial light has to be used to guarantee light in all conditions, time of day and time of year. But of course artificial light is costly to provide, so it's always best to make the most of natural light and use artificial light to provide the rest.

18.6 Lighting types

There is a wide range of lighting sources to choose from and each type has its own unique set of characteristics. These include, capital cost, efficiency, longevity, colour appearance, colour temperature, shadow potential, and start up time. It's important to try to consider the relevance of these when choosing the right lamp type.

The most popular types of lighting are:

- **Incandescent lighting**

Here light is created by passing an electrical current through a wire so that it glows white hot (e.g. Tungsten). Many smaller incandescent lamps are currently being phased out of the market because they are so inefficient. Tungsten halogen lamps use the same basic technology, but are slightly more efficient thanks to the addition of halogen gas within the glass surrounding the tungsten element. In recent years, the low voltage versions of tungsten halogen lamps have had their efficacy improved by around 30%.

- **Discharge lamps**

In these lamps the generation of light occurs within a gas filled envelope which is excited by an electric current.

Most commercial discharge lamps use glowing gas discharges and/or phosphors to create light and modify light colour. Examples of lamps that use these processes are:

- Fluorescent
- Low pressure sodium
- High pressure sodium
- High pressure mercury
- Metal halide
- Ceramic metal halide.

Efficiencies are generally high and lamp life is good. Some of the lamp types take a minute or so to reach full output and colour rendering and appearance can be compromised in some cases.

- **Solid state**

A new generation of lamp is now available which generates light at the junction of a semi-conductor (e.g. light emitting diodes (LEDs)). The application of these devices has developed rapidly over the past few decades and their use in commercial lighting is starting to become viable. They have a very long life, typically 50,000 hours and their efficacy is increasing all the time. Unlike other lamps, LEDs are often integrated into the light fixture so there is no lamp replacement. Organic LEDs (OLEDs) are still very much in development as a light source, so not yet viable for commercial use. They produce light from a flat panel giving an even, diffused light, and may become commercially available in the near future.

Table 21 gives a list of lamps which can be effectively used in dairy lighting and their basic characteristics. (136)

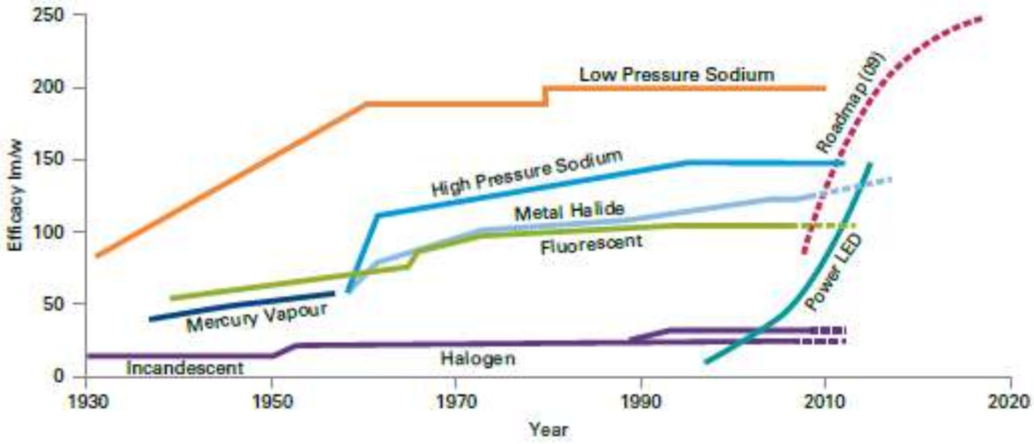
Table 21

Category	Type	Overall luminous efficacy (lm/W)	Overall luminous efficiency (%)	Colour appearance /rendering	Life (hours)	Comments
Incandescent 	100–200 W tungsten incandescent (230 V)	14	2.1%	White/good	1000	Cheap to buy. Expensive to run. Being phased out for small bulbs.
	100–200–500 W tungsten halogen (230 V)	17	2.5%	White/good	2000	Cheap to buy and widely used for yards. Expensive to run if operated for long hours. Best used on a proximity sensor.
Light-emitting diode 	7 W LED to 15 W	55.1–81.9	8–12%	White/good	50,000	Currently very expensive to buy and less efficient than most discharge lamps. Newer types promise high efficiencies. Very directional. Most efficient at cold temperatures.
	7 W LED PAR20 (110–230 V)	60.0	8.8%	White/good	50,000	
	Theoretical limit	260.0–300.0	38.1–43.9%	White/good	50,000	
Fluorescent 	T12 tube with magnetic ballast	60	9%	White/good	8,000	Old type of tube 1½ inches in diameter – being phased out.
	9–32 W compact fluorescent	46–75	8–11.45%	White/good	5,000	Natural replacement for tungsten bulbs with lots of new designs, some dimmable.
	T5 or T8 tube with electronic ballast	80–100	12–15%	White/good	15,000	Workhorse for commercial buildings where good quality low shadow efficient light is needed. Newer ballast

						types more efficient and dimmable.
Gas discharge 	Metal halide lamp	65–115	9.5–17%	White/good	15,000	White appearance. Alternative to sodium. Takes a few minutes to warm up.
	High pressure sodium lamp	85–150	12–22%	Yellow/medium	20,000	Yellow appearance. The most popular light for wide span buildings. Takes a few minutes to warm up.
	Low pressure sodium lamp	100–200	15–29%	Harsh yellow/bad	25,000	Monochromatic yellow light. Very basic light for use outside. Takes a few minutes to warm up.

Efficiencies of lamps have improved over the years. Figure 18 (137) shows how the efficiencies of lamps have changed and are forecast to change over the next few years.

Figure 18 – Efficiency of lamps



18.7 Control of lighting

Good lighting control is the key to managing the use of light and to ensure that the right light is provided in the right place and at the right time.

Automatic lighting controls are based either on one, or a combination of these three factors:

1. Movement.
2. Time.
3. Ambient light.

18.8 Movement sensors – include passive infra-red (PIR), ultrasonic and microwave. PIRs are the most common and cheapest sensor, although they are quite coarse in operation. At the other extreme microwaves are very sensitive but will react to the slightest movement. Some of the best control systems use PIRs to switch lights on and a microwave sensor to maintain the on-state.

Plate 46 – Movement sensor

18.9 Timers – are either time switches or time delays devices. Time switches usually have a 24 hour cycle or a 24 hour, 7 day cycle. The latter is useful where operational times change on certain days of the week. The best timers have a battery reserve so they continue to keep time if the electricity supply fails. You can use ‘solar’ time switches to control outside lights. These are pre-programmed to allow for the change in day length which occurs through the year.

18.10 Delay devices – switch off lights after a preset time. They are used for areas of temporary occupation—like walk-ways or toilets—where lights only need to be on for prescribed short periods.

18.11 Ambient light sensors – in their simplest form, switch lights on and off as the ambient light levels cross a particular value. They are positioned outside to sense ambient lighting conditions.

Light sensors can also be used to maintain lighting at a particular level inside a building, where some natural lighting is available. They signal to the lighting system to increase lighting output incrementally to supplement or replace daylight.

Hybrid systems using these techniques can be used to obtain the necessary functionality. So, for instance, an ambient light sensor may be used to switch lights on as daylight fails, and a time switch used to switch lights off in the late evening, when high lighting levels are not required by staff.

18.12 Lighting design

The design is important as it will determine the performance of the lighting for the life of the system. The preceding sections have covered the issues of lighting level, light uniformity, shadows and colour, and control all these things must be considered in the design process.

A few additional points may need to be examined.

- Consider the way lighting is used on an everyday basis. Where is the right place for the switches? Is it possible to get different lighting levels by simply grouping and switching the lights in banks?
- Are the lights in a position where they can be easily cleaned and where the bulbs can be safely changed?
- Consider reflectivity of roofs and walls. Colouring surfaces white or a light colour can increase the lighting level dramatically.
- Fittings in most cases will have to be water and dust proof. Make sure the ones you choose are up to standard.

The number of lights required in any particular area will be determined by the type of light chosen, its wattage, the lighting level required and local conditions like reflectivity of surfaces and room size.

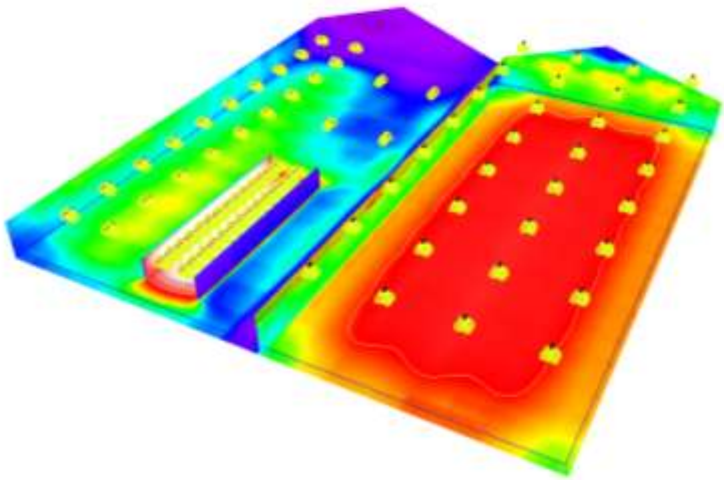
Table 22 gives a very approximate indication of lamp rating for different lamps types.

Table 22 – Lamp Ratings

Lamp type	W per m2 per 100 lux of lighting level required
Fluorescent	2.4 W
Mercury Halide	1.9 W
HP sodium	1.6 W

A full design takes into account a multitude of factors and can produce light rendering diagrams such as the example in Figure 19.

Figure 19 – Light rendering diagram



17.0 BIO-SECURITY

17.1 Bio-security and the dairy farm

Bio-security is the protection of livestock from exposure to disease causing organisms.

Dairy farms in general tend to be very open in terms of policies regarding visitors. This is not generally the case with other livestock species, especially poultry and pig enterprises.

Large scale pig and poultry producers typically have in place policies that apply to anyone entering the premises. Clearly, the first line of defense is to do whatever is necessary to keep infectious material off the farm by limiting who enters the premises.

Pig and poultry enterprises have recognised the risks associated with an open farm policy and apply stringent visit procedures. They may include walking through a disinfecting footbath or showering and then changing into disposable clothing and footwear in order to enter livestock areas. When leaving the premises, the disposable clothing is left behind and the footwear is disinfected again.

When Foot and Mouth disease broke out in 2001, there was an up-surge in the implementation of bio-security measures on many dairy farms. These include;

- Limiting access to livestock areas
- Ensuring milk tankers and delivery lorries do not enter livestock areas
- Foot baths at all points of entry

Unfortunately, the initial enthusiasm for improved bio-security has reduced as the period of time since the last major disease out break has increased.

All farms, irrespective of scale, need to ask themselves a number of questions regarding the potential risk of disease entering their farm and have in place a bio-security strategy.

17.1 Badgers and Housed cattle

Badgers and dairy herd health is a contentious issue, with the balance of scientific opinion indicating the risk of TB being spread from badgers to dairy cows. Studies by CSL (Central Science Laboratories) have shown badgers frequently visiting farmsteads throughout the year. Dietary analysis from badger faeces appears to indicate the importance of farm-derived foods to badgers with a peak in use during summer and a smaller one in winter (although this is far from conclusive). When adverse weather (drought or frost/snow) limits the availability of earthworms, the frequency of badger visits increases.

To minimise the risk from badgers, new buildings should be designed to prevent cattle and badgers coming into direct and indirect contact. The benefit will depend on the level of TB in the area and the frequency of breakdowns experienced, which has increased in the past decade. Exposure at grazing cannot be prevented but with a significant housing period, badger-proof building will reduce the risk. This will be more cost effective in the initial building phase instead of remedial action later.

Buildings should be made badger proof by blocking up walls and having sheer sides where possible to limit badgers climbing. Badgers can squeeze through a 75mm gap and so all holes and gaps need to be less than 75mm wide. Also prevent badgers from entering buildings by ensuring that gates are hung so that they are as close to the floor level as possible. All gates should be fully clad to ensure that badgers and cattle cannot come into direct contact with each other.

Perimeter feeding increases the opportunities for badgers to access the cows' feed. It is not possible to make a farmstead totally badger proof, and badger resistant fencing will need to be sunk approximately 0.5 m below ground level, increasing the cost, and be at least 1.2 m in height to limit their potential access. Gateways and personal access points will often be an area of weakness as they may not be closed, and therefore automatic gate closures should be considered. An alternative to fencing is filling a 0.5 m perimeter trench with concrete and erecting concrete panels to a height of at least 1.2 m. Again, access points need to be carefully considered.

Many farms are now securing their premises against badgers by installing electric fences around all the buildings. This effectively provides a badger free environment.

17.2 Birds

Many species of birds (including starlings and pigeons) can access cattle buildings. Not only do these birds eat the feed dispensed for the cattle, but they can also deposit faeces on the feed surface and associated metal work, which increases the risk of transfer of contagious infections such as salmonella and *E. coli*.

Plate 47 – Starlings eating TMR

While it is relatively straightforward to make a building bird proof using fine woven nets over all openings, leaving doors open to ease access will defeat the efforts.

In Holland, where curtain sided buildings are common; a fine tensioned net is erected inside the lifting curtain to prevent ingress of birds.

Plate 48 – Bird proof netting

Various bird scarers are available for use – but their efficacy tends not be well proven over time as birds become accustomed to their new “environment”.

20.0 YOUNGSTOCK AND HEIFERS

The principles of housing and management that apply to adult cows are no different to those for youngstock and heifers. Regulations, legislation, welfare codes and quality assurance schemes are all embracing, from birth to the abattoir.

Therefore regardless of the age of the youngstock from calf or down-calving heifer or type of housing (cubicles, straw yards, pens or hutches) the accommodation must provide for the animal's most basic needs.

Air space is just as crucial as floor area. One of the major causes of mortality and less than optimal performance throughout the life of cattle is pneumonia. It is especially common in housed animals and the disease can often be avoided if buildings are designed and operated correctly with good ventilation and are well drained and managed, i.e. not overcrowded and animals of different age groups are not mixed together.

As with adults, there are advantages and disadvantages of housing youngstock in cubicles and strawyards. If cows are to be housed in cubicles then it is arguable that cubicles for the young cattle should be the housing of choice. However, it must be stressed that the cubicles are suitably sized for the age, which means cubicles of various sizes for age groups.

20.1 Calf Housing

It is essential to provide calves with a clean, dry bed in well ventilated but draught free conditions, i.e. where air flow is less than two metres per second. Housing calves individually or in groups is a matter of facilities available. Legislation requires that calf pens are large enough to allow calves to groom themselves, lie down and stretch their limbs and rise without any difficulty and must also allow visual and tactile contact with animals in adjoining pens/hutches. This means that pen divisions must be perforated to allow calves to see and touch one another.

From 8 weeks of age calves must be group housed (unless an animal is kept in isolation on the advice of the veterinary surgeon).

Regardless of housing type, a newborn calf needs to be kept in a temperature of not less than 7ºC. By one month of age a calf can comfortably withstand temperatures around freezing point. It is important though that calves are kept out of draughts, as this has a negative impact on the lower critical temperature. However, rarely are low temperatures a problem in UK conditions with housed animals, quite the opposite with the main issue relating to high temperatures and humidity within a building.

The width of the individual stall/pen for a calf from birth to 8 weeks of age must be at least equal to the height of the calf at the withers, as measured in the standing position. The length shall be at least equal to 'the body length of the calf, measured from the tip of the nose to the caudal edge of the pin bone' multiplied by 1.1. In practice this means pens at least 1.5 x 0.9m, but preferably 1.8 x 1.0m.

A calf should always have a dry bed. Concrete floors should have a minimum slope of 5% (1 in 20) to allow effective drainage of water and urine. The installation of duckboards on which bedding can be placed will also help to keep the calf dry. A drainage channel at the front of the pen will also help to remove water and urine.

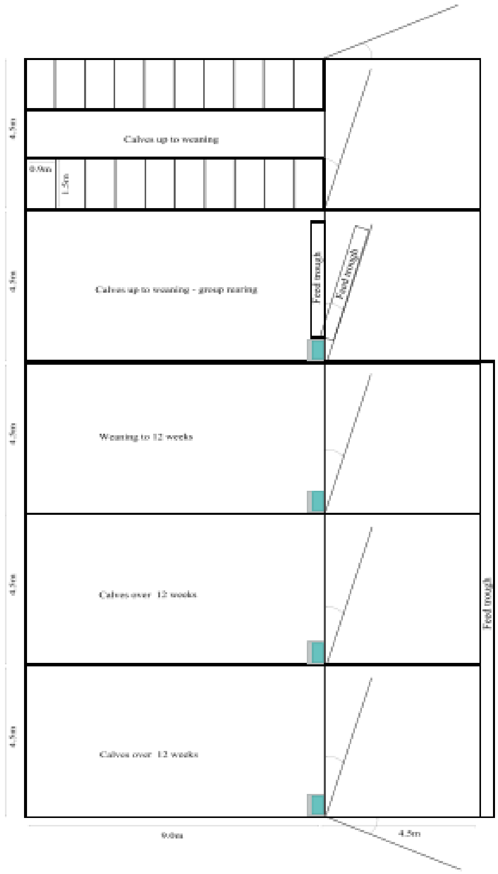
When kept in groups the space allowances are as in Table 23.

Table 23 - Space allowances for group housed calves

Mass of calf (kg)	Approximate age (months)	Minimum (statutory) area (m^2/calf)	Recommended area (m^2/calf)
45	0	1.5	2.0
46-99	0-2	1.5	3.0
100-149	3-5	1.5	4.0
150-199	5-7	2.0	5.0

In practise, this can lead to calf rearing layouts which move animals from individual pens to larger groups of calves as they mature. An example layout is shown in Figure 20.

Figure 20 – Example calf building layout



It is recommended that no more than 12 calves are kept in one group, as this makes it easier to identify sick calves and allow prompt treatment. Not only should there be no more than 30 calves sharing the same air space, they should not share that space with older cattle.

Air space is critical with a minimum of $6m^3$ air space per calf at birth, increasing to $10m^3$ by 2 months of age and at least $15m^3$ by 6-7 months. The greater the number of calves in a single air space, the greater is the risk to health.

Calf hutches are very popular, for good reason. Calves will usually be much healthier than those kept in buildings due to the abundance of fresh air.

They will often be of a size to house individuals, although larger hutches are available to house up to five calves. Each hutch must have an outside run for the calves to move around and be in fresh air. The hutches should be situated on either free draining concrete or on a porous base, such as chalk, ensuring that any effluent goes to a suitable site for disposal. Plenty of clean, dry bedding (normally straw) needs to be provided which should be disposed of after each batch of calves. Ideally the hutches should be moved after each batch to minimise disease risks. Although hutches are considered to be the best form of housing for calves, there are downsides, namely stock people having to feed and check the calves in all weathers.

20.2 Automatic calve feeders

Many farms are now rearing calves on automated machines. This type of rearing system can work well in combination with individual pens. As calves fed on automatic systems will consume significant volumes of milk, pen drainage is essential to remove urine and keep the bedded area dry.

Plate 49 Automated calf feeder

The pen should be designed so that calves can only drink from a concrete standing, away from the bedded area to assist in bed cleanliness. This is sometimes achieved by installing a small slatted area.

There needs to be easy access to the machine for operators to be able to clean and service the machine and the surrounding area needs to be well drained to deal with the waste water produced during the daily cleaning cycle.

20.3 Building Drainage

As previously referred to, prevention of humidity is crucial in youngstock accommodation. This can be aggravated by poor drainage, especially where calves are bucket fed, around automatic feeders and by water bowls and troughs. This may require a drainage channel underneath the buckets with good falls to a drain, usually outside the building. With *ad libitum* milk feeding large amounts of urine are a direct consequence. The profile of the floor must be to allow ready drainage away from the bedding (fall of around 5%).

20.4 Building Ventilation.

Dust and gas can have adverse affects on the health of the calf and young animal which extend through to lactation. Not only does dust irritate the respiratory tract and mucous membranes it leads to permanent damage to the lungs and encourages micro-organisms. Ammonia at levels of 25ppm will irritate the mucous membranes and also make the animal more vulnerable to respiratory diseases.

Studies show that ammonia levels in the first 4 months of life severely impact on the age at first calving. Although carbon dioxide is not poisonous at levels above 3000ppm, it can adversely affect cattle due to less oxygen being present. Hydrogen sulphide is highly toxic with levels above 50ppm known to kill cattle – the main cause of this problem being agitation to below ground slurry stores. Almost all infectious diseases occur by direct aerosol spread between calves so it is vital that there is good ventilation to allow for removal of infectious organisms. Similarly an increase in humidity will favour virus and bacterial survival.

Not only is air space critical but so is the ventilation rate, which is the amount of air replaced within a building in a given time. The aim is a minimum air change within a building of 10 times each hour, increasing in the summer up to around 60 air changes per hour. The purpose is to keep the air fresh. Studies from the USA show that higher humidity and mean temperatures within the calf housing results in a delayed first calving.

Natural ventilation requires the right balance of inlets and outlets. If the warm air is able to exhaust from the ridge of the building, this draws fresh air into the building through the side inlets. This air change ensures the stack effect is maintained. The inlet and outlet areas should be about $0.05m^2$ and $0.04m^2$ per calf respectively, with the outlet being at least 1.5m above the ventilation inlet.

At a relative humidity (RH) above 75%, pathogens and viruses can survive for several minutes which increase their spread from animals to animal. However at RH levels below 75% viruses die very quickly after exhalation. Within many calf buildings, the humidity is such that viruses can survive for around 40 minutes creating a reservoir of infection in the air which means the disease is rapidly spread.

A constant supply of fresh air is essential in preventing respiratory and other diseases together with improving production. Good ventilation removes stale, damp air which helps ensure that viruses and bacteria cannot survive for long outside the animal. Ventilation should never be restricted in an attempt to raise air temperature. In all but the minority of situations natural ventilation will be adequate. However, if artificial (fan) ventilation is required then it must only be controlled manually or by humidity sensors, never by a thermostat.

Natural ventilation is the most efficient and least expensive system for providing an optimum environment within a building. The objective of the ventilation system must be to provide a continuous stream of fresh air to every housed animal at all times of the day or night. Buildings will naturally ventilate best when they are sited at right angles to the prevailing wind direction. Although in practical terms in the UK, the occurrence of the prevailing wind is only slightly higher than that from the other directions.

To ensure adequate ventilation, it is important that the building is designed, or adapted, to:

- Remove excess heat;
- Remove excess water vapour;
- Remove micro-organisms, dust and gases;
- Provide a uniform distribution of air;
- Provide correct air speed for stock.

In the UK, wind speed is above 1m/sec for more than 95% of the time. This means that for the majority of time, there is sufficient generating force to provide the necessary air changes within a correctly designed building by natural ventilation.

Calf and young stock housing tends to be buildings that have been made redundant for adult cattle. It is imperative that the limitations of the old design are overcome for the sake of health and productivity of the next generation of animals to go through the milking parlour.

As with cow housing, the design of a successful natural ventilation system is complex and requires account to be taken of the span of the building, the location of the building relative to other buildings or obstructions (buildings and trees disrupt airflows for a distance of 5–10 times their height), the pitch of the roof, the stocking rate, mass of each animal and the bedding system.

Although the aim is to use natural ventilation, occasionally mechanical ventilation may be required in some calf buildings due to design constraints but should be the last option. This may be essential with summer housed animals to minimise the effects of heat stress. During the summer months fans assist air movement to provide a cooling effect and so increase heat loss from animals.

20.5 Type of bedding

For loose housed animals of any age the options are the same as for cows. With the price of straw becoming a serious issue and with the quality of cereal straw varying from year to year other bedding materials are being looked at. These include sand, sawdust/shavings, bark peelings, waste paper and gypsum waste. Studies of various materials by the University of Arkansas found no significant differences in output of calves housed over a 6 week period on different materials, although straw and wood shavings provided more warmth and absorbency compared to products like sand. However, no cleaning out of pens was done in the trial period which would be uncommon in practice on sand based systems. Although efficient use of bedding is very important, care must be taken to ensure that the cleanliness and welfare of young animals are not compromised.

20.6 Straw Yards

Although all straw yards maybe considered suitable for calves, i.e. animals less than 6 months of age, for older youngstock the bedded area should be supplemented with a scraped concrete feed/loafing passage. The yard should be rectangular in shape. This concrete helps promote hoof wear and will prevent feet becoming over-grown. Aim for a passage width of 2m for animals less than a year of age, which should be scraped regularly at least 3 times per week.

A small step (usually 0.2 m and no more than 0.3 m for older heifers, should be provided between the feeding/loafing area and the straw beds. This will help retain the straw and prevent manure flowing onto the bedded area during scraping.

20.7 Cubicles

Cubicles must provide a clean comfortable lying space for the heifer calf. The calf must be able to enter and leave the cubicle easily and lie down and rise without interference or injury. Poorly designed cubicles and inappropriate management can lead to problems such as cubicle rejection through to adult life, wet and soiled cubicle beds and physical injury to the animals.

The length of the cubicle needs to be adequate to allow the heifer to rest comfortably and rise without injury. The position of the animal when lying down and standing are controlled by brisket boards and headrails. A correctly located heifer calf means that urine and dung fall into the scraped passage and not on to the cubicle base.

There needs to be sufficient distance between cubicle divisions to allow the calf/yearling to lie comfortably while ensuring she is unable to turn around. She should not come into contact with the cubicle partition in such a way that could cause injury, be it when she lies down or rises. When an animal rises from a lying position, it lunges forward to transfer its weight from the hindquarters onto the forequarters. To accommodate this transfer of weight, the animal thrusts the head forward and this lunging space must be designed in the cubicle. If the forward lunging space is restricted then difficulty in rising will be experienced.

20.8 Cubicle Dimensions

Cubicles need to be designed for the size of animal at the end of the housing period. Researchers in Denmark produced guidance in the Housing Design for Cattle booklet (138) which outlines cubicle dimensions for youngstock. This is illustrated in Table 24.

Table 24 – Danish cubicle dimensions

Weight (kg)	**100**	**150**	**200**	**300**	**400**	**500**
Width (m)	0.55	0.6	0.7	0.85	0.95	1.10
Length (against wall –m)	1.5	1.6	1.7	1.95	2.15	2.4
Length (head to head – m)	1.4	1.5	1.6	1.8	2.0	2.25

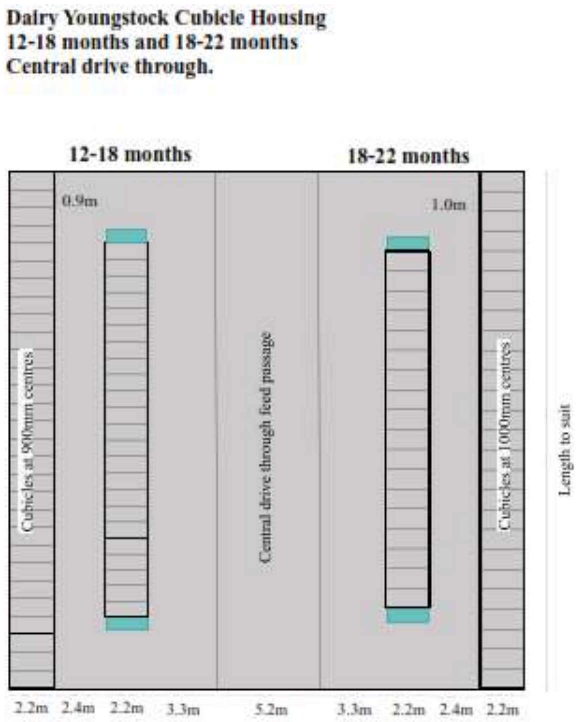
Cubicle Length - The total length of the cubicle should provide body space, head space and lunging space. Cubicle length is very dependent on the size of the animal. It is better to have a cubicle too long as the effective length can always be reduced. As a guide for calves (0-6 months) the cubicle should be 1.6m long when installed against a solid wall increasing to 2.15m for animals up to 12 month of age. Knowing the weight of the youngstock at each stage is essential.

Cubicle width - Cubicle width must allow the animal to rise and lie easily. But if the width is excessive, the animal will tend to lie at an angle in the stall or turn around. The width of the cubicle will be determined not only by the size of the animal but in part by the choice of cubicle division. Slightly wider widths are required if there is a rear support leg. For calves the width will be around 0.55m increasing to 0.95m for animals up to 12 month of age.

Division design - There are many types of cubicle division on the market. Whatever the type they must provide the animal with maximum comfort, provide security/protection, prevent injury and ensure that she is correctly positioned both standing and lying. The space sharing division, such as the suspended cantilever type offer more room allowing slightly narrower widths.

The main benefit of the suspended cantilever division is that both height and width spacing can be altered at any time. This provides flexibility, especially where animals are growing rapidly.

Figure 22 – Example layout for youngstock cubicles



20.9 Number of Cubicles

As with dairy cows there should always be at least 5% more cubicles than animals within a calf management group. Overcrowding leads to reduced lying times and increased lameness which is carried through to adult life. There is also more bullying with an increased risk of injuries. As with layouts of cubicles buildings for adult animals, there should be no dead ends and cross passages provided at approximately every 20 cubicles.

20.10 Space Allowance for Feeding

Although feed may be *ad lib* and available 24 hours per day it has to be recognised that there are peak periods for feeding during the day, e.g. immediately after fresh feed is put down the trough. If there is competition for feed space during this period, subordinate animals will give way to dominant animals, modify their feeding behaviour and their growth rates are likely to suffer. If bulling animals, pregnancy rates are likely to suffer. Feed trough space is given in Table 25.

Table 25 – Feed face required for young cattle eating simultaneously.

Mass of animal (kg)	Width of feed face (m)
<100	0.30
100-199	0.35
200	0.40
300	0.50

Animals should be able to pass behind those already feeding without disturbing them. This means the passage should be at least 2m wide.

20.11 Water

As cattle are herding animals they are sociable in their behaviour. Adequate trough space or water bowls must be provided to allow at least 10% of the group to drink at anytime. The water trough should be located at the correct height for the animal – again often a problem in practice with rapidly growing animals.

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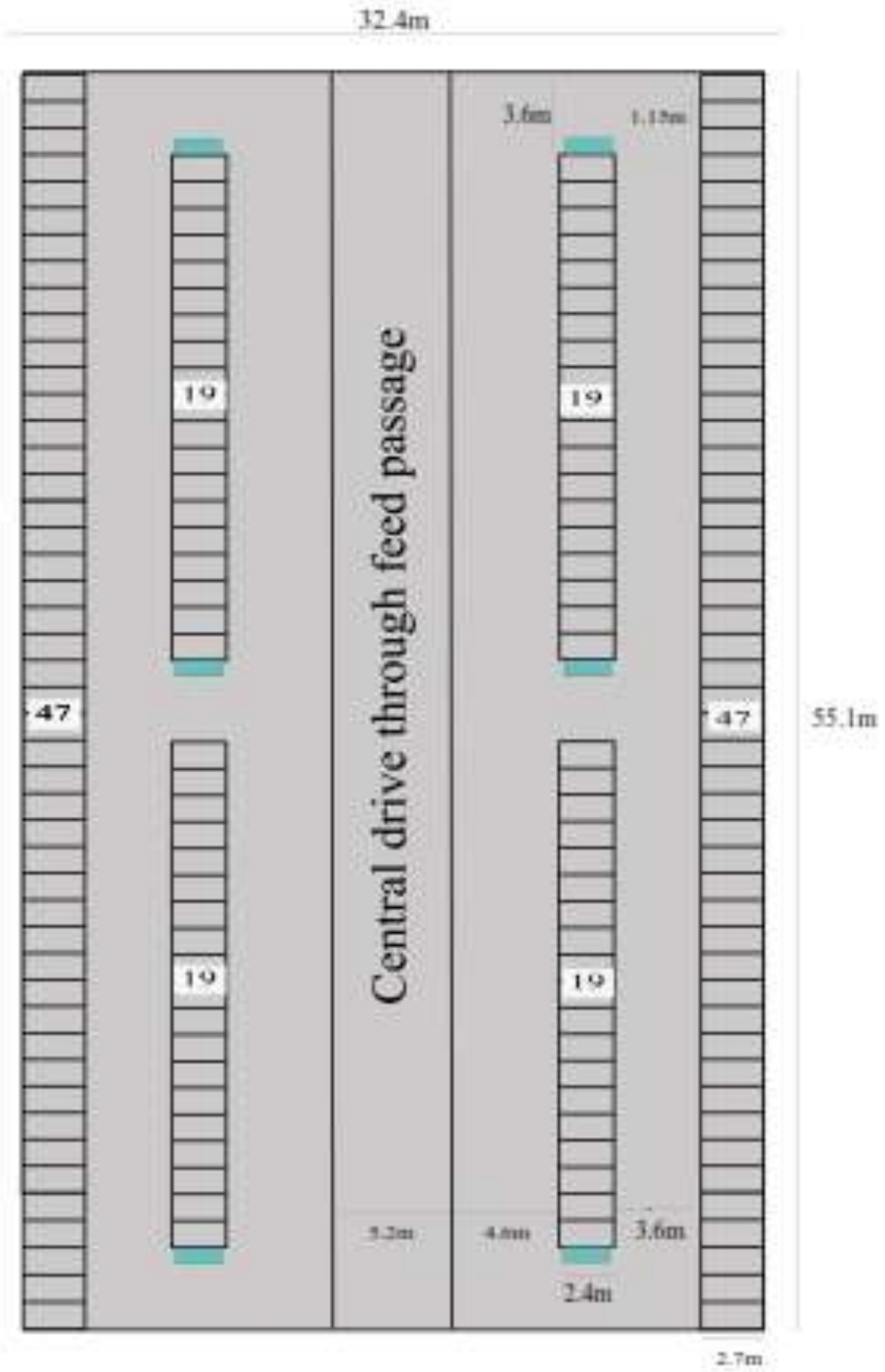
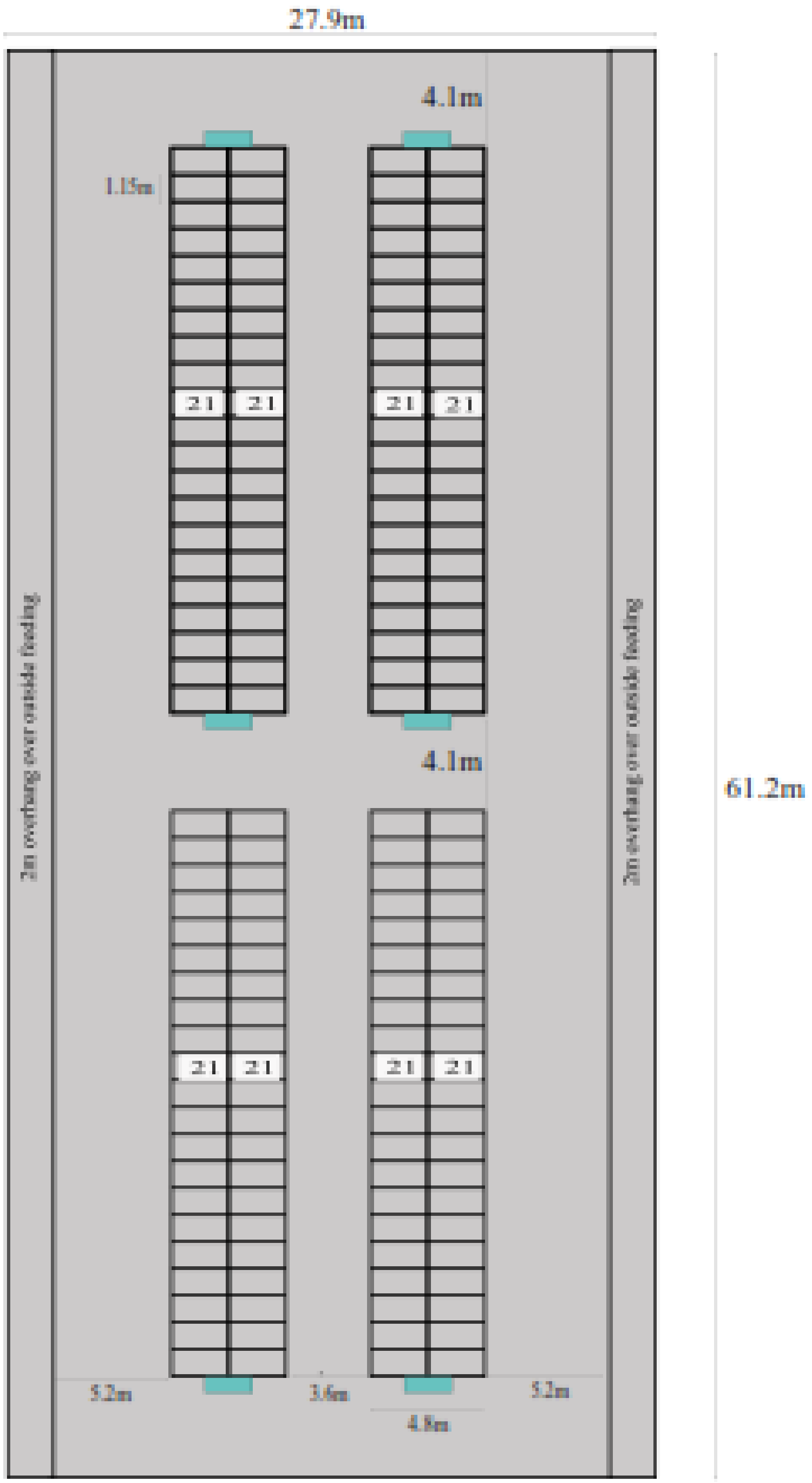
APPENDIX 1

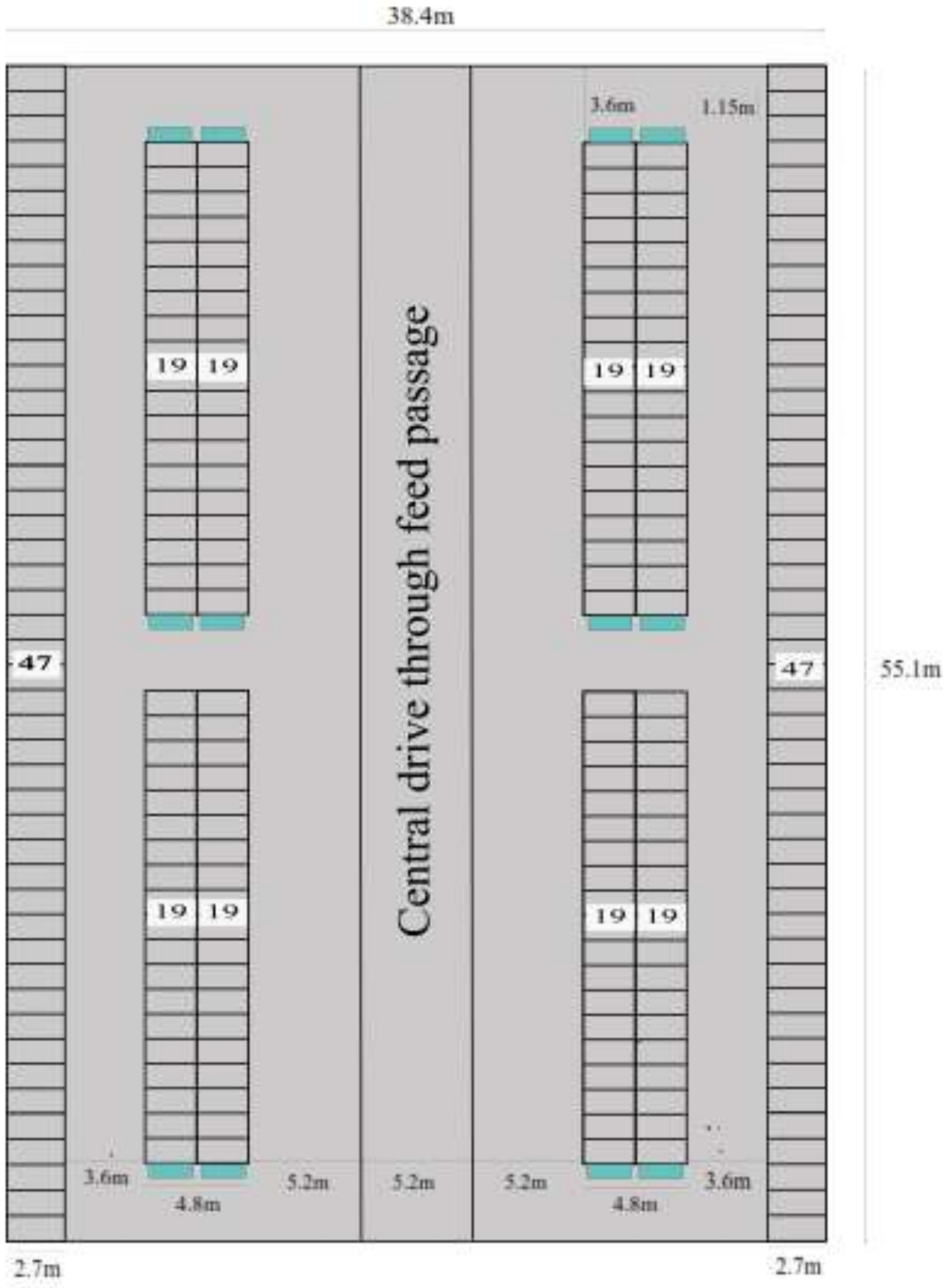
Example layout of central drive through 2-row per side cubicle building for 162 cows with 5% extra cubicles (81 cows per side)



Example layout of perimeter feeding, with 2-double row cubicle building for 160 cows with 5% extra cubicles, kept in one group. 2.0 m overhang on each side of the building

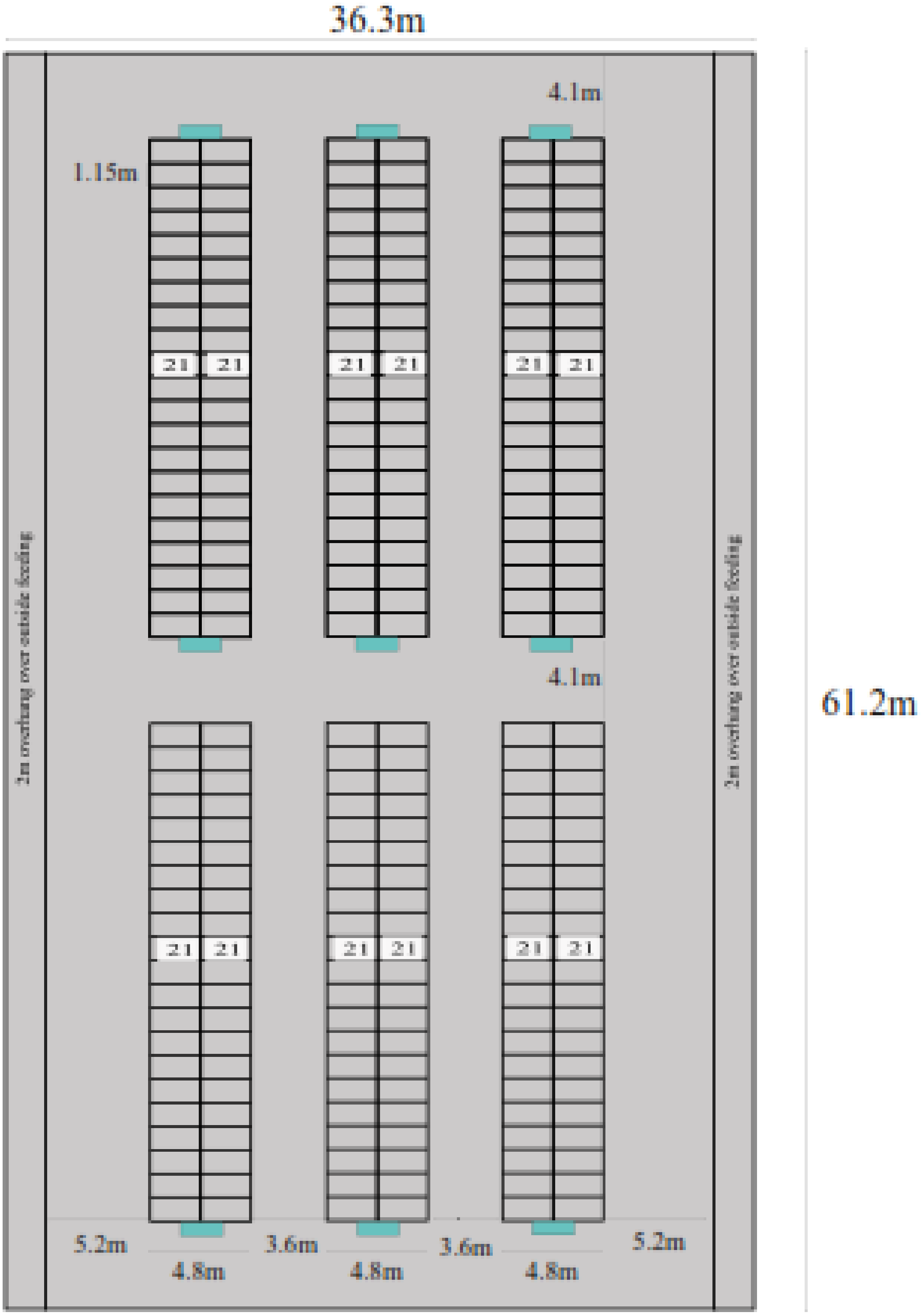


Example layout of central drive through 3-row per side cubicle building for 234 cows with 5% extra cubicles



55.1m long (9 x 6.096m bays)

Example layout of perimeter feeding, with 3-double row cubicle building for 240 cows with 5% extra cubicles, kept in one or two groups. 2.0 m overhang on each side of the building

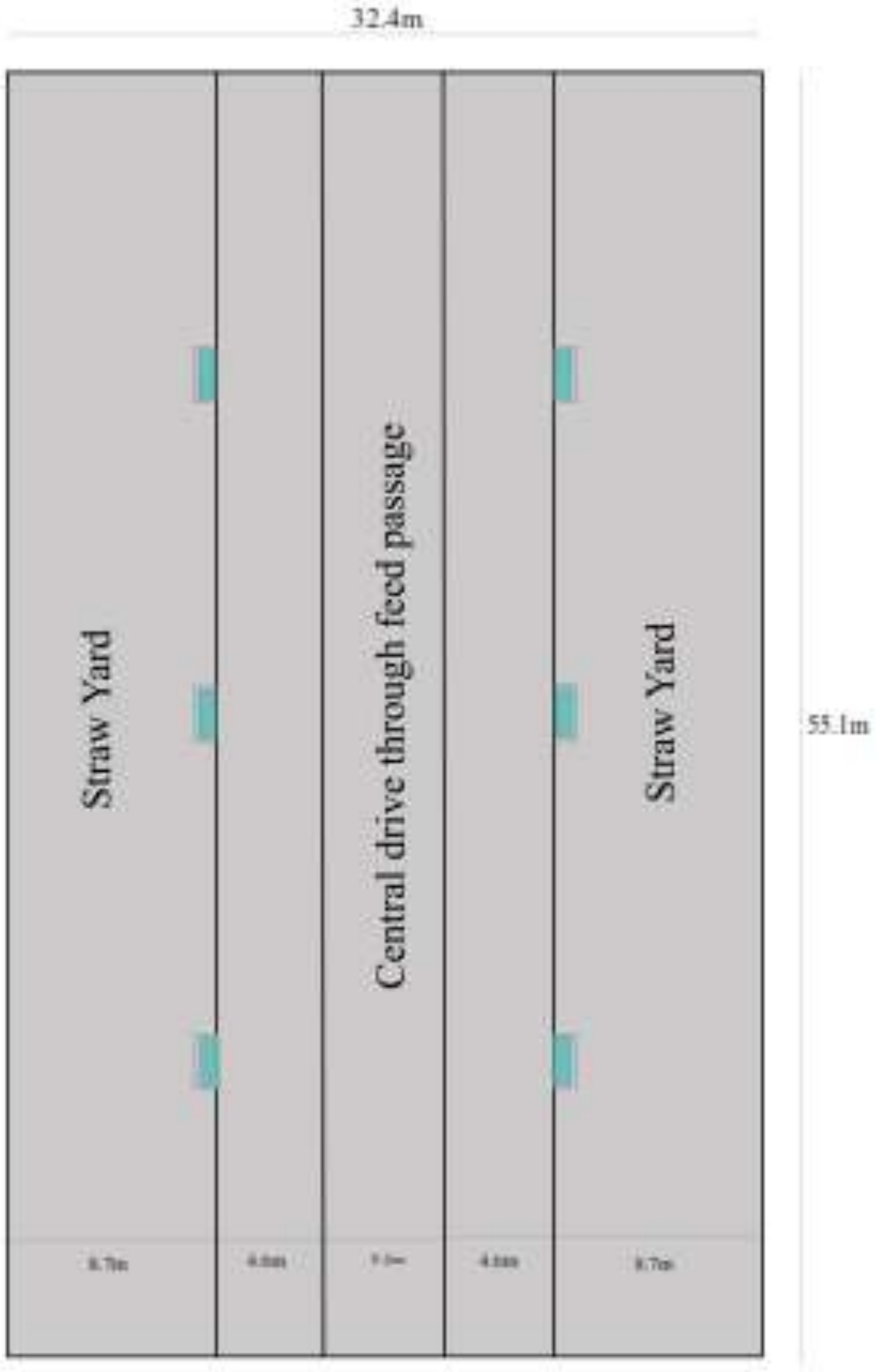


Example layout of perimeter feeding, with 1-double and 2-single row cubicle building for 164 cows with 5% extra cubicles, kept in one or two groups. 2.0 m overhang on each side of the building

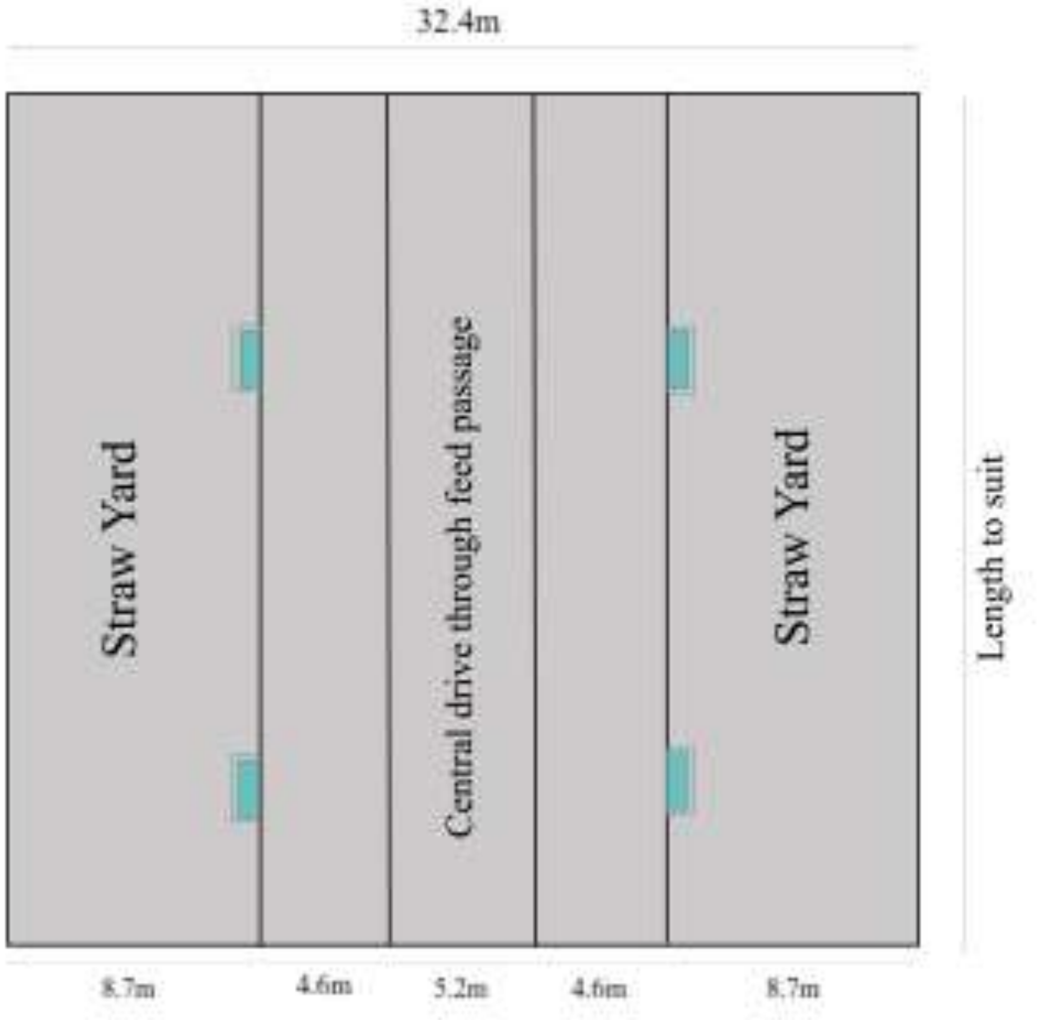
Example layout of perimeter feeding, with 2-double and 2-single row cubicle building for 240 cows with 5% extra cubicles with cows in one group. 2.0 m overhang on each side of the building

Example layout of central drive through feed passage, plus outside feeding on one side for a third cubicle group. Building for 150 cows with 5% extra cubicles

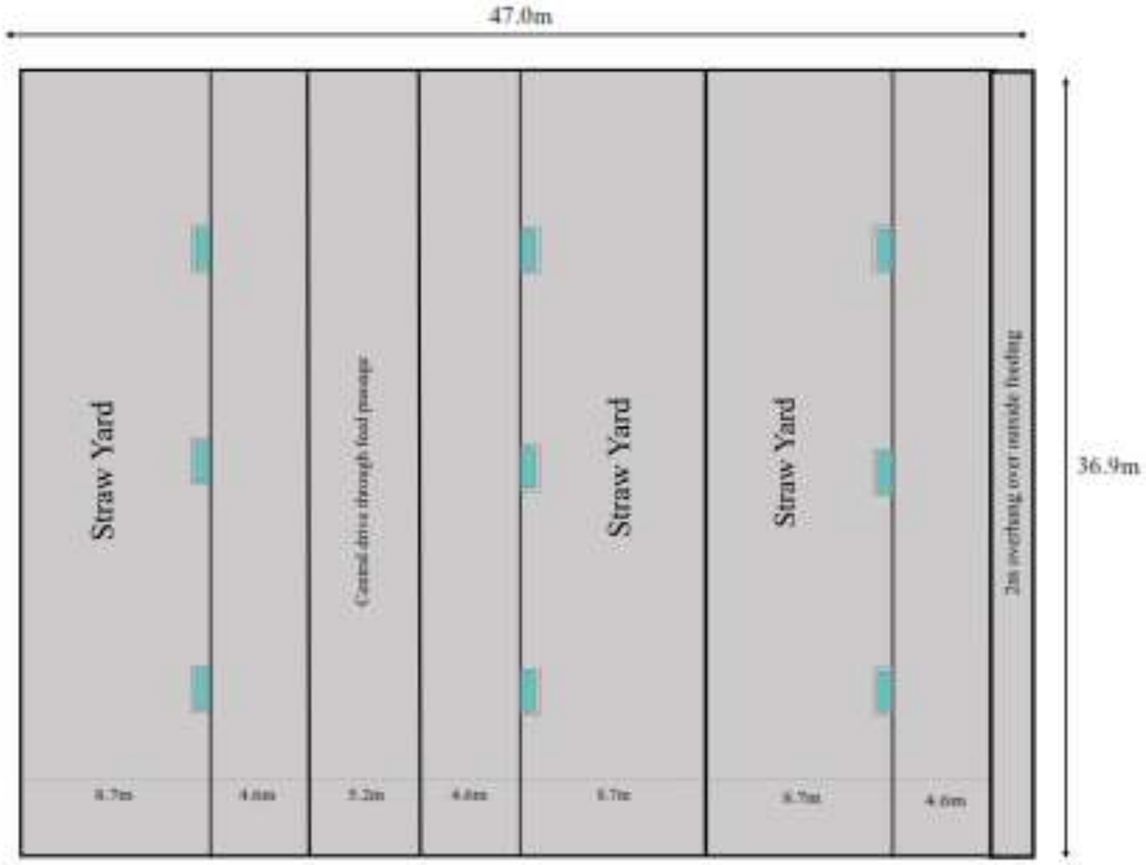
Example layout of dairy cow straw yard with central drive through feed passage. Stocking rate for 96 cows – 48 cows per bedded area at 10m^2/cow



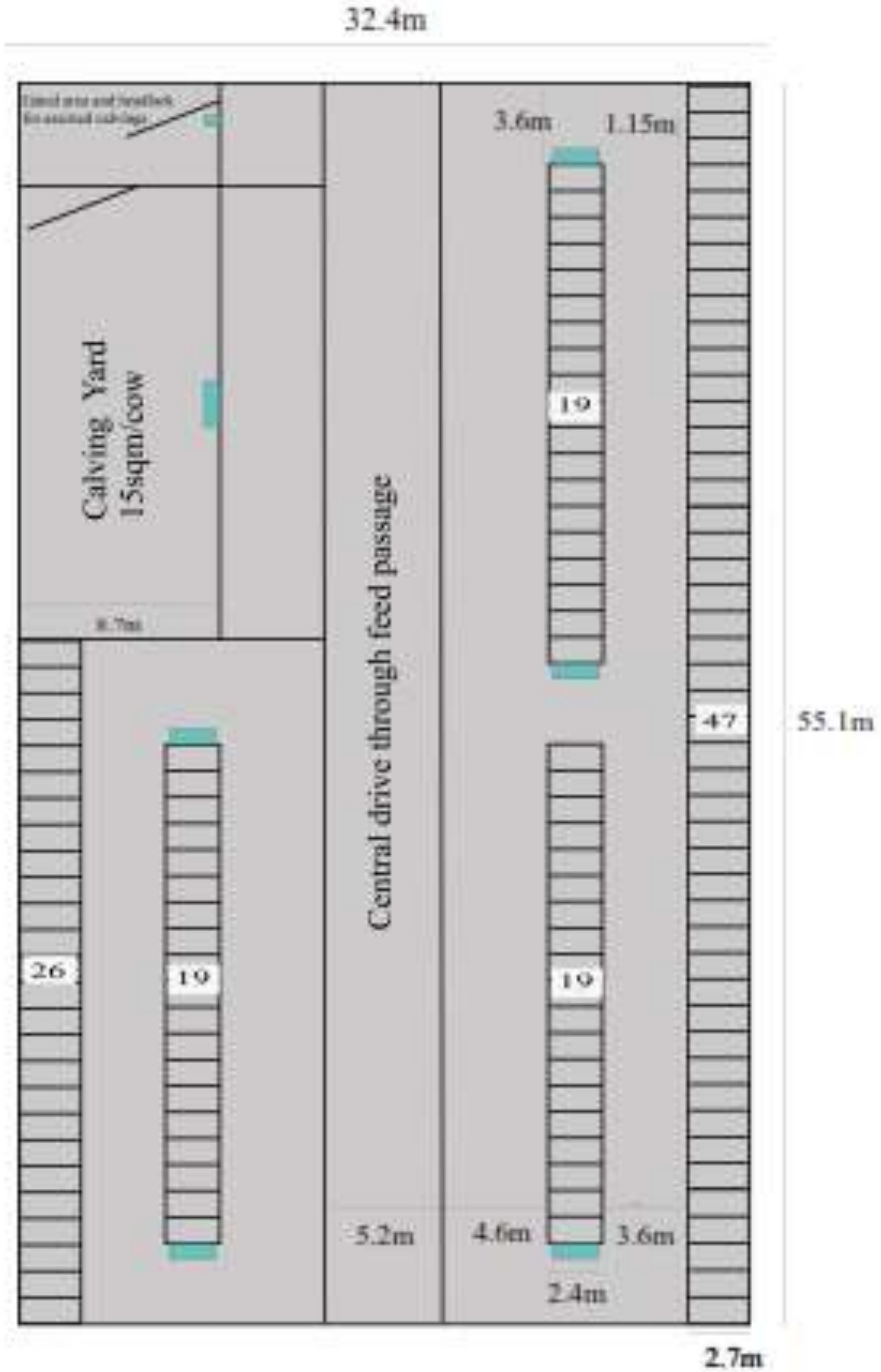
Example layout of dairy cow straw yard with central drive through feed passage. Stocking rate on bedded area at 10m^2/cow.



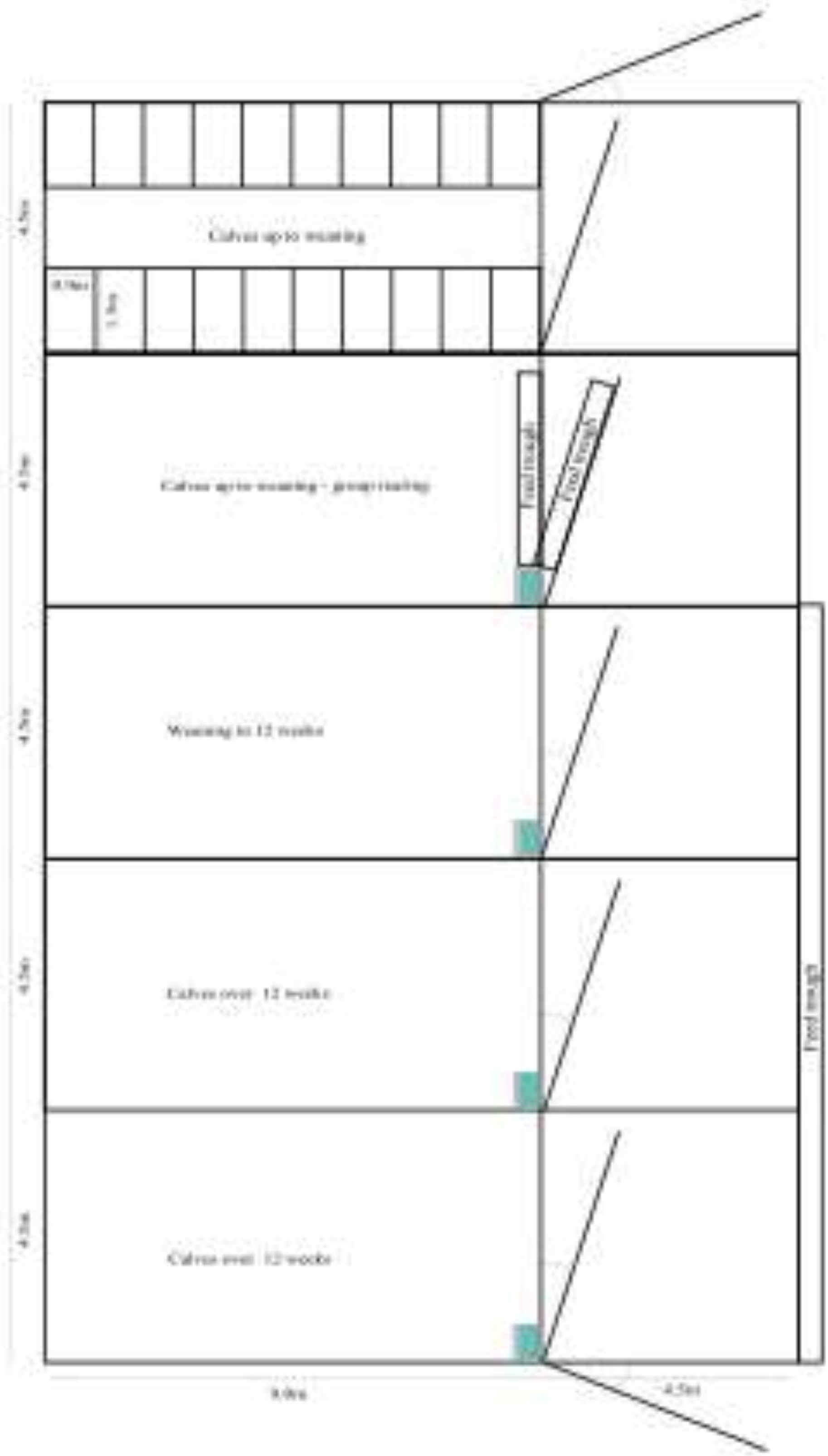
Example layout of central drive through feed passage, plus outside feeding on one side for a third straw yard group. Building for 96 cows at a stocking rate of 10m2/cow



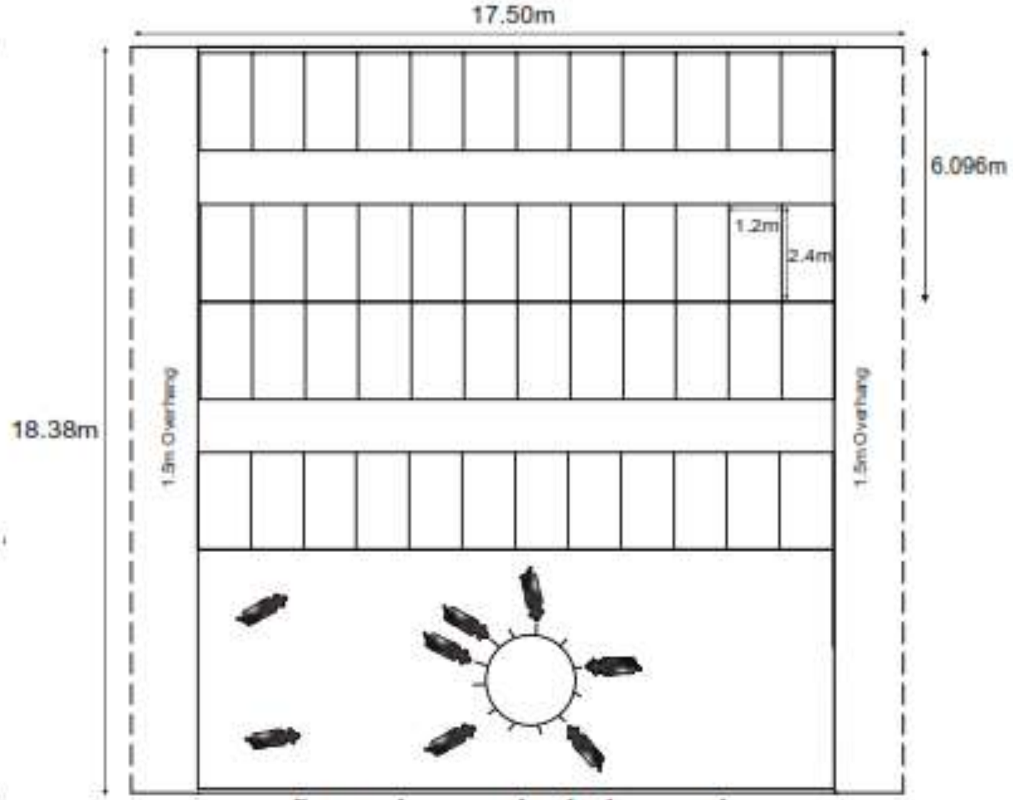
Example layout of dairy cow cubicle house with calving yard for 14 cows with central drive through feed passage. This layout provides the opportunity to provide further calving boxes, although this will reduce the number of dry cows housed



Example layout of a youngstock calf building allowing for individual pens or rearing in groups


4.5m
Calves up to weaning
4.5m
Calves up to weaning - group rearing
Feed trough
Feed trough
4.5m
Weaning to 12 weeks
4.5m
Calves over 12 weeks
4.5m
Calves over 12 weeks
Feed trough
4.5m

Example layout of a youngstock calf building allowing for individual pens or pens for calves grouped with automatic feeding



Pens can be removed and calves reared on an automated calf rearing machine

Example layout of a dairy youngstock cubicle building with central drive through feed passage, for cattle 12 – 18 months and 18 – 22 months