197 State Route 18, Suite 3000 S. East Brunswick, New Jersey 08819
www.MechanicalinsulatorsLMCT.com
Pete Ielmini, *Executive Director* 732-210-7084 **Gina Walsh,** *Deputy Director* 314-683-6136

The following pages will outline a case study, which shows the benefits in energy and cost savings of properly installed mechanical insulation.

Insulation is a proven means for conserving energy, reducing greenhouse gas emissions, increasing process productivity, providing a safer and more productive work environment, controlling condensation (which can lead to mold growth), supporting sustainable design technology and a host of other benefits.

Mechanical insulation does all of this, while providing a return on investment (ROI) rate, which is seldom rivaled. Despite the proven ROI, insulation is often overlooked and its benefits undervalued. Insulation is truly the lost or forgotten technology. Can you think of a more important time than now to think about how insulation can help you?

An insulation system is a technology, which needs to be engineered and maintained throughout the entire process. Several studies have estimated roughly 10 to 30 percent of all installed insulation is now missing or damaged.

The practice of not replacing or maintaining an insulation system in a timely and correct manner reduces the full benefits of insulation, and in return, decreases the ROI. In many cases, significant other issues - such as excessive energy loss, corrosion under insulation (CUI), mold development, increased cost of operations and reduced process productivity or efficiency - develop.

You can learn more on www.MechanicalInsulatorsLMCT.com, where additional case studies can be viewed.

Please do not hesitate to contact me should you have any additional questions.
Thank you,

Peter Ielimi

Executive Director
Mechanical Insulators Labor Management Cooperative Trust

Montana Mechanical Insulation
Energy Appraisal Report

The State of Montana
Mechanical Insulation Energy Appraisal

Christopher P. Crall
Ronald L. King

Executive Summary

A mechanical insulation energy appraisal was conducted on a variety of State of Montana facilities located in and around Helena, Montana. The appraisal was a part of the Montana Mechanical Insulation Assessment Pilot Program (Pilot Program). The objective of the Pilot Program was to determine the energy, cost, and emission reduction opportunities available via the repair, replacement, and/or maintenance of mechanical insulation systems in Montana's State facilities. The assessment addressed mechanical rooms in 25 facilities pre-selected by State of Montana personnel based on the potential for energy savings.

Each of the facilities chosen for analysis had at least a few items that needed insulation. Overall, approximately 3,500 items were identified in the 56mechanical rooms visited. Estimated energy savings were approximately 6 billion BTUsper year. The resulting overall payback period was 4.1 years, with an annualized rate of return of 24%. These projected savings are primarily savings in natural gas usage and represent roughly 8% of the total natural gas consumption of the facilities analyzed. Associated reductions in CO_2 emissions are estimated at 300 Metric Tonnes per year. On a square foot of gross building area basis, the energy savings averaged 4.6 kBtu/sf/yr, while energy cost savings averaged \$0.043/sf.

Background and Objective

The National Insulation Association (NIA) and the International Association of Heat and Frost Insulators and Allied Workers (International), in May 2009, created an Alliance to work together to educate industry on and promote the benefits of mechanical insulation. One of the major initiatives of the Alliance is the Mechanical Insulation Education and Awareness Campaign (MIC).

The MIC is being executed under the umbrella of the U.S. Department of Energy's Industrial Technologies Program. Project Performance Corporation (PPC) and the NIA, in conjunction with its alliance with the International are working together to design, implement and execute the MIC.

The MIC is a program to increase awareness of the energy efficiency, emission reduction, economic stimulus, and other benefits of mechanical insulation in the industrial and commercial markets. The potential of mechanical insulation to play a significant role as a tool to reduce energy intensity is immense. However, the lack of sufficient data to support energy efficiency potential, combined with a deficient understanding of what mechanical insulation is and how it could be utilized, impedes policy makers and actors in industrial and commercial sectors in making a supportable case for increased use and maintenance of mechanical insulation.
The Pilot Program was completed as an integral part of the data gathering component of the MIC.

Approach

The overall approach used for this Pilot Program was to assemble a team of insulation professionals to conduct a mechanical insulation appraisal of State of Montana facilities in the Helena area.

The buildings were preselected for visits by State of Montana personnel based on the potential for energy savings. The assessment team, with assistance from State of Montana personnel, performed the following tasks:

1. Identified opportunities to improve insulation in the mechanical rooms visited
2. Estimated costs to improve or upgrade the insulation systems
3. Estimated the savings (in dekatherms, dollars, and CO_2 emissions) associated with the insulation upgrades, and calculated the resulting payback period and return on investment

The list of candidate buildings in the Helena area was developed and prioritized by State of Montana personnel based on the potential for energy savings from mechanical insulation. Buildings with steam and/or hydronic heating systems were therefore included while buildings with forced air furnaces were excluded. As a point of reference, the 25 facilities visited included a variety of building types (office buildings, assembly facilities, dormitories, maintenance facilities, and museums) and represent roughly 1.3 million square feet. The scope of this study was limited to the assessment of the mechanical insulation on piping and equipment in the mechanical rooms of the selected facilities. Opportunities for repair and replacement of insulation on piping and ductwork located within the building proper were not considered. This effort should not be considered an energy audit of the buildings visited. Energy conservation opportunities related to envelope insulation or sealing, lighting, controls, ventilation, or equipment maintenance were considered outside the scope of this study.

For each mechanical room, an insulation summary that identified items where insulation was missing or had sustained significant damage was developed. The team also identified the thicknesses that would bring the insulation level up to the level of the existing insulation. No attempt was made to “optimize” the level of insulation or to identify whether the existing insulation levels would meet or exceed levels required by local building codes or other requirements. Also no assessment was made of the efficiency of existing insulation. Additional savings may be possible by upgrading the existing insulation level but these savings would be small compared to insulating the uninsulated or damaged items identified in the appraisal.

During the field visits, additional information was collected about the energy systems in each mechanical room to enable the estimation of energy savings. This included the location of the mechanical room within the building, operating temperatures, estimated hours of operation, estimated efficiency of the equipment, and general control strategies. Budget type cost estimates were also developed based on the summary information on a by-facility basis.

Results

Each of the facilities chosen for analysis had at least a few items that needed insulation. The smallest number of individual items was a building where 14 items were identified (1 12-ft. length of 2-in. copper tube; 1 3-ft. length of ¾-in. copper tube; 6 2-in. 90s; 5 2-in. ball valves; and 1 ¾-in. ball valve). The largest concentration of items was in the Boiler Plant that provides central steam and domestic hot water to four buildings in the Capitol Complex. Approximately 400 individual items were identified in this facility (including the tunnels), and savings due to insulation provided an estimated payback of 4.0 years.

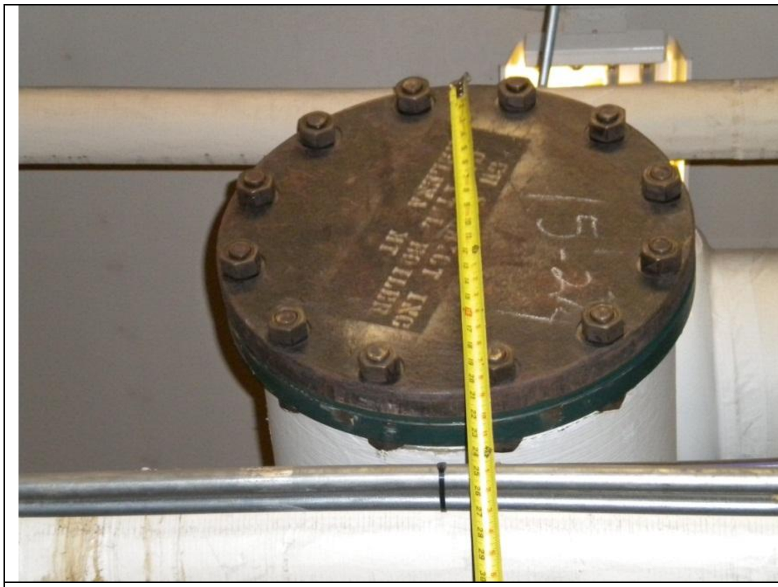

Figure 1. Uninsulated End Cap on Steam Header

Overall, approximately 3,500 items were identified. Estimated total savings were approximately 6 Billion BTUs per year with an estimated payback of 4.1 years and an annualized rate of return of 24%. These projected savings are primarily savings in natural gas usage and represent roughly 8% of the total natural gas consumption of the facilities analyzed.

As expected, some of these items identified were large (for example, the uninsulated flanged end-cap on a large, low-pressure steam header shown in Figure 1).

The majority, however, were relatively small (like the uninsulated unions and valve bonnets on the hot water heating lines shown in Figure 2). While the savings from any single item is small, the aggregated total savings from thousands of small items is significant.

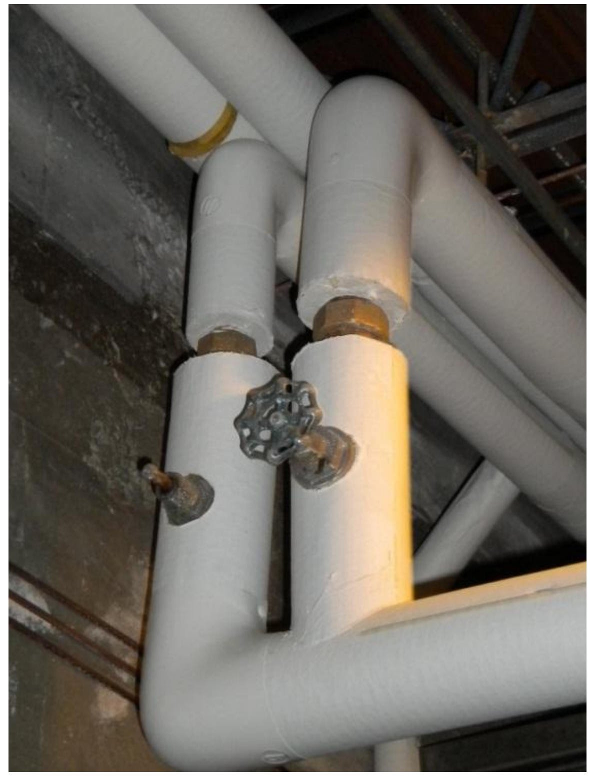

Figure 2. Uninsulated Unions and Valve Bonnets in HHW Lines

Table 1 summarizes the overall results of the appraisal, sorted in order of decreasing energy savings. Building energy usage information (columns 5-7) was derived from data provided by State of Montana personnel and, in most cases, is the average usage over a four-year period (FY 2007-FY 2010)[1].

Energy Use Intensity[2] (EUI, column 5) is the annual building site energy consumption (electrical and natural gas) per square foot of gross building area. Units are kBtu/sf/yr. Available[3] EUIs for the Helena buildings range from a high of 193 to a low of 47. The unweighted average EUI for the Helena buildings is roughly 92 kBtu/sf/yr. For reference, the U.S. Energy Information Agency's CBECS[4] survey for this climate zone lists average EUI values for offices at 92 and assembly buildings at 102.

[1] Annual Heating Degree Days over this four year period averaged 7,751, or about 0.9% higher than the long term average for Helena.
[2] For site EUI calculations, 1 kWh of electrical energy is 3,412 Btu and 1 dekatherm is 1,000,000 Btu.
[3] Electrical consumption at the Montana Law Enforcement Academy Complex is billed from a master meter, so EUI could not be broken out for the portion of that campus analyzed.
[4] U.S. EIA, 2003 Commercial Building Energy Consumption Survey (average for climate zones with HDD>7,000).

Table 1. Summary of Results

Building Info				Energy Usage Info			Insulation Upgrade Info					
1	2	3	4	5	6	7	8	9	10	11	12	13
Building Number	Name	Gross Area, Sq Ft	Heating System	Energy Use Intensity, kBtu/sf/yr	Avg Natural Gas Usage, kBtu/sf/yr	Avg Natural Gas Usage, DKT/yr	Energy Savings, DKT/yr	Energy Savings, kBtu/sf/yr	CO_2 Savings, MT/yr	Savings, $/sf/yr	Payback, yrs	Rate of Return, %
9	Boiler Plant and Tunnels	NA		NA	NA	NA	977	NA	52.0	NA	4.0	25%
10	Capital Building	202,520	LP Steam/HHW	97.4	50.0	10,122	869	4.3	46.2	$0.04	3.7	27%
61	Law Enforcement Academy Complex	54,096	LP Steam	NA	225.9	12,222	739	13.7	39.3	$0.14	3.7	26%
11	Museum	91,363	LP Steam	94.7	70.5	6,440	644	7.0	34.3	$0.06	1.8	54%
43	Aviation Support Facility	42,541	LP Steam/HHW	112.7	97.6	4,152	588	13.8	31.3	$0.12	5.0	20%
14	Corrections	27,790	LP Steam	70.2	49.6	1,377	301	10.8	16.0	$0.10	2.1	47%
13	Metcalf Bldg	93,275	Heat Pump Loop	60.0	14.9	1,387	245	2.6	13.0	$0.02	3.8	26%
71	HQ Building	189,821	Hot Water	98.5	44.5	8,440	223	1.2	11.9	$0.01	5.1	19%
20	Scott Hart	78,035	Hot Water	77.2	51.7	4,035	175	2.2	9.3	$0.02	5.5	17%
37	Original Governors Mansion	12,825	LP Steam	49.0	47.2	605	158	12.3	8.4	$0.12	2.4	41%
16	Fish, Wildlife & Parks HQ	22,966	Hot Water	95.9	45.2	1,037	147	6.4	7.8	$0.06	6.1	16%
7	Old Livestock Bldg	7,936	LP Steam/HHW	72.4	48.8	387	130	16.4	6.9	$0.16	4.7	21%
6	Mitchell Bldg	130,320	LP Steam/HHW	125.8	48.4	6,304	116	0.9	6.2	$0.01	5.8	16%
51	Helena OMS	19,315	Hot Water	93.7	70.5	1,361	100	5.2	5.3	$0.05	4.4	22%
18	Dept of Natural Resources	27,962	Hot Water	73.7	30.1	843	95	3.4	5.1	$0.03	8.2	11%
1	Executive Residence	11,185	Hot Water	65.6	47.9	536	88	7.9	4.7	$0.07	6.7	14%
44	5 Last Chance Gulch	53,875	Hot Water	98.6	25.7	1,387	75	1.4	4.0	$0.01	6.7	14%
4	Old Board of Health	8,265	LP Steam	138.1	120.4	995	63	7.6	3.4	$0.07	2.3	44%
31	Historical Preservation	3,656	Hot Water	96.5	80.7	295	60	16.4	3.2	$0.18	7.0	13%
38	Helena Job Service	9,400	Hot Water	193.1	151.4	1,423	55	5.9	2.9	$0.05	9.4	9%
12	Justice Building	103,981	Hot Water	62.9	25.7	2,672	41	0.4	2.2	$0.00	4.6	21%
5	DPHHS	48,682	Hot Water	124.0	63.0	3,066	35	0.7	1.9	$0.01	4.8	20%
22	Diane Bldg	5,759	Hot Water	46.6	22.2	128	32	5.6	1.7	$0.08	10.7	7%
30	FWP Parks	2,114	Hot Water	61.8	54.9	116	21	9.9	1.1	$0.11	7.7	12%
3	Walt Sullivan Bldg	51,243	LP Steam/HHW	111.8	67.9	3,479	15	0.3	0.8	$0.00	4.3	23%
		Total		**Average**	**Average**	**Total**	**Total**	**Wghtd Avg**	**Total**	**Wghtd Avg**	**Wghtd Avg**	**Wghtd Avg**
		1,298,925		**92.2**	**64.8**	**72,809**	**5,992**	**4.6**	**319**	**$0.043**	**4.1**	**24%**
				Savings (8) as a % of Natural Gas Usage (7)			**8.2%**					

Average natural gas usage is given on an absolute basis in column 7. Note that no natural gas usage is shown for Building 9, the Boiler Plant. Natural gas fired boilers in the Boiler Plant generate low pressure (5 psig) steam for distribution to four other buildings. Natural gas usage in the Boiler Plant has been allocated to those buildings.

Estimated energy savings due to identified insulation opportunities are given in column 8. Column 9 gives those energy savings normalized to building area. A number of key assumptions were required to develop the energy savings estimates, including the operating hours of the mechanical systems involved (heating systems are assumed to operate for eight months during the winter or 5,840 hours per year). Additional assumptions include the operating temperatures and the ambient conditions inside the mechanical rooms (assumed to be 80°F with 1 mph wind speed).

The total estimated savings are approximately 6 Billion BTUs/yr. The weighted average savings are 4.6 kBtu/sf/yr. This represents 8.2% of the natural gas usage in the facilities studied. Note that in most cases, the insulation opportunities identified will reduce natural gas consumption. However, a few of the buildings have electrically heated domestic hot water systems, so in those buildings, a small portion the energy savings due to mechanical insulation will show up as electrical energy savings. These electrical energy savings have been expressed as dekatherms and included in the estimates in columns 8 and column 9.

The savings estimates in column 8 are converted to the associated reductions in carbon dioxide (CO_2) emissions in column 10 (Metric Tonnes per year) and to financial savings ($/sf/yr) in column 11.

Insulation cost estimates were prepared on a by-facility basis using the summaries developed during the site visits. The estimates assume a variety of insulation systems depending upon the application. The primary insulation systems utilized in the estimates was fiberglass pipe insulation with all service jacket and removable/replaceable flexible insulation covers.

Column 12 shows the estimated payback periods of the insulation project in years, while column 13 gives the annualized rate of return (assuming a 20-year life and no fuel cost escalation[5]). The estimated payback periods range from 1.8 years to 10.7 years. Corresponding annualized returns range from around 54% to 7%.

As might be expected, the steam-heated facilities generally show shorter payback periods. Steam supply piping operates at roughly 230°F during the heating season while hot water supply temperatures are normally reset in a range from 120°F to 180°F based on outdoor temperatures. Insulating steam systems will therefore exhibit not only greater energy savings but also faster payback periods.

Note that the variation in financial returns is not unexpected. All the buildings inspected had mechanical insulation on their steam and hot water lines, although some systems were in better shape than others. Several had been recently upgraded to high-efficiency condensing boilers with well insulated piping (Figure 3). While several small items were identified in each of these facilities, it is clear that the "low-hanging fruit" had already been gathered.

On the other end of the spectrum, several buildings have insulation opportunities that will yield more immediate returns (see for example Figures 4-6).

[5] Energy costs are volatile and notoriously difficult to predict. While long-term energy costs are expected to increase, recent natural gas costs have been falling. A fuel cost escalation rate of 0% seems reasonable for this analysis. If a 3% annual fuel cost escalation rate was assumed, annualized returns would increase by about 3%. For example, the 27% return estimated for the Capitol Building would increase to 30% if a 3%/yr. fuel cost escalation rate was used.

Figure 3. Diane Building (22) Boiler Installation

Figure 4. Uninsulated Condensate Tank in Corrections Building (14)

Figure 5. Condensate Piping in Original Governor's Mansion (38)

.

Figure 6. Uninsulated Steam Valve in Fish Wildlife and Parks Building (16)

Discussion of Results

The results of this study demonstrate that there are numerous opportunities for improving the mechanical insulation application in steam and hydronic heated buildings in Montana. One question prompted by the appraisal is “Why are there so many pieces of missing insulation?” In many locations, it was obvious that some maintenance task had required removal of the insulation which was simply not replaced after the maintenance was completed. This was observed in several locations where a DHW storage tank had been removed and replaced with a newer tank, and piping connections to the tank were left uninsulated. It is likely that the personnel performing this work did not have either the materials available or the proper training to complete the job.

Some areas were observed where either mechanical damage or leaks had occurred and the damaged insulation had not been replaced. The more common occurrence, however, was items that were never insulated to begin with. For buildings and systems designed and built when energy was cheap, the “extent of insulation” was not nearly as complete as it is today. Items like pipe unions, strainers, steam traps, condensate tanks, expansion joints, valves, flanged joints, pumps, and tanks were routinely left uninsulated.

The domestic hot water systems in the buildings visited illustrated the interactions often present in energy conservation projects. A number of the buildings contained newer high-efficiency DHW storage tanks. Some buildings however, used older conventional style gas fired water heaters. For the older DHW tanks, we analyzed the addition of a 1 ½ in. thick tank-blanket to minimize heat loss. These DHW tanks typically operate year round (8,760 hours per year). For a typical 24 in. diameter by 60 in. tall tank, energy savings can be on the order of $30 per year. These savings were included in the analysis where applicable. Depending on the age of the DHW tank, it may be, more reasonable to consider replacing these tanks with high efficiency units. This alternative (and mutually exclusive) option was not investigated in this study.

A related interaction issue concerns the domestic hot water circulating systems. Most of the buildings in the study utilize circulating pumps in the DHW loops. These pumps minimize city water consumption since occupants have hot water at fixtures on demand (rather than having to wait for hot water). Some of the facilities have been fitted with timers to limit the hours of operation of the circulating pumps (and the associated heat loss from DHW piping) to occupied hours. In other buildings, the circulating pumps run continuously. For these buildings, the insulation replacement items look very attractive (since savings are directly proportional to operating hours). The alternative option of installing a timer to limit hours of operation would reduce the savings from insulation. The two options, however, are not mutually exclusive and installation of timers should be considered in addition to replacing any missing insulation in the DHW loop.

Extrapolation Statewide

One of the objectives of this pilot study was to use the results to estimate the savings possible if the pilot study was expanded to cover all the similar state-owned buildings in Montana. The State of Montana has a statewide inventory of approximately 3,800 buildings, with a combined area of over 27 million gross square feet, including all types of facilities needed to support the missions of the State’s universities, public safety, social service and administrative departments and agencies maintaining their transportation systems, natural resources and state parks. Many of these facilities are small, seasonal, and with specialized usage and/or limited occupancy. The results of this study will obviously not apply to many of these facilities, so extrapolation to all state buildings in Montana is not meaningful. Projections to similar state-owned facilities are possible and may be useful.

The initial step towards that objective was to review a list of state office buildings provided by State of Montana personnel. The facilities on the list were considered potential candidates for inclusion in mechanical insulation upgrade projects. The information provided included building designation and location, year built, occupancy code, gross area (in square feet), number of stories, and number of full time employees. The list contained a total of 142 buildings with a total gross area of 2.35 million square feet.

The distribution of those 142 buildings by occupancy code is shown in Table 4 as follows:

Table 4. Distribution of State Building Types

Occupancy	Number	Gross Area, sf	% Breakdown
OFFICE	110	1,396,674	59%
GOVERNMENTAL BLDG	11	495,833	21%
LABORATORY	3	147,901	6%
MUSEUM	4	114,006	5%
LIBRARY	1	103,981	4%
EDUCATION	8	68,526	3%
OTHER	4	15,416	1%
JAIL	1	7,685	0.3%
Totals	142	2,350,022	100%

The pilot study of Helena buildings covered several of the larger state buildings on the list and represents a significant percentage of the total. Overall, approximately 55% of the square footage identified on the candidate list was included in the pilot study. The following table breaks this percentage down based on occupant code.

Table 5. Percentage of Total Covered in Pilot Study

Occupancy	Statewide Candidates, sf	Analyzed in Pilot Study, sf	%
OFFICE	1,396,674	633,134	45%
GOVERNMENTAL BLDG	495,833	392,341	79%
LABORATORY	147,901	-	-
MUSEUM	114,006	104,188	91%
LIBRARY	103,981	103,981	100%
EDUCATION	68,526	54,096	79%
OTHER	15,416	11,185	73%
JAIL	7,685	-	-
Totals	2,350,022	1,298,925	55%

As a first order estimate, the energy savings from the Helena Pilot study can be prorated based on building area. Annual energy savings from the 25 facilities analyzed in Helena averaged about 4.6 kBtu/sf/yr,about $0.043/sf/yr. If these savings could be simply pro-rated to the statewide candidate list (2.35 million square feet. Additional analysis could refine this estimate. We know, for example, that steam-heated and hydronic heating systems will have more opportunities for mechanical insulation than forced-air heating systems. In addition, we know that some of the candidate buildings have already been addressed. More information about the building inventory statewide would allow a more precise estimate, but an order-of-magnitude savings of 10 Billion BYUs (8% savings yr based upon the selected buildings) statewide is not unreasonable. We would expect installation costs to be similar so that annualized returns of 24% could be achieved.

Summary

Approximately 3,500 items were identified in 25 buildings (56 mechanical rooms). Estimated energy savings were approximately6 Billion BTU's per year.With the resulting overall payback period being 4.1 years with an annualized rate of return of 24%. These projected savings represent roughly 8% of the total natural gas consumption of the facilities analyzed. Associated reductions in CO_2 emissions are estimated at 300 Metric Tonnes per year. On a square foot of gross building area basis, the energy savings averaged 4.6 kBtu/sf/yr while energy cost savings averaged $0.043/sf. similar results, 8% savings of natural gas consumption, could be reasonably expected in similar Montana facilities.

While the savings from any single item is small, the aggregated total savings from thousands of small items is significant. The appraisal results confirm again the value of addressing missing, damaged or uninsulated areas. Little things do matter. The payback period and internal rate of return are based upon actual operating conditions, 80^{o} F ambient temperature, service temperature and hours of operations which in many cases are less than six months per year.

The results tell an impressive story for maintenance of mechanical insulation in commercial building applications. The findings confirm the energy savings, emission reduction and financial benefits of looking at mechanical insulation differently. What is the energy saving potential in your facility?

Acknowledgements

The authors would like to thank the State of Montana for their assistance during the study. Also thanks to Performance Contracting Inc .for participating in the field visit and developing the cost estimates and to Auburn Manufacturing for consultation and assistance relative to removable/replaceable insulation covers

Authors

Christopher P. Crall
Christopher P. Crall, P.E., is a mechanical engineer with experience in thermal insulation and energy usage in commercial buildings and industrial applications. He is currently providing consulting services in the areas of building energy standards, energy analysis, heat and moisture transport, and mechanical insulation specifications and applications. He is an active ASHRAE member and was the primary author of the 2005 ASHRAE Handbook chapter titled "Insulation for Mechanical Systems." He is also active as a member of the ASTM Committee on Thermal Insulation (C-16),. He can be reached at 614-855-2240 or ccrall@gmail.com

Ronald L. King
Ron King is a past president of the National Insulation Association (NIA), the World Insulation and Acoustic Organization and the Southwest Insulation Contractors Association. He was awarded the NIA President's Award in 1986 and again in 2001. He is a 40-year veteran of the commercial and industrial insulation industry, during which time he held executive management positions at an accessory manufacturer and a specialty insulation contractor. He recently retired (2004) as the chairman, CEO and president of a large national insulation distributor/fabricator. He is currently a consultant and advisor to NIA and in that capacity is currently the Chairman and Vice Chairman of the National Institute of Buildings Sciences National Mechanical Insulation Committee and Consultative Council respectively.. He can be reached at 281-360-3438, or RonKingRLK@aol.com.