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CONTENT

ROI, FSMA compliance and energy savings with effectively vapor sealed building envelope on a retrofit freezer/cooler

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Abstract

This paper's purpose is to elucidate the Return on Investment (ROI) when complying with the United States' Food Safety Modernization Act (FSMA), made applicable to European facilities, when considering the energy effects of a properly installed building envelope on freezers and coolers. Its conclusions are based upon industry research and the results from a 2-year long case study on 2 separate full building envelope installations in the Mid-west and Southern U.S. From the case studies, the results show 100% compliance with the ice and condensation restrictions of FSMA, an energy savings of 48% and 40% and the ROI of four years, 1month (24.48% ROC) and 3 years 10 months (26.08% ROC), respectively.

The primary objectives and scope of the study were to objectively determine what the effect of installing a state-of-the-art building envelope (correct insulation, vapor barrier and roofing membrane) on an existing freezer/cooler, if any. The rationale for the study was to obtain this missing information for Building Managers, General Contractors, Operational Teams and building owners to help determine a rational scope of action to FSMA compliance and energy savings on their current, and to be constructed, freezers and coolers.
Keywords: Case-based ROI/energy savings from vapor barriers

1. Stopping listeria - FSMA requirements

The United States' Food and Drug Administration (FDA) through The Food Safety Modernization Act (FSMA) specifically addressed Listeria: it identifies ice and condensation as contaminates that are not allowed in temperature-controlled facilities that house food or pharmaceuticals. FSMA requires facilities *both domestic and foreign* to have a food safety plan in place that includes an analysis of hazards and risk-based preventive controls to minimize or prevent the identified hazards. [1]

"FSMA Final Rule § 117.20 (b) 4) states in part:
(b) Plant construction and design. The… manufacturing, processing, packing, and holding… plant must:
4) Be constructed in such a manner that….that <u>drip or condensate from fixtures, ducts and pipes does not contaminate food</u>, <u>food-contact surfaces, or food-packaging</u> materials …. (*emphasis added*)

In simple terms, ice and condensation – which is proven to carry Listeria - is NOT allowed in temperature-controlled facilities that store food and pharmaceuticals.

2. Traditional vs effective building envelope installation

The traditional building envelope installation are inferior to an **<u>effective</u>** building envelope installation:
Traditional temperature-controlled building envelope installation consists of:

- a metal deck,
- roofing insulation (PolyIso - Polyisocyanurate, XPS – Extruded Polystyrene**)** applied for an R-value of 35-50,
- reliance on roofing membrane as perimeter vapor barrier with spray foam usage in deck flutes around the perimeter,
- an adhered roofing membrane (TPO or PVC or EPDM).

Effective temperature-controlled building envelope installation consists of:

- a metal deck,
- XPS roofing insulation applied for an R-value of 35-50,
- a Vapor Barrier around the perimeter of the roof deck; and
- a mechanically attached PVC roofing membrane over the top of the Vapor Barrier and insulation.

3. Effect as installed – traditional vs effective installations

The **Traditional** temperature-controlled building envelope installation may not hold temperature, may not keep ice and condensation from entering the building, and, if this occurs the facility will not be FSMA compliant and can contaminate food stored in the temperature-controlled facility.
The **Effective** temperature-controlled building envelope installation will hold temperature, will eradicate ice and condensation and keep each from entering the facility, is therefore FSMA compliant and will not allow contamination from ice and condensation.

4. Insulation usage – XPS versus PolyIso

Objectively, XPS (Extruded Polystyrene) (instead of PolyIso (Polyisocyanurate)) should be installed in all temperature-controlled building temperature zones throughout the typical distribution center building. These typical temperature zones are: -20°F (-28.9°C) ice cream freezer; -5° to -10°F (-20.6° to -23.3° C) freezer; 38°F (3.3°C) cooler / dock; 55°F (12.8° C) ambient room. Once the mean insulation temperature – the average temperature between the inside of the room and the outside – drops below 75ºF (23.9°C), XPS is the favored insulation as it retains its R-value per inch and, moreover, as the mean temperature of the insulation drops below 60ºF (15.6°C), XPS's R-value increases as PolyIso' s R-value drops precipitously.[2] Considering that most mean insulation temperatures for coolers and freezers are below 75ºF (23.9°C) AT ALL TIMES means that XPS is clearly superior.

-5ºF (-20.6ºC) to 55ºF (12.8ºC) Rooms: XPS is superior to any PolyIso installed in facilities whose rooms are at 55º or below in any climate [3]. Specifically:

a) **Efficiency- R-value**: PolyIso begins to lose its R-value significantly starting at 55ºF (12.8ºC) mean insulation temperature and drops by 50% or more at the -20ºF (-28.9º C) range.[3] Which means that it would take almost twice as much PolyIso (in thickness) to equal the same R-value as XPS on an Ice Cream Freezer. If it is assumed the R-value necessary at the Ice Cream Freezer and through to the 55º room is R-50, and IF ALL THE OUTSIDE TEMPERATURES ARE THE SAME:
   - If 8.3" of XPS (R-50/6) is used that equals 16.6" of PolyIso (R-50/3) on the Ice Cream Freezer -20ºF (-28.9ºC) room;
   - If 8.77" of XPS is used that equals 16.6" of PolyIso on the -5ºF (-20.6ºC) room;
   - If 8.9" of XPS is used that equals 13" of PolyIso on the 38ºF (3.3ºC) room; and
   - If 9" of XPS is used that equals 12" of PolyIso on the 55ºF (12.8ºC) room.

   So, as the room temperature reduces, XPS increases its efficiency. [3]

b) **Moisture Performance** - XPS possesses moisture performance over and above roofing grade PolyIso.[4] In the event of condensation build-up or a roofing failure, moisture will be partially absorbed by the PolyIso rendering its R-value as 0. The moisture that is not absorbed by the PolyIso will be passed onto the rest of the building and, in the case of freezers, the PolyIso can become frozen and fully contaminated. Most PolyIso insulation carries a manufacturer's warranty of 15 years. XPS is hydrophobic – it repels water. It does not become contaminated by moisture. If a roof needs replacement, the XPS (with a 50-year warranty) can be re-used. If the whole roof is water slogged, the XPS is unphased and continues its insulating efficiency. The same is true if the moisture or condensation is freezing in between the roof deck and the roof membrane – XPS maintains it insulating capabilities.

As stated earlier, when installing XPS, there is a gradual increase in thermal resistance as the mean temperature is reduced. That is because XPS insulation and roofing grade PolyIso use unique blowing agents and exhibit very different R-value versus temperature behaviors. As the mean temperature reduces the PolyIso insulation R-value drops due to condensation of the blowing agent. XPS behavior shows that XPS thermal resistance continually increases with reduced mean temperature.

Summary re: Insulation

1. **High Insulation Mean** temp over 75°F, (23.9°C) for only office space or ambient rooms **- PolyIso is superior**
2. **Moderate insulation mean** temp under 75°F, (23.9°C), all uses **- XPS is superior**
3. **Cold insulation mean** temperature under 50°F (10°C) all uses **– XPS is superior**

Caveat - Pricing
In any practical discussion regarding construction, material cost becomes a factor. It should be noted that XPS usually costs about 30% more than PolyIso. PolyIso costs between $.29 to $ .32 per board feet. XPS costs between $.39 and $.47 per board foot. On a typical temperature-controlled facility (900,000 bd. ft) the difference in price is substantial difference and is a 31% to 34% differential. However, as of this writing (7/2021), PolyIso, if it can be obtained, is priced at $.39 and XPS at $.41 a mere 5% difference.

5. Roofing membrane usage – PVC vs TPO vs EPDM

- The term PVC stands for Polyvinyl Chloride. PVC materials are produced by a chemical reaction, known as polymerization. PVC is produced by the gaseous reaction of ethylene with oxygen and hydrochloric acid;
- The term TPO stands for Thermoplastic Polyolefin. TPO is a blend of polypropylene and ethylene-propylene rubber; and
- EPDM stands for Ethylene Propylene Diene Monomer. It is a synthetic rubber derived from oil and natural gas (ethylene propylene).

PVC
While it is true that PVC is a relatively hard substance, the PVC that is used for roofing material has the benefit of plasticizers, which are added to make the membrane more pliable. Most PVC membranes are mechanically attached, though fully adhered or even ballasted PVC roofing systems are still occasionally found.

Heat Welded. What is almost universal, though, is that the PVC membranes are heat-welded at the seams. This creates a monolithic structure that is very durable and able to withstand the constant expansion and contraction of the building structure throughout the day, throughout its life. And the reason why PVC membranes are most often heat-welded at the seams is because of the added strength, durability, and stability of the material itself. The seam becomes stronger than the surrounding membrane.
While most other roofing products can come in either reinforced or non-reinforced material, PVC is reinforced right from purchase. Reinforcement typically indicates a polyester scrim, mat, or fabric mesh that is inserted into the material, like rod iron is used to reinforce roads or concrete walls. This reinforcement, which translates to quality, is one of the reasons why PVC is a little more expensive than TPO, though it is still competitively priced against EPDM. If overall quality is the criterion used to decide, PVC should be at the top of the list.[5]

TPO
TPO is probably the most widely used roofing product in the market today for two very good reasons: (1) it is relatively inexpensive and (2) it is white. Cheap does not always make something better, though. And being white is not really anything special, not anymore anyway. So, is there anything about TPO that makes it a viable option for a cooler/freezer roof?

Shrinkage - Over the years TPO manufacturers have revised and re-revised their proprietary formulations simply to get it to work. TPO is known to shrink and pull away from seams and curbs. The roofing consultants of Benchmark, Inc. did an extensive hands-on study of TPO: "Our investigations of our clients' roofs continue to identify issues with some TPO membranes: splitting and crazing along rows of fasteners, accelerated aging along walk pads, polymer erosion to the point of exposing scrim reinforcement; enough issues for us to have concerns [6] TPO's potential susceptibility to deterioration from exposure to high heat and / or UV (solar) loads.[6]

EPDM

EPDM can be either vulcanized, which means it can be dried out and cured into sheets, or it can be non-vulcanized, which leaves the material in a semi-solid state. The vulcanized EPDM is what is used as a roofing membrane. The non-vulcanized EPDM is usually used for detail work or flashing of the cured roofing material.

Shrinkage. A properly seamed and installed black EPDM roof is very good at handling rain, snow, UV rays, abrasions, ozone, and temperature fluctuations. In higher temperatures, however, the membrane – especially at the seams – can begin to shrink and pull apart. Animal and vegetable oils, as well as petroleum-based products are typically not good for EPDM membranes because of the swelling and distortion that can occur when such products meet the membrane.

Maintenance. As with TPO roofing systems, the seams are the most precarious for an EPDM roof. The membrane can last a long time, but the seams – even when properly installed – will dry out, shrink, and create problems. A properly cared-for EPDM roof can last a long time. But it is expensive to maintain.

Summary

PVC seems to be the most cost effective, warrantable, flexible and long-lasting value in the temperature-controlled market. See table 1 below, explaining the valuation propositions of each.

ISSUES	PVC	TPO	EPDM	Advantage
Same Material Top to Bottom	Yes	No	Yes	PVC - More mil thickness on top side of product; UV resistant layer.
Rip-resistant Cross Pattern Rein-forcement	Yes	No	Yes	PVC - poly reinforcement. Superior strength. Lower maintenance.
Custom Prefabricated Deck Sheets	Yes	No	No	PVC - Factory produced with same consistent weld in controlled environment. Less maintenance.
Sheet Construction	Factory prefabricated into panels up to 2,500 sq. ft.	Rolled goods only. 500 sq. ft. coverage per typical roll.	Rolled goods only. 1,000 sq. ft. coverage per typical roll.	PVC - One monolithic sheet when completed. Reduced rooftop labor.
All Flashing Material Reinforced	Yes	No	No	PVC - Factory produced with same consistent weld
Flashing Method	All heat-welded	Glue & heat-welded	Glue	PVC - Proven field-tested method.
Curbs & Stacks Custom Prefabricated	Yes	No	No	PVC - Same materials welded to field sheets
Scuppers and Parapets Custom Prefabricated	Yes	No	No	PVC - Factory produced with same consistent weld. Eliminates the most leak-prone and high-maintenance area on roof.

Seam Method	All hot air welded or dielectrically welded	Inconsistent welding window; glue and heat weld.	Glue	PVC - Most effective heat welding process used. Membrane to membrane bonding. No glues to break down over time.
Seam Strength Equal to Membrane Strength	Yes	Inferior when glued	Inferior	PVC - Maximum strength.
Expansion / Contraction	Beyond building requirements	Beyond building requirements	Beyond building requirements	PVC moves with building's expansion and contraction. No long-term maintenance at changes of plane.
Installation Disruption	Business as usual; minor installation noise.	Business as usual; minor installation noise.	Minor noise; possible fumes.	PVC & TPO - No fumes, harsh chemicals, tar, tankers, or quarantined areas.
Energy Efficient (Title 24 in CA)	Yes	Yes	Yes, with coating and maintenance	High reflectivity and remittance. Solar ready. Meets all required energy standards.
Every Roof Seam Inspected	Yes	No	No	PVC - Tech reps inspect every commercial installation.
Maintenance Requirements	Minimal maintenance required	Minimal maintenance required	Routine maintenance required	PVC and TPO
Recycle Program in Place	Yes	No viable products manufactured from waste.	No viable products manufactured from waste.	PVC 100% post manufacturing recycling. Post-consumer "recycle your roof" program in place.
Warranty				
Coverage For Ponding Water	Yes	No. Typically voids warranty.	No. Typically voids warranty.	PVC
Coverage for Consequential Damages	Yes	No	No	PVC
Warranty Coverage	Repair or replacement	Repair only	Repair only	PVC
Warranty Provided at No Extra Cost	Yes	No - 10 year and 20-year additional cost	No - 10 year and 20-year additional cost	PVC

Life-Cycle Cost Analysis: 10,000 Sq. Ft. Roof Over 20 Years				
Measurable Costs				
Initial roof product	$31,105	$30,816	$32,917	TPO
Installation (labor & overhead)	$9,590	$15,654	$17,442	PVC
Tear-off and disposal	$0	$12,500	$12,500	PVC - Normally required for TPO & EPDM
Regular maintenance (over 20 years)	$5,000	$10,000	$20,000	PVC - "Common sense" maintenance
15-year warranty	$0	$1,000	$1,000	PVC - Standard PVC commercial warranty is provided at no cost to the building owner.
20-Year Measurable Cost Total	$45,695	$72,970	$83,859	
Intangible Costs / Benefits				
Building disruption costs	Very Low	Medium	Higher	PVC
Roof repairs (over 20 years)	Low	Medium	High	Non-curing PVC membrane means lifetime weldability for repairs or other rooftop alterations.
Interior damage repair cost	Zero	More than zero	More than zero	PVC has warranties covering consequential damages.
Potential for energy and cost savings	High	High	Low	PVC and TPO (white) - Very high membrane reflectivity.
Energy rebates / incentives	Regional	Regional	Regional	Typically based on the energy savings delivered by white reflectivity roofs.

Table 1

6. Vapor barrier usage

Vapor Drive - Most construction or maintenance personnel may not know that Vapor Drive is costing them 15% to 35% and more in lost energy costs, and the resulting ice or condensation may violate FSMA, FDA and USDA regulations. What is vapor drive? It is simply the movement of humid warm air from one warm location to another colder location. In temperature-controlled environments, vapor drive results in drastically decreased energy efficiency and ultimately, condensation and ice buildup.[7]

Why Ice forms - Ice formation and contamination seem to be a universal problem in cold storage facilities. Whenever there is a discontinuity in the vapor barrier: warm, moist air flows over the tops of walls; in from loading docks, and between freezer, cooler, and battery rooms. The warmer air condenses from vapor to water, then freezes, contaminating insulation and product, and creating a costly, ongoing cleanup project.[8]

Current Practice - roofing detail

From experience, the author knows that General Contractors rely on roofing manufacturers and roofing installers to address the vapor or air barriers on a temperature-controlled construction project. We have been unable to find public details regarding vapor or air barriers from roofing manufactures addressing vapor barriers in temperature-controlled buildings. However, there are numerous articles by the roofing manufacturers that speak to vapor retarders and air barriers as they relate to roofing systems. One of those came closest to the issues when it was stated (emphasis added):

> "When we use a vapor retarder in a roof system it will also act as an air barrier as long as it is sealed at all perimeters and penetrations and is tied to the wall air barrier. …. A roof design that includes an adhered roof membrane with multiple layers of insulation (with board joints offset and staggered) over a vapor retarder/air barrier helps lower the risk that air—and the moisture it carries—will infiltrate the roof system. That reduction of air and moisture infiltration can then help improve roof longevity".[9]

There are 3 issues needing review that immediately arise from this approach:

1) with what is the roof system "sealed" (see note re: Spray Foam, below);
2) how is the retarder "tied" to the wall barrier; and
3) helps "lower the risk" of Vapor Drive but not eliminate it.

Those details are NOT included with most construction details from the roofing manufacturer. Most architects put in their plans that the detail "will be supplied by others". The General Contractor relies on the roofing contractor and the roofing contractor "seals" the "vapor retarder" as they are used to doing. Like a roof. No one is taking responsibility for the vapor barrier, and we could find no roofing manufacturer, nor General Contractor, nor Architect, nor roofing installation company that would guarantee that their vapor barrier would eradicate the ice/condensation cause by vapor drive and eliminate its reoccurrence.
A roof as traditionally installed is a great water barrier. As the above points out, all penetrations and all perimeters must be sealed to make it an air barrier.

Effective practice – install separate Vapor Barrier system stopping air

When one understands the nature of vapor drive and understands the industry's approach as delineated above, then one can understand the following comment:

"The goal of using an air (vapor) barrier is to reduce the leakage of conditioned air out of a building. Therefore, air barriers must be part of the building envelope. This should be a hint that air barriers are systems — a combination of materials — and the individual components of the building envelope have to all link together in such a way as to prevent air leakage. It should be obvious that roofing materials block air and might therefore be considered "air barriers." But to fully function as air barriers, they need to be installed correctly and tied into the wall elements and penetrations in such a way as to ensure there are no air leaks at those junctions and penetrations (emphasis added).[10]

Accordingly, Vapor Barriers should tie in all the building envelope components – roof membrane, roof insulation and wall structures. The Vapor Barrier should be a separate system but integrally linked to each building envelope component.

Use of Spray Foam. Many roofing and panel installers use spray foam to fill in the deck flutes before insulating the deck on the perimeters. They also use spray foam as a perimeter vapor seal. Spray foam works as long as the building does not contract or expand. Every temperature-controlled building contracts and expands (on the average about 1inch (2.54 cm) for every 400 feet (122 meters), 24 hours a day) and therefore the spray foam disconnects from the surfaces within months of application - its use as a vapor barrier is temporary, at best.

Separate Vapor Barrier system integrated to the roof membrane, insulation, roof deck and outside wall. There is a U.S. manufacturer (Vapor Armour, Inc.) that installs a vapor barrier with integration with the roof deck, the wall structure, the insulation and the roof membrane. It is a separate system, but integrated.

This system, according to Vapor Armour sales literature, is adhered to the roofing membrane and buried underneath it.

Summary – the experts agree that to stop air infiltration, ice and condensation from Vapor Drive the vapor/air barrier must be separate from and integrated into the building envelope.

7. Return On Investment – ROI

Although a well-researched and planned cost estimation and budget is necessary for the successful completion of any project, completing a return on investment (an ROI) analysis on specific projects is prudent to determine which types of projects deliver the best returns. Return on investment calculations are commonly used in conjunction with the decision-making process. Working through the figures on an individual project basis provides the opportunity to determine a projects' potential financial impact.

Initial Cost Analysis
Before doing the calculation, first assess the costs associated with the project. In construction projects, the bid/proposal usually includes a detailed cost analysis with a breakdown for different categories. Assessing costs for a simple ROI analysis on a single project will not factor annual expenses like the lease on building space and capital investments. The formula is isolated to the single project and only includes costs and returns associated with that individual event.

Construction Project ROI Formula – return on cost (ROC) analysis
There are different ways to calculate return on investment. However, for a project that has an immediate return of expense savings, it is preferred to see the ROI as a Return on Cost percentage. The analysis is then stated in terms of HOW MANY YEARS (months) it takes to recoup the cost of the project – to get a Return of the Cost of the project.[11]

So, first determine the contribution of the project (to expense reduction, profit, etc.) and then determine the project cost. Divide the cost of the project by its yearly/monthly contribution. The final figure is the number of years/months it takes to get a full return on the project cost. To determine the percentage return, divide 100 by that final figure.

Example 1
If you spend $500,000 on a project that contributes $100,000 a year in energy savings after the project is completed, you will have a Return of Cost in 5 years – the project pays for itself in 5 years. (Cost of project $500,000 divided by yearly contribution $100,000 = 5) You divide 100 by the Return of Cost final figure and you get the percentage ROI/ROC as 20% (100 divided by 5).

Example 2
If you spend $500,000 on a project that contributes $10,000 a MONTH in energy savings after the project is completed, you will have a Return of Cost in 50 MONTHS (4.16 years) – the project pays for itself in 4.16 years. (Cost of project $500,000 divided by monthly contribution $10,000 = 50 months; 50 divided by 12 is 4.16) You divide 100 by the Return of Cost final figure and you get the percentage ROI/ROC as 24% (100 divided by 4.16).

Completing the cost analysis and the returns is the most time intensive aspect of the process. The final calculation for the ROI requires only a few minutes when all of the figures are in order.

8. Case studies summarized - ROI analyzed

Information applied – actual building envelope projects' value indicators

We have discussed complying with the FDA/FSMA requirements (no ice or condensation allowed). We have set forth the requirements of an effective building envelope – roofing membrane (PVC recommended), insulation (XPS recommended), vapor/air barrier (separate from and integrated into the building envelope).

We have discussed how to determine the project's ROI and ROC. Now we must focus on determining the value (ROI/ROC analysis) of actual projects to determine whether constructing an effective building envelope is worth the cost of so doing. We offer two Case Studies that involve retro-fitting total building envelope replacements – roofing membrane, insulation removal and replacement and vapor barrier installation. In each instance the ROI/ROC were objectively determined over a 24-month time period, they were dramatic and prove out the representations made, above. (NOTE: Full Case Studies can be obtained, by contacting the Author or viewing them at: https://vaporarmour.com/case-studies. What follows are the summaries of each:

Case study 1 – Florida, United States

1. PRE-INSTALLATION - From the Forensic Evaluation, it was determined:
   a. Of the Facility's total roof deck's 98,400 Square Feet (9,142 m^2), at least 17,220 square feet (1,600 m^2) (17.5%) was contaminated;
   b. Of the Main Freezer and Ice Cream Freezer's roof deck's 48,096 square feet (4,468 m^2) at least 10,336 square feet (960 m^2) (21%) was ice contaminated
   c. Of the Ice Cream Freezer's roof deck's 7750 square feet (726 m^2) 100% was ice contaminated.

Final determination – Vapor Armour (VA) determined that:
- the vapor barrier had been compromised around the perimeter of the facility, around the perimeter of the Ice Cream Freezer, the dividing wall between Main Freezer and Loading dock and a viable vapor barrier needed to be installed
- the Polyisocyanurate (PolyIso) Insulation had been totally contaminated – moisture and ice had destroyed its R-value - and it needed to be removed and replaced with Extruded Polystyrene Insulation (XPS)
- The ammonia pipes needed to be vapor barriered, insulated and sealed
- Because the PolyIso insulation was compromised and the age of the roof, the roofing membrane needed to be replaced.

2. INSTALLATION – VA was contracted to
   a. remove all contaminated roof insulation and replace with XPS, in this case DOW "Blue Board";
   b. re-roof the whole facility in PVC roofing membrane, in this case Duro-last membrane;
   c. install Vapor Armour™ vapor barrier to the Main Freezer, Ice Cream Freezer, Loading Dock perimeters and dividing wall;
   d. Install Pipe Lock™ vapor barrier to the 15 pipe stands;

3. RESULTS

We analyze the results from this project in at least 3 variants: Energy Savings, ROI, and FSMA regulatory compliance.

   a. Energy Savings – **48%** We have reviewed the energy consumption for the 24 months previous to the project and for the 12 months after the project. We have been informed and have determined that the total reduction in Energy usage attributable to the total Building Envelope was 48% - representing a yearly savings of $276,379
   b. Return on Investment – ROI – 24.48%
   On a simple pay back analysis (ROC), the cost of the project ($1,129,000) divided by the energy savings alone gives a payback of 4 years 1 months – a 24.48% per annum return.
   c. FSMA and other Regulatory Compliance
   With this building envelope replacement and its 20-year systems warranty, the customer and the building can be FSMA, FDA, USDA and OSHA Compliant for 20 years.

Case study 2 – Illinois, United States

1. PRE-INSTALLATION - From the Forensic Evaluation, it was determined:
   - -10° F(-23.3°C) Freezer - freezer perimeter had extensive frozen insulation 40 feet into the roof field – over 54% of the roof's insulation was frozen

- 35°F (1.7°C) Cooler – of the 98,175 sq. ft. (9,121 m^2), 76,800 sq. feet (7,174m^2) of insulation was contaminated -- which is 78.2%
- 40° (1.7°C) Loading dock – 18,400 sq. feet (171 m^2) – 100% of the insulation was contaminated

Final determination – VA determined that:

- the vapor barrier had been compromised around the perimeter of the facility, including the Freezer, Cooler and Loading dock and a viable vapor barrier needed to be installed
- the Polyisocyanurate (PolyIso) Insulation had been totally contaminated – moisture and ice had destroyed its R-value - and it needed to be removed and replaced with Extruded Polystyrene Insulation (XPS)
- Because the PolyIso insulation was compromised and the age of the roof, the roofing membrane needed to be replaced.

2. INSTALLATION – VA was contracted to
   - install Vapor Armour™ vapor barrier to the Freezer, Cooler and Loading Dock perimeters;
   - remove all contaminated roof insulation and replace with DOW “Blue Board” XPS; and
   - re-roof the whole facility in Duro-last PVC roofing membrane.

3. RESULTS

The results from this project come in at least 3 variants: Energy Savings, ROI, and FSMA regulatory compliance.

a. **Energy Savings** – 40% We have reviewed the energy consumption for the 13 months previous to the project and for the 24 months after the project. We have been informed and have determined that the total reduction in Energy usage attributable to the Building Envelope was 40% - representing a yearly savings of $357,888

b. **Return on Investment – ROI – 26.08%**
On a simple pay back analysis, the cost of the project ($1,359,744) divided by the energy savings alone ($357,888) gives a payback of 3 years 10 months – a 26.08% per annum return.

c. **FSMA and other Regulatory Compliance**
With this building envelope replacement and its 20-year systems warranty, the customer and the building can be FSMA, FDA, USDA and OSHA Compliant for 20 years.

9. Discussion - ROI ramifications of FSMA compliance and energy savings with an effective building envelope

The primary objective and scope of this paper and corresponding Case Studies were to objectively determine what the effect of installing a state-of-the-art controlled temperature building envelope (correct insulation, vapor/air barrier and roofing membrane) on an existing freezer/cooler, if any. We have tried to clearly explain the effects a properly installed building envelope on freezers and coolers will have on Food Safety Modernization Act (FSMA) compliance and energy savings. We also have attempted to illustrate, by actual case studies, the proven ROI values on a return of cost basis for these Energy saving installation projects. The industry research and the results from a 2-year long case study on 2 separate full building envelope installations in the Mid-west and Southern U.S. show the results:

An effective temperature-controlled building envelope includes:

- XPS roofing insulation applied for an R-value of 35-50,
- a separate Vapor Barrier around the perimeter of the roof deck;
- a mechanically attached PVC roofing membrane over the top of the Vapor Barrier and insulation;
- all installed in a manner that the IMP walls, roof deck, and roof insulation are tied into the separate vapor barrier system

The results of this properly installed effective building envelope are:

- keeps Lysteria from entering the facility through Vapor Drive and congregating in the ice/condensation;

- 100% compliance with the ice and condensation restrictions of FSMA, USDA, FDA and OSHA restrictions on Ice and Condensation
- A <u>provable</u> energy savings of as much as 48% and 40%, respectively.
- A Return on Investment of 24.48% and 26.08%, respectively

The purpose of this study was to educate Building Managers, Operational Teams and Building Owners to help determine a rational scope of action towards building envelope construction in temperature-controlled facilities which: 1) complies with FSMA regulatory demands; 2) obtains energy savings; and 3) has the ROI justification for such projects on current, or to be constructed, freezers and coolers.

10. References

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