Measuring Heat Flux?

Measuring radiant barrier coating thermal values with thermocouples is not as simple as measuring temperatures on bare surfaces or on traditional materials.

Indicated temperatures on surfaces are subject to an instrument's ability to effectively measure different spectrum (wavelengths) than heat energy flux.

· Electronic thermocouples only sense heat flux from visible light to near infrared range.

· Glass mercury thermometers can sense heat flux from visible light to mid infrared range.

· The human hand can sense heat flux from visible light to far infrared range.

This is why executives at Fluke Instruments have stated, “We measure temperature, not heat”.

And it’s another reason why ACS relies on indirect methods to measure performance, with the exception of a “thermesthesiometer”.

Methods for showing thermal values?

- Performance references from the field.
- Indirect testing: side-by-side comparisons measuring amperage, steam condensate, or fuel consumption.
- "Calibrated" IR Instruments with Emissivity set to 0.84.
- Indirect measurements on cold side or direct measurements on warm side.
- Direct measurement using the basis for personnel protection standard testing, a "Thermesthesiometer". (ASTM C1057-03)

Performance from the field

This chart's data was gathered from reports from vessels working in the regions shown. They specifically cited successful performance based on the Ceramic Insulation Coating (CIC) thicknesses shown.

	Operating Zone	Under Insulation - 2" Fiberglas Board or Blanket	With Paneling & Air Gap	With Insulated Paneling & Air Gap	Exposed Coating Only	Surface Treatment or Top Coat
Interior Surface with Exterior or Weatherdeck Exposure	Pacific Northwest or Temperate Climates	40 mils/ 1mm	60 mils/ 1.5mm	40 mils/ 1mm	60 mils/ 1.5mm	Latex or Urethane
	Alaska	40-60 mils/ 1-1.5mm	80 mils/ 2mm	60 mils/ 1.5mm	80 mils/ 2mm	Latex or Urethane
	Arctic Antarctica	80 mils/ 2mm	120 mils/ 3mm	80 mils/ 2mm	120 mils/ 3mm	Latex or Urethane
	Arabian Gulf	80 mils/ 2mm	80 mils/ 2mm	80 mils/ 2mm	120 mils/ 3mm	Latex or Urethane
Interior Surfaces without Exterior Exposure	Pacific Northwest or Temperate Climates	40 mils	40 mils/ 1mm	40 mils/ 1mm	40 mils/ 1mm	Latex or Urethane
	Alaska	40-60 mils/ 1-1.5 mm	40-60 mils/ 1-1.5mm	40 mils/ 1mm	80 mils/ 2mm	Latex or Urethane
	Antarctica	60 mils/ 1.5mm	60 mils/ 1.5mm	60 mils/ 1.5mm	80 mils/ 2.5mm	Latex or Urethane
	Arabian Gulf	60 mils/ 1.5mm	60 mils/ 1.5mm	60 mils/ 1.5mm	100 mils/ 2.5mm	Latex or Urethane
Exterior Application for Hot Climate Solar Heat Loading	30-40 mils (1.5mm)					Urethane

Indirect Testing measuring amperage of side-by-side heated cylinders

Thickness (mils)		Primer thickness (mils)	Net Coating Thickness	Time tested (hours)		Temperature (input)		KW usage difference from control
*95.3		3.2	92.1	24:10		200°F		14.7%
*116.6		3.2	113.4	24:00		200°F		17.6%
*144.2		3.2	140.8	25:52		200°F		21.0%
*145.8		3.2	142.6	72:00		200°F		38.3%

The test results at the bottom were taken with a 5 mph wind blowing across the cylinders. (Courtesy of JBT Food Tech, Madera, CA)

Indirect testing measuring condensate volumes from side-by-side steam lines on food processing equipment demonstrated 25% efficiency

Bill Riker of DelMonte Foods measured steam condensate produced in side-by-side 6” steam lines.

Steam traps were used to capture condensate at front and back-ends of coated/uncoated lines.

Net difference was 25% less condensate produced by insulated pipe.

Condensate volume value-based “steam cost model”

ENERGY SAVINGS				
	Incoming Raw Water Temp To Boiler	(deg F)	60	
	Length Of Cooker Service Per Year	(days/yr)	90	
	Average Daily Cooker Operation	(hrs/day)	21	
	Length Of Cooker Service Per Year	(hrs/yr)	1890	
	Average Condensate From Heat Loss	(lb/hr)	250	
	Heat Of Steam Entering Cooker	(btu/lb)	1196	
	Heat Of Raw Make-Up Entering Boiler	(btu/lb)	28	
	Heat Lost By Condensate	(btu/lb)	1168	
	Heat Lost By Condensate	(btu/hr)	292,000	
	Boiler Efficiency	(pct)	94.0%	
	Gas Required For Heat Loss	(btu/hr)	310,638	
	Portion Of Heat Loss Eliminated	(pct)	25%	
	Heat Loss Eliminated	(btu/hr)	77,660	
	Unit Cost Of Natural Gas	($/mmbtu)	$5.000	
	Natural Gas Savings	($/hr)	0.388297872	
	Natural Gas Savings	($/yr)	733.8829787	
INSTALLATION COST				
	Houlry Wages Of Application Crewmen	($/hr)	$30	
	Size Of Crew	(men)	2	
	Shell Cleaning Rate	(sq ft/crew hours)	275	
	Application Rate	(sq ft/crew hours)	825	
	Number Of Layers To Apply	(count)	5	
	Average Shell Size	(sq ft)	825	
	Labor Required For Cleaning	(man-hours/shell)	6	
	Labor Required For Coating	(man-hours/shell)	10	
	Labor Required, Total	(man-hours/shell)	16	
	Labor Costs	($/shell)	$480	12.1%
	Coating Coverage Rate	(sq ft/gal)	41.25	
	Material Required	(gal/shell)	100	
	Unit Material Cost	($/gal)	$35.00	
	Material Cost	($/shell)	$3,500	87.9%
	Total Cost	($/shell)	$3,980	
	Utility Rebate Rate	(pct)	25%	
	Net Cost	($/shell)	$2,985	
PAYBACK				
	Simple Payback With Utility Rebate	(years)	4.1	
	Simple Payback Without Utility Rebate	(years)	5.4	

This chart shows the factors of cost to produce steam and the 25% savings from using ACS CIC to insulate steam-based cooking equipment. The data was generated by Bill Riker, Chief Engineer for Del Monte Foods. His test measured volumes of steam condensate cooled to water gathered from steam traps on side-by-side steam lines. One line was coated with ceramic insulation coating and one was un-insulated. This value is less than the 38% savings advised by JBT Food Tech, the world’s leading maker of food cooking equipment. This value also does not account for the equipment operating while in service, only to warm up to service temp.

Indirect measurement of fuel consumption for 2 seasons

- Kinder Morgan insulated 5 tank tops at their Staten Island terminal and measured fuel oil used to heat the #6 oil tanks.
- A 9% difference was measured between one year and the next during the months of October, November & December.

This allows ROI modeling based on fuel cost, application cost and savings for a payback time of 2.8 years based on original costs. Coating cost could be adjusted downward to provide a 2 year or less ROI.

ThermTest, Inc.
Conductivity Testing - June, 2014

Table 2. .75 mm Double Sided Coat - Directional Thermal Properties at 100°C

Temperature (°C)	Axial Thermal Conductivity (W/m·K)	Axial Thermal Diffusivity (mm^2/s)	Radial Thermal Conductivity (W/m·K)	Radial Thermal Diffusivity (mm^2/s)
100	0.1180	0.1852	0.1772	0.2781
	0.1179	0.1850	0.1766	0.2773
	0.1179	0.1851	0.1776	0.2788
	0.1171	0.1838	0.1805	0.2833
	0.1170	0.1837	0.1810	0.2841
	0.1177	0.1847	0.1796	0.2819
Mean	0.1176	0.1846	0.1788	0.2806
Standard Deviation	0.0004	0.0006	0.0017	0.0026
RSD (%)	0.3	0.3	0.94	0.94

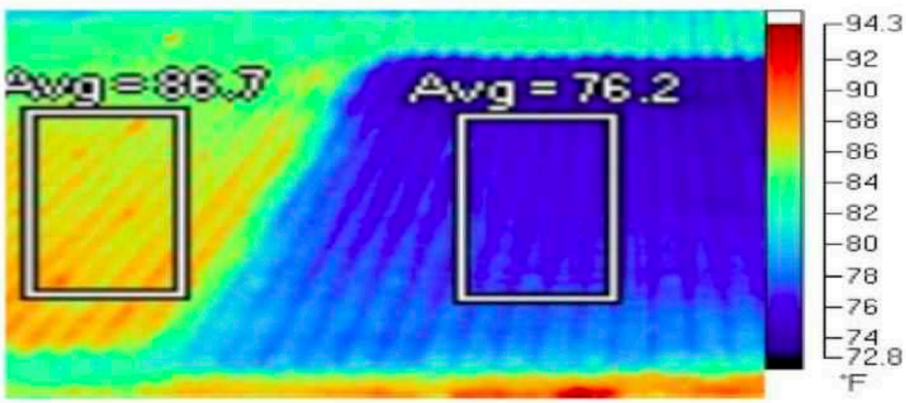
Notes: Measurements were made using the TPS Anisotropic Analysis Method and TPS sensor #5501 (6.403 mm radius) with Kapton® insulation. A test time of 40 seconds and output of power to the TPS sensor of 0.025 Watts was determined to be optimal measurement parameters.

Conductivity value is based on measuring rate of heat transfer through mass. Because thin insulation coating has little mass and primarily blocks radiant heat transfer, conductive-based testing hasn't accurately measured CIC's full range of thermal efficiency. To our knowledge, ThermTest's equipment provides appropriate testing of thin materials conductivity-based thermal efficiency. However, it doesn't measure radiation barrier characteristics of CIC.

"Calibrated" Infrared Scan #1

The building below was coated with several test patches of ACS Ceramic Insulation Coating (CIC) and scanned with infrared thermography. The results show a surface temperature that's 10F lower than white paint and 9F lower than the ambient temperature at that time of day. The coated section is over a cold storage room at 42F and accounts for the lower surface temperature.

Roof section temperature comparison white paint vs. ACS ceramic insulation -#5

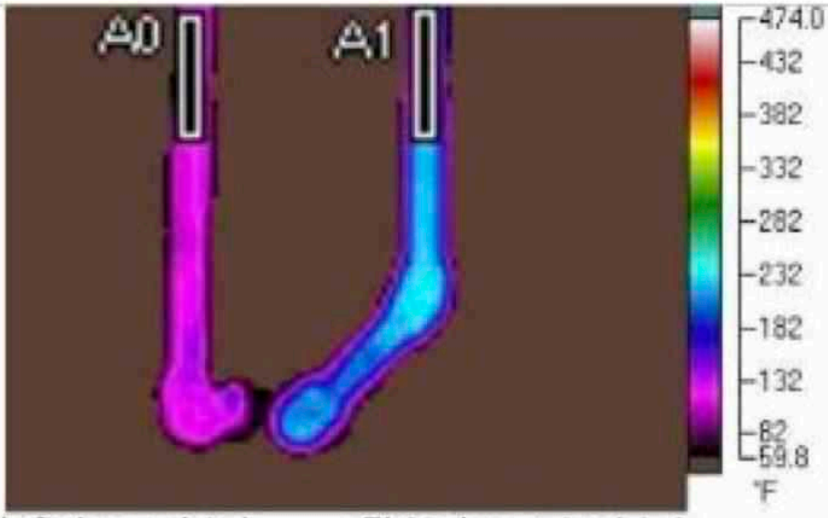


Background temperature	85.0°F
Image Range	70.3°F to 96.1°F
IR Sensor Size	128 x 96

Main Image Markers

Name	Avg	Min	Max
Insulation Coating	76.2°F	74.1°F	78.2°F
Standard white paint	86.7°F	84.0°F	90.2°F

Calibrated Infrared Scan #2



Left pipe - painted   Right pipe - not painted

Left pipe-painted   Right pipe-not painted

Name	Avg	Min	Max	Emissivity
A0	119.9°F	88.3°F	131.8°F	0.84
A1	214.6°F	171.9°F	228.9°F	0.84

Background Reflective temperature	390.0°F
Emissivity	0.84
Average Temperature	56.8°F
Image Range	40.9°F to 234.0°F
Camera Model	FLUKE-TI20 US
IR Sensor Size	128 x 96
Calibration Range	5.0°F to 680.0°F

The steam pipe on the left was coated with ceramic insulation coating and the right is not. The surface temperature reduction was approximately 44% as measured with the FLIR equipment calibrated to 0.84 Emissivity. According to Mitchell Stuart, Sr. Product Marketing Manager at Fluke Corporation, this is a valid calibration when all other guidelines are followed.

"Indirect" measurement of underside of insulated roof – Stemilt Growers, Chinchiolo, CA

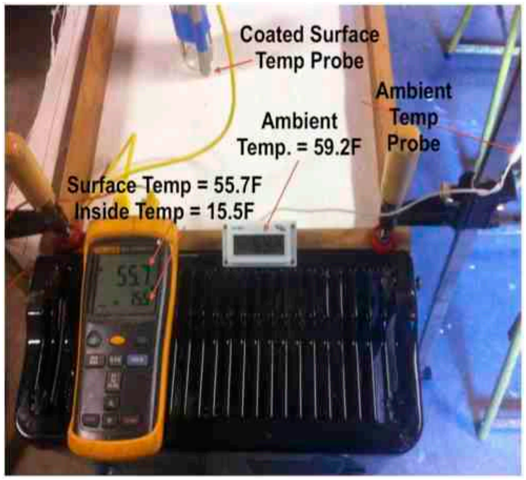
Date	Time	Below Roof Temp F (uncoated)	Below Roof Temp F (coated)	Coated vs Uncoated Temp Difference in F
8/02/13	0:00	61.52	65.66	4.1
8/02/13	1:00	60.26	64.22	4.0
8/02/13	2:00	60.44	64.22	3.8
8/02/13	4:55	55.76	60.26	4.5
8/02/13	5:00	55.4	59.9	4.5
8/02/13	6:00	56.66	60.26	3.6
8/02/13	7:00	60.8	62.24	1.4
8/02/13	8:00	75.38	68	-7.4
8/02/13	9:00	87.98	77.36	-10.6
8/02/13	10:00	96.08	85.82	-10.3
8/02/13	11:00	105.62	95.9	-9.7
8/02/13	12:00	113	100.76	-12.2
8/02/13	13:00	117.68	105.26	-12.4
8/02/13	14:00	118.58	107.78	-10.8
8/02/13	15:00	119.3	108.68	-10.6
8/02/13	16:00	114.26	106.34	-7.9
8/02/13	17:00	109.4	103.28	-6.1
8/02/13	18:00	101.12	98.24	-2.9
8/02/13	19:00	91.76	92.84	1.1
8/02/13	20:00	81.86	85.1	3.2
8/02/13	21:00	74.48	78.8	4.3
8/02/13	22:00	70.52	74.48	4.0
8/02/13	23:00	66.74	70.16	3.4

Temperature from thermocouples beneath coated and uncoated insulated roof decking logged by Schrader Mechanical.

Local Modesto weather that day was a low of 55.6F, a high of 91.9F and a mean of 73.7F.

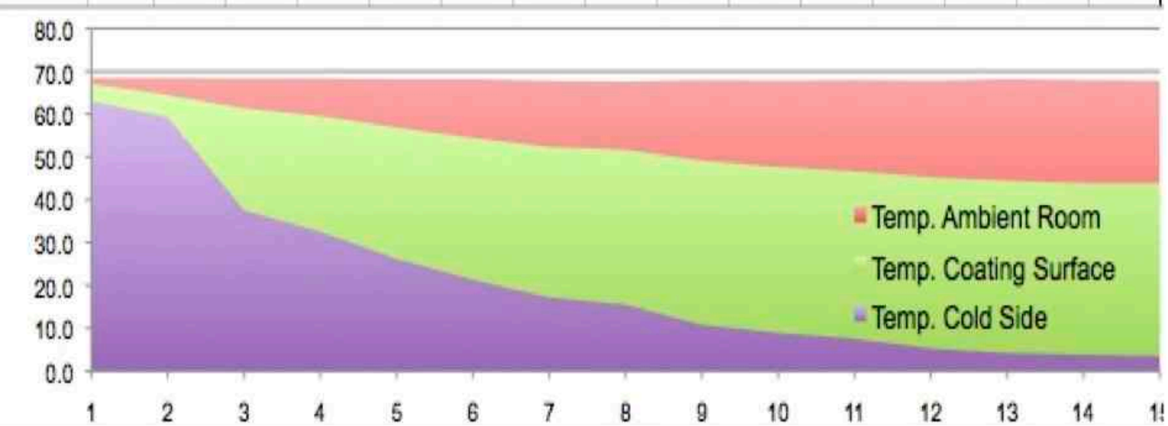
The temperature extremes show solar heating on radiated roof top and that effect underneath. Surfaces heat up far above ambient levels, causing building roofs and walls to radiate inside.

Direct measurements taken on the warm side of insulation coating over the top of a freezer box. This models ship use of CIC on interior surfaces and forms a foundation for the Hybrid Marine Insulation System



Cold Wall Performance Using a Freezer Box with 1mm of ACS CIC in Fahrenheit

Minute Logged	1	5	10	15	20	25	30	35	40	45	50	60	70	80	90
Temp. Ambient Room	68.5	68.5	68.4	68.4	68.2	68.2	67.8	67.6	68.0	67.8	68.0	67.8	68.2	68.0	67.8
Temp. Coating Surface	67.1	64.5	61.4	59.6	56.9	54.5	52.4	51.7	49.2	47.7	46.7	45.3	44.5	43.9	43.9
Temp. Cold Side	63.0	59.3	37.5	32.5	26.2	21.3	17.2	15.5	10.8	8.9	7.5	5.3	4.2	3.8	3.5
Temp. Difference Warm & Cold Side	4.1	5.2	23.9	27.1	30.7	33.2	35.2	36.2	38.4	38.8	39.2	40.0	40.3	40.1	40.4



Direct Measurement: The thermesthesiometer was developed in the '50's to measure glass cook top temperature to prevent burns. This still defines the ASTM C1057-03 personnel protection burn standard. This equipment is now produced by Therm-X of Hayward, California (www.therm-x.com).

This device is calibrated to measure heat flux-based temperatures that burn flesh. It is the designated measurement device for the ASTM-based personnel protection standard (ASTM C1057-03). The original version used tubes and is in limited supply. This is the successor to the original and can accurately measure surface temperatures on ACS Ceramic Insulation Coating.

Thermal Performance Summary

1/ Ship Performance = *Reference-based Application Chart from marine users*.

2/ Indirect:

a) *Amperage = 14% to 28%*

b) *Steam condensate = 25%*

c) *Fuel consumption = 9% for about 50% of insulated surface.*

d) *W/mK value of 0.1176 (This is a "Direct Measurement").F*

3/ "Calibrated" IR = *9F to 18F difference on exterior building envelopes. 44% lower on steam line surfaces measured.*

4/ Indirect on cold side = *10F to 13F on building envelope.*

5/ Direct on warm side = *40F DeltaT on freezer box temperatures.*

6/ Direct with "Thermesthesiometer" = *30% to 60% surface temperature reduction on hot surfaces, subject to temperature and coating thickness.*