



Lighting System Considerations and Design Options for Application of Photoperiod Management for Freestall and Tie Stall Barns

by

C.A. Gooch, P.E.¹, D.C. Ludington, Ph.D.²

INTRODUCTION

Photoperiod manipulation, also known as long-day lighting, is the management practice of using a designed lighting system to artificially extend the duration of light that a lactating cow is exposed to with the goal of increasing milk production. Photoperiod manipulation was first pioneered in the late 1970's and gained much wide span industry interest in the late 1990's. Supplementing lactating cows with 16 to 18 hours of continuous light at an intensity of 15 to 20 footcandles (fc) has been shown to increase milk production from 5 to 16 percent above cows exposed to less than 13.5 hours of light in research trials (Peters et al., 1978, 1981, Marcek and Swanson, 1984, Stanisiewski et al., 1985, Bilodeau et al., 1989, and Phillips and Schofield, 1989). Research has also shown the balance of the 24-hr. period needs to be dark in order to achieve a favorable response.

Reports from photoperiod manipulation studies mainly focus on cow related variables and provide little information relative to the lighting system designs employed. Light levels are generally reported but lack lighting uniformity information. Consequently, little dairy-specific background information is available for lighting designers to use when designing lighting systems for photoperiod manipulation. The objective of this paper is to provide information for designing lighting systems for photoperiod manipulation based on experience obtained from designing systems for six production dairy farms (three tie stall barns and three freestall barns) that are participating in a field trial in New York State.

LIGHTING DESIGN CONSIDERATIONS

Producers intending to employ photoperiod manipulation should consider two groups of variables when designing their lighting systems: barn specific variables and luminaire specific variables. Barn specific variables include size and spatial issues. Luminaire specific variables include those variables that influence the design and maintenance of the light source. Both barn specific and luminaire specific variables are identified and discussed below.

¹ Senior Extension Associate, Dept. of Bio. and Env. Eng., PRO-DAIRY Program, Cornell University, Ithaca, NY

² President, DLtech, Incorporated, Ithaca, NY 14850



Barn Size

The length and most especially the width of the barn impact lighting design by affecting the number of fixtures required to provide lighting. Wider barns require more rows of luminaires to provide target illumination levels than narrower barns. Experience has shown that most two-, three-, four- and six-row barns need at least one, two, three, and four rows of lights, respectively to provide adequate lighting for photoperiod management. The exact number of rows required also depends on the design of the chosen luminaire and its mounting height.

Luminaire Mounting Height

The mounting height is generally defined as the distance from the work plane to the bottom of the luminaire. Mounting heights can vary significantly depending on the structural design of a barn. Barns that use a conventional truss system usually will have luminaires mounted to or suspended from the bottom chords of the trusses. With a given sidewall height, this results in mounting heights that are generally less than those obtained in barns that use a rafter system or a glue-laminated arched truss system. The preferred mounting height with respect to the building's structural system needs to be kept in mind when evaluating luminaire options. Examples of outfitting various barn layouts using different structural systems with luminaires are shown in the Appendix.

Work Plane Height

Work plane height is the distance above the floor surface that a lighting intensity measurement is taken. For photoperiod management lighting systems, the work plane height should be two feet. This represents the height of cows' eyes above the cow alley floor (freestall barn) or the litter alley floor (tie stall barn) when resting in the stalls. Targeted light levels of 15 to 20 footcandles are desired at cow eye level to create a response (Dahl, 2001). Using a work plane height of two feet will result in higher light levels reaching the cows' eyes when they are in a standing position.

Reflectivity of Interior Surfaces

Reflectivity levels for walls, ceiling, and floors impact the number of luminaires needed to provide desired light levels. Higher surface reflection coefficients result in increased light levels measured at the work plane height. Care should be taken on the part of the lighting designer not to use reflectivity levels found in barns that are new. Dirt quickly builds up on wall, ceiling and floor surfaces resulting in measurable losses in reflectivity.

Reflective values for walls is zero for freestall barns (worst case scenario is curtains fully open) and up to 10 percent for conventional tie stall barns (minimum light reflected off walls due to normally dirty conditions). Values for ceilings are generally zero since most ceilings (if present) are dirty and/or the light fixture is designed to direct output light in a predominately downward direction. Floors generally have little light reflectance since they are covered with manure. Ten percent can be used and is considered a



conservative design value.

Design Light Level at Feed Alley and Front of Stall

Appropriate light levels for implementing photoperiod manipulation management for lactating dairy cows is between 15 and 20 footcandles (Dahl, 2001). Freestall barns that use conventional truss systems that are not clear span and/or other barns that use convective cooling fans to provide summer-time heat stress relief may require special attention when designing lighting systems due to shadowing. It does not appear to be understood at this time if in-the-barn shadowing adversely affects photoperiod response.

Uniformity of Light Level Along Feed Alley and Front of Stall

Uniform light levels, that might imply equal light levels over the floor area of a freestall barn, do not appear to be necessary. However, light levels in the head area of stalls and feed bunks (where the comfortable cows will spend most of their time), should be designed to provide a minimum level of 15 footcandles after a defined service period that is based on a predicted light loss factor (discussed below). The Appendix has examples of both targeted lighting design (lighting areas where cows are doing productive activities, i.e., eating or resting in stalls) and uniform lighting of all cow areas.

Type of Luminaire

The type of luminaire that can be used to provide lighting includes metal halide (MH), high-pressure sodium (HPS), and fluorescent. Dahl (2001) indicated that these three light sources will create a milk yield response. There may be personal preferences with regard to MH and HPS luminaires. HPS lights deliver more lumens per Watt than MH, 120 vs. 80 for example. This is obviously an economic advantage because fewer luminaires are needed to obtain the same average light level (number of lumens measured at the work plane) and lower connected load (kW). However, achieving “uniform” lighting is easier to provide when using more, lower wattage fixtures. Generally HPS luminaires also have a higher average lamp life. However, MH have a higher color rendition index (CRI), a measure of the luminaire’s output light color. MH luminaires have a more white output light color while HPS luminaires have a yellowish/orange output color. Lighting system designers should consult with the dairy producer and determine their preference for luminaire output light color.

Fluorescent lights have a lamp life similar to MH. However, fluorescent lamps have a lower lamp lumen depreciation factor meaning that they stay brighter longer. In fact, mean light output for fluorescent lamps can be 95 percent of the initial light output while MH may be 65 percent. Mean light output is defined as the light output after 40 percent of average life. Figure 1 shows the comparison of the LLD for three lamps. The rated average life for fluorescent and MH lights is determined when 50 percent of the installed lights are still operating.



Type of Ballast/lamp

Pulse start MH lamps and fixtures have higher initial light output and a lower lamp lumen depreciation factor when compared to standard probe start MH luminaires. For 320 and 450 W pulse start MH, rated life is determined when 70 percent of the lights installed are still operating.

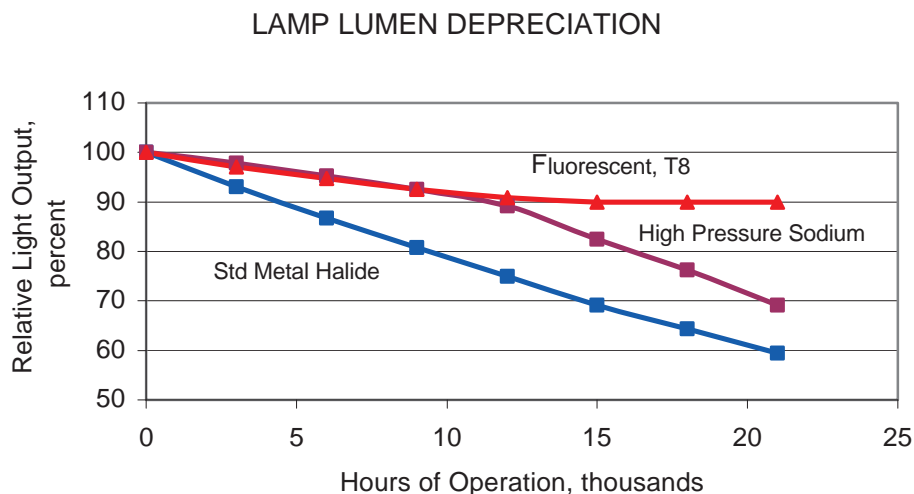


Figure 1. Lamp lumen depreciations for T-8 fluorescent, high pressure sodium, and standard probe start design metal halide luminaires.

Design of Light Diffuser

The distribution of light (lumens) from a fixture varies with the design of the diffuser (lens). This can have a significant affect on the number and location of the luminaires. Manufacturer's photometric data should be consulted and used when evaluating a specific luminaire with respect to the intended mounting height. A comparison of four combinations of housings and lenses for a 250 Watt MH luminaire is shown in Figure 2.

Light Loss Factor

Light loss factor (LLF) is a function of lamp lumen depreciation (LLD), luminaire dirt depreciation (LDD) and room surface dirt depreciation (RSDD); $LLF = LLD \times LDD \times RSDD$. Lamp lumen depreciation is a measure of the decrease in lumen output of a luminaire due to use. Manufacturers of lighting elements have data tables for the LLD of their products. LLD is influenced by the operating cycles. For MH, operating cycle of 11 hrs on and 1 hr off is suggested by IESNA and 3 hr cycle for fluorescent lamps. Dirt depreciation is a measure of the decrease in lumen output of a luminaire due to dirt build up on the luminaire's diffuser. Dirt buildup is based on the environment the luminaire is exposed to. Significant dirt build up occurs from dirt particles settling on the

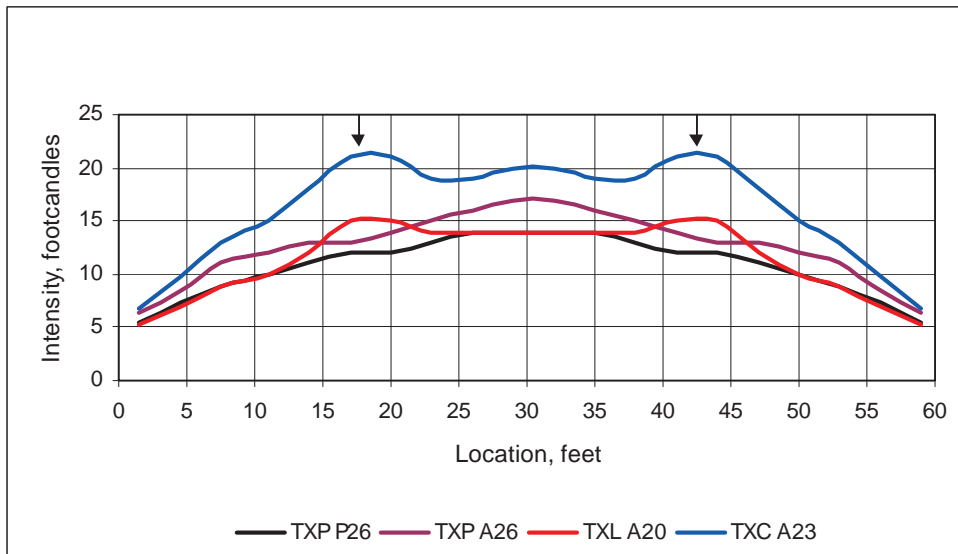


Figure 2. Comparison of different combinations of housings and lenses for a 250 Watt low bay pulse start luminaire. Luminaire spacing and mounting height of 25 and 17 feet, respectively.

light diffuser as well as particles attracted by electrostatic forces. Fly dirt also is deposited on diffusers in dairy barns. While significant design data exists for dirt depreciation of luminaires used in residential, commercial, and industrial settings, no similar data exists for dairy facilities. At this time designers must use data from these applications to approximate the environment found in dairy barns. The authors are developing dirt depreciation data from the field studies currently being conducted.

The effect of LLD on lumen output for 5 different luminaries is shown in Figure 3; 400 W standard MH, 320 W pulse start MH, 350 W pulse start MH and 360 W pulse start Stay Bright pulse start and a 360 W Watt-Miser. All the pulse start luminaries have lower LLD than the standard MH. Using 16 hours per day for photo manipulation is equal to 5,800 hours per year. For the standard MH the lumen output has been reduced nearly one-third while the lumen output from the 350 W PS lamp has decreased only 21 percent.

Both LLD and DDF are a function of time. Consequently, designers must design lighting systems that provide the target level of light at some point of time after lights are first turned on. For photoperiod controlled lighting systems, experience has shown that initial light levels may be designed for 20 to 25 footcandles in order to have ensure a minimum of 15 footcandles after 2 years of service life. Lighting systems for freestall barns largely consist of using metal halide or high pressure Sodium high intensity discharge (HID) fixtures. Due to the LLD factor for these fixtures, the suggested



relamping schedule is 2 years. Using data from industrial applications to approximate the DDF in a dairy environment, it is recommended at this point that the fixtures be cleaned every six months.

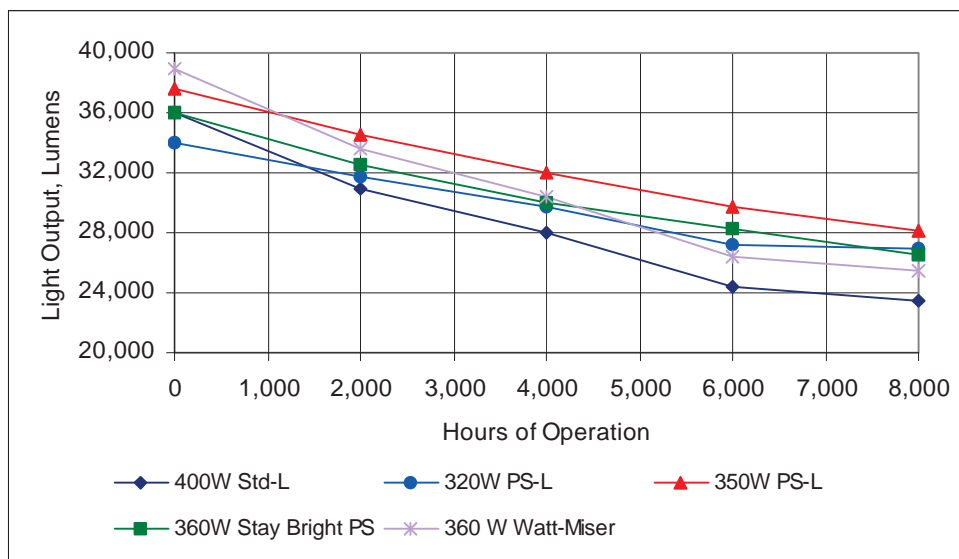


Figure 3. Lamp lumen depreciation for metal halide lights with various wattages and lamp strike methods.

A prudent photoperiod lighting system design will specify luminaire relamping and cleaning schedules. Systems designed with more frequent maintenance schedules will require fewer fixtures and therefore less initial capital cost to install them and less cost for operation. However, the increased maintenance frequency will result in increased annual maintenance costs.

Impact of Air Temperature

The temperature of the air adjacent to a luminaire can affect its lumen output, as shown in Figure 4. Field research has shown that the light output from fluorescent fixtures is reduced by approximately 50 percent as temperatures dropped to 10°F or below in freestall barns. This is a minor problem since most commercial freestall barns would be illuminated with HID light fixtures which do not negatively respond to temperatures like fluorescent fixtures do, coupled with the fact that tie stall barns that use fluorescent lighting are temperature moderated in extreme winter conditions. However, older freestall barns that have low (< 10 foot) sidewalls many require fluorescent fixtures to illuminate the outside rows of stalls.

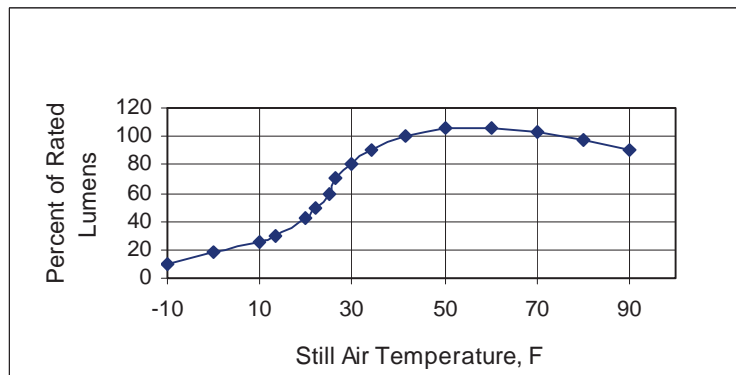


Figure 4. Effect of ambient air temperature on light output for a T-12 high output luminaire.

Electrical Demands

Luminaires

The electrical demand needs to be calculated for each different luminaire that is used. The total demand for each luminaire consists of the demand created by the lamp/bulb and the ballast. Many times the ballast demand is omitted because manufacturers market luminaires based on the wattage of the lamp/bulb only. The input power for the HID luminaire is approximately 115 percent of the lamp wattage. Using an average value of 115 percent, the total demand for the manufacturer's 250 Watt fixture is 285 Watts.

Control Clocks

The controls for the luminaries used for photoperiod manipulation all have ballasts which means there will be inrush current when the ballasts are energized. The current rating for ballast loads is considerably lower than for resistive loads. One timer/controller has a rating of 30 amps resistive and 6 amps ballast. Solid state relays, that will handle 10 times the inrush current, and magnetic contactors are suitable.

Light Level for Dark Period

The definition of "dark" during the 6 to 8 hr. lights off period is not well understood by researchers. In other words, there does not appear to be a quantitative value that establishes the threshold for dark. Dahl (2001) indicated that all photoperiod lights should be turned off during the continuous dark period. The use of security lights or other night lights is generally not recommended as light levels above 5 footcandles are believed to potentially adversely affect milk production response. Difficulty arises in providing completely dark periods in large barns on farms that milk three times daily and operate around the clock, and on farms where much emphasis is placed on stall cleanliness and observing cows for general well-being and signs of estrous. Dahl (2001) recommended the use of low wattage red lights located in barns as a means to provide lighting for human needs during the dark period. Field experience showed that two rows of low wattage red lights mounted directly above stall rows and spaced 24 feet

apart with a mounting height of 18 to 20 feet above the floor surface do not provide sufficient light in large freestall barns to meet human needs. Minimal lighting was obtained on one of the participating study farms by replacing the red lights with white incandescent bulbs and installing a dimmer on each lighting circuit. By adjusting the dimmer switch, the measured light level at the work plane was lowered to 0.2 footcandles and deemed acceptable by the farm owner when considering his other goals. At 0.2 footcandles cows can easily be seen and identified by ear tags and stall beds can be cleaned and maintained. It is undecided whether providing this low-level lighting adversely affects photoperiod milk response.

Lighting for Milking Center

Lighting design for a milking center is generally focused on providing target light levels at cows' udders. With the implementation of photoperiod manipulation on the farm, more consideration must be given to lighting design to ensure that cows receive 15 to 20 footcandles of light in the holding area and cow decks if they are in these areas during their scheduled "lights on" period and no light if during the dark period. The "lights on" period is easy to accommodate by designing a lighting system that will provide lighting throughout these areas. The "lights off" period is more difficult due to the continued need to provide lighting for milking purposes. Although not researched by the authors to date, a suitable system that meets the needs for no light at the cow's eye yet provides sufficient light at the udder should be able to be designed.

SUMMARY

The design of lighting systems for photoperiod manipulation needs to consider two specific groups of lighting design variables: barn specific variables and luminaire specific variables. Barn specific variables include size and spatial issues. Luminaire specific variables include those variables specific to luminaire design and in-service maintenance. Additional research is needed to determine the minimal level of allowable light during the dark period and the uniformity of light needed during the lit period to achieve a response. Minimal lighting is required in many barns due to the presence of near continuous activity that involves humans. This additional information will be helpful to lighting designers.

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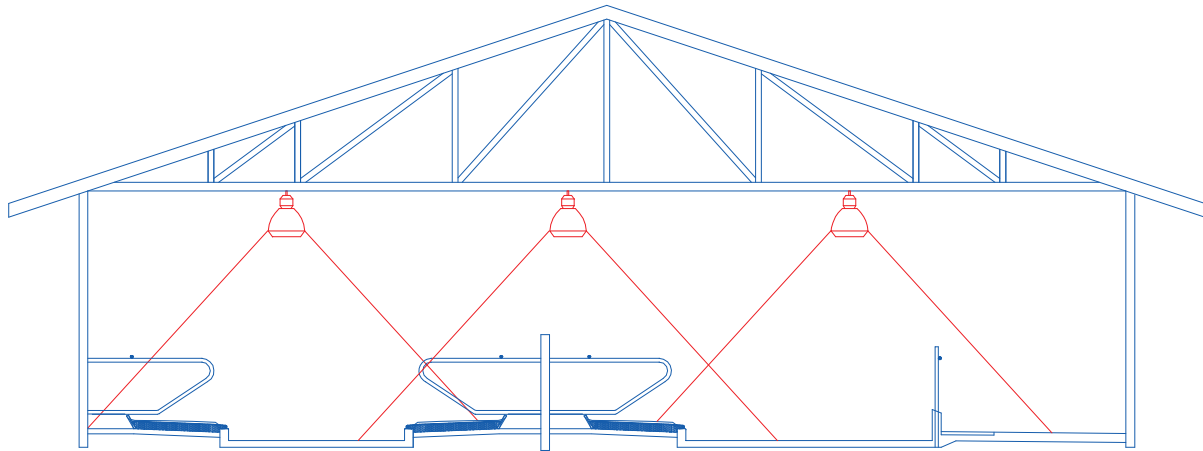
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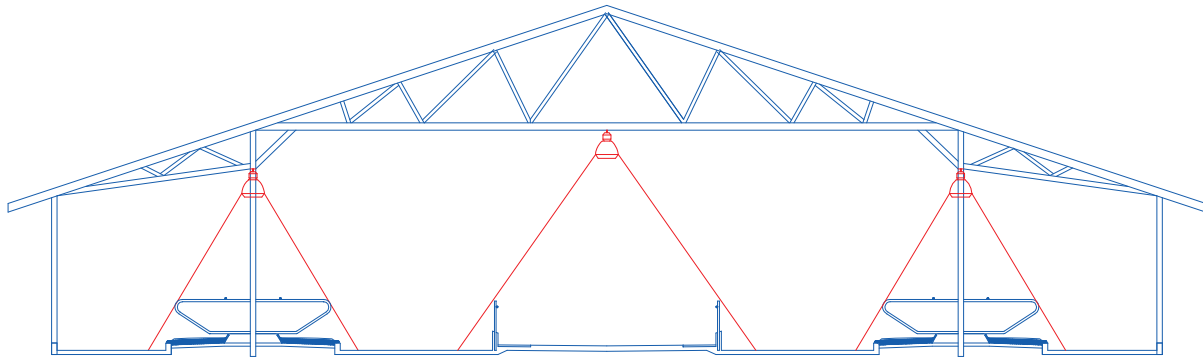
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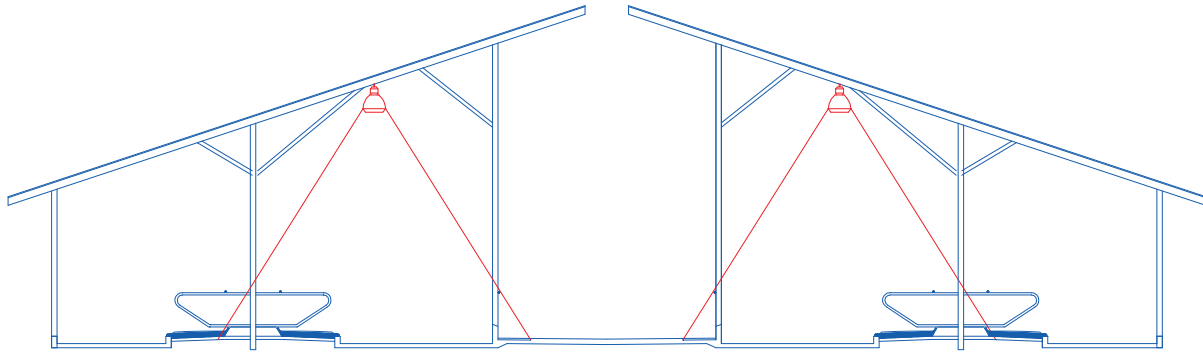
APPENDIX



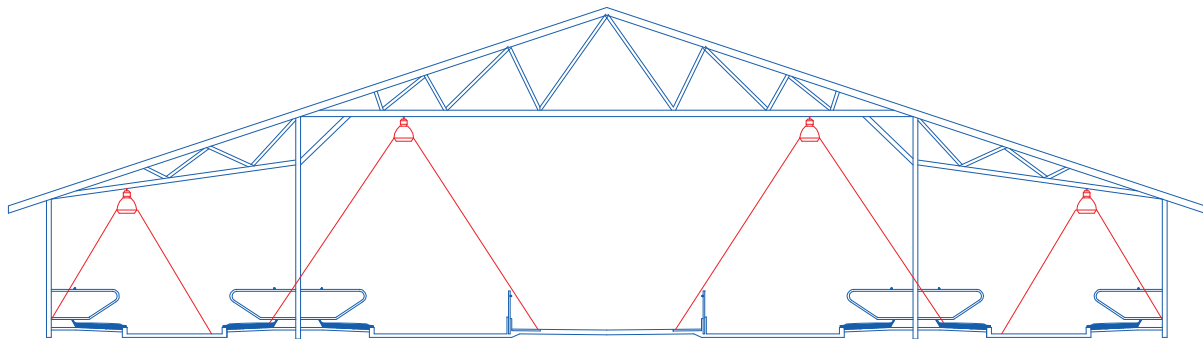
Uniform lighting system for a 3-row freestall barn with conventional truss design.



Targeted lighting system for a 4-row head to head freestall barn with conventional truss design.

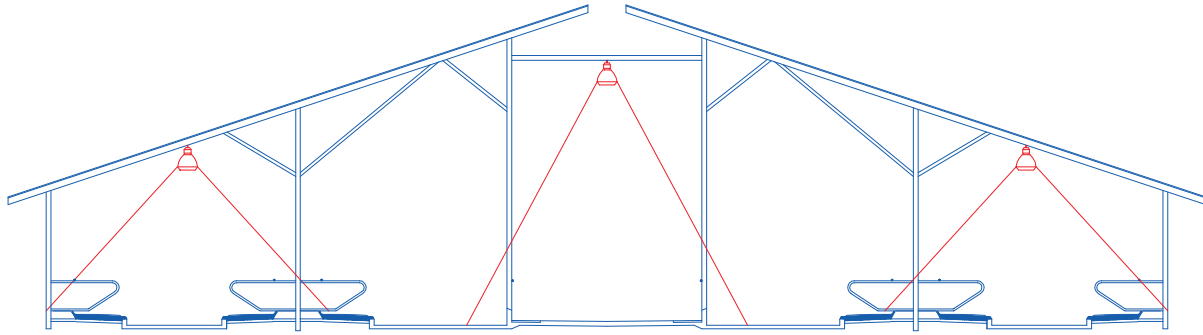


Targeted lighting system for a 4-row head to head freestall barn with rafter design.

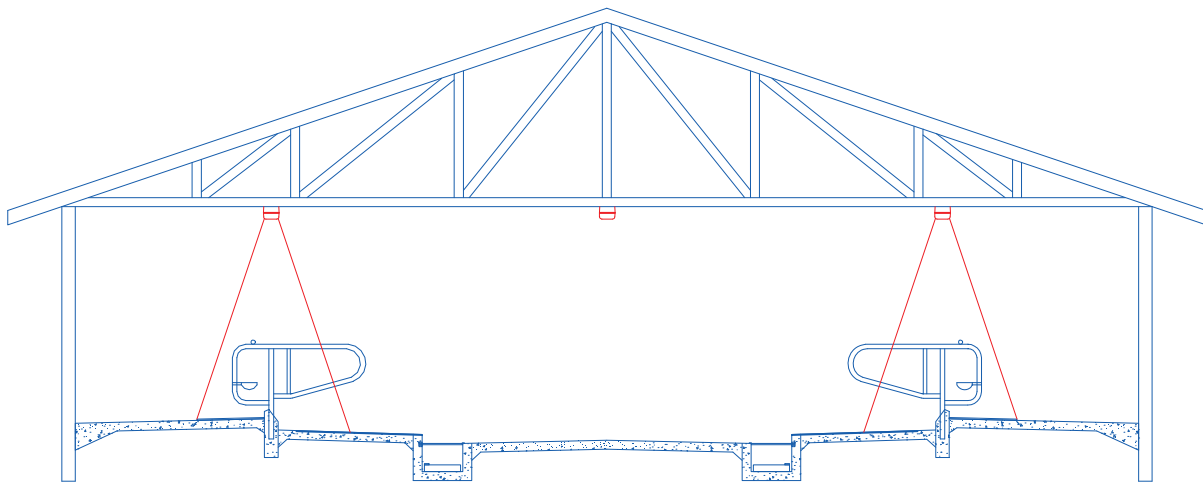


Targeted lighting system for a 6-row freestall barn with conventional truss design.

PRO-DAIRY



Targeted lighting system for a 6-row freestall barn with rafter design.



Targeted lighting system for a 2-row freestall barn with conventional truss construction.