Thermal / Shade Curtains for Greenhouses January 2010
By Scott Sanford, Sr. Outreach Specialist, University of Wisconsin

This narrative is a supplement for the presentation entitled Thermal / Shade Curtains for Greenhouses. It was developed as part of a North Central Region SARE Professional Development grant.

Slide # Description

1) This presentation will describe what a thermal curtain is, how it saves energy, describe the different types of installations, the screen materials used, and some nuts and bolts about how it is installed. This is the second of four presentations in the Greenhouse Energy Series.

2) Disclaimer - Products mentioned in this presentation do not reflect an endorsement of that product. Likewise, a lack of mention does not imply that a product is not recommended. Photo Credit: Scott Sanford unless noted otherwise

3) An Energy Curtain or Screen (both terms are used in industry but I favor using "Curtain") is an insulating blanket that adds an additional thermal boundary and may reduce the volume of the greenhouse to be heated. They are used at night and on cold cloudy days to reduce heat loss from the greenhouse. The curtain is supported by a track system or cables and must seal along the edges. The curtains can be manually opened and closed or be automatic systems with mechanical drives and controllers. They can save 30 to 50 percent in heating costs. Energy curtains can also be used for summer shading or light control. The difference between a system for shade and one for heat retention is the type of curtain material used if for shade only and the edges don't need to be sealed for shading.

4) In a greenhouse about 80% of the heating occurs at night so reducing heat losses at night can have a major impact on heating costs. Since at night we are not concerned with sunlight, we could add a non-translucent blanket to reduce loss. A greenhouse with a double poly glazing and a internal thermal curtain will have U-value of about 0.4 Btu/hr-F-ft2 versus 0.7 for a double poly glazing alone, a 40% reduction in heat loss. The curtains must be seal at the edges to prevent a chimney effect - heat going up around the curtain while cold air from above the curtain drops down. These curtains can double as summer shades or day length control depending on the curtain material used. Aluminized shade cloths can reduced greenhouse temperatures by 10°F when used as a shade cloth. The commercially available curtain systems can be automated with mechanical opening and closing of the curtain. System costs can range from $2.00 to $4.00 per square foot installed but it varies depending on the complexity of the installation. An example project, a curtain system quote for a 2 bay, 42' by 120' greenhouse (82' x 120') was about $25,000 installed. For a spring seasonal grower with a small greenhouse, the payback on this type of system may be long than desirable. A cost reducing option for small stand alone greenhouse would be a manually opened curtain system that uses a hand crank or pull / push by hand.

5) What is the potential Energy Savings from a Thermal Curtain? In example one, a half acre gutter connected greenhouse was chosen with double poly film glazing, power vented heater, growing bedding plants from Feb to June in Madison, WI. The propane gas cost is $1.50 per gallon. The heating cost is estimated at $20,590 per year. If a thermal curtain is installed that covers 100% of the roof with a heat retention value of 52%, the greenhouse will use $14,435 in gas and save $7155 per year or 35%.

6) The second example is a stand alone 30 foot by 96 foot with 3 foot side walls and a gable roof covered with double poly film. The growing season is February to June in Madison, WI and the propane cost is $1.50 per gallon. The heating cost will be approximately $3120 per year. A 45% shade screen that covers 100% of the roof will reduce the heating cost to about $2130 for an annual savings of $1000 per year or 32%.

7) For gutter connected greenhouses, there are two basic designs for curtains: Gutter to Gutter and Truss to Truss. For heat loss reduction, there is little advantage of one over the other. The curtain in the gutter to gutter design runs the entire length of the greenhouse as illustrated in the upper left and travels across the width. The truss to truss type has a curtain section between each truss so for example a 100 foot long greenhouse with 10 foot truss spacing could have 10 curtain sections on. When the curtain is opened or closed each section moves at the same time and the same amount, covering the area between trusses as illustrated in the lower right.

8) Could curtains be installed in this greenhouse? ____ Yes – But…. One of the issues with greenhouses is that growers like to hang things from the rafters.

9) The largest issue with installing curtains in an existing greenhouse is the re-location of the thing that have been attached to the trusses: hanging baskets, irrigation piping, heating pipes, air distribution tube (commonly called poly tubes), heaters… the list goes on. It may be necessary to build a secondary structure to support these items which adds to the cost of installing a curtain. If the greenhouse has gable vents or fans or roof vents or is an open roof type of greenhouse, a non-porous or semi-porous curtain will not be able to be drawn fully closed without restricting ventilation. The option in these cases may include changing the curtain materials used for summer and winter, using a porous curtain material or restricting the amount the curtain is closed so ventilation is maintained when used for shading.

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11) This is a photo of a slope-flat-slope truss-to-truss design curtain. The curtain follows the roof line and then goes horizontally across the roof, allowing the use of a poly tube air

distribution system and hanging baskets. The curtains are shown partially closed. This curtain is a sliding curtain that is supported on monofilament line.

12) This shows the same curtain fully open. There will be some minor shadowing from the frame and curtain at each truss.

13) Almost any material can be used for a thermal curtain by adding an additional thermal boundary. The typical materials used for thermal curtains can be divided into three categories: Non-porous, semi-porous and porous. An example of non-porous material would be a poly film. Non-porous materials will have high heat retention but are not typical used because they are impervious to water. Condensation that drips onto the upper side of the curtain can collect in puddles on top and be a nuisance when rolling up the curtain or in severe cases cause the curtain to fail / fall down due to the weigh of the water. Semi-porous materials are typically a woven material and provide high heat retention but allow moisture to migrate though. Porous materials allow condensate and rain leakage to freely pass through but also have lower heat retention because the air can rise through it. An example of a porous material would be the shade material Aluminet. Curtain materials with higher shading factor will also provide higher heat retention.

14) Here are some examples of curtain materials. These are woven materials with aluminum strips to reflect the heat back into the greenhouse or away depending whether it's being used for shading or heat retention. The percentages along the bottom indicated the % of light transmission of the materials. The total light block material on the left will retain more heat than the translucent material on the far right. These material are constructed similar to the blue tarps that can be purchase from your local hardware store but are not water proofed.

15) Here is a table that has semi-porous and porous materials. The center column list the average light transmission and the estimated energy savings in the right column. You can see that as the as the light transmission level decreases, the energy saving potential increases even with the porous materials listed on the lower section of the table. There is significant difference in energy savings between the semi-porous materials and porous material. If we compare the bold face lines, they all allow 50 to 58% light transmittance but the semi-porous material provides a 52% energy savings while the porous materials only provide a 20% energy savings. For those who might not be familiar with Aluminet, it has a mesh-like construction.

16) I want to use a curtain for shading and heat retention, which shade factor should I choose? During the heat of summer the light level can reach 10,000 foot-candles of light however most bedding and flowering plants don't utilize the additional light above 4000 to 5000 foot-candles. The greenhouse glazing and structure will provide some reduction of light: Glass will be about 90% while a double poly glazing will be about 80%. If we look at a 55% light transmission material as a option for a double poly covered greenhouse, then it would be 10,000 fc x 80% for the double poly glazing reduction, times 55% light transmission for the curtain, it calculates to 4400 foot-candles, in the middle of the range for the maximum light plants can use. If a semi-porous material is used the expect energy savings would be 52% for the area covered by the curtain.

17) There are some other parameters that are important when selecting a material aside from the shading and porosity. Flammability: many of these curtains are plastics and some are

flammable which may be an important factor especially if being installed in a publicly owned facility. Another factor is how the curtain will be stored. Curtains can be rolled up, bunched up or pleated so the curtain will fold up like an accordion. This will be specified depending on the curtain system. If you are growing short day crops during the summer it will be necessary to control day length with a black-out curtain to simulate short days.

18) Curtain can be supported by stainless steel cables or monofilament line. If the curtain slides on top of the cables, monofilament lines are recommended while cables are recommended for suspended curtains. The photo shows monofilament lines that are stretched across the greenhouse to support a sliding curtain. Additional purlins (horizontal supports) were added between the rafters to anchor the support lines. Monofilament line will stretch so it will need to be tightened on occasion.

19) Opening and closing a curtain system can be done using a motorize system, a hand crank or simply be pulling on the leading edge and sliding the curtain. The motorized curtains have the advantage of using automated controls to open and close the curtain, reducing labor and possibly being more timely. A hand crank can be used on small systems to reduce initial costs but requires a person to be available on a timely manner to open and close the curtain. For hobby greenhouses, the leading edge can be grasped and pulled to move the curtain.

20) Motorized systems have the advantage of being able to be controlled by air temperature, sunlight level or a time clock. The photos show the drive system in a multi-bay gutter-connected greenhouse with a slope-flat-slope type curtain system. There is one motor drive for this 8 bay greenhouse. The power is transferred to each bay by a continuous shaft that the drive cable is wrapped around. The shaft starts at the drive unit, drops to a jack shaft under the gutter and then extends up into the adjacent bay. There are 3 shaft sections in each bay that follow the profile of the slope-flat-slope curtain system. The drive cable is wrapped around the shaft and runs in a loop to each end of the greenhouse. The curtain sections are clamped to the cable. There are four cable loops per bay used to open and close the curtain in this greenhouse.

21) The second type of drive system that is used to open and close curtain systems uses a rack and pinion drive, item 3. The rack is connected to a push rod (item 4) that extends the length of the greenhouse. This type of drive is used on truss to truss curtain system. The leading edge of each curtain section is clamped to the push rod (item 5). When the curtain is opened or closed the motor (item 1) is powered which turns a drive shaft (item 2) that the pinion gear is attached to. The rack will travel a distance of one curtain section or approximately the distance between trusses. The drive shaft can be extended into multiple bays of a greenhouse using universal joints and jack shafts.

22) For small systems a hand crank attached to a drive shaft can be used open and closed the curtain. Depending on the torque requirements to open/close the curtain, it may be necessary to split the curtain system into several sections so it can be moved by hand. A cable system that is wrapped around a drive shaft will have a limit to the travel distance of the curtain because the cable will “walk” or translate along the drive shaft as the shaft is rotated (upper center photo). The cable translation will change the tension on the cable and angle the cable enters pulleys. The amount the cable translates along the drive shaft will be affected by the shaft diameter and opening distance. The cables can be wrapped around a drive shaft in multiple locations. The

drive shaft will be supported by bearings (upper left photo) and a thrust collar. The major disadvantage to a hand crank is someone has to be available to open and close the curtain. A drive motor could replace the hand crank at a future point in time.

23) Another method of a cable winch drive. The cable is wrapped around the shaft with enough wraps to equal the travel distance of the curtain. As the drive shaft is turned the cable is wrapped up on one side of the spool and un-wrapped from the other side. A larger pipe will reduce the number of wraps of the cable for a given distance.

24) The leading edge of the curtain will have a tube or pipe inside of a pocket so that the leading edge moves in unison and has some rigidity for sealing. The curtain drive system drive cable or push rod will be connect to the leading edge by a clamp of some type. If the curtain is a sliding curtain on top of cables, a gathering device will be needed so that the curtain material will not slide past the leading edge when opened. The gathering device can be a "V" shaped piece or a connector that is connected to a wire above and below the curtain.

25) A curtain will have one fixed side and three sides that have to be seal to prevent convection air movement from below to above the curtain. The side edges are typically sealed by forming a gutter out of a piece of fabric that is supported by a pair of cables. One side of the gutter will typically be tight against a greenhouse side wall creating a seal and the other side of the gutter will be about 6 to 8 inch away from the wall. The gutter fabric is folded over the cables and stapled using a stainless steel staple. The edge of the curtain hangs in the gutter and when the curtain is closed, the curtain will contract one of the fabric wrapped cables to form a seal. The upper left photo shows a the sealing gutter in the center of a free standing greenhouse with the curtain on the left closed and one on the right open. The upper right photo shows the curtain material hanging in the gutter and making contact with the edge of the gutter. The lower left photo shows the support lines for a sliding curtain and the fixed edge.

26) This shows a different sealing system. The curtain travels under a flap with a weighted edge. As the curtain closes the sealing edge lays on top of the curtain. The weighted edge assures a tight seal.

27) The heavy monofilament line is used for support lines for a sliding curtain while stainless steel cables are generally recommended for suspended curtains. For the sliding curtain, the support lines are 12 to 18 inches apart and can be wrapped around an anchor point and tied. The cable spacing for a suspended curtain can be wider (36 to 48 inches) with some closer spacing at the edges. The spacing typically determined at the time of ordering the curtain material. A fabric tape is often sewn to the curtain material to provide extra strength for the curtain hanger clips attachment points. Additional purlins and supports are sometimes needed to have a place to anchor the support lines and cable drive systems.

28) In a gutter to gutter greenhouse the curtain material can extend from one greenhouse to another by looping it under the gutter and into the next bay therefore eliminating the need for a sealing gutter at each gutter (Left Photo). The upper right photo shows a fully opened curtain with the edge bunch up in the gutter. The leading edge of the curtain material can sometimes fall out of the gutter (lower right photo), so maintenance time is needed to push the edges back into the gutters and adjust the curtain and gutter to eliminate the problem.

29) One has to be creative to make a seal at the gutter ends and transition it to the leading edge seal. The important thing is that when the curtain contacts the leading edge seal that there is also a seal in the transition into the sealing gutter. There is no right or wrong way to accomplish this.

30) It may not always be possible to have the curtain cover the entire roof area due to the location of vents, fans and heaters in the end walls. If the vents and fans are mounted above the bottom cord of the truss and it is not possible to move them lower in the end wall, then the curtain can not be extended to the end wall without affecting the ventilation system . In this case the curtain can be installed up to the last truss and then the truss is covered with a sheet of polyethylene film to seal the "attic" space above the curtain.

31) The leading edge can be seal in a number of ways. The above photo shows an aluminum extrusion that is used to space and support the support lines and has a rubber lip (under arrow) that seals to the leading edge of the adjacent curtain section when it comes in contact with the extrusion. The opposite side of the seal is the fix side of the adjacent curtain.

32) Above is the seal system for a grower installed curtain. A section of fabric was folded over a monofilament line running tight to the double polyethylene glazing and stapled. A pocket was formed on the other side of the fabric that would accept a small diameter plastic pipe. The fabric was long enough to extend below the curtain support lines. Vertical cuts were made in the fabric to allow the support lines to go through the fabric. The fabric was pulled around each support line and then the plastic pipe was slid into the pocket. When the leading edge of the curtain contacts the vertical fabric, the fabric is pushed forward until it has pulled the pipe up against the curtain support lines. The fabric is pulled snug against the leading edge and takes up variations in the leading edge of the curtain. The lower photo shows the curtain leading edge approaching the seal.

33) Curtain systems can be controlled by light levels, time, temperature or a combination. The curtain can be opened or closed in stages. Curtains can be controlled by a central controller, stand alone controller or manually controlled. The photo is an example of a stand alone controller for a curtain system that can open or close the curtain based on outdoor solar levels, onset of night or temperature. The controller can be manually overridden with toggle switches. Using light levels to control curtains is the most desirable because it doesn't need to be changed with the changing seasons.

34) There are several important management considerations to manage a curtain system successfully for heat retention. The edge seals need to be maintained otherwise cold air will leak down under the curtain and can chill plants. Opening the curtain in the morning also needs to be done in a manner so the plants are not chilled. The air above the curtain can get down to 35 to 40 °F or colder so the curtains need to be opened in a way to minimize negative affects on the plants. The first suggestion is to allow the air above the curtain to warm up before opening. This may not always be possible so opening the curtain in stages or slowly over a period of 30 minutes or more will allow the cooler air to mix and warm up. During periods of cold weather it may be possible to have ice form on the inside of the glazing along with condensation. If snow is expected, the curtains should be left open to aid in melting the snow off the roof.

35) Material costs for curtain systems will vary depending on size, type of curtain system, type of screen material and number of obstructions. Typical cost are in the $2 to $4 per square foot installed although any relocation of utilities (lights, fans, heating pipes…) would be an additional cost. Gutter connected greenhouses are easiest to install curtain systems in although they can be adapted to almost any type of greenhouse.

36) Energy curtains are in reach for small greenhouses as well as large ones. The next few slides show one way to install an energy curtain in a 30 x 96 freestanding greenhouse. The project used off-the-self components or, if something needed to be built, it had to be fabricated using tools normally found in a farm shop. You'll see from the right photo that there is a hanging rack down the middle of the greenhouse, fans hanging from the bottom cord of the greenhouse truss along with lights and electrical outlets. The greenhouse was heated with two unit heaters that were in opposite corners and louver inlets at the west end and fans at the east end.

37) The plan for this greenhouse was to install a curtain under the bottom cord of the rafter and have it anchored on the north side and translate across the width of the greenhouse. Therefore we needed to find another way to hold all the items that were previously attached to the bottom rafter cord indicated with the orange arrow. A sub frame was installed 12 inches below the truss bottom cord. It was anchored to the rafters on the sides and supported by a post near the center of the greenhouse as indicated by the yellow arrows. All of the items that used to hang from the bottom rafter cord are now attached to the new frame, leaving a 12 inch clear span across the greenhouse for a curtain ~ 23 feet.

38) This shows a suspended curtain that is closed half way.

39) For this greenhouse a commercial kit was quoted at a cost of $7500. This was a Truss to Truss system that would cover 100% of the roof area. A grower installed curtain was installed that covers about 60% of the roof area and then roll up sides are planned to cover the remaining roof area at a cost of approximately $5500 in materials. It uses a hand crank to open and close the curtain.

40) This is a list of the companies that specialize in producing curtain systems. They are two supplier that provide curtain materials with Svensson being the most used. Many greenhouse manufacturers also produce curtain systems for their greenhouse structures.

41) There are some other emerging technologies that have been introduced to reduce night heat loss that inject foam in between the double poly films on a greenhouse. The concept is not new, back in the 1970-80 the concept was to fill the cavity with foam pellets at night and remove them during the day. The largest issue was that they couldn't consistently remove the pellets. The energy claim is that injecting foam will save 50% in energy costs. The foam dissipates over time so foam has to be added frequently to maintain. The foam is washed away after sun up to let the sunlight in. If you go to the link provided company has an explanation.

42) This is an illustration of the system. Bubbles are continuously introduced to increase the insulation values between the double poly films at night and then rinse away during the day.

43) A photo from inside the greenhouse with foam bubbles being rinsed away.

44) Energy Grants - The best source of information for energy grants is the Database of State Incentives for Renewables and Efficiency (DSIRE) at www.dsireusa.org. The site has information for federal and state renewable and energy efficiency grants. One can click on the state of interest and it will list all of the grant programs by utility for business, residential and renewable energy.

45) An example of a state program is Wisconsin's energy efficiency program called Focus on Energy. It has grants for energy efficiency for electric and natural gas and grants for renewable energy such as heating with biomass instead of natural gas or using solar to produce heat or electricity. Grants can cover up to 25% of a project cost and are based on annual energy savings or production. The utility serving the greenhouse must be participating in the Focus on Energy program which includes about 85% of them. Some of the electric coops have their own programs rather than participating in the Focus on Energy Program.

46) There is a federal energy grant program called Rural Energy for America Program or REAP which was part of the 2002 farm bill and re-authorized in the 2008 Farm Bill. This grant money is open to all rural businesses (population centers of less than 50,000) through a competitive grant process, and will cover up to 25% of the project costs. Types of projects include renewable energy, energy efficiency, and feasibility studies. The minimum grant for an energy efficiency project is $1500 with a maximum of $250,000. For renewable energy projects the minimum grant is $2500 with a max of $500,000. A thermal curtain system or high efficiency heating system is an excellent project for this program and in fact two Wisconsin growers have been awarded grants for thermal curtain systems.

47) There is also a low interest loan program as part of REAP. Loans can be for up to 75 to 85% of eligible costs with a minimum loan of $5000 up to $25,000,000. Application are accepted continuously and awarded quarterly. A grant and loan combination is also available. Please go to the web sites listed for more information.

48) Question – Ending Slide