Thermal Performance Evaluation of Innovative Metal Building Roof Assemblies

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U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
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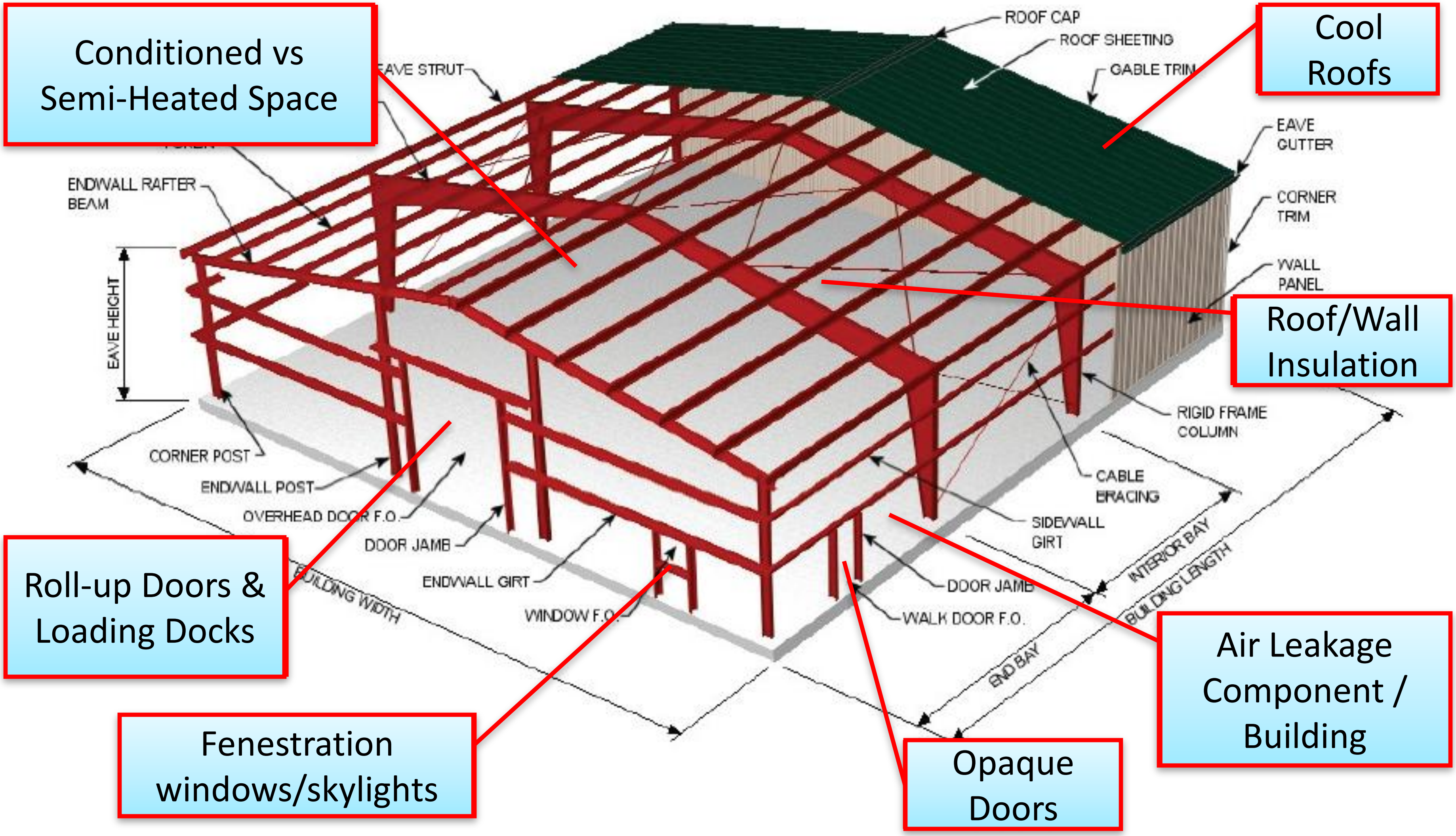
Disclaimer

- **MBMA does not promote the use of any particular type or combination of insulations to meet the codes**
- **The roof systems shown are still in development and may not be appropriate for use at this time**

Anatomy of a Metal Building



Metal Building Applications

Sports Facility

Health Care Facility

Community Facility

Aircraft Hangar

Restaurant

Office Building

Introduction – Why This Work Was Needed

- The demand for increased energy efficiency in commercial building energy codes & standards
  - I-Codes
    - International Energy Conservation Code (IECC)
    - International Green Construction Code (IgCC)
  - ASHRAE
    - 90.1 – Energy Standard for Buildings Except Low-Rise Residential Buildings
    - 189.1 – Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings

What Drives Code Development?

- Building Codes
  - IBC, NFPA 5000 are life-safety codes
  - Minimum standards are set to protect loss of life
- Energy Codes
  - IECC, ASHRAE 90.1 set minimum requirements for energy conservation → this is not a life-safety issue
  - Minimums can be set in two ways:
    1. Economic Justification (i.e. cost effectiveness)
    2. Legislative Mandates (the law)

Construction is Getting More Complicated

- In order to meet the coming energy codes, multiple layers of various insulation types will be required
  - Example is fiberglass insulation in walls with rigid board on the exterior
- The demand for greater efficiency has pushed insulation levels beyond the cavity depth
- Education of design professionals, building officials and contractors is needed to ensure that performance levels are being achieved

Assembly U-Factors vs R-Values

- U = Thermal Transmittance
  - Measured in Btu/h•ft^2•˚ F
- U is the reciprocal of R (U = 1/R)
  - Technically true, but for insulation only
  - Assemblies are comprised of many R's that vary
- So really, U-Factor = 1/R_{Total}
- How are U-Factors derived?
  - For MBS - Only from hot box tests or computer modeling
  - You can not add R-values of insulation unless they are continuous and uncompressed

More About U-Factors

- Lower U-Factors have better performance
- Higher U-Factors have worse performance
- Therefore, U-0.04 is better than U-0.05
  - How much better?
    - U-0.04 = R-25
    - U-0.05 = R-20
- Why should we use U-Factors?
  - R-values don't tell the whole story
  - U-Factors allow flexibility in what you can provide
  - Codes & standards are moving toward U-Factors
    - 2009 IECC added U-Factors, ASHRAE always had them
    - Advantage of using U-factors:
      - COMcheck has trade-off capabilities for roofs and walls
      - You can use U-factors to trade-off roof and wall insulation as well as fenestration performance

Evaluation of Metal Roofing Systems-Scope of Work

- Cooperative Research with ORNL & MBMA
  - MBMA provided design concepts and donation of materials and labor
- Promising roofing systems with improved thermal performance over the levels accepted in the ASHRAE 90.1 standard
  - Evaluation in the Large Scale Climate Simulator (LSCS)

    ASTM C1363
  - Up to 10 systems
  - Evaluation at winter and summer conditions
  - U values of 0.040 (R-25) or better
- Identify more cost-effective ways of constructing “next generation” metal roofing systems with improved thermal performance

Why This Work is Needed

- Codes & standards developing entities are pushing for higher insulation assemblies
  - ASHRAE 90.1, IECC
  - ASHRAE 189.1, IgCC, LEED
- Current code requirements have already "maxed out" the known performance of common systems
- Some of the "high" performance systems in codes were developed using R-values long ago and may not be the best option now

IECC 2009 – Metal Building Insulation (Roofs)

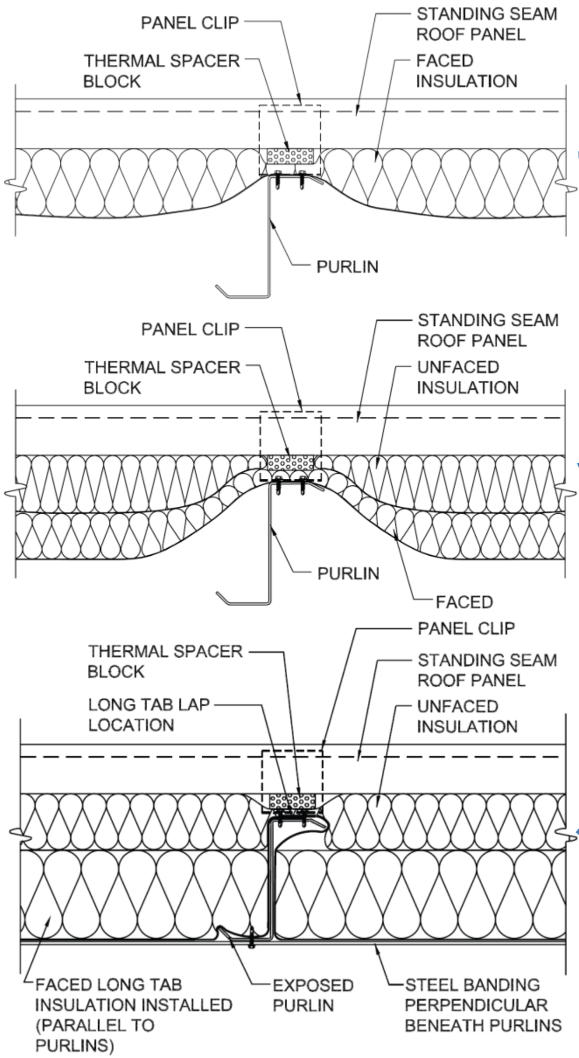
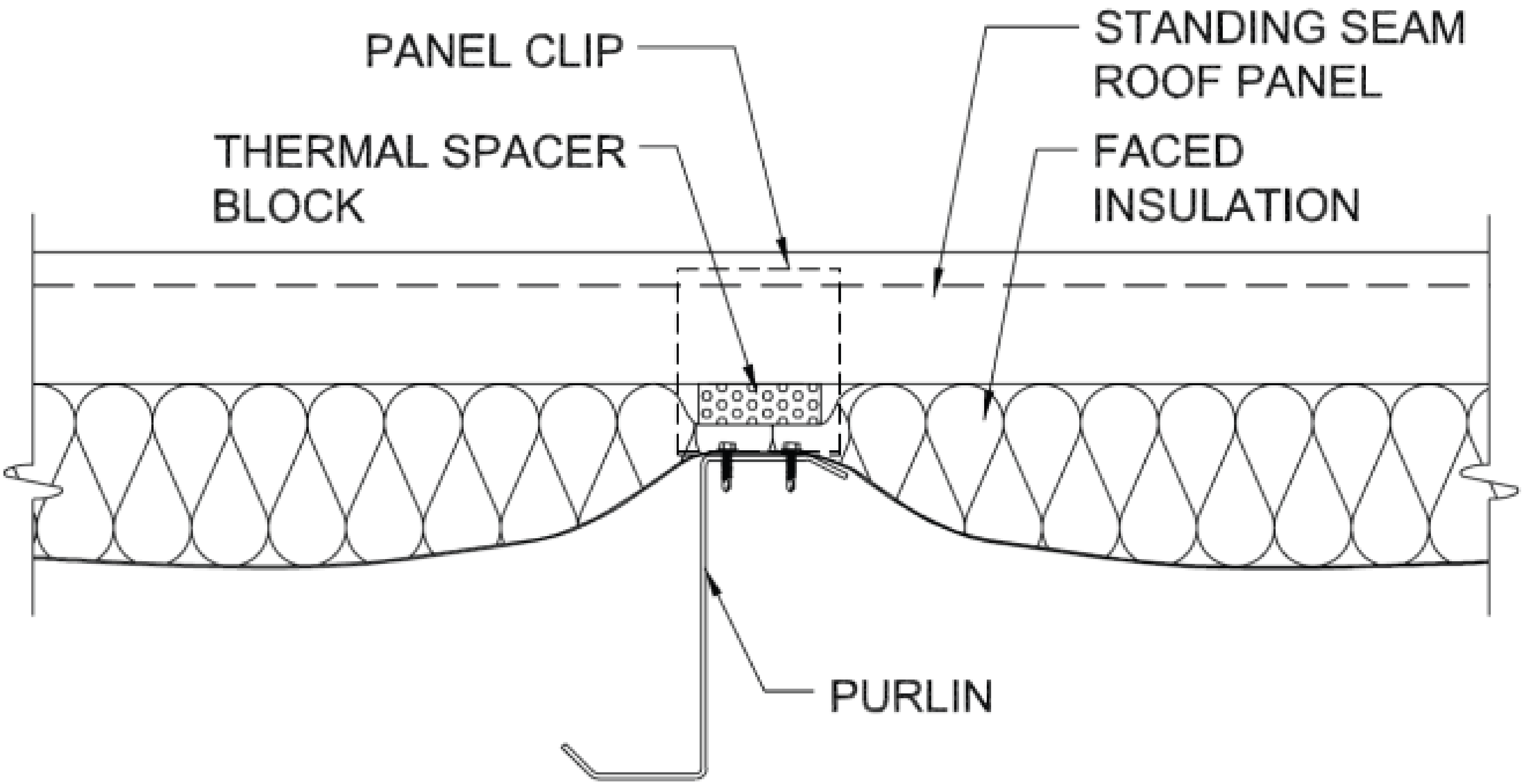


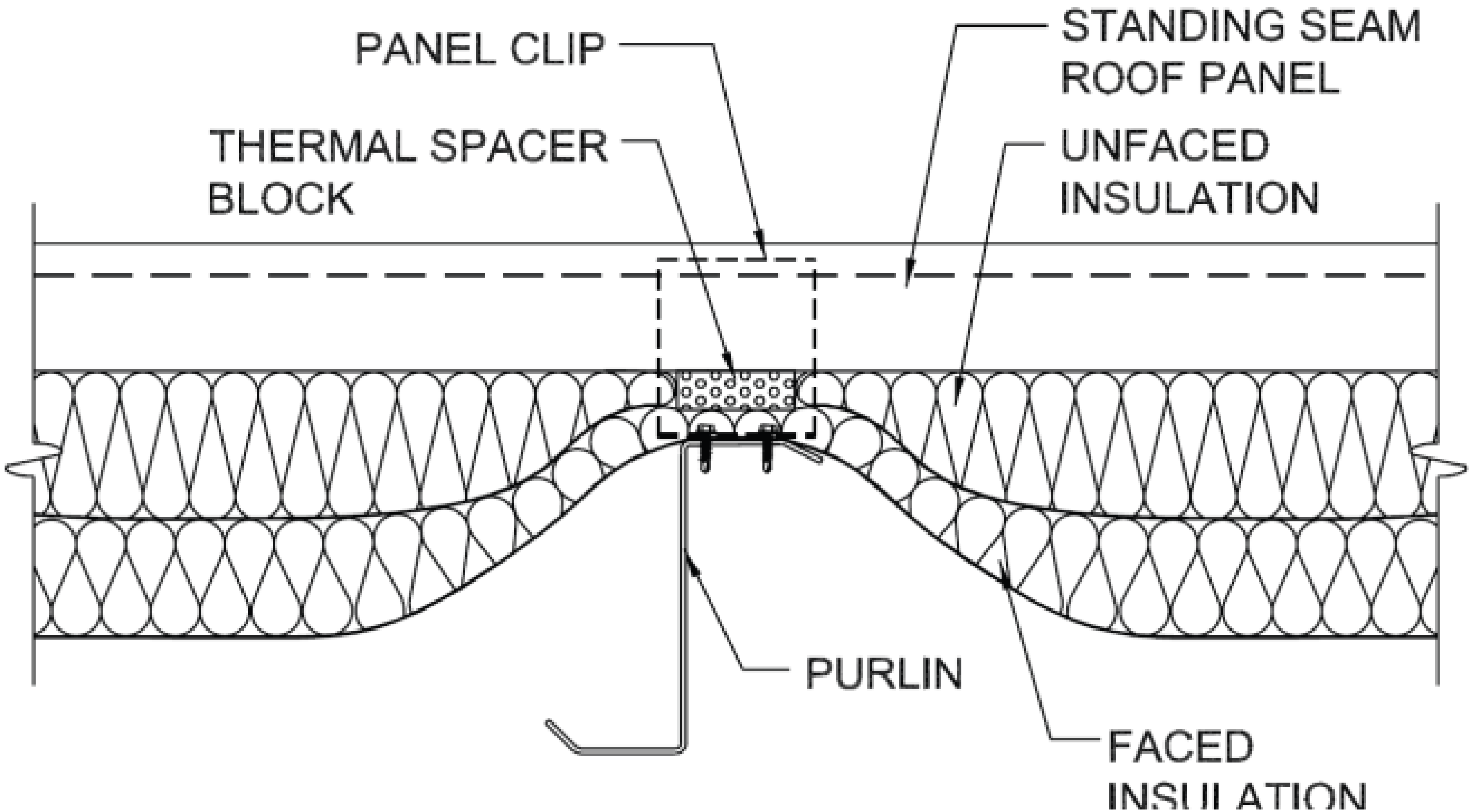
TABLE 502.2(2)
BUILDING ENVELOPE REQUIREMENTS–OPAQUE ASSEMBLIES

ROOFS	DESCRIPTION
R-19	Standing seam roof with single fiberglass insulation layer. This construction is R-19 faced fiberglass insulation batts draped perpendicular over the purlins. A minimum R-3.5 thermal spacer block is placed above the purlin/batt, and the roof deck is secured to the purlins.
R-13 + R-13 R-13 + R-19	Standing seam roof with two fiberglass insulation layers. The first *R*-value is for faced fiberglass insulation batts draped over purlins. The second *R*-value is for unfaced fiberglass insulation batts installed parallel to the purlins. A minimum R-3.5 thermal spacer block is placed above the purlin/batt, and the roof deck is secured to the purlins.
R-11 + R-19 FC	Filled cavity fiberglass insulation. A continuous vapor barrier is installed below the purlins and uninterrupted by framing members. Both layers of uncompressed, unfaced fiberglass insulation rest on top of the vapor barrier and are installed parallel, between the purlins. A minimum R-3.5 thermal spacer block is placed above the purlin/batt, and the roof deck is secured to the purlins.
WALLS	
R-16, R-19	Single fiberglass insulation layer. The construction is faced fiberglass insulation batts installed vertically and compressed between the metal wall panels and the steel framing.
R-13 + R-5.6 ci R-19 + R-5.6 ci	The first *R*-value is for faced fiberglass insulation batts installed perpendicular and compressed between the metal wall panels and the steel framing. The second rated *R*-value is for continuous rigid insulation installed between the metal wall panel and steel framing, or on the interior of the steel framing.

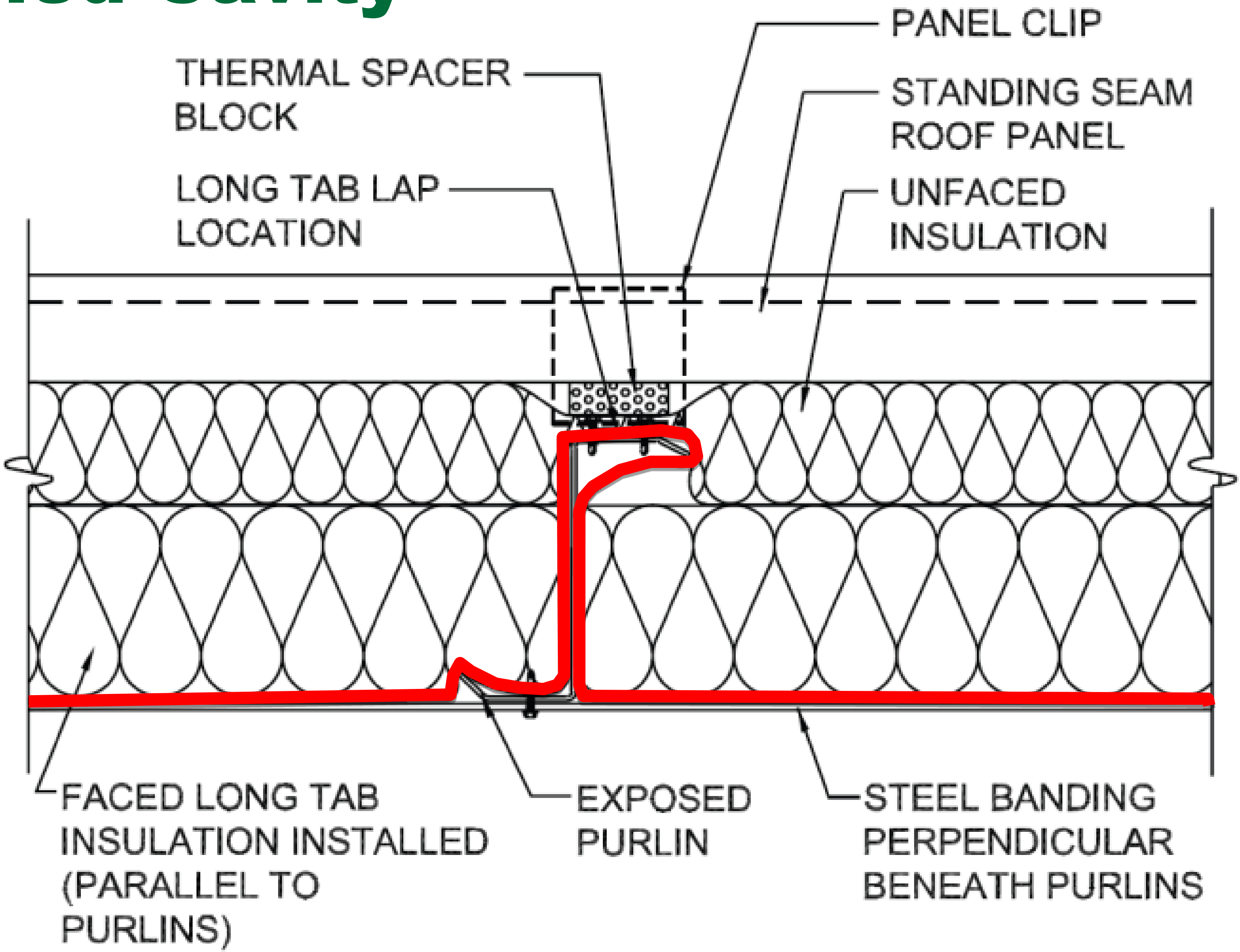
Single Layer of Fiberglass



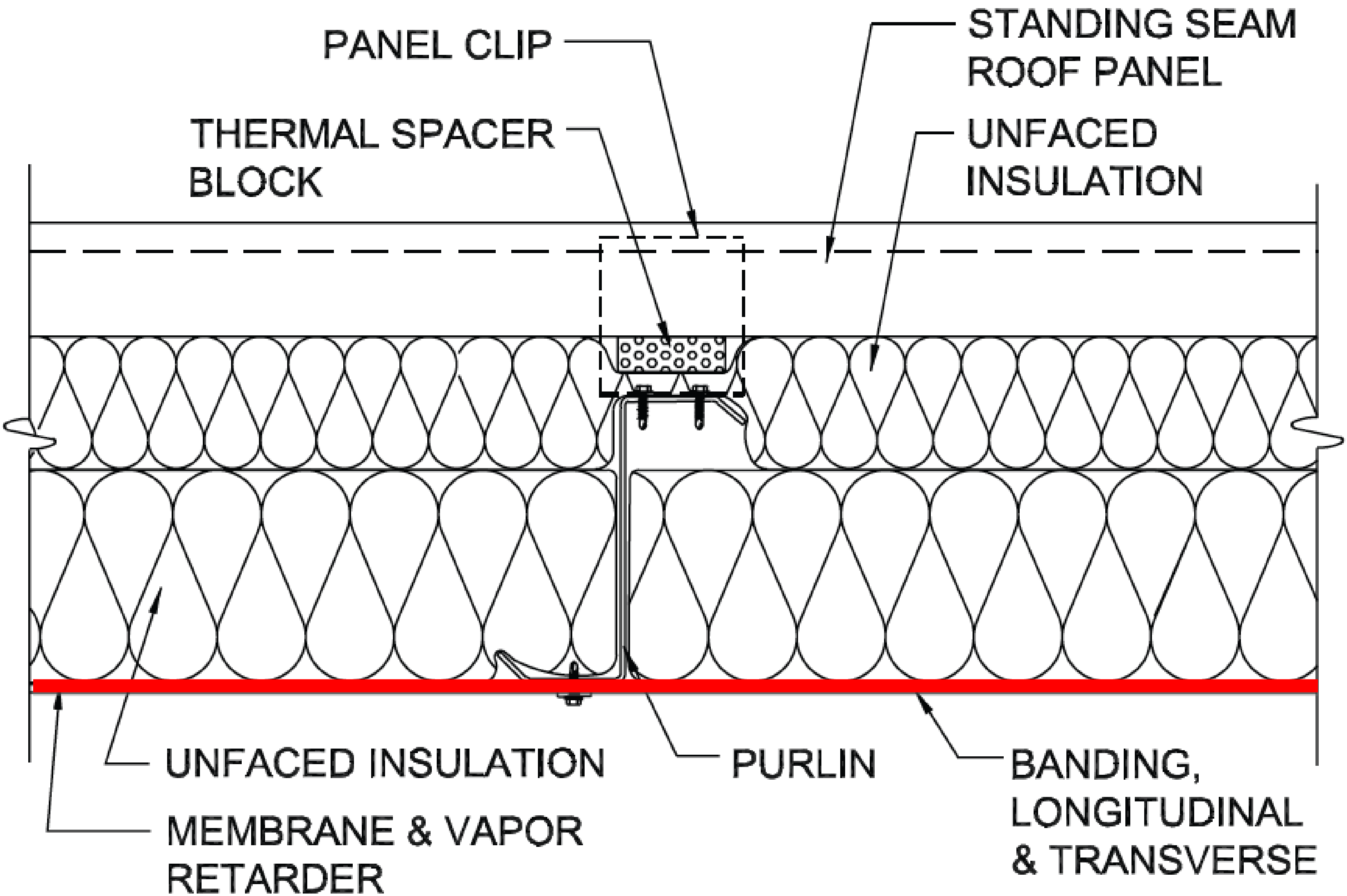
Double Layer Fiberglass



Filled Cavity



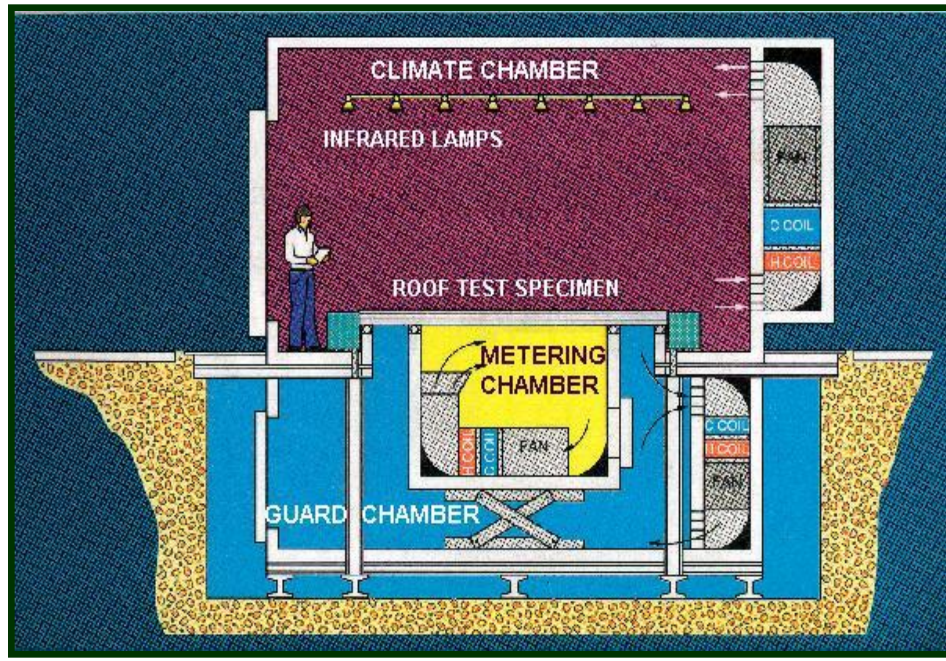
Liner System



The Experiments

Steady-State Guarded Hot Box Evaluation in LSCS (ASTM C1363)

- Standing-seam metal roofs (SSR) with purlins 4 ft oc
- LSCS provides controlled conditions above & below roof test sections
- Test module 12.5 ft square with metering area of 8 ft square
- Completed 4 test modules



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One Basis of Comparison

- To make an apples-to-apples comparison, we make the following comparison:

$$\Sigma R_{measured} / \Sigma R_{rated}$$

- For example, R-13 fiberglass between 2x4 stud wall spaced 16" o.c. ($U_{ASHRAE} = 0.089$)

$$1 / 0.089 = R_{total} = 11.2$$

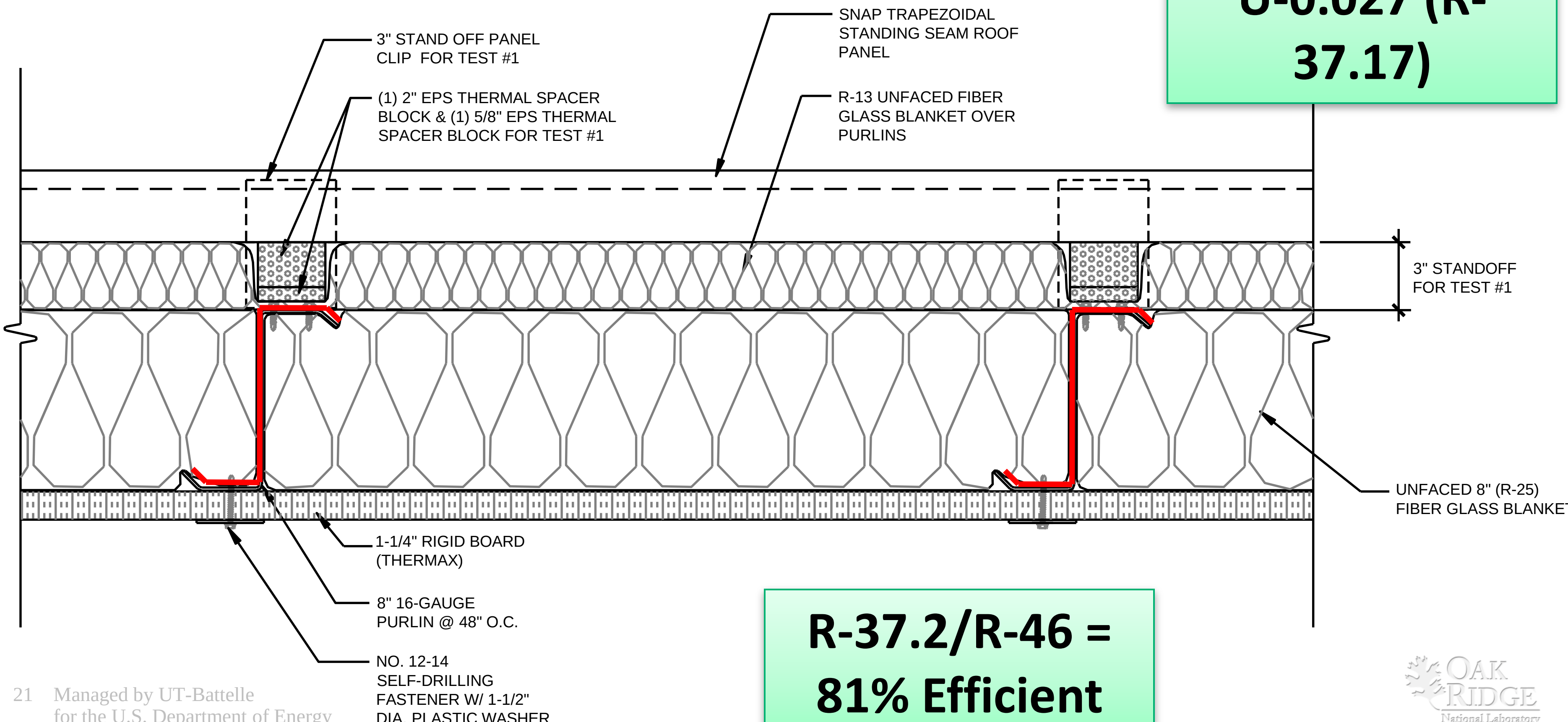
$$11.2 / 13 = \underline{86.4\%}$$

The Assemblies

MBMA – Module 1

- 3” stand off panel clips (specially fabricated for this experiment)
- R-13 over the purlins and R-25 between purlins with 2-5/8” expanded polystyrene thermal blocks between clips
- 1.25” faced polyiso board below the purlins

Result:
U-0.027 (R-37.17)

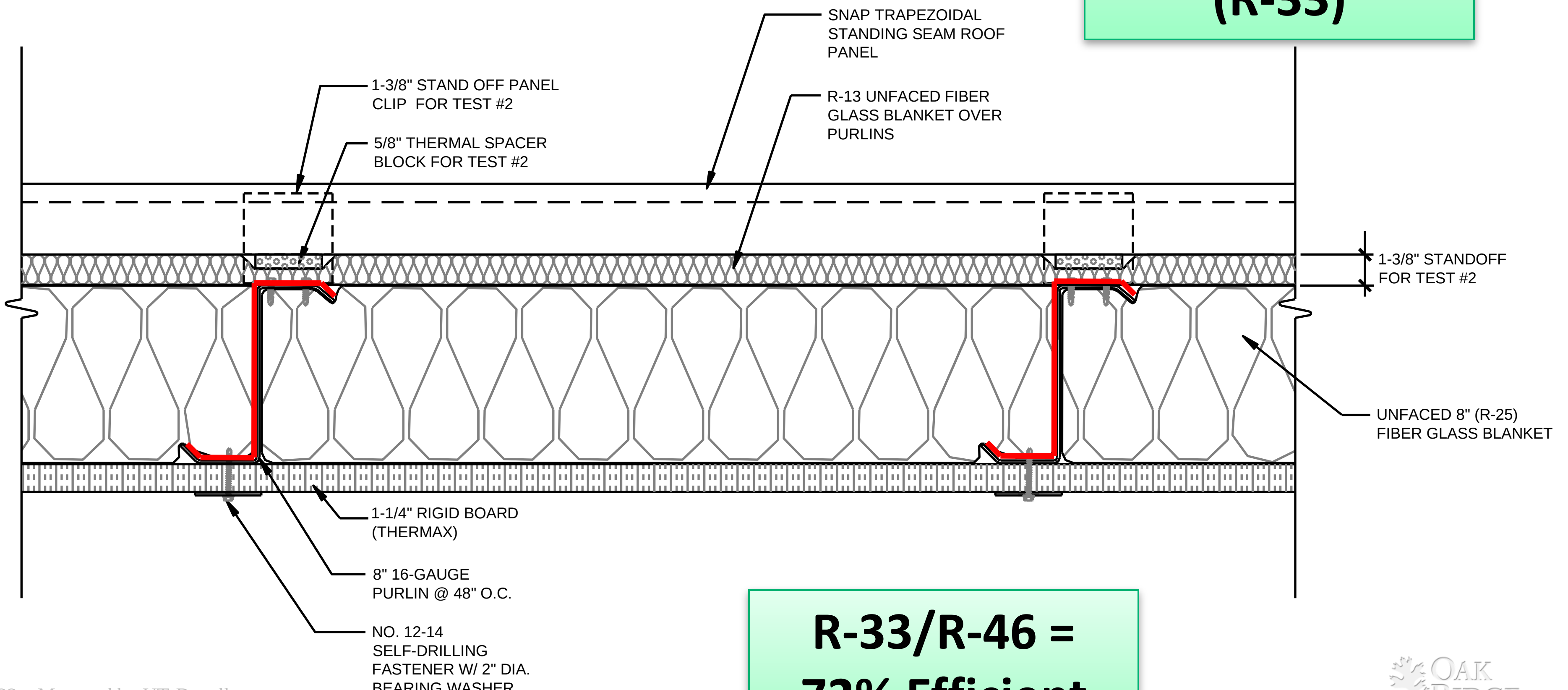


R-37.2/R-46 = 81% Efficient

MBMA – Module 2

- 1 3/8" stand off panel clips (standard clips)
- R-13 over the purlins and R-25 between purlins with 5/8" expanded polystyrene thermal blocks between clips
- 1.25" rigid board at the bottom of the purlins

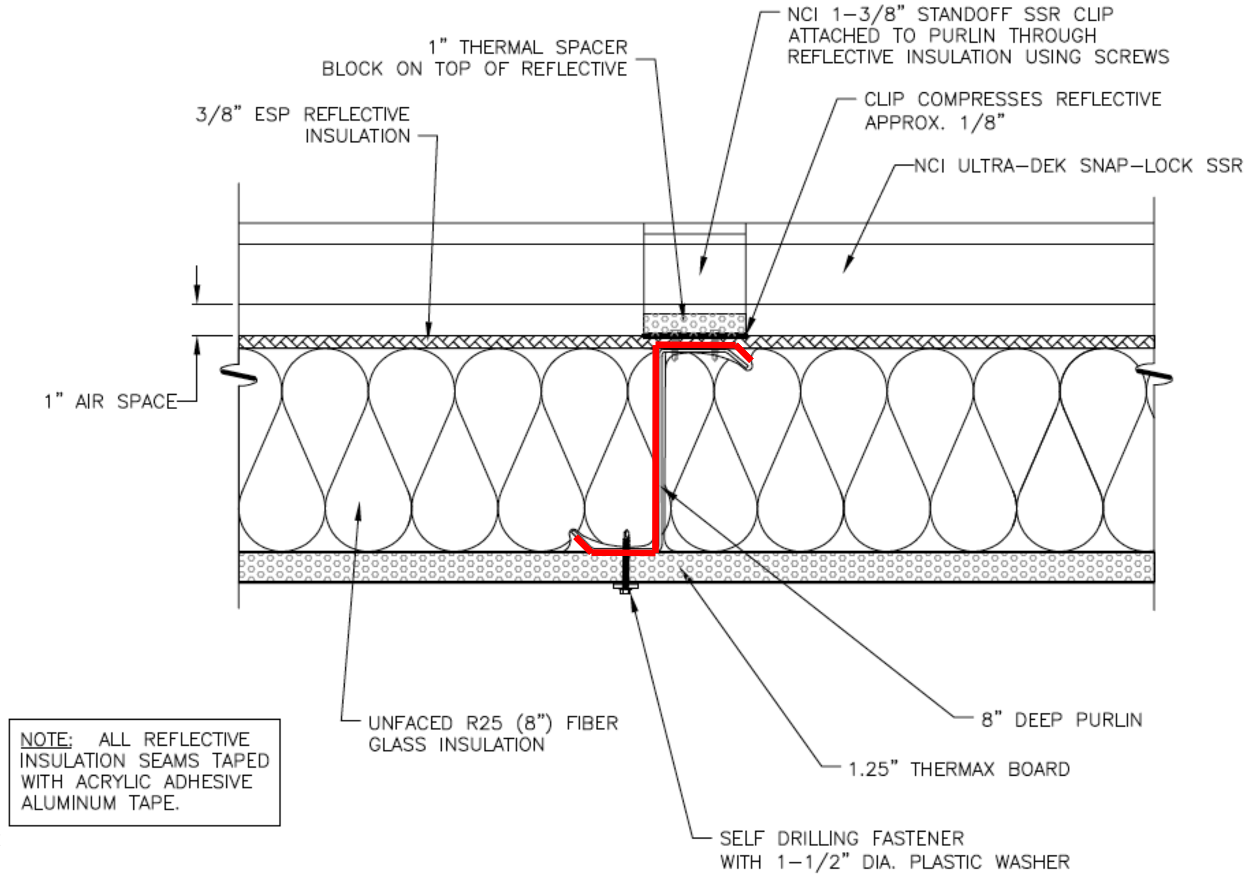
Results:
U-0.030
(R-33)



R-33/R-46 = 72% Efficient

MBMA – Module 3

- 1 3/8” stand off panel clips
- 3/8” reflective insulation over the purlins and R-25 between purlins with 1” thermal blocks between clips
- 1.25” rigid board at the bottom of the purlins



Results:
U-0.033 up
U-0.038 down

R-30.6 up
R-26 down

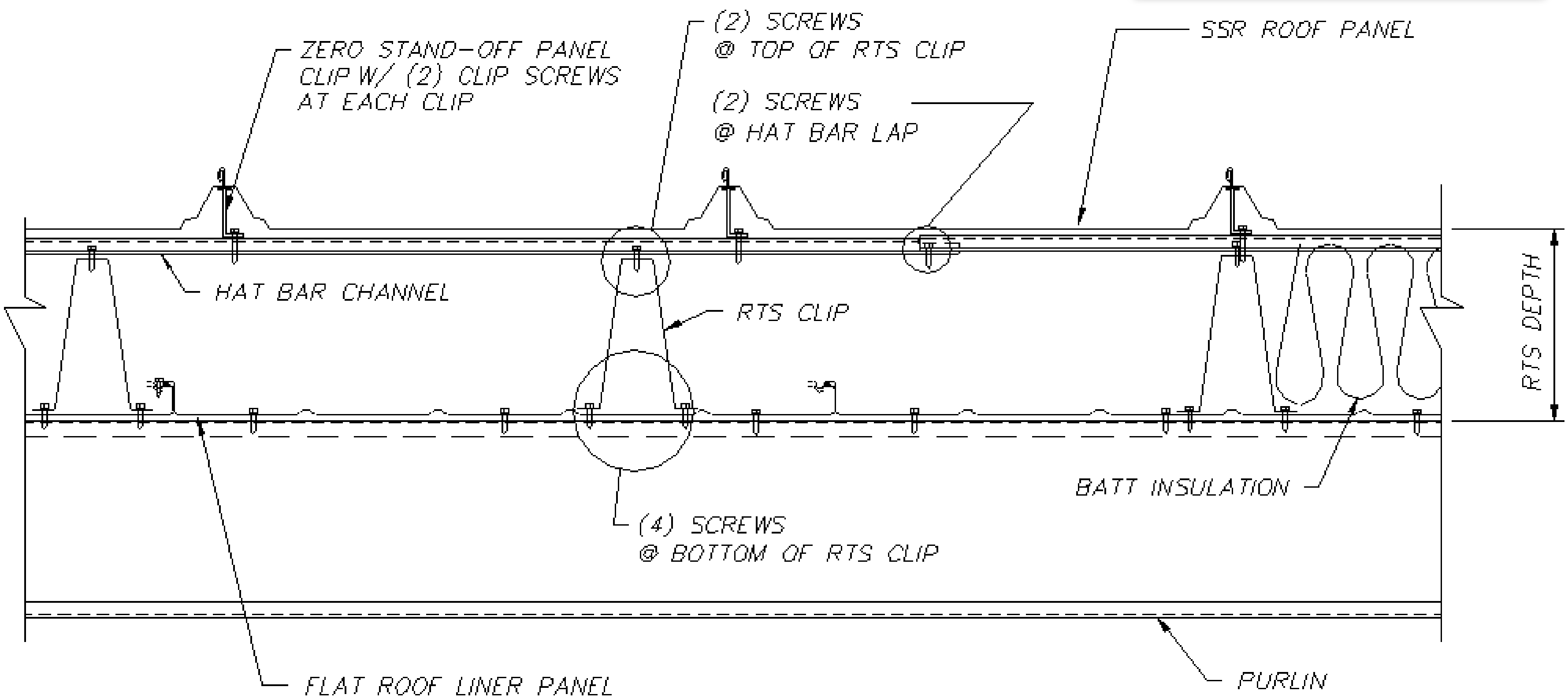
R-31/R-36.13 =
85% Efficient

MBMA - Module 4

- Twin skin – two metal panels used, first one is metal liner over purlins
- 12” Tall roof standoff clip raises roof surface above purlins
- Zero clearance roof clip attaches to hat channels
- R-30 + R-13 fiberglass laid on top of metal liner panel

<u>Results:</u>
U-0.032 (R-31)

R-31/R-43 =
72% Efficient



Future Plans

- Continue this collaborative work to evaluate additional modules
  - Possible further investigations on parameters of the first four modules
  - Improved metal building walls are also of interest to MBMA

In Closing…

- These experiments show the potential for improving metal building roof thermal performance
- Additional work is currently being done by several stakeholders, so the data is expanding
- These experiments are for R&D purposes, and may not be viable for immediate use
  - The following are among the things not investigated in this study
    - Structural performance
    - Fire resistance
    - Durability
    - Constructability on full-scale buildings