

Current Options in Cheese Aging Caves: An Evaluation, Comparison and Feasibility Study

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Thank you to the following farms and creameries for sharing
their experience and knowledge:

Hahn's End
Little Falls Farm
Northland Sheep Dairy

I. INTRODUCTION

This booklet is an exploration of the steps cheesemakers have taken to create optimal conditions for aging cheese. Across the country cheesemakers have experimented with different options, but while the individual cheesemakers know what works and what doesn't there's been no means for sharing that information. In the creation of this handbook, we've surveyed cheesemakers across the country to see what they were utilizing to age cheese and then drew some conclusions from the results.

We conducted a survey of cheesemakers across the country ¹ and from these surveys and visits to cheese facilities we can generalize that most people are using the following types of systems for aging cheese:

- Regular upright refrigerators
- Standard walk-in coolers with compressors and evaporative loops
- Partially underground insulated rooms
- Fully underground cheese caves

Most operations utilizing upright refrigerators are very small operations. They have either adjusted the settings on the units to their lowest levels or use a thermostat / thermoregulator to monitor the temperature inside the unit and cut the power on and off accordingly. Every time the door to such units is opened there is a significant loss of cold air, and this type of standard unit creates a drying environment not well suited for cheese. Additionally, many of these units are old outdated units no longer fit for retail stores. They are not as well insulated as newer units and as such are not energy efficient. An individual upright reach-in cooler cannot hold very much cheese, making a fleet of aging refrigerators more common for cheese aging if refrigerators are used on the farm. As such, we have opted not to examine this option for this project.

The cheese aging spaces examined in the booklet can be divided into three types : i) above-ground spaces, such as walk-in coolers, ii) below-ground spaces, such as cheese caves, and (iii) partially below-ground spaces. This booklet examines each type of space and compares them from a cheesemaker's standpoint. The chief factors we looked at were (i) initial cost, (ii) energy efficiency and environmental impact, and (iii) operation and maintenance costs.

In addition to the surveys, we sought input from soil scientists, cheese consultants, refrigeration experts, and energy consultants. Throughout this project we identified areas for improvement in aging scenarios, and as such have provided discussion on those areas as well. To round out the handbook we've included stories from individuals with

¹ Survey results on p. 25

particularly interesting set-ups to let them share in their own words what they did and how they could improve it for next time.

II. CHEESE AGING SPACE DESIGN

When designing an aging space for cheese there are many factors to consider. We've identified the choices individuals must make and discuss the merits of the available options.

Above Ground vs. Below Ground

In terms of getting an aging space up and running swiftly an above ground space is faster to set up and start operating. Excavation and drainage adds considerably to the cost of a comparably sized underground aging space and cement work is more costly than either a stick built or prefabricated walk-in cooler. Consequently there is less of an initial capital investment in above ground aging spaces. An additional benefit to an above ground space is more flexibility in terms of placement. An above ground facility can be placed anywhere...inside or outside, above, below or beside the make-room, allowing for easy access and a smooth flow of products.

Underground placement is more challenging. Good drainage (see below) is an absolute must, digging into the side of a hill the best option, and ideally on a north facing slope. Wetlands, ledge, and clay would all pose considerable challenges and if not completely ruling out a cave would increase the initial cost substantially. Long term the benefits of an underground aging space play out in saved energy consumption. In this day and age the cost of electricity can be viewed in terms of actual currency as well as environmental cost. The additional insulating factor of the soil surrounding an underground cheese cave and the temperature moderation of the deep soil being conducted up through the cement floor creates an opportunity for the cheesemaker to save substantially -- if not entirely -- on the electricity required to maintain appropriate cool temperatures.

A third option is setting up a space partially below ground. This can combine the best of both alternatives -- faster to create and start operating than a full underground cave, but receiving the benefit of increased temperature moderation through the cement floor.

Location, Location, Location

Location is critical not just for a space utilizing temperature regulation from the soil, but also for placement of a walk-in cooler, or custom built insulated room. On farms we often end up using the space we have available, even if it sometimes is not ideal or perhaps the best thought out plan. Think about where you are positioning your cheese aging room. One poor choice from my own experience would be placement of a walk-in cooler in a south facing room full of windows (often referred to as "the sunroom"). In

terms of energy usage we have used a lot of energy during the summer months to air condition the space outside the walk-in cooler in an effort to ease up on the strain on the conventional refrigeration cooling the walk-in. Not only is the location critical for energy usage, but also accessibility. You want to position your aging space for ease of moving product in and out.

Another less than ideal situation would be aging in the attic of a barn, particularly the southern facing side. Yet several cheesemakers do this, and one operation carries the wheels of cheese in tubs up a ladder to the aging space. There could be specific reasons for such a choice, such as available unused space or proximity to an existing ice builder with ability to cool the rooms, but below ground or north facing rooms are preferable. When looking at a potential location for an insulated room in the basement, avoid proximity to furnaces, boilers and other heat sources. Insulate around these items with insulation approved for this use. Again the north side of the building is preferable.

A note about drainage for below-ground caves

As mentioned in the previous section, proper drainage is essential for underground cheese caves. Adequate drainage starts with well drained soil. Whoever is siting the cheese cave *must* know their land and know what parts of their land become soggy at different times of year. A functioning cheese cave *cannot* be built in such a spot. If the farm or land where the cheese cave is going to be sited is unfamiliar or new, it is better to wait at least a full year to get a sense of where the drier spots in the soil are.

Once a reasonably well drained area is selected and the excavation is done, the next step is to pour the footer and then lay at least 2" of gravel followed by drainage tile around the interior and exterior of the footer. This drainage line is then run off to a lower well drained area away from the facility. Any floor drains in the cave should be tied in as desired at this point.² It is important to remember that drainage tile must be installed with the holes down so that water seeping up from below can get into the pipe and run off, rather than having to rise up above the pipe. If the pipe is laid with the holes facing upward you would need to take additional precautions to prevent soil and stones from clogging the holes once the back fill is done.

Construction material

Below ground cheese caves are generally constructed of rebar reinforced poured concrete, sealed on the outside with a spray sealant and foam insulation. For a domed roof the spray foam insulation, though more costly, is preferable because it creates a better seal and is more resistant to R-value drift from exposure to humidity. For the sides of a below ground cheese cave foam boards are sufficient, as the straight walls make it easy to snugly seal the seams with tape.

² For additional information see the section on floor drainage, p. 5

In my home state of Maine, our state dairy inspector approves of concrete as an appropriate interior aging space surface. Several farms reported satisfaction in utilizing a lime wash on the interior walls.³

Choices that would not be wise in the construction of a cheese aging space would be anything susceptible to high humidity such as sheetrock or pine. This is particularly important if you're custom building a stick built insulated room. With such humid conditions you either want concrete on the interior or FRP board. Wood on the interior is going to have a propensity to rot. The use of pressure treated lumber is discouraged in the aging space due to the release of chemicals.

Foam insulation and FRP paneling both act as a vapor barrier preventing moisture from penetrating the walls and causing mold in the wood framing. FRP can be purchased either mounted on plywood boards or unbacked. The mounted boards are approximately 33% more expensive. The contractor we consulted indicated he would put up plywood walls and then fix the unmounted FRP to those walls to save money over purchasing the pre-mounted FRP. We've seen it done both ways, and it basically comes down to a question of expense versus convenience.

In building any cheese aging space insulation is one of the most important elements to consider. A minimum of 4" of insulation for an above ground space is recommended. New technologies with spray insulation make for higher R values in less space and better sealing and vapor barriers.⁴

Ceiling – Vaulted vs. Flat

With the highly humid environment in the cheese aging space there will be a tendency for condensation to form on the walls and ceiling. Having a vaulted roof, while more expensive initially will allow the condensation to run down the ceiling to the sides rather than dripping onto your product. The vaulted ceiling also lends an old world aesthetic to the space.

Floor Drainage

Drainage in the cheese make room itself is a requirement and as such cheesemakers should be familiar with acceptable methods of floor drainage in their respective principalities. Some folks with partially or full underground aging spaces have simply tied in the floor drain of their aging space to the standard drainage lines run inside and outside the circumference of the footer. Anyone planning to do this would need to lay the pipe for the floor drain before pouring the foundation walls and the cement floor. Draining in such a way does present two risks. First you open yourself up to problems should any cleaning chemicals be mistakenly dumped down the drain. Secondly if there was ever a problem with the drainage around the footer water could backflow into your

³ For recipe, see p. 43

⁴ For detailed information and comparisons of insulation, see p. 43

aging space. The most responsible type of drainage would require running the floor drain off to a holding tank. This would basically be a smaller version of a septic system.

Standard walk-in coolers do not generally come equipped with a floor drain, and when building an insulated room in a basement the decision on whether or not to have a floor drain was made when the cement floor was poured in the basement. A good rule of thumb would be to always put in a floor drain if you are pouring a concrete floor. Those fortunate enough to have a floor drain situated in their basements are lucky and can build the aging space around the drain. A drain makes cleaning much easier. Several of the folks surveyed indicated that if they had to make their aging space again they would have put in a floor drain.

Shelving

The objective with shelving is to allow the cheese to be exposed to air. Coupled with periodic turning of the wheels the shelving promotes even and uniform rind development. Cheesemakers are currently aging on wood, stainless steel, plastic, and plastic coated wire racks. Again the biggest challenge for shelving is the high humidity. As such the plastic coated wire racks, though inexpensive initially, are not ideal, because they rust and require replacement.

Other individuals have put wooden boards on steel frames (not stainless). While this is less expensive than stainless at the onset the hassle of having to remove the frames to have them repainted periodically is a huge drawback.

Some individuals have recommended rough cut wood boards. These help to let air circulate beneath the cheese, and it is even possible to cut cross grain grooves to facilitate air movement under the wheels. Regulations which require smooth easily cleanable surfaces may preclude that in certain states (like my own state of Maine).

One design that does not require a metal frame to hold the shelves is one utilized by Mary and John Belding of Little Falls Farm. They patterned their system after the shelving at Vermont Shepherd and have customized it to suit their particular needs. According to John:

"Our racks are made of maple, simply because we have a lot of it on hand. The only part of the rack which is permanent is the plate we screwed to the ceiling, which the rack leans against. Otherwise the whole thing can be easily removed. Each piece fits through the door. The shelves are pine, with some blue stain, but I don't think that will harm the cheese. The boards are planed on one side and edged, so the top is rough that the cheese sits on. Ours are two feet long, but could be longer. The screws are stainless steel."



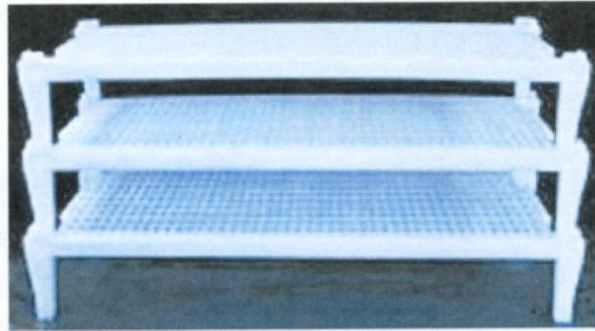
Photo 1. and 2. This is the first rack we built. Photos provided by Little Falls Farm ©



Photo 3. The second rack built at Little Falls Farm.
Photo provided by Little Falls Farm©

The third photo of the second rack we built, is a better design than the first rack. The horizontal pieces are recessed in to the upright brace, making it stronger, but might not be necessary."

Other types of shelving that are available include stackable plastic shelves (see photo below from Dairy Connection). Available at Glengarry Cheesemaking and Supply, Dairy Connection and Fromagex.



Plastic stackable shelving.
Photo provided by Dairy Connection. ©

My own creamery uses stainless steel stackable wire racks from Glengarry Cheese. We have also seen them available through Fromagex. The benefit to the stainless racks is that you can clean them with in a COP sink if you're equipped with one.

Utilities - Electricity and Water

You are going to need a light source in your aging space. As such electricity is necessary, though depending upon your set-up could be provided by solar or batteries. Lighting as shown in the above pictures of the aging space at Little Falls Farm is ideal, as it is easy to access and can be wired or tied into if desired. Light fixtures must be encased in a protective cage, as should a light blow you do not want broken glass making its way to product.

Water – not all aging spaces have an easily accessible source of water. This was an area that some individuals identified as one they would improve upon next time. At a bare minimum a hand washing sink and a hose for washdown is strongly recommended. Sinks for washing racks are also ideal. If you are not set up to wash the racks in the aging space itself, you will need to remove the racks from the aging space and take them elsewhere. Racks and shelves must be washed in between batches. Washing stations in the aging space must be positioned to prevent water spray from reaching the cheese. Some operations have enclosed the wash area with a shower curtain to prevent such contamination. For individuals without any source of water in the aging space religious use of gloves would be extremely important as hand washing in the aging space would not be possible.

State and Federal Regulations

According to our Maine State Dairy Inspector, Audrey Slattery, there is nothing in the state's regulations specifically dictating criteria for cheese aging space. She prescribes common sense: a floor drain would be good (though not required), as well as building the set-up to allow for periodic cleaning of walls, ceiling and floors. In terms of shelving, she did permit us to use wood boards to age our cheese, but again they must be kept clean. We scrub them down with salt and vinegar and let them air dry in between batches of cheese. She required us to put a polyurethane on the exposed wood that holding up the shelves in our aging space. As wide variety exists from state to state, it is recommended to check with your state inspector prior to construction of a new space.

We contacted Rebecca C. Toulouse, Food Specialist for the U.S. Food and Drug Administration to inquire about requirements for cheese aging facilities. We were referred to the FDA's Good Manufacturing Practices regulations, which are attached in the appendix.

III. Climate Control

In the quest to create optimum conditions for aging cheese, just what are we looking for? Basically the ideal climate is going to depend very much on the types/s of cheese being made. We wanted this booklet to provide information that would be helpful to a wide array of folks, so rather than creating an aging space for a particular type of cheese we've opted to provide options that would provide some degree of control to the cheesemaker. In making great cheese, having the ability to change the temperature of the aging space, or the relative humidity is a valuable tool indeed. Folks requiring information about specific aging requirements for different types of cheeses would do well to take the upcoming class in September 2009 with Mark Druart, **Affinage: Behind the Scenes**. The University of Guelph's website is also a good source for temperature and humidity requirements for various types of cheese.

A. Temperature control

The optimum temperature for aging cheese varies widely depending upon the type of cheese being aged (from 46 degrees to 57 degrees Fahrenheit). An above ground or partially underground insulated room is going to require some sort of temperature moderation. Several options are available :

- Radiant cooling from cool water piped through space - condensation can be a real problem with this, as in such a humid environment condensation is constantly forming on the cool pipes.
- Forced Air Handler with Sweet Water System – utilizes sweet water from an ice builder to cool air and cycle it into the aging space. A good system if you already have an ice builder, but the majority of small scale cheesemakers do not. This

system has the advantage of not have the drying effects seen in conventional refrigeration.

- Conventional refrigeration – most cheesemakers end up utilizing conventional refrigeration with a standard condenser / compressor and evaporative loop. This is the option that refrigeration installers are most familiar with, and as such it can be installed quickly and relatively inexpensively. In conventional refrigeration, there is a coil system of tubing which contains a "freon" fluid, a compressor, an expansion valve, and one or two fans. The tubing forms a closed loop which is coiled on two sides. One side faces inside and the other outside. The tubing goes from the coil on the inside through a compressor. The compressor compresses cool freon gas, causing it to become hot, high-pressure freon gas. This hot gas runs through a set of coils so it can dissipate its heat, and it condenses into a cool liquid in the process. This hot freon gas dissipates by passing through a maze of coils that typically have a fan blowing the heat from the coils to the outside of the building (or into the room outside the cooler). The remaining cooled freon liquid runs through the expansion valve where it expands and in the process evaporates to become cold, low-pressure freon gas. This cold gas runs through a set of evaporative coils that allow the gas to absorb heat and cool down the air inside the building. There is typically a fan/s here as well blowing the cooled air around the coils into the room.
- Conventional air conditioning – Works in the same manner as conventional refrigeration but without an insulated box. Not suitable at the temperature range required for aging cheese. An air conditioner does not have the appropriate fans and surface area to dissipate the cold and the air conditioner would eventually freeze up.
- CoolBot with Conventional Air Conditioning – This is the rising star of this list of temperature control options! It is a relatively new device that several cheesemakers are utilizing with success. The CoolBot works to trick a standard air conditioner into cooling to lower temperatures without freezing. Please see John Belding's write-up on his experiences with the CoolBot on page 24. Whereas conventional refrigeration utilizes several large fans that are blowing constantly (and end up contributing up to 60% of the electricity used by the unit) the CoolBot only has the single unit of the AC unit running, and only when it is actually cooling. At other times the fan is off. For more information see <http://www.storeitcold.com/how.php>
- Passive Temperature Moderation By Soil Only – Beneath the frost line, and at the depths necessitated for an underground cave, soil temperatures remain steady throughout the year. These temperatures do vary by region and we were unable to find a map listing monthly soil temperature at the depths prescribed. In the Northeast average soil temps are going to be between 48 and 54 degrees. As such, an underground cheese cave may be able to rely on the soil temperature

alone. The key would be to have proper depth -- a floor at least 12 feet below soil surface and a ceiling at least 5 feet below, along with proper placement (north facing slope is ideal) and insulation of the entry wall. Having some sort of back up like the CoolBot or conventional refrigeration is still advisable. The major benefit of passive temperature moderation is the energy savings. The major drawback is the lack of flexibility to adjust the temperature, which would preclude making certain types of cheese.

- **Evaporative Air Conditioning** - These units are also known as air, swamp or desert air conditioners. Utilizing the principle that evaporation requires energy, evaporative air conditioners use a fan that draws in air and moves it through a wet filter. As the hot air passes through the filter (usually made of paper or straw), the water evaporates which cools and humidifies the air. Depending on temperature and external humidity, evaporative air coolers can reduce indoor temperatures by as much as 30° F (17° C). An evaporative cooler is highly effective in dry air climates. Used in a humid environment it would be totally ineffective. As such evaporative air conditioning is not a viable option for cooling a cheese aging space.

B. Ventilation and Air Circulation

Ventilation is the act of supplying fresh air and getting rid of foul air. In creating an optimum aging space you will need to have some sort of ventilation. In doing the research for this project we came across aging spaces with little to no ventilation, as well as some with poorly thought out ventilation. In one instance the space had an inlet and an outlet but they were placed at the same height right next to each other. There was no fan to facilitate air movement and thus not a lot of air movement taking place. Many facilities (including my own) have relied on opening and closing the door to provide the necessary ventilation, and depending upon how much cheese you've got in the space and how often you're working with it this may not be enough. A significant number of operations providing information for this project listed ventilation as an area they would improve if they had it to do over again.

Ventilation requirements vary by type of cheese. Marc Druart, a Cheese Technician at Vermont Institute of Artisanal Cheese, explained there are two different rates here:

The air renewal rate: This is the amount of new (fresh) air that must be brought from the outside in order to balance the composition of the ageing room. If you are looking at a semi-hard/hard cheese, the air renewal rate will be between 0.5 to 1 volumes per hour.

The air movement rate: This is the amount of air volume that will be stirred by the evaporator. It will allow homogeneous air composition. For a semi hard/ hard cheese the air movement range is btw 20-30 volume per hour. As a comparison, in a regular warehouse the air movement rate is normally up to 4 volumes per hour. Some

cheesemakers create air movement with fans within the aging room. These fans are not moving air in or out of the space but just slowly mixing the air within.

A third rate that should be considered is the **speed of the air moving over the cheese**. According to Patrick Anglade, Cheese Technician from Centre Fromager de Carmejane the speed of the air moving over the cheese should be low (depending upon the type of cheese) – around 0.2-0.5 m/s because moving air dries the rind too much. In the experience of Margaret Morris from Glengarry Cheesemaking and Supply the lower the speed the better for washed rind and bloomy rind cheeses. To slow the air moving over the cheese nylon boots or ventilation socks on a conventional refrigeration system are recommended. This evenly disperses the air throughout the aging space and reduces its speed. Nylon is preferred as the boots are machine washable, and while they slow the air down they also help to filter out any dust and debris in the air. Neville McNaughton of CheezSorce strongly recommends the use of ventilation socks if using conventional refrigeration. We did not find anyone utilizing an air conditioner and CoolBot with air distribution socks, but they may very well be compatible.

Diagram : Two variations of air distribution socks.

Methods of ventilation include:

- **Passive** – On the simplest end of the spectrum you can have passive ventilation. Remembering that hot air rises and cool air falls, this method consists of two vent pipes (4-6" in diameter) placed flush against the wall. One is high and one is low. The lower pipe is the inlet allowing fresh cool air to enter the room and the higher pipe is the outlet allowing the warmer air to exit. It is imperative that you have a cap on both of the inlet and the outlet to allow you to open and close them as needed. This system is particularly well suited to spring and fall when the night temperatures fall lower than the temperature in the aging space. Some cheesemakers in the Northeast have successfully lowered their winter electric bills by allowing for fresh cold winter air to enter the space, basically eliminating the need for their compressors to run during the cold winter months. In addition to closing off these pipes, we recommend covering with a wire mesh to prevent rodents from entering.
- **Passive with louvers running on thermostat** – This utilizes the passive vent system described above but incorporates two thermostats to control the flap opening of the inlet pipe. The positive pressure from the cool air entering the inlet pipe causes the

flap opening on the outlet pipe to swing open, allowing the warmer air to exit. The initial cost and electricity usage for this system are minimal.

- Fan in passive vent system – Several cheesemakers have found that the passive system alone is not enough to create the airflow necessary for proper ventilation. They have solved this problem by inserting a small computer fan or muffin fan. The power requirement for this is quite low and could be provided by solar power if desired. This set-up could be combined with two thermostats so that the fan would operate when the outside temperature was lower than the temperature inside the aging space.
- Air to Air Exchanger – A device that helps to cool the air entering the aging space. One end draws fresh air from outside which is passed through a chamber surrounded by indoor air. The exchanger extracts the heat from the air and then ducts the fresh air inside while expelling the warm air outside. Depending upon the model they can help increase the humidity of the air entering the space as well. A bit costly in terms of initial set-up but depending upon the amount of air being moved into the space does reduce the amount of electricity required to cool the incoming warmer air during the months when the outside air is warmer than the inside air.

C. Humidity Control

Absolute humidity refers to the amount of water vapor present in a unit volume of air, usually expressed in kilograms per cubic meter. In this project we are dealing primarily with relative humidity (RH). Relative humidity is a function of both temperature and moisture content. It is expressed as the amount of atmospheric moisture present relative to the amount that would be present if the air were saturated. Colder air does not hold as much water as hot air.

Depending upon the type of cheese being made the desired humidity level varies (typically between 80-95%RH). Generally the greatest challenge is getting the humidity high enough though several cheesemakers surveyed indicated using methods to dry the air at certain times of the year.

Methods to modify the humidity include:

- Pouring water on the floor – no electricity required. Works well for those with a cement floor.
- Misters on hose running through the periphery of the room – people seem satisfied with this system. Need to be certain mist is not actually hitting the aging cheese and is just going into the air. Misters would require a booster pump to provide enough pressure for an appropriate number of nozzles. Capital outlay for

this is low. Depending upon the spacing between the nozzles \$140-240 for a 20'x20' room.⁵

- Fogger – More costly initially, but specifically designed for use in the cheese aging room.⁶
- Humidifier – not ideal for a cheese aging space. Humidifiers create heat, so running one inside an aging space requires compensation from your cooling mechanisms to offset the increase in temperature.
- Dehumidifier – as with the humidifier this would produce heat in the room. Not advised.
- Sawdust – one individual described throwing shavings from a local woodworker on the floor and allow the shavings to absorb moisture before sweeping them up. This is an ingenious low tech way to reduce humidity, but you may run the risk of introducing new molds to your space.

III. Comparison of each type of aging space

With the above information in mind we have put forth profiles of FOUR aging scenarios.

For all of the scenarios we set the following parameters:

Dimensions: 20'W x 20'L x 8'H

Acceptable temp range: 8-14 degrees Celsius (46.4-57.2 degrees Fahrenheit)

As different cheeses require different temps we would want to be able to set the control to maintain a 5 degree F window (i.e. 46-51 or 52-57).

Acceptable humidity range: 80% - 95%

As different cheeses require different humidity would want to be able to set the control to maintain a RH range of 80-85% or 85-90% or 90-95%.

Required ventilation: Moving air 1-3 vol/hr. Again different cheeses require more or less ventilation, so we would want to be able to control this, and turn off or set on timer if desired. Most cheesemakers get by with far less ventilation than this (many just rely on open and closing the door when they enter and leave the space) but this is a significant problem area.

Speed: – 0.2-0.5 m/s because moving air dries crust too much

Pounds of cheese: 23,000 lbs maximum limit.

Entering at what temp: Maximum would be 500 lbs entering at 75 degrees at one time

⁵ One source is EZmister.com

⁶ Available through Fromagex.

Scenario 1: The Standard Walk-In Cooler

Foam lined metal panels: 4-inch thick urethane insulation core, encased in sheet metal panels. Same material on floor and ceiling. This unit to be housed inside a barn or other building, so any heat producing elements of the conventional refrigeration system are placed outside on a cement slab.

Cheesemaker's Perspective : From a cheesemaking standpoint there are both pros and cons to this type of system. The benefits of the system are that temperature can easily be controlled. If the operator found that bloomy rind cheeses were ripening too quickly the temperature could easily be lowered. If of suitable size and not overfull the space is relatively easy to clean. Refrigeration technicians are familiar with this type of system and consequently you can procure a walk-in and get it up and running in short order. The negative aspects of this system are that it can be difficult to keep the cheese from drying out, though measures certainly can be taken to increase the relative humidity. In terms of natural flora you are not starting with much in the space itself, but certainly could inoculate the space with desired molds and yeasts. Another problem associated with this system is that the rate of air movement is much too high. Most units like this do not come equipped with floor drains. And then there's an aesthetic consideration. From a purely nostalgic point of view, a walk-in cooler doesn't carry the same romance of a domed underground cave. This has a practical effect as well -- most cheesemakers agree that cave aged cheese has a marketing edge. Overall, on a scale of 0-5 this gets a rating of three stars. ***

Environmental Impact and Energy Efficiency – Higher usage of electricity than all other scenarios, due to lower insulation and not utilizing the cooling power of the soil.

1 star *

Initial Capital Cost – A walk-in unit of this size (with conventional cooling system) could be found for \$15k plus freight. Used could be had for half that. 4 stars ****

Yearly Cost for Operation & Maintenance – This system utilizes more electricity than the other systems analyzed. If it breaks down it is a crisis as the temperature in the space is going to rise faster than the temperature in the other systems which employ the cooler soil temps to help maintain the steady cool temperature. Maintenance itself is comparable to that of the other systems. 2 stars **

Comments - This system could be improved upon by building an 8' x 8' entryway which would create a sort of air lock. When the door to the aging space was open the door between the entryway and the rest of the building (or the outside world) would be closed, and vice versa. With the fans going constantly this would prevent such a large loss of cold air every time you open the door. Ideal cooling would be with a CoolBot and standard air conditioner. The key would be having an exterior wall so that the air conditioner could be installed to vent outside.

Scenario 2: Insulated room in basement (ceiling is one foot underground)

In corner of basement so two walls and floor are cement with tar-like sealant and 2" foam board coated with light block sealant on outside, and 2" foam board and FRP dairy board on the inside.

Cheesemaker's Perspective – Most of the folks who had this sort of set-up also had a standard compressor/evaporator to use during the warmest months, and those that didn't wished they did. Without being entirely dependent on cool soil temps temperature control would not be a problem, and with the compressor not running for much of the year the high humidity would be easier to achieve and maintain. In terms of cleaning, it is preferable to have a floor drain. If this is going into an existing basement, the lack of a floor drain would make cleaning more of a challenge. Natural microflora would be more prevalent in this partially underground room and aging in a partially underground room sounds a bit more rustic from a marketing standpoint.

Rating : 3 of 5 stars ***

B. Environmental Impact and Energy Efficiency – As this is located below ground the compressor/evaporator unit will only need to be run two or three months out of the year. As such this receives a rating of three stars ***

C. Initial Capital Cost – the initial capital cost of this set-up is less than the cost of an out of the box walk-in cooler. It is conceivably a one-person or family job. Four stars ****

D. Yearly cost for operation & maintenance – As only projected to be used 2 or 3 months out of the year operational cost is significantly lower than the walk-in cooler model. As less use and less wear and tear, maintenance would be less too. Three stars ***

Comments: This would be a great candidate for the CoolBot, if the air conditioner was appropriately sized. Be sure to take a look at the difference between the drawing for this scenario and the drawing for the Hahn's End scenario. More insulation, particularly on the interior walls, as well as incorporation of dead air space would be an improvement to this scenario.

Scenario 3 - Fully underground cave built with poured concrete, 8' x 8' entry room before cave. Dome ceiling in 20' x 20' section.

Ceiling is 5' feet below soil surface. Floor is 16.33' feet below soil surface. Cement walls and floor and cement vaulted ceiling with tar-like vapor barrier and earth berm, and 2" foam insulation on top. If buried in the ground as opposed to on a hill has an entry room extending up above ground allowing entry at ground level. In that case has 4' x 4' dumbwaiter to send a rack or coolers of cheese down to aging room and back up again. Hillside location preferable. If had to have access and entry room above ground would want to double insulation on wall between entry room and aging room (so 2" foam board on each side of cement wall) and vapor barrier on interior of entry room wall to prevent warm moist air from outside from coming in and condensing on cement wall. Would need a light block sealant to exposed foam board insulation of entry room.

A. Cheesemaker's Choice – If this unit is paired with temp and humidity controls then this scenario passes muster for ease of control. Walls, ceiling and floor are all cement with a simple lime wash and as such are easy to clean. A floor drain helps a lot. With the high humidity and steady cool temps and the exposed concrete you will get a faster proliferation of natural microflora than in the other scenarios, and there is a marketing advantage to true “cave aged” cheese. The romance factor with this set-up is quite high. Five stars *****.

B. Environmental Impact and Energy Efficiency – This facility in itself may provide cool enough temps without the use of any temperature modification mechanisms at all. It all depends on how much variation in temperature you can handle. The temperature will definitely get lower in the winter, slowing down the rate of your aging cheese. If winter is a slower time for you sales wise that may work for you. Throughout the year the soil temps at 16'+ will certainly help moderate the temperature of the aging space. As such the amount of energy required to maintain an appropriate steady temperature is minimal compared to the other systems. Four stars ****

C. Initial Capital Cost – With the excavation, drainage, and cement work required for this scenario the initial capital cost is significant when compared to the other systems. For a comparably sized space you are looking at more than three times the price. Two stars **

D. Yearly cost for operation & maintenance - With the soil acting as both insulation and thermal regulator, as well as increasing the humidity, you are looking at a lower operational cost. As the temp and humidity regulators are used less, maintenance calls should be fewer, and when they do occur it should be less of an emergency as soil temps will help moderate the temperature and prevent it from climbing as swiftly as in an above ground facility. Five stars *****

Comments – We love the idea of just using soil temperature to regulate the aging room temperature, but would have a hard time sleeping if we did not have something available to decrease the temp if needed. In the survey we conducted the folks with aging caves that relied on soil temp alone to moderate the temperature had a much wider range in temperature than what we would like to see in an aging space. The soil temp alone might be enough, but we'd feel better having more flexibility. Thus an improvement to this plan would be building the cave to accommodate two good sized air conditioners hooked into an external tunnel to the outside (could be two appropriately sized rectangular tunnels on either side of the 8' x 8' entryway). This would allow us to utilize the CoolBot and would allow us to spend less on the refrigeration system. It may never be used at all. As discussed in the potato storage scenario (scenario 4) there are folks with underground structures who have had no problems maintaining a cool temp without additional cooling mechanisms.

Scenario 4 – Potato Storage Model

In doing the research for this project we looked at other types of climate controlled storage facilities to see if there were other products stored with similar climatic requirements. Apple storage was too cool, but potato storage was quite similar to the conditions required for aging cheese. The required conditions for storage of potatoes vary by the type and future use of the potato. Processing potatoes (think French fries) are optimally stored at 95% Relative Humidity, a temperature of 48-55 degrees Fahrenheit, and a continuous rate of ventilation 0.6-0.7 cubic feet per minute/cwt of potatoes. The temp and humidity are right on for aging cheese, and the ventilation exceeds what would be required for cheese, but could certainly be reduced, particularly with the variable speed fan.

In looking at different types of potato storage facilities we saw many built in the Quonset style (like a hoop house). This would work well to help condensation run down the walls and not on the cheese.

Construction: Quonset style – (looks like a hoop house) arched metal sheets, factory formed corrugated sheets assembled on site or arches formed on site with special equipment – sprayed on polyurethane insulation on the arched metal sheets, foundation, and end walls. Urethane insulation is left raw on inside. 55 feet is a standard width, but nearly any width is possible. 100 feet long, and 16 feet high would be typical.

According to Stephen Belyea, Project Engineer from the Potato Market Improvement Fund, Maine Department of Agriculture new above ground storage facilities have a typical R-value of R35-40 on the walls, and R40-60 in the ceilings. Cost per square foot for a turnkey operation is \$50-55/sq ft. (this would include the temperature, humidity and ventilation mechanisms for potatoes). A typical but small sized facility would be 5,000 sq ft. so about \$250,000. If you were to put one of these new structures underground it would cost more initially, but would be extremely efficient.

The draw back to this type of structure for aging cheese is two fold. First it is quite large and as such will exceed the needs of the typical small scale cheesemaker. Secondly it is quite tall (ceilings of 16 feet are common). To make the most of the space, one would need to create a framework within the facility with a catwalk and for cheesemakers to access wheels on the second level. A dumbwaiter would be necessary to add to and remove product from this second layer.

Climate controls: 10 - 12 horse power refrigerator for that small sized project (5,000 sq ft). Biggest problem is the evaporator coil/defrost cycle due to freezing up because of the high humidity. If built above ground electricity cost is \$200 - \$500 / mo. depending on fan operation and heater use. Sometimes owners have to add a little heat to force the ventilation systems to intake fresh air and exhaust excess CO₂. Heat is usually supplied by a 4,000 watt resistance heater, but is used frugally. If the storages are at least $\frac{3}{4}$ full of potatoes, the potatoes produce enough heat of respiration to maintain 48 – 55F setpoint temperature even during -20F outside temps.

Cheesemaker's Perspective - If combined with a climate control system this would be very easy to maintain the temp and humidity. Ventilation could be achieved through inlet and outlet vents with a fan. Cleaning would be a bit difficult given the height of the walls and ceiling. Enhanced marketability from being aged underground. Four stars ****

Environmental Impact and Energy efficiency – Would not have to run cooling equipment throughout most of the year. Very well insulated with soil. Four stars ****

Initial Capital Cost – The most costly of the scenarios we examined, but more economical than the other models if calculated by the square foot. Even so, it is no small investment, and as such only gets 3 stars ***

Yearly Cost for Operation & Maintenance – Repairs and maintenance next to \$0 for the first 5 – 10 years. For an average over the design structure life, use 1 – 1.5% of new cost per year (so \$2,500/year). Higher than the repairs and maintenance of the other systems profiled. Two stars **

Comments: We liked this system because there are people who specialize in building potato storage facilities and as such they would not be recreating the wheel. Putting the unit underground would make us more interested in this possibility, though would add to the initial cost. The larger size might make sense for a cooperative of cheese operations to age in a single facility. Or a larger cheese operation to offer their affinage and marketing services (similar to the case of Jasper Hill and their 22,000 square foot aging caves built in 2008 in collaboration with Cabot).

Case Study – Bellanger & Sons Underground Potato Storage Facility

We could not at first find any potato storage facilities located underground. Steve Belyea explained that there's a lot of ledge in potato country in Maine and as such it's difficult to find a suitable spot to put a structure of this size underground. With Steve's help we connected with Rick Belanger, of R. Belanger and Sons Farm in Lewiston, Maine. Rick has the only currently used underground potato storage facility known in Maine. We visited Rick's facility and indeed it felt right for cheese.

Rick's facility was built back in 1984. It is 40' x 100' x 16'. There's 3 feet of soil on top. The sides and floor are concrete. It was constructed just like a regular house foundation, but with a 3' bond out on top. Then a crane came and put in the ceiling (prestressed concrete). Ceiling is somewhat crested for drainage. Outside on the top the roof is 4-5" spray on urethane insulation on top of the sealed cement. There is spray insulation on the top of the walls (about 4' down). Rick has a humidifying system that he runs from time to time as needed, as well as a ventilation system designed specifically for potatoes. The ventilation system utilizes a plenum under the floor. He has no means to regulate the temperature. He has had no problems with the temperature. The temperature in the summer is 55 degrees Fahrenheit and it is about 40 degrees Fahrenheit in winter.

IV. CASE STUDIES --

Cheese Aging Stories In the Words of the Cheesemakers Themselves

Underground Insulated Room in Basement – Hahn's End

Hahn's End
Deb and Drew Hahn
Phippsburg, Maine

We are a small cheesemaking operation located in midcoast Maine. We buy in our milk from two local dairies. Bisson's Farm in Topsham supplies us with raw milk from a herd of (mainly) jersey-holstein for our aged cheeses. Smiling Hill Farm in Westbrook supplies us with pasteurized milk from a herd of holsteins. We make aged raw milk cheeses throughout the year. Our pasteurized cheeses that are aged less than 60 days are made from April to November. We currently purchase about 13000 gallons of milk per year. We were licensed to sell cheese in 2000.

The story of our aging space

After a visit to several farms in Vermont early on in my cheesemaking career. I told my husband we were going to need a cave to age our cheese in. (Up to this point I had been making small batches of aged cheese which I tried to wax and age in a refrigerator with no success.) We felt that construction of an underground cave would be cost prohibitive in this early stage of our business and thought we could create cave- like aging conditions in our (poured cement) cellar which was humid and cool throughout the year.

Our first aging space was 8feet x 12feet. The three walls were 2x4 construction with 1/2 inch strand board on the exterior, a layer of Owens corning R13 fiberglass insulation, and the interior wall was coated fiber board.

The ceiling was constructed the same way. The poured cement cellar of the house made up one wall and the floor. The door was painted wood. The shelves were coated wire shelving. Capacity was about 250 (10lb) wheels of cheese. About half of those wheels were stored vertically on two movable v-shaped shelving units. The following year we bought a traditional cooling unit as the temperature in July and August was hard to maintain less than 55 degrees F with the opening and closing of the door.

Drawbacks: Eventually the door warped from the humidity and the coated fiber board became water logged.

Our second aging space is 12foot x 16foot with an adjoining 10 foot x 18 foot prep room used for pre drying, cutting and wrapping. It also contains refrigerators for storing wrapped cheese for market. An enclosed hallway leads from the prep room to an exterior

door. My market equipment is stored in the hallway and from there I load my truck with tents, tables and coolers for market.

The three walls of the aging space are 2x6 construction. Starting from the interior wall: dairy board, 3/4inch plywood, Dow SuperTuff 1/2 inch foam insulation (R3.3), 2x6wall with fiberglass insulation (R19), exterior poly, and the interior wall is dairy board. The 7 foot ceiling is a dairy board drop ceiling, 8 inch dead airspace, reflective bubble wrap, 1.5 inch dead airspace, 12 mil poly, fiberglass insulation (R25). The door is a high quality steel exterior door. The shelves are coated wire. The capacity is about 500 (10lb) wheels of cheese. The cooling unit is the same one we had in the first room. I also added another fan to improve circulation when the room is filled to capacity.

The second space stays at 50-55 degrees F year round. I use the cooler only during the summer months and only when the temp goes above 55. I measured the humidity for several months with a psychrometer and it stays at about 93%. If the room appears to be too dry I just soak the floor with water.

Drawbacks: Nothing major.

Things to do differently: Dead air space in the walls. We had no plans to go by so all in all it has worked out quite well. It was nice that we had built a small room in the beginning, learned what we really needed, then expanded when we had more capital to invest.

Comments: Dead air space a great idea. It is of interest that the wall in the aging space that consists of the foundation wall is not insulated, but is left as just the concrete wall. Our plans for the insulated room in the basement call for insulating the inside of that wall, as well as digging down outside against the foundation wall to apply additional insulation there too. 2 x 6 construction instead of the 2 x 4 construction we called for allows for more insulation. If they ever needed to replace their standard refrigeration system this would be a good candidate for the CoolBot.

Northland Sheep Dairy – Partially Underground Insulated Room

Northland Sheep Dairy
Donn Hewes and Maryrose Livingston
3501 Hoxie Gorge - Freetown Rd.
Marathon, NY 13803

My husband, Donn Hewes, and I came to Northland Sheep Dairy in 2002 to work in partnership with the farm's founders, Jane and Karl North, and to eventually buy the farm from them so they could retire. We began building our passive solar, strawbale house on the farm in 2004, and our design included a full basement for aging cheese. We

finished the house in November 2006, and began using our new cheese cave in Spring 2007, just as we completed the purchase of the farm.

We now milk 45 100% grass-fed ewes, and produce about 1800 – 2000 pounds of raw milk cheese per year. We make a couple of Pyrenean-style hard cheeses, and a Roquefort style blue cheese. We milk seasonally, and make cheese May through October. Prior to using the cave, all of our cheeses had been waxed, and I very much wanted to eliminate waxing in order to create a hard cheese with a natural rind. I prefer the flavor profile and aesthetics of the natural rind cheese. We age our hard cheeses for 4 months to two years, and market them based on flavor and rind development.

Our cave was designed to be naturally cooled with natural ventilation. The main aging room has a 6-inch ventilation pipe at the bottom of the north wall and a similar ventilation pipe at the top of the east wall. We have since added a very small fan to the bottom vent pipe to facilitate air exchange. The cave is constructed of concrete slab floor, concrete block walls and the ceiling is stucco coated Styrofoam attached to a concrete slab. This provides a complete thermal barrier between the cave and our house upstairs. The walls and ceiling are lime washed. Our original design had the cave completely below grade, but we encountered bedrock at 6 feet, so two feet of the cave is above grade, which probably contributes to higher temperatures in the summer than we'd like. By mid- to late-summer summer, the cave reaches 64° F, and we'd like to maintain temperatures below 55. Our wintertime temperature stays pretty steady at 48° F, which I consider ideal. The warmer temperatures in the cave make the cheese mature a little too quickly for my taste, and creates a thicker, less edible rind on the cheeses.

We have little to no problem with humidity control - I just pour water on the floor periodically in order to maintain approximately 85% relative humidity.

We are planning on purchasing a small cooling unit for the cave (equipment and installation will cost <\$1500) in order to prevent summertime temperatures from going above 55° F. We hope to have it installed in Spring 2009, and it will be used only during the hottest months of the summer. My hope is that the lower summertime temperatures in the cave will result in an even more flavorful cheese, with a more refined rind. Additionally, our blue cheese is still vacuum packed and stored in a walk-in cooler. We hope that the lower temperatures in the cave will allow us to store the blue cheese there, and allow us to retire the walk-in cooler, resulting in a net energy savings on the farm overall.

Comments: We would recommend more insulation. As 2' of the walls are above ground would want more insulation on the interior (and exterior of the walls). More insulation and dead space between the ceiling and the floor of the house above (as described in Hahn's End plan) would help too. Would be a good candidate for the CoolBot if appropriately sized to the space.

Little Falls Farm

John & Mary Belding
Little Falls Farm
250 Walker Mills Road
Harrison, Maine 04040

Little Falls Farm, owned and operated by John and Mary Belding, is a MOFGA Certified Organic Farm in Harrison, Maine. The farmstead's major focus is 100% organic, aged, raw milk, goat cheese. Their cheese, "Riffle", is made using culture and animal rennet produced on the farm and aged over eight months in their temperature and humidity controlled, above ground "cave", that is powered in the summer by the home photovoltaic system.

Our experience with the CoolBot continues to be very positive. We have used one for two years now. As you know, the CoolBot itself is not the cooling mechanism, but the combination of it with an appropriately sized air conditioner. In designing our aging space cooling requirements I used a Cooling Load calculation program from an internet site (Trenton Refrigeration). The program was free. By entering the R-Values of the walls, floor and ceiling, door opening size, number of openings per day, weight of cheese to be aged and added each day, etc. it calculates the BTU requirements. In our case I put as much insulation into the exterior of the room as I could manage. We have 8" of foam surrounding most of our space. We use a 6,000 BTU high efficiency air conditioner that cost \$400. The CoolBot was \$250 when we purchased it. So, our total refrigeration expense was around \$650 for an 8' x 8' x 16' aging space. What is the cost for one service call with a refrigeration contractor? During 90 degree weather last summer the Air conditioner came on 4 times an hour for 3 minutes each time. We keep our cave at 49 degrees, but a CoolBot can definitely cool the room below that. The tighter and more insulation the room has, the less refrigeration and energy is needed to cool it. I believe it is much more energy efficient to put money into insulation and a smaller cooling mechanism.

I do not feel a CoolBot is too small for a 20 x 20 aging space. A CoolBot would work with any size air conditioner and I know they make air conditioners three times the size of ours. As a matter of fact, I would consider two air conditioners w/CoolBot's in a large space, that way if one should fail, the other would still be working. In our case, I purchased an extra Air conditioner for back up. If anything happens to the cooling unit, I would just slide it out of the sleeve which goes through the wall and then slide in the new one. No service call!

Comments: Wow. 8" of foam insulation!

Options in Cheese Aging Survey Results:

We sent out over 300 surveys and received 42 responses.

Survey Results:

1. What do you age your cheese in?

Walk-in Cooler	24.4%
Walk-in Insulated Room	14.6%
Refrigerator/s	14.6%
Partially Underground Cave	7.3%
Underground Cave	4.9%
Other*	34.1%

*Individuals who selected other indicated:

Cave and walk-ins

Cellar

Refrigerated cargo container

Walk-in cooler with wine chiller instead of compressor

Insulated room in underground cellar

Basement

And other variations on the above

2. How long have you been aging cheese with this set-up?

Less than 1 year	7.5%
1-4 years	45.0%
5-9 years	27.5%
10+ years	17.5%
25 years	2.5%

3. What are the approximate dimensions of your aging space?

Average of responses

Feet in width	12.5
Feet in length	20.1
Feet in height	7.8

4. What was the approximate cost to build the structure?

Less than \$500	7.9%
\$500 - 999	15.8%
\$1,000 - 4,999	34.2%
\$5k - 9k	5.3%
\$10k - 19k	5.3%
\$20k - 49k	15.8%
\$50k - 99k	2.6%

\$100k - 249k	2.6%
\$250k - 499k	0%
\$500k or more	0%
Other	10.5%

Included in other responses:

4 caves, 2,500 sq ft total, cost \$250-499K

\$1.8 million

5. What was the approximate cost for the temp/moisture controls?

Less than \$500	18.4%
\$500 - 999	7.9%
\$1,000 - 4,999	39.5%
\$5k - 9k	5.3%
\$10k - 19k	2.6%
\$20k - 49k	0%
\$50k - 99k	2.6%
\$100k - 249k	0%
\$250k - 499k	0%
\$500k or more	0%
Other	23.7%

Included in other responses:

No control mechanisms, naturally low on both - winter drying only,

6. What type of energy do you use to regulate temp and/or humidity? (Respondents were allowed to select multiple answers.)

None	7.7%
Electricity	79.5%
Solar	0%
Batteries	2.6%
Other	17.9%

Included in other responses:

elec and underground buffers

We are off-grid so it's primarily solar/wind power, even though it's 'electricity

Digital controllers on high-humidity fridges with constant blowers

Steam from boiler

walk-in temp with cheese in white cheese wrap/paper

underground stone basement

electricity and none

7. What is the approximate cost per year to run your aging space?

Less than \$100	16.7%
\$100 - 199	11.1%
\$200 - 499	16.7%
\$500 - 999	13.9%
\$1,000 – 4,999	19.4%
\$5,000 – 9,999	0.0%
\$10k - 19k	2.8%
\$20k - 49k	0.0%
\$50k or more	0.0%
Other	19.4%

Included in other responses:

Unknown due to many things on the same bill

don't know, guess \$1,000-\$4,999

we have no separate metering for our cheese building

not sure

winter only

8. What is the approximate cost per year for repairs and maintenance?

Less than \$100	42.1%
\$100 - 199	15.8%
\$200 - 499	23.7%
\$500 - 999	5.3%
\$1,000 – 4,999	7.9%
\$5,000 – 9,999	0.0%
\$10k - 19k	0.0%
\$20k - 49k	0.0%
\$50k or more	0.0%
Other	5.3%

9. How do you regulate temperature in your aging space?

Passively via the soil	13.2%
With a standard compressor/condenser unit	65.8%
With a standard air conditioner	0.0%
With a standard air conditioner and a CoolBot (to “trick” the air conditioner to cool to a lower temp)	5.3%
Geothermal	2.6%
Radiant cooling in floor	0.0%
Radiant cooling from pipes running water through aging space	7.9%
Other	23.7%

Included in other responses:

compressor supplemented with outside winter cooling

Unique unit made to run our chilled water over fan unit
 pipes contain water, glycol mix
 combo compressor/radiant(fin tubes)/geothermal
 wine chiller
 passively via the cement basement floor and wall
 compressor in July/Aug, natural rest of year
 above ground (3) with compressors - (2) underground saves \$\$
 48-52 degrees / 40-42 degrees (two spaces)

10. What is the average temperature in your aging space?

Average of responses: 50.03
 Highest response: 58.0
 Lowest response: 42.0

11. What is the highest annual temperature (in your aging space)?

Average of responses: 54.6
 Highest response: 67
 Lowest response: 42

12. What is the lowest annual temp (in your aging space)?

Average of responses: 44.1
 Highest response: 55
 Lowest response: 30

13. How do you regulate humidity in your aging space?

We don't	27.8%
Humidifier (please list type if you know it)	11.1%
Mats with water	19.4%
Towel hanging from pan of water	2.8%
Comments/other	61.1%

Included in other responses:
 Dehumidifier
 amount of cheese and wet floors
 We have a fresh water line misting into the air
 if it's a dry summer i throw water on the floor
 various, water on floor, mister, wet boards
 during june/july I may use a humidifier
 pour water on concrete floor
 wax cheese

water on the floor, sometimes, in the summer
Pouring water on the floor
wet washcloth draped down side of crock
FINE MIST SYSTEM FROM SWITZERLAND
stays pretty constant
fogger in July/Aug not rest of year-natural
too humid in summer and have to use de-humidifier
water on the floor or small dehumidifier
I believe a higher humidity is achieved when the walk-in is full of ripening cheese
garden hose runs perimeter with adjustable nozzles ever 8-10 feet
But primarily rely on volume of cheese
custom made, booster pump with agriculture misters

14. What is the average annual relative humidity in your aging space ?

Average of responses: 83.6%
Highest response: 95%
Lowest response: 60%

15. What is the highest annual relative humidity in your aging space?

Average of responses: 92.08%
Highest response: 100%
Lowest response: 80% (but this individual is intentionally drying the cheese in the aging space)

16. What is the lowest annual relative humidity in your aging space?

Average of responses: 72.4%
Highest response: 93%
Lowest response: 30%

17. Please briefly describe construction:

Basement with thick concrete walls, wood shelving, and passive cooling coils on the ceiling.
Prefab refrigerated box mounted on cement curb with epoxy flooring that is covered with custom unit to provide temperature control and humidity control as described above.
panels from Energy Panel Systems.
8 inch concrete walls with 2 rooms, frame construction roof
2x6 walls with fiberglass insulation, a layer of foil back insulation, sheet rock and dairy plastic.
walk in cooler

2X6 framing Insulated with fiberglass, and vapor barrier inside and out directly adjacent to cheese make kitchen

new concrete pad with 55 year old walk-in

an all metal shipping container

Typical walk-in

Our cave is a cement block basement built specifically for cheese aging underneath our strawbale house.

Four 8' x 8' rooms, 4' x 8' Energy Panel Structure (EPS) foam panels, walls and ceilings, 4" thick, aluminum on one side, fiber glass on other, with doors. Seams sealed silicon.

Valence heat exchangers (about 7.5' long) hung along ceiling/wall joint.

We just use an old household refrigerator with extra shelves with temp turned down.

TILE WALLS--CEMENT FLOORS WITH EPOXY COVERING

typical modular type walk-in

panels

Existing underground stone structure

Cellar of an old farmhouse.

underground concrete with earth berm and insulation over top

we bought a used walk-in cooler from a local milk processor who went out of business

Metal exterior with insulated wall and ceiling panels. Floor is concrete.

This is really a freezer type of unit. It is frozen pizza del. box w/out the truck. Thermostat on to keep cool in summer. but use heat in winter to keep it from freezing.

rebar reinforced concrete

Insulated walls sheathed with RFP. Foam insulation all around.

standard commercial reach-in refrigerators with auxiliary temp control, used only seasonally (we primarily make fresh cheeses)

Standard frame construction, concrete flooring, radiant heating in make room - passive heat only in curing portion of building. We designed and constructed this ourselves. We also have an observation room and two below ground cold storage rooms.

Traulsen all SS fridges with digital controller, constant blowers. Have 2

18. What are the walls made of?

Cement	24.2%
Foam board	9.1%
Spray in foam insulation	6.1%
FRP (fiberglass reinforced panels)	33.3%
Stone	3.0%
Other (please specify)	45.5%

Included in other responses:

one wall and floor cement ceiling and three walls a combo of plywood, plastic and foam board and fiberglass

Metal covered insulation panes

insulated cement block painted

metal with fiberglass insulation

Stainless steel

walk-in panels

EPS 4" foam panels (see above)
 Antique or new stoneware crock
 WHITE DAIRY CERAMIC BLOCKS
 foam insulated metal?
 manufactured panels
 Galvanized metal exterior with foam insulation
 plywood on the exterior
 dairy board over insulated frame construction
 stainless steel

19. What (if anything) are the walls coated with?
 white paint
 dairy board
 metal
 melamine
 paint
 we put new thin metal over the old
 Lime wash
 Panels are FRP on inside.
 ceramic glaze
 nothing
 painted steel
 nothing
 plaster
 dairy board
 nothing
 paint.

20. What is the ceiling made of?

Cement	12.1%
Foam board	9.1%
Spray in foam insulation	6.1%
FRP (fiberglass reinforced panels)	33.3%
Stone	0.0%
Other (please specify)	48.5%

Included in other responses:
 same as walls but also a layer of coated bubble wrap
 Metal covered insulation panes
 wood frame fiberglass covering
 Painted sheetrock
 metal roof
 metal
 Aluminum panels
 Same

Stucco-coated styrofoam attached to concrete.

EPS

same as the walls

Galvanized metal exterior with foam insulation

powder-coated metal panels in a make room, dairy board all others

stainless steel

21. What is the R-value (if known) of the following?

R-value of ceiling	24.4
R-value of walls	20.29
R-value of floor	1.5*

*only four respondents answered this question and three of those indicated 0

22. Is the ceiling flat or vaulted?

Flat	97.1%
Vaulted	2.9%
Other (please specify)	0.0%

23. What is the floor made of?

Concrete	73.5%
Epoxy flooring	5.9%
Tile	2.9%
Stone	0.0%
Linoleum	2.9%
Soil	0.0%
Metal	11.8%
Other (please specify)	14.7%

Included in other responses:

same as walkin

some sort of non-slip stuff

Stainless steel

24. Is there floor drainage in the aging room?

Yes	40.0%
No	57.1%
Other (please specify)	2.9%

Included in other responses:

slope to door

25. Do you have a water source in the cave (i.e. sink and/or hose for washing)?

Yes	33.3%
No	63.6%
Other (please specify)	3.0%

Included in other responses:
bucket of water from milkhouse to pour on floor

26. What is your method of ventilation?

Opening and closing door	62.9%
Two passive vents for air (inlet placed low in wall, outlet placed high in wall). Closed when not needed.	0.0%
Fan in vents described above – but run only when we need it	17.1%
Air to Air Exchanger (this helps to modify the temp of the air we bring in so we're not bringing in significantly warmer air) can be run on a timer	8.6%
Other (please specify):	22.9%

Included in other responses:
Specialized unit with "wind sock" along the ceiling and outlet lower in corner of room
from 1-3 fans inside aging room
fan runs all the time
walk-in fan
none other than fan with refrigeration
fans
we are installing passive vents this month in 3 curing rooms
solar chimney

27. What type of shelving do you have?

Wood	32.4%
Plastic	21.6%
Stainless steel	16.2%
Other steel	18.9%
Pallets (cheese vac sealed and/or boxed prior to aging)	2.7%
Other (please specify)	29.7%

Included in other responses:
plastic coated wire racks
wood, plastic
epoxy covered metal w/ plastic mats
metal coated shelving on which we place ripening mats
FIBERGLASS COATED WOOD
epoxy coated steel
wood with glassboard for raw product, wood for finished product

Cheese hangs from wooden dowels
 cheese is in plastic 5 gallon buckets
 Any cheese open in the walk-in in on top of plastic matting, or in plastic boxes or shrink wrapped or waxed
 coated metal

28. What was the approximate cost for the shelving?

Less than \$100	5.4%
\$100 - 199	10.8%
\$200 - 499	24.3%
\$500 - 999	18.9%
\$1,000 – 4,999	13.5%
\$5,000 – 9,999	2.7%
\$10k - 19k	2.7%
\$20k - 49k	0.0%
\$50k or more	0.0%
Other (please specify)	21.6%

Included in other responses:

We use nesting SS shelves on rolling carts so shelves are not permanent
 about \$10 per pound of cheese initial cost
 we made it
 not sure
 we harvest boards here and make them from the woods
 included with the refrigerator units

29. Has the FDA paid a visit to your cave?

If Yes, please specify any recommendations they had.

No	57.6%
Yes	42.4%

FDA recommendations:

Very complimentary especially about cleanliness

None

replace shelves with rust

Store everything up off the floor. I refused to use wooden pallets as they suggested, so I just moved a shelf to just above the floor. Makes it really hard to wash the floor.

he'd like me to change the recording thermometer sheets for 2 of the curing rooms more often, but admitted that since this is not a requirement, we do not have to do it

30. Please indicate which (if any) rodent/pest problems you have had in your aging space.

Flies	12.0%
Cheese mites	36.0%
Spiders	0.0%
Mice and other rodents	8.0%

Undesirable mold/s	36.0%
Other (please specify)	8.0%

Included in other responses:
mucor in reach in cooler, nothing bad in walk in
absolutely none

31. What methods have you taken to control them?

None	7.1%
Traps	14.3%
Pheromone and sticky boards	17.9%
Reduced humidity	10.7%
Fumigation	0.0%
Handbrushing wheels	42.9%
Machine brushing wheels	3.6%
Air filtration system	0.0%
Other (please specify)	39.3%

Included in other responses:
screens on external vents
wash/brush cheeses and shelves
frequent turning, washing
routine cleaning of rooms
The cage I built within the stone basement is rodent proof and approved by pest controller. The side walls are tight mesh wire screen for airflow and the top is plexiglass. I've trimmed the mesh screen with moulding to prevent any unwanted pests. The plexiglass top is weighted on all corners.
This aging/storage system keeps mice out.
Threw away the bad cheese; changed recipes and techniques
constant cleaning
vacuuming
Wipe down the walls to control black mold.
chlorine-based sanitizing

32. Do you feel that cave aged cheese has an advantage in the marketplace over conventionally aged cheese?

No, not a higher price	15.6%
Yes, somewhat of a higher price	46.9%
Yes, a significantly higher price	21.9%
Other (please specify)	15.6%

Included in other responses:
Not so much locally, yet!

yes, but this is all about marketing than a reflection of the quality of the finished product
Think most consumers don't know how variable "cave" construction is!

33. Hindsight being 20:20 what would you do differently next time?

Different aging rooms?

An entry room for packaging?

make partially underground

Better drainage, more access to water source,

We have 2 aging rooms each aging 2 different cheeses. Next time we would build smaller rooms and have a separate room for each cheese.

have a system for transporting cheese from make room to ripening area other than carrying it by hand

Filter on fans, bigger, better ventilation

more/bigger rooms for operations; build an inground cave for long term aging

We have an entry room.

bigger aging room packaging room/entry room

Entry room for packaging would be great and an underground or partially underground would help maintain the temp better passively

Married a wealthy man who would milk cows ;~> Put in an underground cave before putting in plant.

we put it all together on a small budget, so I can't say we would do anything different.

But--next time, when we expand, we will have a room for washed rind, one for natural rind, and one for soft-ripened which we age in adapted refrigerators. We will have a sink close and devoted to washing cheese, better ventilation and a room for packaging.

We would include a drain in the cave, and make our ventilation vents larger.

Instead of using a bulk tank, used a chiller; and would have put the aging rooms at least partially under ground to regulate temperature.

MORE VENTILATION

we want an underground cave

Use something else. We are using a walk-in and refrigerator now too.

domed ceiling and larger.....

I would build from scratch. This was totally a price driven decision-whole unit was \$1000.00.

more insulation in the entry way wall

Bigger!

happy with current set-up for our level of production

more lab space, less observation room, and maybe some landscaping

More space so I could age more raw milk cheeses.

Those of you with a partially or fully underground cave please answer the following questions:

34. Did you take steps to ensure good drainage under cave (i.e. did you lay down drainage pipes and/or crushed rock or gravel underneath the cave)?

No	27.3%
Yes (please specify)	72.7%

Specified steps taken include:

gravel and drainage but only because that's how we built the house
all of the above

We laid drainage pipe under the cave.

pipes and crushed rock and overflow outlet for water dripping down walls from back walls

Sits elevated on timbers, which are on a built up bed of gravel.

drain tile to daylight

crushed stope, sloped perf. piping.

35. What is the depth of your cave floor in feet?

Average of responses: 11.6'

36. What is the depth of your cave ceiling in feet?

Average of responses: 5'

37. Anything else you think we should know?

Responses included:

the aging room was set up years ago so I have less info on its set up than you may want.
Thank you for doing the survey because this is an area that is so hard to find anyone who knows anything about! I will be very interested in the results.

We may install a small refrigeration unit so the summer temperatures stay 50 - 55 degrees. Also, our ceiling is 2 feet above grade, but I couldn't enter that number.

A person can make terrific cheese at home using nearly free conditions at hand; historically this was the norm anyway.

survey way too long... Sorry

We would be interested in a copy of your report.

Our cheese is packaged in a vacuum-sealed can. Relative humidity doesn't affect our product.

I am still very much a novice at this and am still learning and am looking forward to the responses from this survey.

do your homework

we have several curing rooms 10x12, 10x12, and 12x20 - for aging different types of cheese as well as allowing rotation of rooms for cleaning (and just in case a compressor breaks, we have someplace to move product so there is no emergency)

Your outlet location comment above is incorrect. The outlet should be low and inlet high.

Ammonia is heavier than air and will sink. If you put the outlet high you are going to short circuit the ventilation. My 2 cents anyway.

APPENDIX

FDA Regs:

Title 21: Food and Drugs

PART 110—CURRENT GOOD MANUFACTURING PRACTICE IN MANUFACTURING, PACKING, OR HOLDING HUMAN FOOD

Subpart B—Buildings and Facilities

§ 110.20 *Plant and grounds.*

(a) *Grounds.* The grounds about a food plant under the control of the operator shall be kept in a condition that will protect against the contamination of food. The methods for adequate maintenance of grounds include, but are not limited to:

(1) Properly storing equipment, removing litter and waste, and cutting weeds or grass within the immediate vicinity of the plant buildings or structures that may constitute an attractant, breeding place, or harborage for pests.

(2) Maintaining roads, yards, and parking lots so that they do not constitute a source of contamination in areas where food is exposed.

(3) Adequately draining areas that may contribute contamination to food by seepage, foot-borne filth, or providing a breeding place for pests.

(4) Operating systems for waste treatment and disposal in an adequate manner so that they do not constitute a source of contamination in areas where food is exposed.

If the plant grounds are bordered by grounds not under the operator's control and not maintained in the manner described in paragraph (a) (1) through (3) of this section, care shall be exercised in the plant by inspection, extermination, or other means to exclude pests, dirt, and filth that may be a source of food contamination.

(b) *Plant construction and design.* Plant buildings and structures shall be suitable in size, construction, and design to facilitate maintenance and sanitary operations for food-manufacturing purposes. The plant and facilities shall:

(1) Provide sufficient space for such placement of equipment and storage of materials as is necessary for the maintenance of sanitary operations and the production of safe food.

(2) Permit the taking of proper precautions to reduce the potential for contamination of food, food-contact surfaces, or food-packaging materials with microorganisms, chemicals, filth, or other extraneous material. The potential for contamination may be reduced by adequate food safety controls and operating practices or effective design, including the separation of operations in which contamination is likely to occur, by one

or more of the following means: location, time, partition, air flow, enclosed systems, or other effective means.

(3) Permit the taking of proper precautions to protect food in outdoor bulk fermentation vessels by any effective means, including:

(i) Using protective coverings.

(ii) Controlling areas over and around the vessels to eliminate harborages for pests.

(iii) Checking on a regular basis for pests and pest infestation.

(iv) Skimming the fermentation vessels, as necessary.

(4) Be constructed in such a manner that floors, walls, and ceilings may be adequately cleaned and kept clean and kept in good repair; that drip or condensate from fixtures, ducts and pipes does not contaminate food, food-contact surfaces, or food-packaging materials; and that aisles or working spaces are provided between equipment and walls and are adequately unobstructed and of adequate width to permit employees to perform their duties and to protect against contaminating food or food-contact surfaces with clothing or personal contact.

(5) Provide adequate lighting in hand-washing areas, dressing and locker rooms, and toilet rooms and in all areas where food is examined, processed, or stored and where equipment or utensils are cleaned; and provide safety-type light bulbs, fixtures, skylights, or other glass suspended over exposed food in any step of preparation or otherwise protect against food contamination in case of glass breakage.

(6) Provide adequate ventilation or control equipment to minimize odors and vapors (including steam and noxious fumes) in areas where they may contaminate food; and locate and operate fans and other air-blowing equipment in a manner that minimizes the potential for contaminating food, food-packaging materials, and food-contact surfaces.

(7) Provide, where necessary, adequate screening or other protection against pests.

Title 21: Food and Drugs

PART 110—CURRENT GOOD MANUFACTURING PRACTICE IN MANUFACTURING, PACKING, OR HOLDING HUMAN FOOD

Subpart B—Buildings and Facilities

§ 110.35 Sanitary operations.

(a) *General maintenance.* Buildings, fixtures, and other physical facilities of the plant shall be maintained in a sanitary condition and shall be kept in repair sufficient to prevent

food from becoming adulterated within the meaning of the act. Cleaning and sanitizing of utensils and equipment shall be conducted in a manner that protects against contamination of food, food-contact surfaces, or food-packaging materials.

(b) *Substances used in cleaning and sanitizing; storage of toxic materials.* (1) Cleaning compounds and sanitizing agents used in cleaning and sanitizing procedures shall be free from undesirable microorganisms and shall be safe and adequate under the conditions of use. Compliance with this requirement may be verified by any effective means including purchase of these substances under a supplier's guarantee or certification, or examination of these substances for contamination. Only the following toxic materials may be used or stored in a plant where food is processed or exposed:

- (i) Those required to maintain clean and sanitary conditions;
- (ii) Those necessary for use in laboratory testing procedures;
- (iii) Those necessary for plant and equipment maintenance and operation; and
- (iv) Those necessary for use in the plant's operations.

(2) Toxic cleaning compounds, sanitizing agents, and pesticide chemicals shall be identified, held, and stored in a manner that protects against contamination of food, food-contact surfaces, or food-packaging materials. All relevant regulations promulgated by other Federal, State, and local government agencies for the application, use, or holding of these products should be followed.

(c) *Pest control.* No pests shall be allowed in any area of a food plant. Guard or guide dogs may be allowed in some areas of a plant if the presence of the dogs is unlikely to result in contamination of food, food-contact surfaces, or food-packaging materials. Effective measures shall be taken to exclude pests from the processing areas and to protect against the contamination of food on the premises by pests. The use of insecticides or rodenticides is permitted only under precautions and restrictions that will protect against the contamination of food, food-contact surfaces, and food-packaging materials.

(d) *Sanitation of food-contact surfaces.* All food-contact surfaces, including utensils and food-contact surfaces of equipment, shall be cleaned as frequently as necessary to protect against contamination of food.

(1) Food-contact surfaces used for manufacturing or holding low-moisture food shall be in a dry, sanitary condition at the time of use. When the surfaces are wet-cleaned, they shall, when necessary, be sanitized and thoroughly dried before subsequent use.

(2) In wet processing, when cleaning is necessary to protect against the introduction of microorganisms into food, all food-contact surfaces shall be cleaned and sanitized before use and after any interruption during which the food-contact surfaces may have become

contaminated. Where equipment and utensils are used in a continuous production operation, the utensils and food-contact surfaces of the equipment shall be cleaned and sanitized as necessary.

(3) Non-food-contact surfaces of equipment used in the operation of food plants should be cleaned as frequently as necessary to protect against contamination of food.

(4) Single-service articles (such as utensils intended for one-time use, paper cups, and paper towels) should be stored in appropriate containers and shall be handled, dispensed, used, and disposed of in a manner that protects against contamination of food or food-contact surfaces.

(5) Sanitizing agents shall be adequate and safe under conditions of use. Any facility, procedure, or machine is acceptable for cleaning and sanitizing equipment and utensils if it is established that the facility, procedure, or machine will routinely render equipment and utensils clean and provide adequate cleaning and sanitizing treatment.

(e) *Storage and handling of cleaned portable equipment and utensils.* Cleaned and sanitized portable equipment with food-contact surfaces and utensils should be stored in a location and manner that protects food-contact surfaces from contamination.

[51 FR 24475, June 19, 1986, as amended at 54 FR 24892, June 12, 1989]

Title 21: Food and Drugs

PART 110—CURRENT GOOD MANUFACTURING PRACTICE IN MANUFACTURING, PACKING, OR HOLDING HUMAN FOOD

Subpart B—Buildings and Facilities

§ 110.37 Sanitary facilities and controls.

Each plant shall be equipped with adequate sanitary facilities and accommodations including, but not limited to:

(a) *Water supply.* The water supply shall be sufficient for the operations intended and shall be derived from an adequate source. Any water that contacts food or food-contact surfaces shall be safe and of adequate sanitary quality. Running water at a suitable temperature, and under pressure as needed, shall be provided in all areas where required for the processing of food, for the cleaning of equipment, utensils, and food-packaging materials, or for employee sanitary facilities.

(b) *Plumbing.* Plumbing shall be of adequate size and design and adequately installed and maintained to:

(1) Carry sufficient quantities of water to required locations throughout the plant.

(2) Properly convey sewage and liquid disposable waste from the plant.

(3) Avoid constituting a source of contamination to food, water supplies, equipment, or utensils or creating an unsanitary condition.

(4) Provide adequate floor drainage in all areas where floors are subject to flooding-type cleaning or where normal operations release or discharge water or other liquid waste on the floor.

(5) Provide that there is not backflow from, or cross-connection between, piping systems that discharge waste water or sewage and piping systems that carry water for food or food manufacturing.

(c) *Sewage disposal.* Sewage disposal shall be made into an adequate sewerage system or disposed of through other adequate means.

(d) *Toilet facilities.* Each plant shall provide its employees with adequate, readily accessible toilet facilities. Compliance with this requirement may be accomplished by:

(1) Maintaining the facilities in a sanitary condition.

(2) Keeping the facilities in good repair at all times.

(3) Providing self-closing doors.

(4) Providing doors that do not open into areas where food is exposed to airborne contamination, except where alternate means have been taken to protect against such contamination (such as double doors or positive air-flow systems).

(e) *Hand-washing facilities.* Hand-washing facilities shall be adequate and convenient and be furnished with running water at a suitable temperature. Compliance with this requirement may be accomplished by providing:

(1) Hand-washing and, where appropriate, hand-sanitizing facilities at each location in the plant where good sanitary practices require employees to wash and/or sanitize their hands.

(2) Effective hand-cleaning and sanitizing preparations.

(3) Sanitary towel service or suitable drying devices.

(4) Devices or fixtures, such as water control valves, so designed and constructed to protect against recontamination of clean, sanitized hands.

(5) Readily understandable signs directing employees handling unprotected food, unprotected food-packaging materials, of food-contact surfaces to wash and, where appropriate, sanitize their hands before they start work, after each absence from post of duty, and when their hands may have become soiled or contaminated. These signs may be

posted in the processing room(s) and in all other areas where employees may handle such food, materials, or surfaces.

(6) Refuse receptacles that are constructed and maintained in a manner that protects against contamination of food.

(f) *Rubbish and offal disposal.* Rubbish and any offal shall be so conveyed, stored, and disposed of as to minimize the development of odor, minimize the potential for the waste becoming an attractant and harborage or breeding place for pests, and protect against contamination of food, food-contact surfaces, water supplies, and ground surfaces.

APPENDIX B

Recipe for Limewash

To get started you just need hydrated lime from your hardware store. All you have to do is mix it with water to get a cheap and attractive wall covering. Lime wash paint is perfect for exterior and interior paint work. You don't need to measure your ratio of hydrated lime to water, but you do need to watch the consistency. When it is the consistency of thick cream, you have added enough water. You can make as much or as little as you need, in a plastic bucket that has a lid, or in an empty ice cream container for small jobs. Make sure the mixture is lump free and don't use it right away. Cover and leave for a few days and then add more water until it has the consistency of milk. There still may be some lumps that won't dissolve so it is wise to strain the paint through a fine strainer or muslin. Discard the lumps. Your paint is ready to use.

APPENDIX C

Insulation: Profile of types from U.S. Department of Energy - Energy Efficiency and Renewable Energy – A Consumer's Guide to Energy Efficiency and Renewable Energy

Blanket: Batts and Rolls

Fiberglass

Mineral (Rock or Slag) Wool

Plastic Fibers

Natural Fibers

Unfinished walls, including foundation walls, and floors and ceilings.

Fitted between studs, joists, and beams.

Do-it-yourself.

Suited for standard stud and joist spacing, which is relatively free from obstructions.

Concrete Block Insulation

Foam beads or liquid foam:

Polystyrene

Polyisocyanurate or Polyiso

Polyurethane

Vermiculite or Perlite Pellets

Unfinished walls, including foundation walls, for new construction or major renovations. Involves masonry skills.

Autoclaved aerated concrete and autoclaved cellular concrete masonry units have 10 times the insulating value of conventional concrete.

Foam Board or Rigid Foam

Polystyrene –

Polyisocyanurate or polyiso -

Polyurethane –

Where applicable – Unfinished walls, including foundation walls, floors and ceilings, unvented low-slope roofs.

Interior applications: must be covered with 1/2-inch gypsum board or other building-code approved material for fire safety.

Exterior applications: must be covered with weatherproof facing.

High insulating value for relatively little thickness.

Can block thermal short circuits when installed continuously over frames or joists.

Reflective System

Foil-faced kraft paper, plastic film, polyethylene bubbles, or cardboard

Unfinished walls, ceilings, and floors.

Foils, films, or papers: fitted between wood-frame studs, joists, and beams

Do-it-yourself.

All suitable for framing at standard spacing. Bubble-form suitable if framing is irregular or if obstructions are present.

Most effective at preventing downward heat flow; however, effectiveness depends on spacing.

Rigid Fibrous or Fiber Insulation

Fiberglass

Mineral (rock or slag) wool

Ducts in unconditioned spaces and other places requiring insulation that can withstand high temperatures.

HVAC contractors fabricate the insulation into ducts either at their shops or at the job sites.

Can withstand high temperatures.

Sprayed Foam and Foamed-in-Place

- Cementitious –

- Phenolic –

- Polyisocyanurate –

- Polyurethane –

Enclosed existing wall or open new wall cavities, unfinished attic floors.

Applied using small spray containers or in larger quantities as a pressure sprayed (foamed-in-place) product.

Good for adding insulation to existing finished areas, irregularly shaped areas, and around obstructions.

Structural Insulated Panels (SIPs)

- Foam Board or Liquid Foam Insulation Core -

- Straw Core Insulation -

Unfinished walls, ceilings, floors, and roofs for new construction.

Builders connect them together to construct a house.

SIP-built houses provide superior and uniform insulation compared to more traditional construction methods; they also take less time to build.

Polystyrene Insulation Materials

Polystyrene—a colorless, transparent thermoplastic—is commonly used to make [foam board or beadboard](#) insulation, [concrete block insulation](#), and a type of [loose-fill insulation](#), which consists of small beads of polystyrene.

Molded expanded polystyrene (MEPS)—more commonly used for foam board insulation—is also available as small beads of foam. This type is often used as a pouring insulation for concrete blocks or other hollow wall cavities. However, be aware that poured beads are extremely lightweight and take a static electric charge very easily. They are also notoriously difficult to control. Any wind at all often results in the beads flying all over the place. Also, if there is a hole in the wall, the foam beads will continue to fall out of the hole.

Other polystyrene insulation materials similar to MEPS are expanded polystyrene (EPS) and extruded polystyrene (XPS). EPS and XPS are both made from polystyrene but the manufacturing process is different. EPS is composed of small plastic beads that are fused together. XPS begins as a molten material that is pressed out of a form into sheets.

XPS is most commonly used as foam board insulation. EPS is commonly produced in blocks. Both MEPS and XPS are also often used as the insulation for [structural insulating panels \(SIPs\)](#) and [insulating concrete forms \(ICFs\)](#).

The thermal resistance or R-value of polystyrene foam board depends on its density. They typically range from R-3.8 to R-5.0 per inch. Polystyrene loose-fill or bead insulation typically has a relatively lower R-value (around R-2.3 per inch) compared to the foam board.

Polyisocyanurate Insulation Materials

Polyisocyanurate or polyiso is a thermosetting type of plastic, closed-cell foam that contains a low-conductivity gas (usually hydrochlorofluorocarbons or HCFC) in its cells. The high thermal resistance of the gas gives polyisocyanurate insulation materials an R-value typically around R-7 to R-8 per inch.

Polyisocyanurate insulation is available as a liquid, [sprayed foam](#), and rigid [foam board](#). It can also be made into laminated insulation panels with a variety of facings. Foamed-in-place applications of polyisocyanurate insulation are usually cheaper than installing foam boards. They also usually perform better since the liquid foam molds itself to all of the surfaces.

Over time, the R-value of polyisocyanurate insulation can drop as some of the low-conductivity gas escapes and air replaces it. This phenomenon is known as *thermal drift*. Experimental data indicates that most thermal drift occurs within the first two years after the insulation material is manufactured. The R-value then slowly decreases. For example, if the insulation has an initial R-value of R-9 per inch, it will probably eventually drop to R-7 per inch. The R-value then remains unchanged unless the foam is damaged.

Foil and plastic facings on rigid, polyisocyanurate foam panels can help stabilize the R-value. Testing suggests that the stabilized R-value of rigid foam with metal foil facings remains unchanged after 10 years. Reflective foil, if installed correctly, can also act as a [radiant barrier](#), which adds another R-2 to the overall thermal resistance. Panels with foil facings have stabilized R-values of R-7.1 to R-8.7 per inch.

Polyurethane Insulation Materials

Polyurethane is a closed-cell foam insulation material that contains a low-conductivity gas (usually hydrochlorofluorocarbons or HCFC) in its cells. The high thermal resistance of the gas gives polyurethane insulation materials an R-value typically around R-7 to R-8 per inch.

Over time, the R-value of polyurethane insulation can drop as some of the low-conductivity gas escapes and air replaces it. This phenomenon is known as *thermal drift*. Experimental data indicates that most thermal drift occurs within the first two years after the insulation material is manufactured. The R-value then slowly decreases. For example, if the insulation has an initial R-value of R-9 per inch, it will probably eventually drop to R-7 per inch. The R-value then remains unchanged unless the foam is damaged.

Polyurethane insulation is available as a liquid [sprayed foam](#) and rigid [foam board](#). It can also be made into laminated insulation panels with a variety of facings.

Sprayed-Foam Polyurethane Insulation

Sprayed or foamed-in-place applications of polyurethane insulation are usually cheaper than installing foam boards. These applications also usually perform better since the liquid foam molds itself to all of the surfaces.

All closed-cell polyurethane foam insulation made today is produced with a non-CFC (chlorofluorocarbon) gas as the foaming agent. Some polyurethane foam combines with a HCFC gas. These types don't insulate as well as insulation made with a CFC gas, but the non-CFC gas is less destructive to the ozone layer. However, these foams still have an aged R-6.5 per inch thickness. Their density is generally 2.0 lb/ft³ (32.0 kilograms per cubic meter [kg/m³]). There also are low-density open-cell polyurethane foams (0.5 lb/ft³ [8 kg/m³]). These foams are similar to conventional polyurethane foams, but are more flexible. Some low-density varieties use carbon dioxide (CO₂) as the foaming agent.

Low-density foams are sprayed into open wall cavities and rapidly expand to seal and fill the cavity. One manufacturer offers a slow-expanding foam, which is intended for cavities in existing homes. The liquid foam expands very slowly and thus reduces the chance of damaging the wall from overexpansion. The foam is water-vapor permeable, remains flexible, and is resistant to wicking of moisture. It provides good air sealing and yields about R-3.6 per inch of thickness. It is also fire resistant and won't sustain a flame.

Soy-based, polyurethane liquid [spray-foam](#) products are also available. The cured R-value is around 3.7 per inch. These products can be applied with the same equipment used for petroleum-based polyurethane foam products.

Rigid Polyurethane Foam Board Insulation

Foil and plastic [facings](#) on rigid, polyurethane [foam panels](#) can help stabilize the R-value, preventing thermal drift. Testing suggests that the stabilized R-value of rigid foam with metal foil facings remains unchanged after 10 years. Reflective foil, if installed correctly, can also act as a [radiant barrier](#), which adds another R-2 to the overall thermal resistance. Panels with foil facings have stabilized R-values of R-7.1 to R-8.7 per inch.

APPENDIX D

The following is a narrative from an energy firm. They put the scenarios we profiled out to bid, and did not receive much back in the way of information, or even a solid quote. I think the high humidity seemed the biggest challenge.

FROM: Bob Hardina, Bill Morgner
Mid-Coast Energy Systems, Inc.
P. O. Box 1118 Midcoast Road
Damariscotta, ME 04543
207-563-5147 800-890-7196
www.midcoastenergysystems.com

RE: Cheesemaking HVAC

There are three concerns that need to be addressed, temperature control, humidity control and air changes.

For the first three scenarios we would use conventional refrigeration equipment with R410 refrigerant. The compressor would be located outside the area requiring temperature control. The fan coil, usually found in a walk in cooler, would be located outside with air ducted into the conditioned area. Controls for this unit would be standard, off the shelf, controls by standard manufacturers, available through Grainger or Johnston Controls. In the rare situation where heat is needed to maintain the proper temperature the most cost effective solution may be a small electric resistance coil.

Humidity is a problem. Steam humidifiers would be inappropriate and it is unlikely that a traditional evaporative humidifier would produce the humidity level you desire. The rather high humidity levels can be obtained by using misters strategically located throughout the conditioned area. A humidistat in the airflow to the conditioned area would control the operation of the misters. The high humidity level will necessitate the use of stainless steel or non-ferrous ductwork. The refrigeration coil will have to be rated for high humidity

Air exchanges can be accomplished with an air to air heat exchanger rated for high humidity areas.

I see no reason why nylon socks or boots cannot be incorporated into the air distribution system.

Accurately determining costs is virtually impossible, as each situation is different. One consultant ventured an installed cost of \$20,000 - \$25,000 dollars.

Refrigeration units should be checked and maintained on a regular basis to keep coils clean, motors lubricated and electrical connections checked. Preventive maintenance will go a long way toward preventing costly repair.

The CoolBot is an interesting device. In limited situations it might be a very good solution. The cheese cave is very challenging. Since it will require very little heating or cooling you might find that a split system with an outside compressor and wall mounted evaporators would be a good answer.

We are still trying to get more information.

APPENDIX E

Construction Estimates from Jerry DesRoberts, Contractor

Scenario 1

20' x 20' x 8' Room housed in barn / Standard Walk-in Cooler

-Cement slab required if floor drain needed for hose down application (additional fee)

Construction:

-2" x 4" walls	\$320
-Styrofoam insulation on walls - R 17.5	
Fiberglass insulation on ceiling – R 30	\$1700
-Fiberglass insulated door	\$300
-Interior walls and ceiling will be plywood with FRP wall paneling.	\$1150
-Exterior of walls to be covered with 7/16" OSB sheathing to protect insulation.	\$8.39/sheet
-Refrigeration by Pelreco, Pine Point Road Scarborough, ME (additional fee)	

Estimated Cost w/ contractor = \$7380

Scenario 2

20' x 20' x 8' Insulated room in Basement (ceiling one foot underground)

-FRP board will provide enough vapor barrier on interior of concrete walls with 2" x 4" construction and 2" Styrofoam insulation.

-Styrofoam insulation board and plywood interior with FRP paneling over. Reflectix insulation (flexible insulation) 3/8" thick would be applied to ceiling before styrofoam, plywood and FRP board to prevent condensation.

-The foundation to be sealed from the outside would have to be dug down to the base to be sealed with 2" insulation board for proper seal and insulation. From the inside, walls could be sealed with UGL water seal before insulation, framing and finish applied.

Interior Construction:

Framing	\$320
Insulation	1700
Entry Door	300
FRP	1150
Glue, molding, wall sealer	600
Total	4070
Cost w/ contractor	7870

Insulation will be Styrofoam versus thermax. Styrofoam does not hold moisture and/or condensation like thermax. Polyvapor barriers can create condensation and mold. Styrofoam and FRP board are adequate barriers for this application.

Scenario 3

Fully Underground Cave (dug into hill, or with 8x8 bumpout extending above ground with 4' x 4' dumb waiter).

Built with poured concrete 20' x 20' x 8' footprint with concrete ceiling and 8' x 8' bumpout for entry.

Construction

-The concrete walls would be constructed with standard 8" thickness - 1/2" rebar (2 rows on top and 2 rows in bottom) sealed with 2" Styrofoam, R 10 spray sealer. \$79 per running ft.

-8" x 16" footing

-Ceiling would be 6" concrete with rebar reinforcement, 4" Styrofoam, sealed with spray sealer.

-Concrete floor with vapor barrier \$2200

-Spray insulation will create better R value according to thickness.

-Excavation cost \$1200/day plus the trucking in and out of materials.

-The more drainage needed, the higher the price. Standing water, extreme mud, moss and vernal pools are not adequate building areas. Additional fees would be associated with permitting and engineering.

-Ledge is very costly - pretest \$500-1500

-Blasting estimated price 10' x 10' x 3' deep \$2000 (priced on square footage (100 sq. feet per 3 foot depth)) – depends on location, surrounding buildings. Radon could be a concern in closed room on ledge.

The above is a standard foundation with insulation and ceiling. A proposed foundation and ceiling as such can cost up to 3 times more by registered architect. Drainage will be an issue at the depth of the room and location. Stone may be required with trenching.

Scenario 3.5 (LATER ABANDONED THE CEMENT BLOCK VERSION)

Specs quoted: cement block foundation is not recommended because of ground pressure at that depth. Moisture problems are inevitable with the number of mortar joints in place. Back filling and ceiling weight may cause a collapse w/o proper reinforcement.

Spray foam versus styrofoam panels: different thickness can be applied and will create a tighter seal especially on the north side of a hill (cold side of building).

Dumb waiter possible, insulation would be 2" styrofoam exterior. Roof could be truss system with 5/8" Advantech sheathing and architect shingle in hill application. Still recommend FRP board for interior – for cleaning purposes.

Construction Cost for Scenarios 3 and 3.5

Foundation	\$7742
Concrete Floor and Vapor Barrier	\$2200
Ceiling	\$6500
Excavation	\$1200/day + truck and material
Roof Truss System w/ shingles	\$8800
1 exterior door	\$300
Drainage	additional fee
w/ contractor fees	\$31,580

Permits and architect fees not included. Prices quoted are for information provided. Registered architect plans would be required for this project with more information and specs. Prices are estimated only. Proposal prices to be quoted with more information.

Scenario 4

Potato Storage Facility

Excavation Costs = \$1200/day + trucking in and out of materials

APPENDIX E

Other resources

Cheese Consultants

- Margaret Morris, Glengarry Cheesemaking and Supply
- Patrick Anglade, Cheese Technician from Centre Fromager de Carmejane
- Peter Dixon, Dairy Foods Consulting
- Neville McNauton, CheezSorce

Great photos of cheesecave construction!

www.bonniebluefarm.com

Recommended source for low energy cement buildings.

<http://www.formworksbuilding.com/>

Information on the CoolBot

<http://www.storeitcold.com/how.php>

About the Author: Jennifer Betancourt is Head Cheesemaker and Co-owner of Silvery Moon Creamery. The creamery is located in a big red barn at Smiling Hill Farm in Westbrook, Maine and is a collaboration between Jennifer and the farm. Silvery Moon crafts cheese from the farm's all natural milk as well as milk from nearby Harris Farm in Dayton, Maine. Jennifer lives in Edgecomb with her husband David, and daughter Isabella as well as a large clan of jovial extended family.

Special thanks to Amanda DesRoberts for her good humor, tireless research and patience!

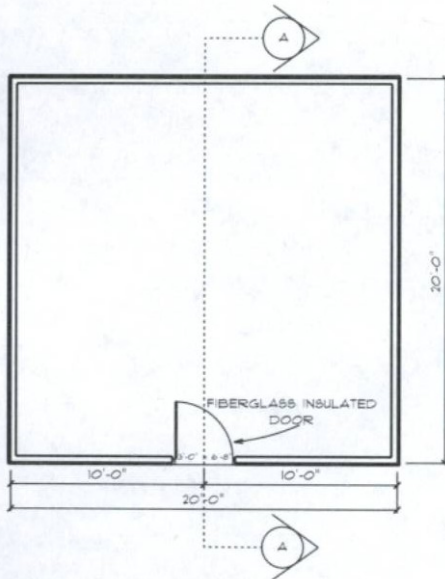
Thank you for technical help from:

Stephen Belyea, MidCoast Energy Solutions, Dan Libby Refrigeration, Jerry DesRoberts, Gary Anderson, Margaret Morris, Peter Dixon, Patrick Anglade, Marc Druart, Steve Emery and others.

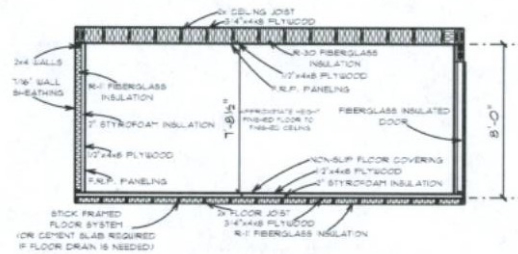
Thank you also to the following farms and creameries for their willingness to share:

Ancient Heritage Dairy
Appleton Creamery
Black Mesa Ranch
Black Sheep Creamery
Bleu Mont Dairy

Bonnie Blue Farm
Bonnieveiw Farm
Boucher Family Farm/Green Mountain Blue Cheese
Bulger Creek Farm, L.L.C.
Carlisle Farmstead Cheese
Cato Corner Farm
Cedar Grove Cheese
Clover Creek Cheese Cellar LLC
Cranberry Ridge Farm
Doe's Leap
Drake Family Farms Goat Dairy
Finger Lakes Cheese
Fiore di Nonno
Gillis Acres Farm
Gothberg Farms LLC
Hahn's End
Hawthorne Valley Farm
Heamour Farm
Hillman Farm
Hope Farm
Iron Rod Farm
Koons Farm and Kennebec Cheesery
Lazy Lady Goat Dairy
Liberty Fields Farm
Little Falls Farm
Longfellow's Creamery
Meadow Stone Farm
Merryl Winstein Home Cheesemaking
Mossy Oak Creamery
Northland Sheep Dairy
Orb Weaver Farm
Prairie Fruits Farm and Creamery
R. Belanger and Sons Farm
Redwood Hill Farm & Creamery
Silvery Moon Creamery
Smith's Country Cheese, Inc.
South Mountain Dairy
Stoney Acres Sheep Dairy & Cheese Plant
Sunset Acres
Uplands Cheese Co.
Valley View Farm
Via Lactea Farm
Widmers Cheese Cellars
Willow Hill Farm
WSU Creamery

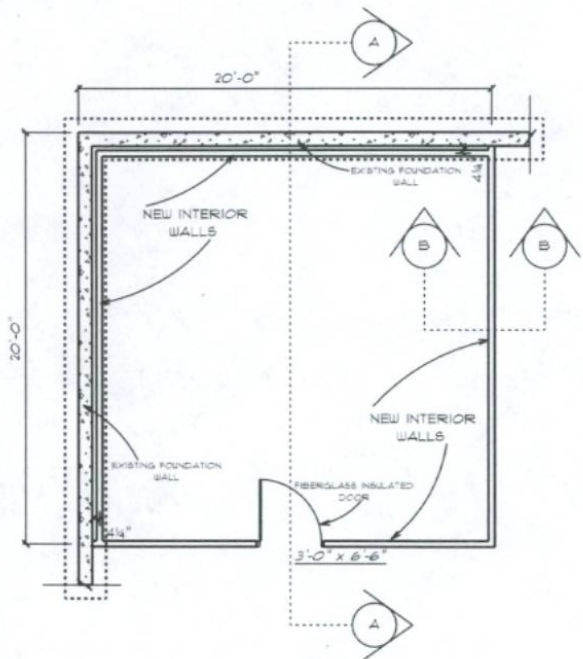


FLOOR PLAN

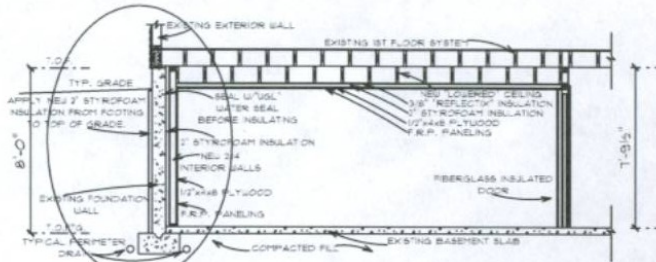


CROSS SECTION - A

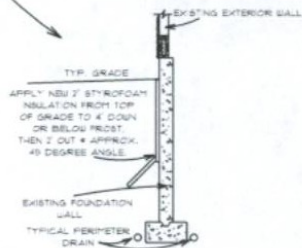
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DATE 3/4/08	REVISED 3/6/08	
SCENARIO ONE		
SILVERLY MOON CREAMERY	DRAWING NUMBER	1 OF 1



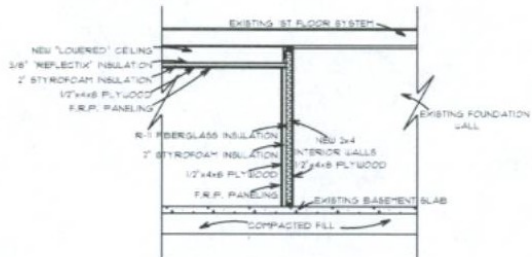
FOUNDATION PLAN



CROSS SECTION - A

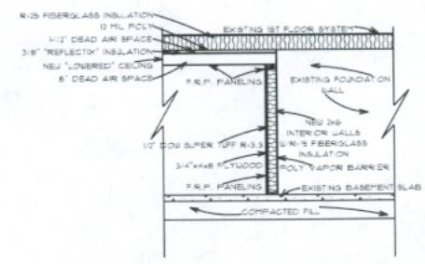
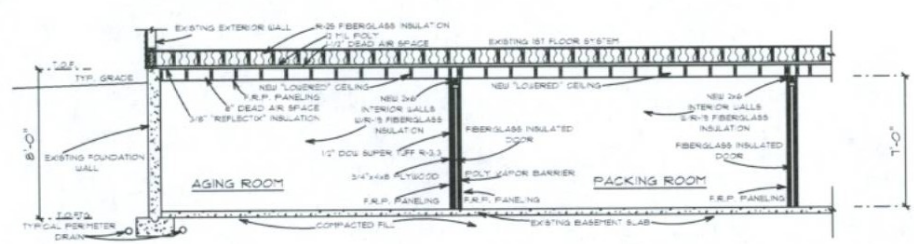
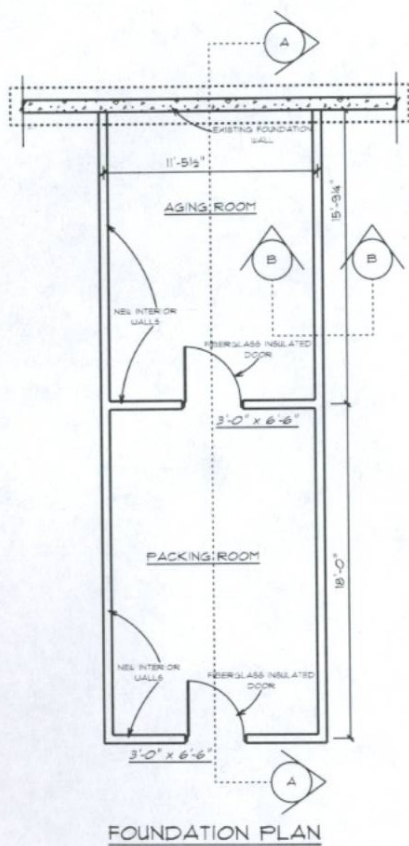


EXTERIOR INSULATION OPTION

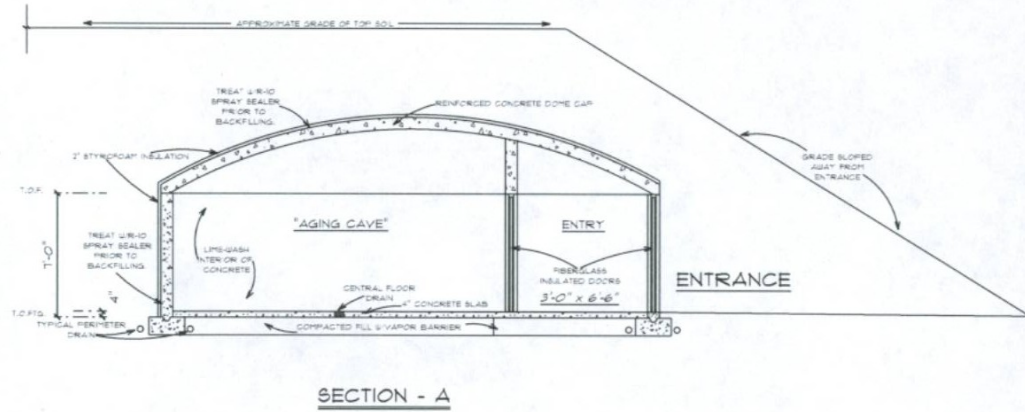
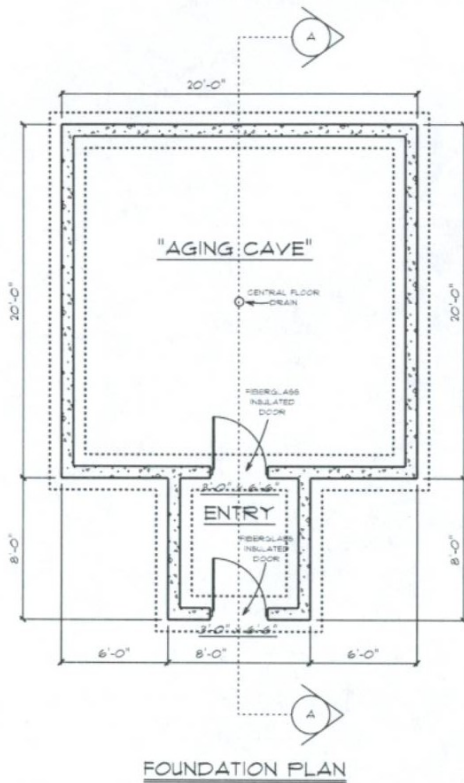


CROSS SECTION - B

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3/4/08	REVIS	3/6/08
SCENARIO TWO		
SILVERY MOON CREAMERY		DRAWING NUMBER 1 OF 1



SCALE		
DATE	APPROVED	DATE
3/6/09		REVISED
SCENARIO 2.5 (HAHN'S END)		
SILVERLY MOON CREAMERY		DRAWING NUMBER
		1 OF 1



SCALE	APPROVED	DATE
3/4/09		3/6/09
SCENARIO THREE		
SILVER MOON CREAMERY	DRAWING NUMBER 1 OF 1	