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Northampton JFK: Gym Retrofit

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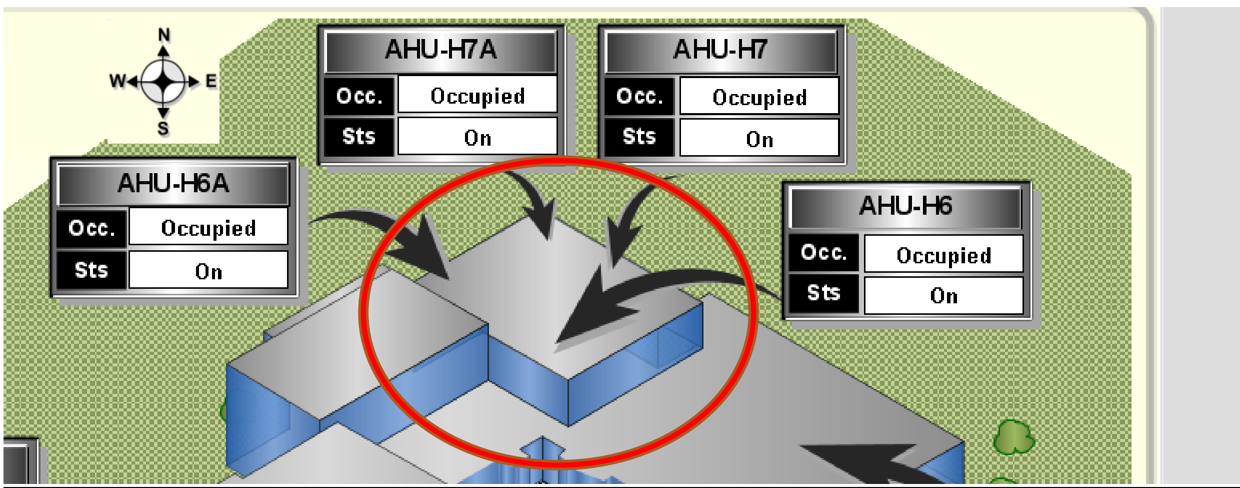
Current Conditions:

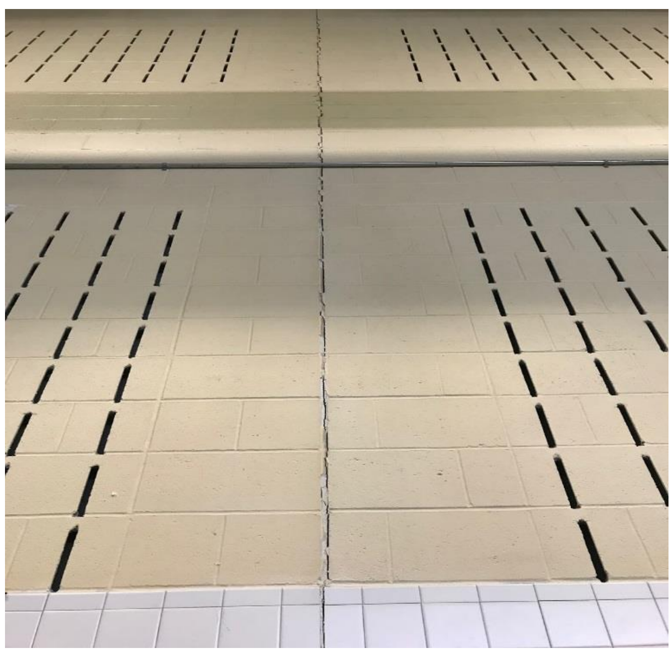
The JFK Middle School was built in the 1960s and has received minor renovations over the years, but many of its original structural elements remain. In the gym, there are four concrete block walls that cover a space of about 8,700 ft^2 and have a height of about 25 feet. These walls are either half-exposed, fully-exposed, or not-exposed. Some walls also contain sound reduction, which is an outdated technology that involved cutting slits into the concrete blocks. This technology does not actually work and leads us to a problem that will be discussed later in this report. Below is a representation of the gym along with both the exposure and the presence of sound-reducing slits for each wall:



	North Wall	West Wall	South Wall	East Wall
Exposure	Fully-Exposed	1/4 Exposed	Half-Exposed	Almost Fully-Exposed
Sound Reducing Slits?	Yes	No	No	Yes

As you can see from the figure above, there are four labeled heating distribution systems (AHU-H6a, AHU-H7A, etc.) for each corner of the gym. These systems force air out and downward toward the lower section of the gym. Regarding the insulation, there is foam board of about R-20 at the ceiling and fiberglass stuffed in between the structural beams at about R-2 pictured below:

At the walls there is no insulation, making it only R-2.8 due to the 4” external brick (R-0.8) and 8” internal concrete blocks (R-2). Along with this, the gym has no form of an air barrier and there is a large crack on the north wall pictured below:

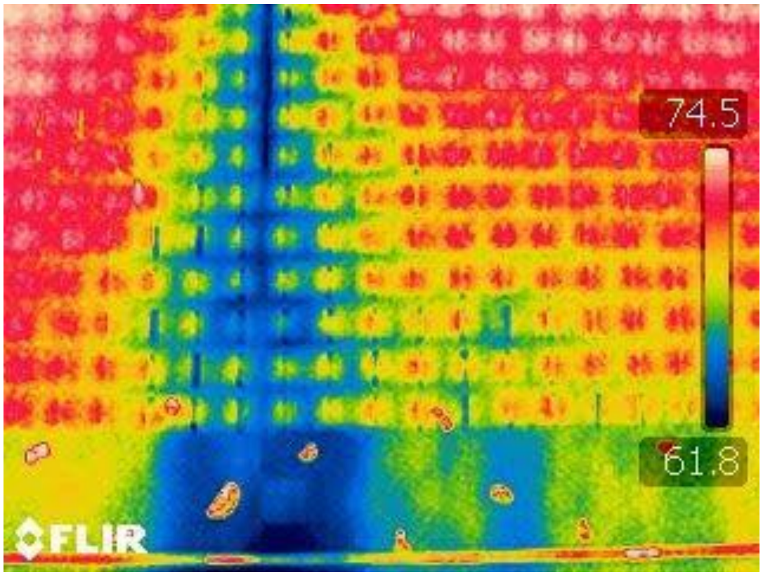


Problems:

The problems that I have come up with target three primary sections of the gym: the walls, the ceiling, and the structural columns:

Problem 1: Walls

With the fact there is no air barrier, large cracks, and the sound reducing slits on some walls, the main problem here is air leakage. The outside air has many ways to get through to the inside causing the cool air to enter. Below is a thermographic image that shows the major air leakage, especially at the major crack:



As you can see, the crack is the blue section which has a much lower temperature (~62°F) compared to the rest of the wall (~70°F) due to the cold air entering. Along with this, the walls are uninsulated and solely rely on their own makeup for insulation. At such a low R-Value (2.8) and air leakage, both a better form of insulation and air barrier needs to be implemented. <u>Note: For the entirety of this project I only considered the exposed walls to be included in calculations and propositions such as heat loss and material costs.</u>

Problem 2: Ceiling

Due to no air barrier and low insulation at the ceiling, cool air enters from above and increases the convection. The cool air drops down below and pushes the hot air up and out through the ceiling. There needs to be a better form of insulation on top of the R-20 and then a vapor-open air barrier.

Problem 3: Structural Columns

There is major air leakage at the structural columns lessening the potential R-Value of the insulation and letting cold air easily pass through. In the video below, you can see the air flow in the open cavity of the two I-beams:

https://www.youtube.com/watch?v=Viwnvf13Stg

We need to implement more insulation here along with an air barrier that is continuous with the wall retrofit.

Current Heat Loss:

To calculate the heat loss, I followed the equation Q = U x A x ΔT for each targeted section. This is necessary to compare to the new estimated heat loss after the proposed retrofit.

Walls:
-R-Value = 2.8
-U-Value = 1/2.8 = 0.357
-Area (only exposed sections) = (78' x 25') + (190' x 25') + ((78' x 25')/2) + ((190' x 25')/4)
= 8,800 ft^2 – 100 ft^2 (column area) = 8,700 ft^2
-ΔT = 70 - 0 = 70°F
-Q = 0.357 x 8,700 x 70 = **217,413 Btuh**

Ceiling:
-R-Value = 20
-U-Value = 1/20 = 0.05
-Area = 190’ x 78’ = 14,820 ft^2
-ΔT = 70 – 0 = 70°F
-Q = 0.05 x 14,820 x 70 = **51,870 Btuh**

Structural Columns:
-R-Value = 2
-U-Value = 1/2 = 0.5
-Area = (2’ x 25’) x 2 = 100’ ft^2
-ΔT = 70 – 0 = 70°F
-Q = 0.5 x 100 x 70 = **3,500 Btuh**

Currently, the total heat loss amounts to **272,783 Btuh**.

Current Air Leakage:

When calculating the air leakage, I included the major crack and sound reducing slits, as they are the only major air leakage sites in the gym.

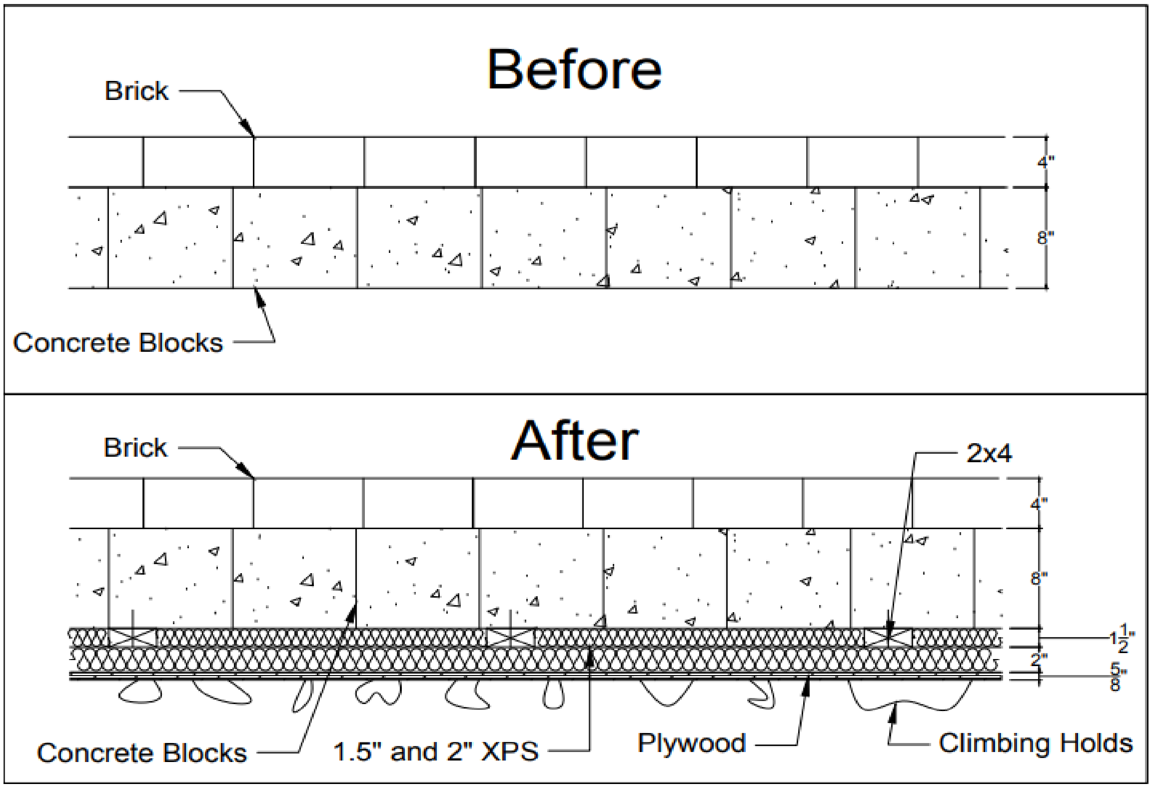
Permanence of Brick = 0.4 CFM50/ft^2
Perimeter = 405 ft
Cracksize = 0.016 ft
Roof-Wall Junction Crack = 6.75 ft^2
Through Brick = 2945.88
Brick ELA = 1.14 ft^2
Total ELA = 7.89 ft^2
CFM50 = 20,450.88
N-Factor = 16.8
CFMnat = 1,217

Solutions:

I have come up with three solutions to mitigate the heat loss and air leakage for each targeted area:

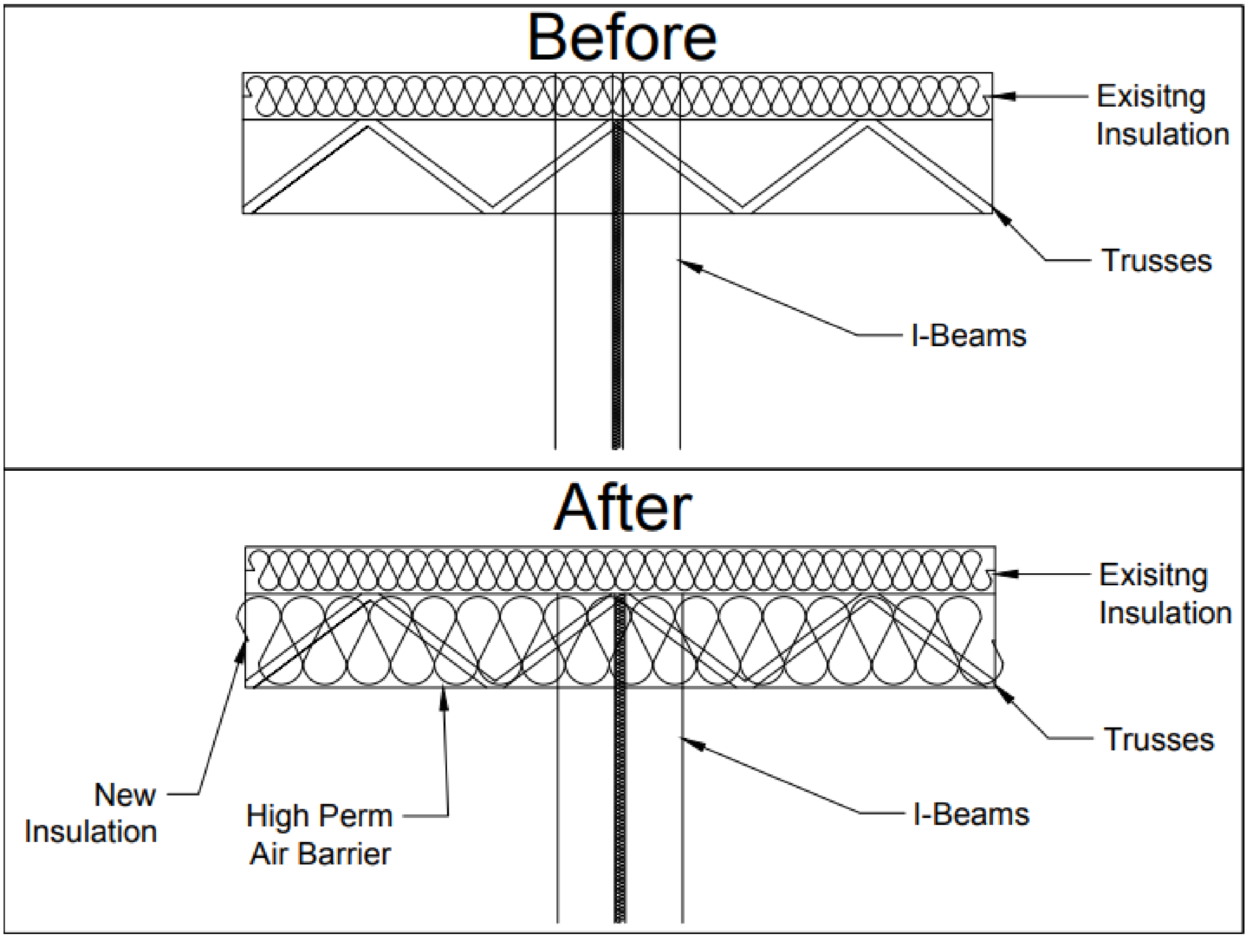
Solution 1: Walls

Air leakage is the first priority here, so a liquid air barrier membrane would be applied to all of the walls. This will be a continuous barrier that covers both the large cracks and sound reducing slits reducing almost all air leakage. On top of that there will be 2x4s drilled into the concrete blocks 27.5" apart on center. In between these gaps, 24" x 1.5" XPS boards will be inserted. XPS is a rigid foam insulation and has an R-Value of R-5 per inch. On top of that layer of 2x4s and XPS, there will be another 2" layer of continuous XPS to increase the R-Value by R-10. Then, 5/8" plywood will be attached through the XPS into the 2x4s and then into the concrete blocks. The plywood will provide the gym with an adequate finish as it is a sturdy material that can stand up to the standard activities that take place in a gym (like basketballs hitting it). An additional proposition is to attach multiple t-nuts into each piece of plywood and add rock climbing holds to increase the recreational value of the gym as well. This is a great opportunity to expand the activities that the gym offers while also supply it with an air barrier and a form of insulation. Below is a CAD drawing showing the before and after of this proposed solution:



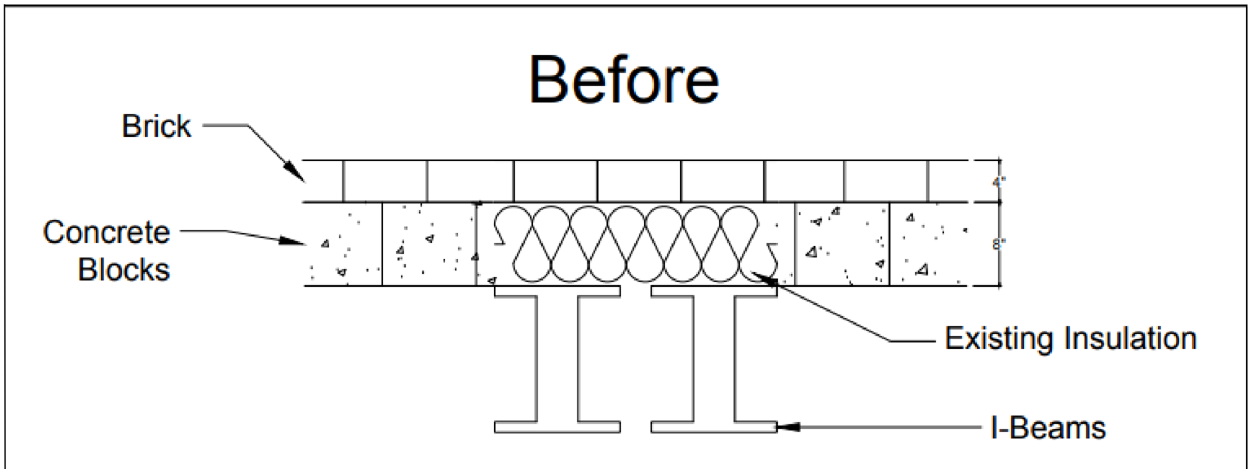
Solution 2: Ceiling

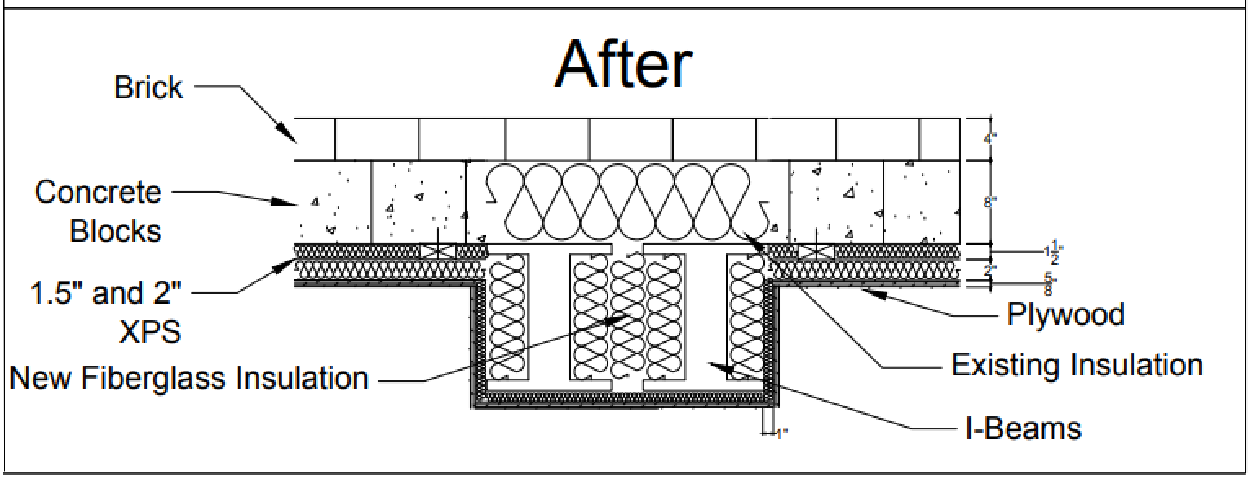
Conveniently, there are trusses beneath the ceiling at an estimated offset distance of 1 foot. This is an adequate space to fill in with fiberglass insulation as it can easily meet and gain structural support from the trusses while also making it a flush and organized appearance. So, 12" thick insulation would be installed to fill that space and add a substantial R-Value to the ceiling. To both cover the insulation and supply an air barrier, a layer of single bonded low density polyethylene with be attached under the fiberglass and into the trusses. Moisture buildup will occur in this filled cavity, so a high perm air barrier is needed, hence the low density polyethylene. With these two materials there will be both a much higher R-Value (R-63.2) and an air barrier that will successfully block air leakage. Below is a CAD drawing showing the before and after of this proposed solution:



Solution 3: Structural Columns

For the columns, the solution must be continuous with the plywood wall finish. To start, fiberglass insulation will be stuffed into the cavity between both I-beams. This will both increase the R-Value and remove the space that air can easily flow through. On top of that will be the air barrier. Closed cell spray foam, which is a dense form of polyurethane foam, will be sprayed to seal and provide an air barrier to the columns. This spray foam will meet with the liquid air barrier from the walls on each side, making a continuous air barrier for the walls of the gym. The plywood will then be attached and also meet with the walls on both sides. Below is a CAD drawing showing the before and after of this proposed solution:





Other Solutions:
The other solutions I came up with that I did not follow through with were using either dense or loose packed cellulose for the ceiling, but due to keeping the costs low I chose fiberglass. I also considered using gypsum board for the finish for the gym walls, but I decided I needed a more sturdy material like plywood.

Retrofit Costs:
Here are the estimated material costs for each solution.

Materials:
1.5”x 3.5” x 96” = $3.26 each
5/8” x 4’ x 8’ Plywood = $32.00 each
Closed Cell Spray Foam = $398.00 each kit
Liquid Air Barrier = $50.00 each gal
12” x 16” x 48” in Fiberglass = $406.98 for 8 bags (8 pieces in each bag)
10’ x 100’ Vapor-Open Air Barrier = $55.00 each
1.5” x 4’ x 8’ XPS = $24.00 each
2” x 4’ x 8’ XPS = $33.92 each
Rock Climbing Holds = ~1.00 each

Solution 1: Walls

Liquid Air Barrier
1 gal covers 28 ft^2
8,700 ft^2 / 28 ft^2 = 310 gal
310 x $50.00 = **$15,500.00**
2x4s
-Area (small wall) = 25’ in height, 78’ in length
    78’/2.3’ = 34
    25’/8’ = 3
    34 x 3 = 102
    102 2x4s needed for each small wall
    Exposed small walls = 1 1/2
    1 1/2 x 102 = 153 2x4s
-Area (large wall) = 300” in height, 2,280” in length
    190’/2.3’ = 83
    25’/8’ = 3
    83 x 3 = 249
    249 2x4s needed for each large wall
    Exposed large walls = 1 1/4
    1 1/4 x 249 = 311 2x4s
Total = 464 2x4s
464 x $3.26 = **$1,512.64**
1.5” XPS
0.29’ x 8’ = 2.32 ft^2
2.32 x 464 = 1,076.48 ft^2 (taken up space by 2x4s)
8,700 ft^2 – 1,076.48 ft^2 = 7623.52 ft^2 (space that will be taken up by XPS)
4’ x 8’ = 32 ft^2
7623.52 ft^2 / 32 ft^2 = 238.23
239 x $24.00 = **$5,736.00**
2” XPS
4’ x 8’ = 32 ft^2
8700 ft^2 / 32 ft^2 = 271 pieces
271 x $33.92 = **$9,192.32**
Plywood
4’ x 8’ = 32 ft^2
8,700 ft^2 / 32 ft^2 = 271 pieces
271 x $32.00 = **$8,670.00**
Rock Climbing Holds
1 hold per ft^2
8700 x 1 = 8700 holds
8700 x $1.00 = **$8,700.00**

Solution 2: Ceiling
Fiberglass
16” x 48” = 5.32 ft^2 x 8 pieces = 42.56 ft^2 x 8 bags = 340.48 ft^2
14,820 ft^2 / 340.48 ft^2 = 43 Pallets of 8 bags
43 x $406.98 = **$17,714.54**

Air Barrier

10’ x 100’ = 1000 ft^2

14,820 ft^2 / 1000 ft^2 = 15 rolls

15 x $55.00 = **$825.00**

Solution 3: Structural Columns

Fiberglass

100 ft^2 – 40 ft^2(I-Beams) = 60 ft^2

60 ft^2 / 42.56ft^2 = 1.4 pieces

2 pieces / 8 pieces = 1/4 of a bag

1/4 of a bag = **$12.70**

Closed Cell Spray Foam

1 kit = 120 ft^2

100 ft^2 /120 ft^2 = 0.83 kit

1 kit = **$398.00**

Plywood

4’ x 8’ = 32 ft^2

100 ft^2 / 32 ft^2 = 3.125 pieces

4 x $32.00 = **$128.00**

Table:

Below is a table to represent the cost of each section and the total cost of the retrofit.

	Cost
Walls	$33,810.96
Ceiling	$18,539.54
Structural Columns	$538.70
Total	**$52,889.20**

New Heat Loss:

With this retrofit there are new and improved R-Values and to display this, I calculated the new heat loss for each targeted section.

Walls:

-R-Value = 2.8 (Existing) + R-17.5 (XPS) + R-0.7 (Plywood) = R-21

-U-Value = 1/21 = 0.047

-Area = 8,700 ft^2

-Q = 0.047 x 8,700 x 70 = **28,623 Btuh**

Ceiling:

-R-Value = R-20 (Existing) + R-43.2 (Fiberglass) = R-63.2

-U-Value = 1/63.2 = 0.015

-Area = 14,820 ft^2

-Q = 0.015 x 14,820 x 70 = **16,414 Btuh**

Structural Columns:

-R-Value = R-2 (Existing) + R-21.6 (Fiberglass) + R-6 (Closed Cell Spray Foam) = R-28.4
-U-Value = 1/28.4 = 0.035
-Area = 100 ft^2
-Q = 0.035 x 100 x 70 = **246 Btuh**

So, with this proposed retrofit, the new heat loss amounts to **45,283 Btuh**. Compared to the current heat loss, you are saving **227,500 Btuh**.

Table:
Below is a table to represent the difference between the current and new heat losses.

	Current Heat Loss	New Heat Loss
Walls	217,413 Btuh	28,623 Btuh
Ceiling	51,870 Btuh	16,414 Btuh
Structural Columns	3,500 Btuh	246 Btuh
Total	**272,783 Btuh**	**45,283 Btuh**

New Air Leakage:
With the installation of a liquid air barrier along the walls, almost all air leakage will be reduced, so with that we can assume that the CFM_{nat} will be close or even completely 0. The reduction will be about 1,200 CFM_{nat}.

Results & Savings:
To display the savings, I first calculated the cash savings in heating fuel, then the installation and contingency cost, then finally the simple payback.

Savings in Fuel and Air Leakage:
Boiler Efficiency = 0.78
Fuel Cost = $1.00 per therm
With current heat loss: $7,145.38/yr
With new heat loss: $673.74/yr
Fuel Savings: $6,471.64
CFM Reduced = 1,217 = $2,289.99
Total Savings = $8,760.63

Overall Savings:
Installation Cost = ~$6.00/ft^2
Contingency = 10% of total = $5,288.00
Total Cost = $58,177.20
Simple Payback = 58,177.20 / 8,760.63 = 6.64

So, in about 6 1/2 years, you will have made all of your money back on the retrofit cost and begin to save money that would have instead been spent on fuel costs. This is a relatively good simple payback period. In conclusion, I hope you consider these proposals.

Sources:
1.5” XPS:
https://www.homedepot.com/p/Owens-Corning-Foamular-150-1-1-2-in-x-4-ft-x-8-ft-R-7-5-Scored-Squared-Edge-Insulation-Sheathing-88WD/202085958

2” XPS:
https://www.homedepot.com/p/Owens-Corning-FOAMULAR-250-2-in-x-48-in-x-8-ft-R-10-Scored-Squared-Edge-Insulation-Sheathing-52DD/202085962

Plywood:
https://www.menards.com/main/building-materials/panel-products/specialty-panels/specialty-sanded/5-8-x-4-x-8-premium-acx-plywood/1251063/p-1444424217907.html

Closed Cell Spray Foam:
https://www.amazon.com/Touch-Density-Spray-Insulation-Closed/dp/B013PSRHJ0/ref=sr_1_1_sspa?ie=UTF8&qid=1525971431&sr=8-1-spons&keywords=closed+cell+spray+foam+kit&psc=1

Liquid Air Barrier:
https://www.globalindustrial.com/p/janitorial-maintenance/paint/liquid-coatings/hydrohalt-water-vapor-barrier-membrane-1-gallon-hydhlt1g?infoParam.campaignId=T9F&gclid=Cj0KCQjw28_XBRDhARIsAEk21FgymRmIcMM5Nu6VjKlbCAgzKttGJQsEfwac3r6UDYXTN_RiBkS_iT8aApVVEALw_wcB

Plastic High Perm Air Barrier:
https://www.uline.com/Product/Detail/S-11178/Plastic-Sheeting/Clear-Poly-Sheeting-6-Mil-10-x-100?pricode=WB0369&gadtype=pla&id=S-11178&gclid=Cj0KCQjw28_XBRDhARIsAEk21Fi0-36SDQGUfWCfQnt_cOCccNcrY_IuXMcWPxZ-z01YoXQlyIQKpUcaAo2bEALw_wcB&gclsrc=aw.ds

2x4:
https://www.homedepot.com/p/2-in-x-4-in-x-96-in-Premium-Kiln-Dried-Whitewood-Stud-161640/202091220

Fiberglass:
https://www.homedepot.com/p/Owens-Corning-R-38-Kraft-Faced-Fiberglass-Insulation-Batt-16-in-x-48-in-8-Bags-BF80/205471413?cm_mmc=Shopping%7CG%7CBase%7CD22%7C22-4_INSULATION%7CGeneric%7CPLA%7CAllInsulation%7c71700000033760329%7c58700003913725483%7c92700032578143900&gclid=Cj0KCQjw28_XBRDhARIsAEk21Fgg40lXOdMxuHAnkMGYBi65HOIMC_vXD6ZG36Fd9k0Q46sHgII4QKwaAntXEALw_wcB&dclid=CMTj5OjN-9oCFVhGDAodAuQPgg

Rock Climbing Holds:

https://www.rei.com/product/780883/metolius-greatest-chips-screw-on-holds-package-of-40?CAWELAID=120217890000797385&CAGPSPN=pla&CAAGID=15877507240&CATCI=aud-54816614184:pla-285203057976&cm_mmc=PLA_Google|404_37072|7808830017|none|c39f2828-1486-4a99-87b8-d03fdb927589|aud-54816614184:pla-285203057976&lsft=cm_mmc:PLA_Google_LIA|404_37072|7808830017|none|c39f2828-1486-4a99-87b8-d03fdb927589|aud-54816614184:pla-285203057976&kclid=c39f2828-1486-4a99-87b8-d03fdb927589&gclid=Cj0KCQjw28_XBRDhARIsAEk21Fh6blBiB_If3iljhCj8k_BrExaR78AOCFrAX-QLHoZB3RgryqrmR5UaAiq2EALw_wcB