# Federal Technology Alert

A publication series designed to speed the adoption of energy-efficient and renewable technologies in the Federal sector

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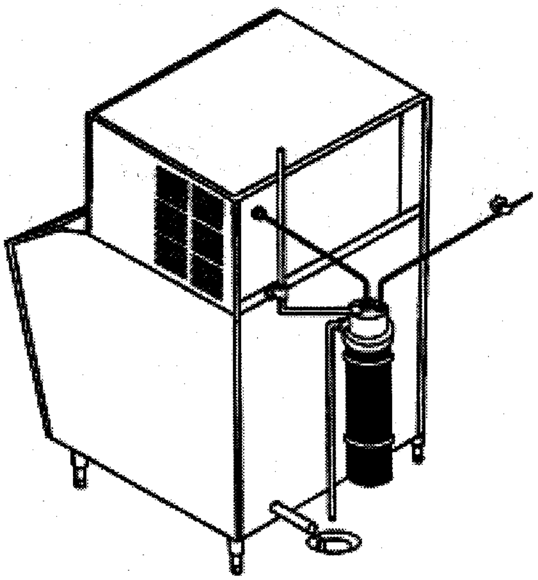
# Waste Chill Recovery Heat Exchangers for Commercial-Size Automatic Ice Makers

*Technology for Improving the Energy Efficiency and Increasing the Capacity of Ice Makers*



Waste chill recovery (WCR) heat exchangers can be retrofit to commercial-size automatic ice makers to improve the energy efficiency and capacity of the ice maker. Residual chilled water, normally sent down the drain, is used to precool fresh makeup water prior to operating the ice maker's refrigeration system.

This *Federal Technology Alert* (FTA), one in a series on new technologies, describes the theory of operation, energy-saving mechanism, and field experience for the technology, and presents a detailed methodology, including example case studies, for conducting a site-specific evaluation.

## Energy-Saving Mechanism

Water charged to the ice maker must first be cooled to the freezing point before ice will form on the evaporator plates. At the conclusion of the ice-making and harvesting cycle, part or all of the residual water, still at or near the freezing point, is purged from the ice maker, and the reservoir is then refilled with makeup water that is often much warmer. Some water must always be purged because the ice-making process concentrates impurities in the residual water. If the impurity concentration is allowed to grow, scale will eventually form on the equipment and/or the ice cubes will become cloudy.

The objective of the WCR heat exchanger is to capture part of the "chill" otherwise lost with the purge water by first absorbing energy from the charge water. Reducing the temperature of the water charged to the reservoir directly lowers the cooling load that must be served by the ice maker's refrigeration system and the electricity required to drive the refrigeration system.

## Technology Selection

The WCR heat exchanger is one of many energy-saving technologies to emerge in the last few years. The FTA series targets technologies that appear to have significant untapped Federal-sector potential and some existing field experience. The WCR heat exchanger met these two criteria and was selected for further review and evaluation via this FTA.

## Potential Benefits

As noted above, the direct benefit of the WCR heat exchanger is to reduce the temperature of the water charged to the ice maker's reservoir, lowering the cooling load served by the ice maker's refrigeration system and the electricity required to drive the refrigeration system. For ice makers with condensers located internal to the building, an important secondary energy benefit also accrues. Reducing the cooling load on the ice maker reduces the heat rejected by the ice maker to the building, which reduces the building cooling load (or increases the building heating load). Because ice demand tends to be concentrated during the summer and cooling loads tend to dominate heating loads in commercial buildings, the net effect is almost always a reduction in a building's HVAC energy loads and energy required to drive the HVAC equipment.

Lowering the initial water temperature in the ice maker's reservoir also reduces the time required to cool the water to the freezing point, which reduces the entire ice making and harvesting cycle. In fact, the increased production rate may be the most valuable impact to users with inadequate ice-making capacity who may otherwise be forced to buy supplemental ice, purchase a supplemental refrigeration unit, or buy an additional ice maker. In addition, reducing the cooling load on the ice maker should result in less "wear and tear," resulting in lower maintenance costs and longer equipment life.

## Application

The cost-effectiveness of a WCR heat exchanger is extremely site-specific; the payback period could be less than 1 year or greater than 100 years. The bulleted items listed below summarize the key favorable conditions that will most likely result in a cost-effective application. Not all of these conditions necessarily need to exist for an application to be cost-effective. Still, if the majority of these conditions do not exist, it is unlikely a WCR heat exchanger will be cost-effective.

- The annual demand for ice is relatively high, generally greater than 30% of its annual production capacity, if operated continuously throughout the year.

- The ice maker operates in a "purge" mode (as described in more detail in the body of the FTA) to charge and discharge its water reservoir.

- The average annual makeup water temperature is relatively high, generally greater than 60°F.

- The ice maker's condenser is located indoors.

- The electricity rate is relatively high, generally greater than $0.08/kWh.

## Field Experience

The WCR technology is being used successfully in a wide range of commercial applications, including hotels, restaurants, convenience stores, and schools. Although few ice machines have been separately metered, the end-user representatives we spoke with indicated an observable decrease in cycle time, indicating a lowering of inlet water temperature. Where test measurements were collected, the WCR technology reduced inlet water temperature by an average of 15.2°F, or 21.9%. Ice production cycle times were reduced by 2.1 minutes, on average, or 18.1%.

## Technology Outlook

WCR heat exchangers for commercial-sized automatic ice makers are currently cost-effective in selected applications. Several factors influence cost-effectiveness, as summarized above. The thermal efficiency of current WCR heat exchangers seems adequate. Assuming that scaling remains a non-problem, the key characteristic that could be improved is first cost. Hopefully, mass production economies-of-scale and/or competition from multiple vendors will result in lower equipment costs in the future. Customer interest may also spark more interest on the part of ice maker manufacturers to offer WCR heat exchangers as part of the original equipment.

**Federal Technology Alert**

# Waste Chill Recovery Heat Exchangers for Commercial-Size Automatic Ice Makers

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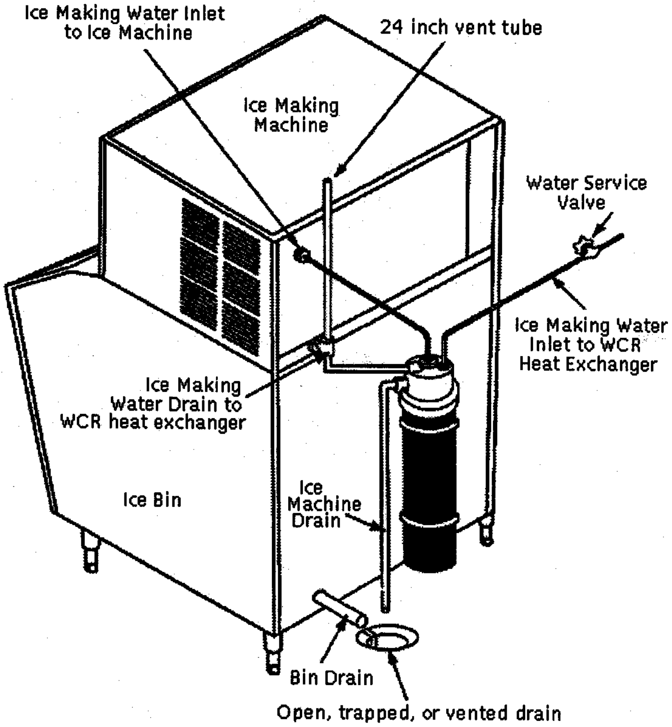

## Abstract

Waste chill recovery (WCR) heat exchangers can be retrofit to commercial-size[a] automatic ice makers to improve the energy efficiency and capacity of the ice maker. Commercial ice cube makers produce ice via a batch process. This ice-making process concentrates any impurities in the residual water, leaving the cube relatively pure and clear. Thus, some portion of the water charged to an ice maker must be purged to avoid scaling within the sump or on other ice maker components and to ensure that clear cubes are produced.

The purge water is often near freezing or at least considerably cooler than the makeup water. The WCR device is a type of “shell and tube” heat exchanger that precools makeup water being charged to the ice maker with cold purge water being discharged from the ice maker. As a result, the amount of heat that must be removed from the water by the ice maker’s refrigeration system is reduced along with the electricity required to drive the refrigeration system. Reducing the amount of makeup water cooling also reduces the cycle time between harvests, which increases capacity.

The cost-effectiveness of a WCR heat exchanger varies considerably depending on machine-specific and site-specific operating conditions. This *Federal Technology Alert* (FTA) presents detailed information and procedures that a Federal energy manager can use to evaluate the cost-effectiveness of potential WCR heat exchanger applications. WCR heat exchanger operating principles, design variations, energy-saving mechanisms, and other potential benefits are explained. Specific procedures and equations are provided for estimating energy savings. Proper application, installation, and operation and maintenance impacts are discussed. Two hypothetical case studies are presented to illustrate the evaluation procedures and equations. Manufacturers, users, and additional references are provided for prospective users who may have questions not fully addressed in this FTA. A description of Federal life-cycle costing procedures and a life-cycle cost summary for the Energy Conservation Investment Program are presented in the appendixes.

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(a) Machines with daily ice production capacities ranging from a few hundred to a few thousand pounds.

# Contents

Appendixes

# About the Technology

A waste chill recovery (WCR) heat exchanger could be applied to any ice maker to improve its energy efficiency. The WCR device is basically a type of "shell and tube" heat exchanger that precools makeup water being charged to the ice maker with cold waste water being discharged from the ice maker. A simplified, generic flow diagram of the concept is shown in Figure 1. Relatively warm makeup water flows through the tube while the near-freezing waste water flows around the tube within the shell of the heat exchanger. Heat is transferred from the makeup water to the discharge water, which lowers the temperature of the water charged to the ice maker's reservoir. As a result, the amount of heat that must be removed from the water by the ice maker's refrigeration system is reduced along with the electricity required to drive the refrigeration system.

The effectiveness of the heat exchanger (i.e., its ability to transfer heat from the makeup water to the discharge water) depends on the amount of heat transfer surface area (tubing surface area) relative to the amount of heat being transferred and the layout of tubing and flow channels within the heat exchanger shell. Increasing heat transfer surface area enhances heat exchanger effectiveness, but increases its size, weight, and cost. A "counterflow" layout that minimizes the temperature difference between the two fluid streams at any point along the tubing (imagine a smaller pipe [the tubing] within a larger pipe [the shell], with the makeup water entering the smaller pipe at one end and the discharge water entering the larger pipe at the other end) is best for heat transfer, but can result in a cumbersome or complex and costly design.

The design variations are practically endless; cutaway drawings of two WCR heat exchangers currently offered for application to commercial ice makers (machines with an ice-making capacity ranging from a few hundred to a few thousand pounds per day) are shown in Figures 2 and 3.

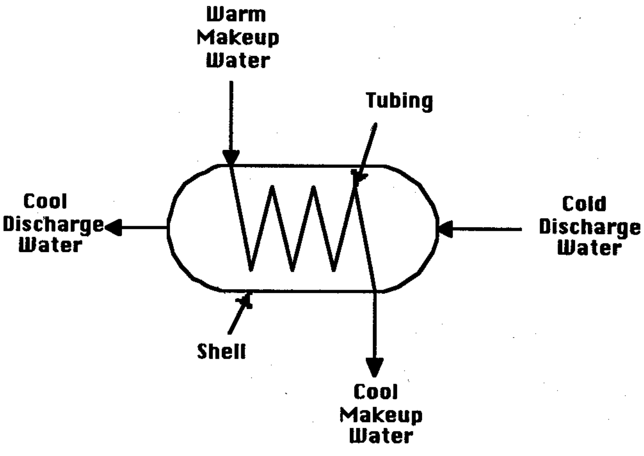

**Figure 1. WCR Heat Exchanger Concept**

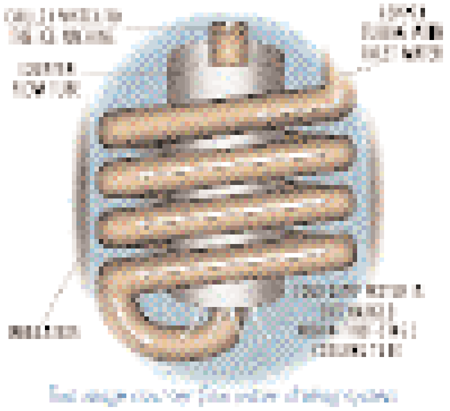

**Figure 2. Maximicer WCR Heat Exchanger**

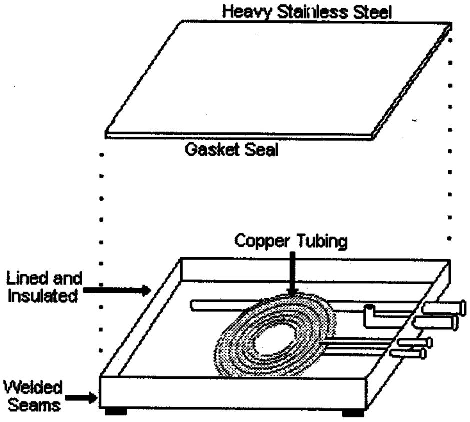

**Figure 3. Fast Ice WCR Heat Exchanger**

## Application Domain

Currently, about 5,000 WCR heat exchangers have been installed on commercial ice makers, but only a few of these have been in Federal facilities. The current stock of commercial ice cube-making machines (not including flake-ice machines) is reported to be approximately 1.2 million in the U.S. (A.D. Little 1996), with about 1.5% of these estimated to exist in the Federal sector. Whether or not these units represent cost-effective applications depends on several site-specific(a) and machine-specific(b) characteristics. Each of these and additional factors are discussed in more detail later in this FTA.

Fast Ice Products, Inc. and Maximicer Foodservice are the only firms known to offer WCR heat exchangers as auxiliary components for the equipment originally supplied by the ice maker manufacturers. Similar devices are not currently offered by the ice maker manufacturers themselves as either a standard or optional feature, but Manitowoc plans to offer the Maximicer WCR heat exchanger as an accessory through its distributors in the near future.

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(a) For example, the demand for ice, makeup water temperature, and electricity rate.
(b) For example, water consumption per pound of ice, water charge and discharge approach, and refrigeration efficiency.

### Energy-Saving Mechanism

Although ice is made from potable water, the water still contains various impurities at different concentrations depending on the source. Common impurities include sodium, calcium, magnesium, and iron, which occur in the form of salts. In addition to these dissolved solids, the water may contain various suspended solids and microscopic organisms. The process of freezing water tends to concentrate the impurities in the water, resulting in ice that is purer than the original water. In particular, ice formed relatively slowly or by the continuous washing of the ice interface (the technique employed in cube ice makers) results in the purest and clearest product.

While clarity is a highly desirable ice attribute, the resulting concentration of impurities in the residual water will eventually cause precipitation and equipment scaling if allowed to grow unchecked. Thus, a portion of the water charged to an ice-making machine is continuously and/or periodically discharged to keep the impurities within a tolerable level. The problem is similar to that encountered in an evaporative cooling tower, where impurities are concentrated in the residual water not evaporated. In an evaporative cooling tower, "blowdown" is the term used to describe water continuously or periodically purged to control impurity concentration.

Water charged to the ice maker must first be cooled to the freezing point before ice will form on the evaporator plates. At the conclusion of the ice-making and harvesting cycle, part or all of the residual water, still at or near the freezing point, is purged from the ice maker and the reservoir is then refilled with makeup water that is often much warmer. The objective of the WCR heat exchanger is to capture part of the "chill" otherwise lost with the purge water by first absorbing energy from the charge water. Reducing the temperature of the water charged to the reservoir directly lowers the cooling load that must be served by the ice maker's refrigeration system and the electricity required to drive the refrigeration system.

For ice makers with condensers located internal to the building, an important secondary energy benefit also accrues. Reducing the cooling load on the ice maker reduces the heat rejected by the ice maker to the building, which reduces the building cooling load (or increases the building heating load). Ice demand tends to be concentrated during the summer and cooling loads tend to dominate heating loads in commercial buildings. Thus, the net effect is almost always a reduction in a building's HVAC energy loads and energy required to drive the HVAC equipment. Either the primary (ice maker) or secondary (HVAC) energy savings can be greater, depending on the efficiency of the ice maker and HVAC equipment.

### Other Benefits

Lowering the initial water temperature in the ice maker's reservoir reduces the time required to cool the water to the freezing point, which reduces the entire ice making and harvesting cycle. In fact, the increased production rate may be the most valuable impact to users with inadequate ice-making capacity who may otherwise be forced to buy supplemental ice, purchase a supplemental refrigeration unit, or buy an additional ice maker. In addition, reducing the cooling load on the ice maker should result in less "wear and tear," resulting in lower maintenance costs and longer equipment life.

### Variations

As noted above and illustrated by Figures 2 and 3, the design approaches for constructing a WCR heat exchanger are nearly endless. The Fast Ice unit consists of a flat spiral of tubing within a rectangular shell. The Maximicer consists of a cylindrical shell within another cylindrical shell, with a helical spiral tube contained within the outer shell and a straight tube contained within the inner shell. The "counterflow" design of the Maximicer unit should result in better heat exchange between the two fluids, but its purchase price is greater than the Fast Ice unit as well.

A comparison of these two or any other WCR heat exchangers must consider the expected reductions in reservoir water temperature and the benefits derived (e.g., reduced electricity consumption, increased ice-making capacity) from the reduced temperatures, as well as the initial costs of the units. **At the time this FTA was written, comparison testing of the two units, under the same operating conditions, was not known to have been completed, so conclusive judgments regarding their relative performance should not be made.**

### Installation

Both the Maximicer and Fast Ice heat exchangers are compact devices designed to fit behind, adjacent, or underneath the ice maker and its storage bin. Retrofit is relatively simple because the interface occurs outside of the ice maker and storage bin walls. Either unit requires four connections; both supply and discharge water lines are cut and re-plumbed to route each line through the heat exchanger. The discharge line entering the heat exchanger and the supply line leaving the heat exchanger should be insulated to prevent warming of the chilled water and potential water condensation on the outside of the tubing.

## Federal Sector Potential

The WCR heat exchanger technology has been assessed by the New Technology Demonstration Program (NTDP) as having significant potential for energy savings in the Federal sector.

### Estimated Savings and Market Potential

Potential applications for the WCR technology presented in this document are any locations where commercial-size ice machines are found. In the Federal sector, these are found in cafeterias, kitchens, dorm-style housing, mess halls, and similar facilities.

As part of the NTDP selection process, technologies are screened to estimate their potential market impact in the Federal sector. For buildings-related technologies, the screening utilizes a modified version of the Facility Energy Decision Screening (FEDS) model[a] to capture all system interaction and secondary benefits of applicable technologies. The screening for the WCR technology used the economic basis required by 10 CFR 436 and included the number, annual usage, and life expectancy of ice machines in the Federal

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(a) Developed for the Department of Energy's Office of Federal Energy Management Program (FEMP), the U.S. Army Construction Engineering Research Laboratories (CERL), and the Naval Facilities Engineering Service Center (NFESC) by the Pacific Northwest National Laboratory (PNNL).

sector. Potential technologies are ranked according to ten different criteria. The first three criteria are financial: net present value, installed cost, and present value of savings. The next ranking criterion is annual site energy savings. Finally, technologies are ranked on their reduction of $SO_2$, $NO_X$, CO, $CO_2$, particulate matter, and hydrocarbon emissions.

The ranking results from the screening process for this technology are shown in Table 1. These values represent the maximum benefit achieved by implementing the technology in every Federal application where it is considered cost-effective. The actual benefit will be lower because not every possible installation could be expected to be realized.

**Table 1. New Technology Demonstration Program Screening Results**

| Screening Criteria | Value Result |
|---|---|
| Net Present Value ($) | 4,766,672 |
| Installed Cost ($) | 4,903,310 |
| Present Value of Savings ($) | 9,636,982 |
| Annual Site Energy Savings (MBtu) | 36,309 |
| $SO_2$ Emissions Change (lb/yr) | 135,959 |
| $NO_X$ Emissions Change (lb/yr) | 50,743 |
| CO Emissions Change (lb/yr) | 2,839 |
| $CO_2$ Emissions Change (lb/yr) | 8,283 |
| Particulate Emissions Change (lb/yr) | 7,813 |
| Hydrocarbon Emissions Change (lb/yr) | 415 |

## Laboratory Perspective

The results of laboratory and field testing show that WCR technology offers the potential for improving ice making capacity and/or reducing energy consumption. Cost-effectiveness, however, depends on several site-specific and machine-specific variables. This FTA discusses in detail the variables affecting performance, such as equipment charge/discharge cycle, makeup water temperature, and ice-making load.

# Application

This section discusses in more detail the issues that must be considered in determining whether or not to install a WCR heat exchanger on an ice maker. Several site- and machine-specific characteristics have a significant bearing on the effectiveness of the WCR device. The variation in these characteristics results in some applications being exceptionally attractive, while others offer practically no benefit at all. Included here are general rules of thumb about what to look for and what to avoid, descriptions of installation and maintenance requirements, and information on equipment warranties, costs, and utility programs.

## Application Screening

The direct objective of the WCR heat exchanger is to reduce the temperature of the water charged to the ice maker's reservoir. Quite obviously, the refrigeration system will require less electricity to make ice from 50°F water than it would from, say, 70°F water. Reducing the cooling load also decreases the time required to generate a batch of ice, thus increasing the ice production rate. In addition, for machines with condensers internal to the building, less heat is rejected to the building, which lowers the space cooling load.(a) Further discussion of the factors influencing the effectiveness of a WCR heat exchanger can be facilitated by examining each variable in the following equations defining the potential energy and dollar savings.

$$\text{IM Energy Savings} = \text{lb ice} * \text{lb } H_2O/\text{lb ice} * DT * Cp * 1/COP_{im} * \text{kWh}/3413\ \text{Btu} \quad (1)$$

$$\text{IM Dollar Savings} = \text{IM Energy Savings} * \$/\text{kWh}_{im} \quad (2)$$

where

IM = ice maker

lb ice = pounds of ice produced

lb $H_2O$/lb ice = pounds of water charged per pound of ice produced

DT = reduction in inlet water temperature achieved with WCR heat exchanger

Cp = the heat capacity of water

$COP_{im}$ = the coefficient of performance(b) for the ice maker

kWh/3413 Btu = the conversion factor equating kWh and Btu

$/$\text{kWh}_{im}$ = the value of ice maker electricity savings

$$\text{IM Energy Rejection Reduction (IMERR)} = (\text{lb ice} * \text{lb } H_2O/\text{lb ice} * DT * Cp) * (1 + 1/COP_{im}) \quad (3)$$

$$\text{Cooling System Energy Savings (CSES)} = \text{IMEER}/COP_{ac} * \text{kWh}/3413\ \text{Btu} \quad (4)$$

where $COP_{ac}$ = cooling system coefficient of performance

$$\text{Cooling System Energy Dollar Savings} = \text{CSES} * \$/\text{kWh}_{ac} \quad (5)$$

where $/$\text{kWh}_{ac}$ is the value of cooling system electricity savings

$$\text{Heating System Energy Penalty (HSEP)} = \text{IMEER}/\text{effh} \quad (6)$$

where effh = heating system efficiency

$$\text{Heating System Energy Dollar Penalty} = \text{HSEP}/1{,}000{,}000 * \$/\text{MMBtu} \quad (7)$$

where $/MMBtu = heating system fuel cost

### ice production ("lb ice")

The first question to consider is the quantity of ice being produced. If the ice maker is used very little, the energy savings will be too small to justify an investment in a WCR heat exchanger. On the other hand, an ice maker that operates continuously, or nearly so, is a good candidate. Although there is no absolute minimum, machines with an annual capacity factor (the ratio of actual annual ice production to the amount of ice that would be produced if the machine operated continuously during every hour of the year) less than 30% are unlikely to be economically attractive applications based on energy savings alone, unless

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(a) Conversely, reducing the amount of heat rejected to the building increases the space heating load, but more ice is generally produced during the cooling season, so the net benefit of this impact is usually positive.

(b) Actually, the ratio of total thermal load, including all sources of heat that must be rejected by the ice maker, to the sum of electric energy input to the compressor, condenser fan, and water pump during the ice-generation mode, with thermal load and electricity input measured in the same units.

compensated by relatively attractive values for the other variables in equations 1-7.

## water charging ratio ("lb $H_2O$/lb ice")

The next factor in the energy savings equation is the amount of water charged to the reservoir per unit of ice produced. This ratio is greater than one because part of the ice formed on the evaporator plates is melted during the defrost cycle (and not included as part of the ice production) and there must be enough residual water left in the reservoir to avoid the precipitation of impurities concentrated by the freezing process.

It is important to note that the ratio of water charged to the reservoir per unit of ice may be less than the ratio of total water consumed per unit of ice, depending on how the reservoir is charged and discharged. Some machines purge all of the water remaining in the reservoir at the conclusion of the ice harvesting cycle and then refill the reservoir to a fixed level prior to starting the next ice-making cycle. For this charge and discharge mode, the two ratios are the same.

Other machines charge the reservoir with fresh water for a period of time (may be fixed or adjustable by the user), mixing new water with old water, and allowing the mixture to overflow to waste for part of the charging period to control the concentration of impurities. The two mechanisms are combined on some machines with the user able to select the purge frequency (every third or fifth or seventh cycle, for example). For overflow and overflow/purge hybrid charge and discharge modes, the total water consumed per unit of ice is greater than the reservoir charge per unit of ice. All else equal, machines with higher ratios of water charged to the reservoir per unit of ice will benefit the most from a WCR heat exchanger. However, this ratio tends to range between 1.2 and 1.8 (A.D. Little 1996), so it is not a significant distinguishing factor. More importantly, all else is not usually equal, as will be discussed next.

## reduction in inlet water temperature ("DT")

The reduction in inlet water temperature achieved with a WCR heat exchanger is the key variable for determining the cost-effectiveness of the concept. Not only does this variable represent the most important direct impact of using a WCR heat exchanger, but the magnitude of this factor varies significantly depending on the makeup water temperature, the type of ice maker, and ice maker operating settings.

The variation of reservoir water temperature reduction with makeup water temperature is illustrated in Figure 4 for Manitowoc, Cornelius, and Hoshizaki ice makers equipped with a Maximicer WCR heat exchanger (similar data were not available for the Fast Ice WCR heat exchanger). These data were recorded for various types of ice makers, representing different water charging and discharging design modes and, presumably (but not documented), different operating settings. As described in the previous paragraph, there are three basic water charging and discharging designs: purge, overflow, and the purge/overflow combination.

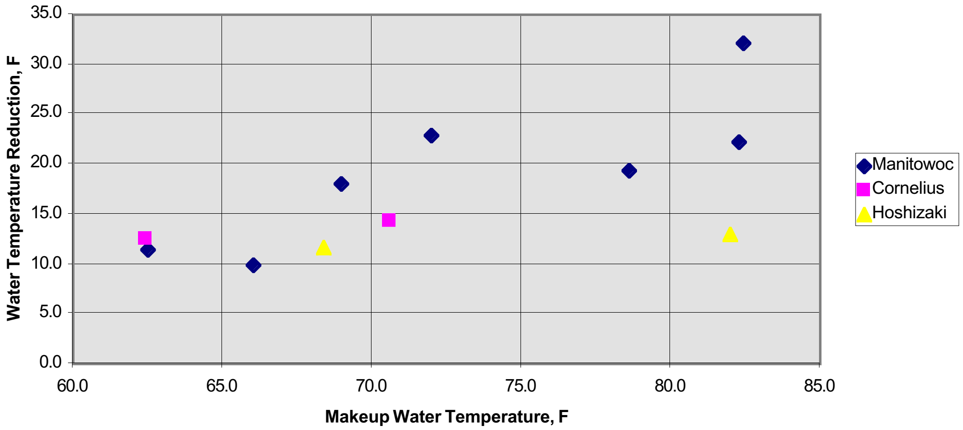

Figure 4. Maximicer Makeup Water Temperature Reduction

The principal consideration in designing the water charging and discharging mechanism for ice makers is to inhibit precipitation of impurities and maintain high quality (clear) ice. Energy conservation is of secondary importance. Unfortunately, improving ice quality and reducing the potential for impurity precipitation generally increases energy consumption and vice versa.

Makeup water quality varies significantly from one site to the next, so most ice makers have adjustment mechanisms that vary the amount of water consumed per unit of ice production. For example, the amount of water charged to the reservoir is usually adjustable in purge-type machines. For overflow machines, the reservoir filling (hence, overflowing) period is adjustable. For purge/overflow machines, the frequency of purging (ice harvesting cycles/purge) is adjustable along with the reservoir filling period.

***Therefore, energy consumption can be reduced simply by adjusting the reservoir charging volume, reservoir filling period, and/or purge frequency down. Reducing water consumption runs the risk of causing impurity precipitation and/or cloudy ice cubes, however, so caution is advised. On the other hand, if the current settings are conservatively set for the makeup water quality at a specific site, changing the equipment settings to reduce water consumption is a simple way to save energy (and water) without investing in additional hardware.***

Another option would be to remove some of the impurities prior to introducing the makeup water to the ice maker (e.g., via a water softener). This would allow less water and energy consumption and is commonly employed as part of industrial ice-making systems, but is cost-prohibitive for individual commercial ice makers.

In general, WCR heat exchangers will have the greatest impact (potential load reduction and energy savings) for purge-type ice makers. For these types of machines, all the water (near freezing) remaining at the end of an ice-making cycle is purged from the reservoir, resulting in a significant loss of "chill" that could be partly reclaimed by heat exchange with the makeup water.

For overflow-type ice makers, estimating the “chill” loss with or without a WCR heat exchanger is more complicated. During the harvest cycle, makeup water is not first purged (drained) from the reservoir prior to filling the reservoir. Rather, makeup water is added directly to the residual water left in the reservoir. Makeup water is added until the mixture of residual water and makeup water overflows the reservoir for an adjustable period of time. Thus, much of the “chill” contained in the residual water is captured in the reservoir, although the overflow water is still cooler than the makeup water. As the filling/overflow period is lengthened, more “chill” is lost, and the reservoir water temperature approaches the makeup water temperature.

Adding a WCR heat exchanger to an ice maker with an overflow type of water charging and discharging system has the following impacts. Significantly less “chill” is recovered compared with a purge-type ice maker because the discharge water is not nearly as cold. In fact, for longer overflow periods, there would be no benefit at all, because the reservoir/discharge water approaches the temperature of the makeup water. However, adding the WCR heat exchanger increases the pressure drop on the inlet line, which reduces the flow rate into the reservoir, which reduces the amount of water overflowing to discharge for a fixed refill/overflow period.

***Thus, for an overflow-type ice maker, a portion of the energy savings benefit accrues simply because the overflow volume per cycle is reduced and not because the makeup water is pre-cooled in the heat exchanger. These savings are taken at the risk of increasing the chances of impurity precipitation and/or reducing ice cube quality***. As might be expected, the impacts described above for purge and overflow-type ice makers are combined for the hybrid purge/overflow ice makers. As a result, one would expect the WCR heat exchanger to work best with purge-type ice makers, worst with overflow-type ice makers, with intermediate outcomes for the hybrid-type ice makers.

## ice maker performance (“$COP_{im}$”)

The coefficient of performance for the ice maker translates the reduction in cooling load into the reduction in electric load. Ice maker performance is more commonly described in terms of kWh per unit of ice production rather than by its system COP, although the latter can be readily calculated from the former for a given makeup water temperature. Unfortunately, the standard cooling system COP is not the correct figure to use in equations 1 and 3. In general, cooling system COP is defined as the ratio of the cooling duty sought (converting makeup water into ice for ice makers) to electrical energy input, with both numerator and denominator energies measured in the same units. The “cooling duty sought” includes only the energy removal required to cool water from its makeup temperature to freezing and to accomplish the phase change. No parasitic thermal loads (e.g., cooling of water that is discharged, melting a portion of the ice formed, heating of the evaporator plates during defrost) are included in the numerator, although their impact is implicitly included in the denominator as the refrigeration system must operate to remove the parasitic thermal loads as well as the “cooling duty sought.”

Reducing the reservoir water temperature not only reduces the “cooling duty sought,” but reduces the parasitic thermal loads as well (specifically, the cooling of water that is discharged). Thus, the correct COP to use in equations 1 and 3 is the ratio of total thermal load (cooling duty sought plus thermal parasitics to electric energy input (compressor plus fan plus water pump) during the ice-making mode. Compressor energy input during the ice harvesting or defrost mode is not included in the denominator as this energy input is not affected by changing the total thermal load. In short, reducing the water temperature charged to the reservoir reduces electrical energy consumption during the ice-making mode in proportion to the reduction in total thermal load. Unfortunately, this peculiar definition of COP (i.e., $COP_{im}$) is not readily available from manufacturers. Fortunately, detailed thermal and electric load estimates presented in A.D. Little (1996) for a typical ice maker show $COP_{im}$ to be about 1.7.

## value of ice maker electricity savings (“$\$/kWh_{im}$”)

Variation in site-specific electricity rates will certainly have a significant impact on the dollar savings achieved with a WCR heat exchanger and could easily make the difference between being a cost-effective investment or not. In general, $\$/kWh_{im}$ should only include electricity energy charges and not the average $/kWh impact of electricity demand charges. For an individual ice maker, demand savings are likely to be at or near zero. In general, the WCR device works to reduce the ice harvesting cycle time rather than reducing its peak power demand. While demand will be reduced at the onset of the ice-making cycle as a lower water temperature in the reservoir translates into a lower head pressure for the compressor, the peak demand for the cycle usually occurs during defrost, and would not be affected by the WCR device.

## cooling and heating system performance (“$COP_{ac}$” and “effh”)

For ice makers with condensers internal to the building, an important secondary impact occurs. All heat rejected from the ice maker to the building must be removed by the building’s cooling system during the cooling season. Cooling system COPs generally range from about 2 to 3, although window units can be poorer and larger centrifugal chiller systems can be better (Colen 1990). Therefore, assuming a value of 2.5 for $COP_{ac}$ is reasonable if a better estimate is not available.

Conversely, heat rejected from the ice maker during the heating season need not be supplied by the building’s heating system. Installation of the WCR device reduces the ice maker’s cooling load per lb of ice, which directly reduces the amount of heat rejected to the building. As the demand for ice is generally higher during the cooling season than during the heating season, this secondary impact generally results in additional dollar savings which should be attributed to the WCR device. During the cooling season, equations 3, 4, and 5 apply, while equations 3, 6, and 7 apply during the heating season. As for cooling systems, heating system efficiency (effh) depends on system type, but will usually be between 70% and 90%. A value of 80% is suggested, if no better estimate is available.

## value of cooling system electricity savings (“$\$/kWh_{ac}$”)

In addition to electricity energy savings, electricity demand savings seem more likely to occur for the cooling system than for the ice makers. Peak building electric demands are driven by space cooling loads, which, like ice making demand, is driven by warm weather. Thus, reduced heat rejection from ice makers, the resulting reduction in cooling equipment electrical demands, and peak building electrical demands are all likely to coincide.

The path for demand reduction does not occur at a single electrical appliance, which is usually either on or off rather than operating at part load, but from integration over a large number of units. The reduced thermal load served by a single cooling system unit will not result in a lower peak demand, but a reduction in the amount of time the unit operates during the peak demand period. Integrated over a number of cooling system units (perhaps in a number of buildings) served by a single meter, the effect is a reduction in peak demand that is proportional to the reduction in peak heat rejection. Thus, the effect of demand charges on the average cost of electricity should be included in $/kWh$_{ac}$.(a)

In summary, for most situations, there will likely be more cooling system units than ice makers served by a single electric meter. In addition, certain ice maker applications, such as food service, seem more likely to result in simultaneous ice maker operation during the peak demand period. Therefore, demand charge reductions seem more likely to accrue from multiple cooling system units than from multiple ice makers.

If space cooling is provided by a non-electric technology, such as absorption chillers, then equations 4 and 5 would be modified to calculate energy savings in MMBtu and dollar savings based on energy savings and the value of energy in $/MMBtu. Similarly, equations 6 and 7 would be modified to look like equations 4 and 5 for electrically driven space heating systems.

## Where to Apply

The previous section described and discussed the key factors affecting the cost-effective application of WCR heat exchangers to ice makers. The bulleted items listed below summarize the key favorable conditions that will most likely result in a cost-effective application. Not all of these conditions necessarily need to exist for an application to be cost-effective. Cost-effectiveness depends on the specific values of the variables identified in equations 1-7. Still, if the majority of these conditions do not exist, it is unlikely a WCR heat exchanger will be cost-effective.

- The annual demand for ice is relatively high, generally greater than 30% of its annual production capacity, if operated continuously throughout the year.

- The ice maker operates in a "purge" mode (as described above) to charge and discharge its water reservoir.

- The average annual makeup water temperature is relatively high, generally greater than 60°F.

- The ice maker's condenser is located indoors.

- The electricity rate is relatively high, generally greater than $0.08/kWh.

## Maintenance Impact

WCR heat exchangers are passive devices with no moving parts that are designed to operate maintenance free. The principal concern is that the internal heat exchanger surfaces may become fouled with impurities that precipitate out of the discharge water. In theory, there is some cause for concern. The common carbonates that cause scaling problems are less soluble in warmer water than colder water. Thus, as impurities are concentrated in the discharge water, warming the discharge water in the WCR heat exchanger will increase the probability of precipitation.

Retrofit of a WCR heat exchanger into an overflow-type ice maker increases supply line pressure drop, which decreases the supply flow rate and the amount of discharge water that overflows. This will further concentrate impurities in the discharge water and increase the odds of precipitation. To minimize the chances of precipitation, consider a WCR heat exchanger that incorporates plastic components at the heat exchanger's inlet and outlet to eliminate stray electric currents that otherwise enhance scaling.

The odds of incurring scaling problems are more strongly associated with local water chemistry and water consumption settings on the ice maker than with the WCR device; none of the current users contacted indicated any scaling problems with their WCR heat exchangers. Still, warming the discharge water can only increase the chances of forming precipitate. Some passive cleaning of the heat exchanger may occur in conjunction with periodic active cleaning of the ice maker and storage bin surfaces, as cleaning chemicals are washed through the heat exchanger. Further experience with WCR heat exchangers will need to be accumulated to better predict actual maintenance requirements.

## Equipment Warranties

Maximicer will refund the customer's purchase price within 6 months of installation should the customer be dissatisfied with their WCR heat exchanger for any reason—if the customer returns the unit to Maximicer. The Maximicer heat exchanger is warranted against any defects in materials or workmanship for 5 years after installation. Fast Ice also offers a 5-year warranty against any defects in materials and workmanship.

## Codes and Standards

The following standards apply to ice makers and (presumably) to WCR heat exchangers applied to ice makers.

National Sanitation Foundation *Standard 12, Automatic Ice Making Equipment*.

Underwriters Laboratories, Inc. *Standard 563-84, Ice Makers*.

Air-Conditioning and Refrigeration Institute Standard 810-79, *Automatic Commercial Ice Makers*.

ASHRAE *Standard 29-78, Method of Testing Automatic Ice Makers*.

Plumbing codes, such as the International Plumbing Code, will address the connection of WCR heat exchangers to the potable water supply and the discharge of purge water to the building sanitary drainage system and will apply as adopted by various agencies.

## Costs

The purchase prices for Maximicer WCR heat exchangers are $400, $500, and $600 for ice makers with daily production capacities up through 450 lb, from 500 through 1,000 lb, and from

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(a) A more accurate approach would be to directly estimate the demand and demand charge reduction, but this approach would require hour-by-hour or similar modeling that was judged to be more complex than justified for the relatively small investment represented by a WCR heat exchanger.

1,100 through 3,000 lb, respectively. Fast Ice offers a single WCR heat exchanger at a price of $395. Rather than offer multiple sizes of WCR heat exchangers, Fast Ice suggests the following installation strategies for different capacity ice makers. For float-control, water-filling machines with a daily capacity of 1,200 lb or less, the Fast Ice WCR heat exchanger should be hooked up to both sump and ice storage bin drains. For solenoid-control water-filling machines and all machines with a daily capacity greater than 1,200 lb, only the ice storage bin drain should be hooked up. Installation is expected to take a refrigeration technician or equivalent personnel from 1-2 hours, resulting in a charge of about $50.

# Utility Incentives and Support

Tennessee Valley Authority, Madison Gas and Electric, and Southern California Edison have or plan to conduct tests on the Maximicer WCR heat exchangers. However, no specific incentives aimed at WCR heat exchangers were identified.

# Technology Performance

Approximately 5,000 WCR heat exchangers had been installed as of mid-1997, with all but a few being installed in non-Federal applications. Technology performance experienced by users and independent testers is described below.

## Field Experience

The WCR technology is successfully being used in a wide range of commercial applications—hotels, restaurants, convenience stores, and schools. Although few ice machines are separately metered, all the sites we spoke with indicated an observable decrease in cycle time indicating a lowering of inlet water temperature. Where test measurements were performed, the Maximicer WCR technology reduced inlet water temperature an average of 15.2°F or 21.9%. The cycle times were reduced by 2.1 minutes, on average, or 18.1%.

The most extensive independent field test was performed by the Tennessee Valley Authority (TVA) using a Maximicer WCR heat exchanger on a Manitowoc Series 600 ice machine located at the Wall Street Deli, Kirklin Building, Birmingham, Alabama. The ice machine was monitored for five periods ranging from 6 to 8 days each. During two time periods, the machine was operated without the WCR device and during the other three the machine was switched to the WCR device.

TVA reported that the ice machine averaged 18.0 kWh/day in normal operation and 12.4 kWh/day with the Maximicer WCR device—a savings of 30.5%. We can extrapolate yearly savings from the daily savings of 5.5 kWh/day. If the electric rate is $0.10/kWh, the WCR device would save $198/year in energy costs. While these results are good, one of the monitoring periods with the WCR device operating extended over the Thanksgiving holiday and it was not apparent that any attempt was made to normalize for a decreased ice demand over the holiday. Therefore, the savings reported may be slightly higher than expected.

Another field test was performed by Madison Gas and Electric Company of Madison, Wisconsin. Maximicer WCR devices were installed on two ice machines in a newly constructed motel. The ice machines were individually metered with totalizing kWh meters and operated for several weeks during late spring 1996. The study showed that operating under similar conditions, a WCR device would save approximately 25% in energy costs, or about 1,600 kWh/year.

Although the motel management was pleased with the technical performance of the device, they were unable to economically justify purchasing additional units. A savings of $86/year (at $0.054/kWh) produces a payback of 5.8 years. The low cost of electricity and the low city water temperature (as low as 45°F in the winter) hinder the implementation of the WCR technology for the Madison region. The energy savings will likely be less during the winter when ice demand is reduced and the incoming water temperature is lower.

Currently, a detailed monitoring study is being performed by Southern California Edison (SCE). However, results were not yet available as this FTA was being prepared. The reader should contact SCE directly for the results of this study.

## Energy Savings

As previously indicated, the field experience has shown energy savings ranging from 10% to 30%. The energy savings for a particular installation will vary widely depending on many factors, including the inlet water temperature (which varies between regions and municipalities), ice machine design, ice machine location, demand for ice, and physical location of waste heat exhaust. In general, the WCR device shows the most potential in warmer climates or where municipal water temperatures are higher.

The maximum energy savings will be achieved on a machine that is used to produce the same amount of ice and is able to run for a shorter period in doing so. However, if the reduced run-time allows the machine to produce more ice in the same amount of time (i.e., increased ice demand), a portion of the energy savings will be traded for additional ice production. The reduction in energy consumption per pound of ice produced will be the same in either case, of course.

## Maintenance

The are no routine maintenance requirements for the WCR technology. The life expectancy of the technology is greater than the life expectancy of any ice machine on which it would be installed. The main concern for this or any heat exchanger is the affect fouling and mineral deposits have on the heat exchanger efficiency. The water drained from the sump at the end of the cooling cycle has a high concentration of impurities. The heat exchanger coils in the Maximicer WCR devices are electrostatically isolated to prevent weak electrical currents, which facilitate the precipitation of calcium carbonate and other minerals.

## Environmental Impacts

There are no negative environmental impacts associated with the WCR technology. The device is made of various plastics and polymers, copper tubing, and/or stainless steel, depending on the manufacturer. It has no active electronics and can be disposed of through normal trash pickup. In conditions where it saves energy and increases the capacity of ice machines, it provides secondary environmental benefits stemming from reduced electricity input, hence reduced emissions at electricity generating plants.

# Case Studies

Two example case studies are presented in this section to illustrate how the cost-effectiveness of a WCR heat exchanger should be evaluated. The first case assumes the ice maker condenser is located indoors; the second case assumes the ice maker condenser is located outdoors. The data presented do not represent any site-specific situation, but are intended to represent realistic conditions that could possibly occur. The results should not be taken as evidence that a WCR heat exchanger is generally cost-effective or not; rather, the cases are only intended to provide instruction on how to evaluate the cost-effectiveness of a potential application.

In general, energy savings are determined by exercising equations 1-2 for ice makers with condensers located external to the building or equations 1-7 for ice makers with condensers located internal to the building. The accuracy of the analysis can be varied by exercising the equations over different time periods. An hour-by-hour annual evaluation would provide the most accurate assessment if accurate hourly data are available for all inputs, but such is not likely the case. On the other hand, an annual average evaluation minimizes data requirements, but may not yield the desired accuracy. The generally recommended approach, described here, is based on input data for average monthly conditions. Thus, the data requirements listed below need to be specified for each month of the year. For several of the variables, a single annual average value may be used for each month if monthly variation is unknown and likely to be minimal. Default assumptions are presented for variables of lesser importance that may be difficult to define. Default assumptions are not provided for the more important variables that must be defined to allow an adequately accurate evaluation.

## Facility Data

The following facility-related data are required to determine WCR heat exchanger cost-effectiveness:

- makeup water temperature, °F
- electricity rate, \$/kWh, based on energy charges only
- electricity rate, \$/kWh, based on energy and demand charges
- fossil fuel or steam rate, \$/MMBtu
- cooling system coefficient of performance (COP)
- heating system efficiency or COP
- space conditioning mode, heating or cooling.

Only the makeup water temperature and electricity rate based on energy charges need to be specified when evaluating ice makers with external condensers.

### makeup water temperature

Makeup water temperature is a key variable affecting WCR heat exchanger cost-effectiveness. Fundamentally, if the makeup water is already cool, there is little point in trying to recover “chill” that is lost with the purge water. Makeup water temperature can vary significantly depending on the region, season, and water delivery system. Well water temperatures vary little seasonally, but vary from about 45-75 °F regionally. Surface water temperatures vary seasonally and regionally, with the combined effect resulting in a range from near freezing to around 100°F.

Makeup water temperature is also affected by the length and location of water supply piping. Longer supply lines located above ground are more likely to yield temperatures close to current ambient conditions. Most supply lines are buried, however, but not too deeply. Near surface ground temperatures tend to track seasonal variations in average daily air temperatures, so even makeup water originating from wells is likely to experience some seasonal variation in temperature, unless the well is practically adjacent to the building with the ice maker.

If makeup water temperature data are not available, the local water supply company should be able to provide average monthly temperature data as it leaves their plant. A comparison with their current temperature and the current temperature at your facility (measured easily with any hand-held thermometer) provides some guidance for estimating average monthly temperatures at your facility throughout the year. Note that the warming or cooling of water in transit between the water plant and your facility will vary depending on the time of year as well as supply piping length and location.

### energy rates

The average monthly electricity rate based on energy charges may be simply defined by the rate structure if flat energy rates apply or may require a quick calculation if time-of-use rates apply. In the latter case, monthly electricity bills can be examined to identify total energy-related charges and kWh consumption. The ratio of these two figures can be used as the average monthly electricity rate based on energy charges. Monthly demand charges must be added to the energy charges and the sum divided by kWh consumption to calculate the average monthly electricity rate based on energy and demand charges.

The fossil fuel or steam rate, typically a flat charge per unit of consumption, must be converted to a \$/MMBtu basis if sold on another basis (e.g., \$/therm, \$/gallon, \$/ton, \$/1,000 lb). If demand charges apply to the fossil fuel, the average monthly rate can be calculated as described for the electricity rate based on energy and demand charges.

### cooling system COP

The cooling system COP will vary with the type of cooling system and ambient air conditions. Systems with air-cooled condensers are affected by the dry-bulb temperature while systems with water-cooled condensers and evaporative cooling towers are affected by the wet-bulb temperature as well. Average monthly COPs can be estimated by comparing performance specifications at rated conditions with average monthly air temperatures. System performance data should be documented in the user’s manual or may be obtained by contacting the vendor.

The National Weather Service should be able to provide average monthly air temperatures for a nearby city, although adequate accuracy is probably obtained by applying one’s judgment and knowledge of the local climate. Lacking better information, a value of 2.5 is recommended for vapor compression cooling systems and values of 0.65 and 1.2 are recommended for single-effect and double-effect lithium bromide absorption cooling systems, respectively.

### heating system efficiency or COP

Heating system efficiency will vary with the type of heating system, and may vary with ambient air conditions. Again, the system user’s manual or vendor should be consulted to establish its efficiency. An efficiency of 0.80 is recommended for fossil-fueled systems if better information is not available. On the same basis, a COP of 2.5 is recommended for electrically-driven heat pumps.

Facility data assumptions for the two case studies are presented in Table 2. Note that electricity energy and demand rate data and cooling system COP data are only required when the building is operating in the cooling mode, while heating fuel rate and heating system efficiency data are only required when the building is operating in the heating mode.

**Table 2. Case Study Facility Data Assumptions**

| Month | Makeup Water Temperature, °F | Electricity Energy Rate, $/kWh | Electricity Energy & Demand Rate, $/kWh | Heating Fuel, Rate $/MMBtu | Cooling System COP | Heating System Efficiency | Building Space Conditioning Mode |
|---|---|---|---|---|---|---|---|
| **Jan** | 60 | 0.06 | 0.065 | 4.50 | 2.9 | 0.80 | heating |
| **Feb** | 55 | 0.06 | 0.065 | 4.50 | 2.8 | 0.80 | heating |
| **Mar** | 50 | 0.06 | 0.065 | 4.50 | 2.7 | 0.80 | cooling |
| **Apr** | 55 | 0.09 | 0.100 | 4.50 | 2.6 | 0.80 | cooling |
| **May** | 60 | 0.09 | 0.100 | 4.50 | 2.5 | 0.80 | cooling |
| **Jun** | 65 | 0.09 | 0.100 | 4.50 | 2.4 | 0.80 | cooling |
| **Jul** | 70 | 0.09 | 0.100 | 4.50 | 2.3 | 0.80 | cooling |
| **Aug** | 75 | 0.09 | 0.100 | 4.50 | 2.4 | 0.80 | cooling |
| **Sep** | 80 | 0.09 | 0.100 | 4.50 | 2.5 | 0.80 | cooling |
| **Oct** | 75 | 0.06 | 0.065 | 4.50 | 2.6 | 0.80 | cooling |
| **Nov** | 70 | 0.06 | 0.065 | 4.50 | 2.7 | 0.80 | cooling |
| **Dec** | 65 | 0.06 | 0.065 | 4.50 | 2.8 | 0.80 | heating |

## Ice Maker and WCR Heat Exchanger Data

The following ice maker and WCR heat exchanger data are required to determine WCR heat exchanger cost-effectiveness:

- ice production

- water charged to reservoir per unit of ice production

- makeup water temperature reduction

- ice maker "COP."

In addition to makeup water temperature, ice production and makeup water temperature reduction are the keys to WCR heat exchanger cost-effectiveness. Each of these three factors can vary significantly, depending on the regional location, application, type of ice maker, and type of WCR heat exchanger.

### ice production

Monthly ice production, as a percent of rated capacity (hereinafter referred to as the capacity factor), tends to be relatively high for ice makers because their built-in storage capacity levels out short-term peak demands for ice. Nevertheless, ice maker capacity factor varies significantly between different service applications (e.g., hotel hallway applications vs. restaurant applications) and varies seasonally for a given application as well. Estimating ice production accurately may be a difficult task. The most accurate approach would be to record the number of ice-harvesting cycles and multiply this by the amount of ice produced per cycle. The latter figure should be documented in the ice maker's user's manual. Alternatively, ice consumption can be estimated using rules-of-thumb presented in ASHRAE (1996) for several different ice maker applications.

### water charged to reservoir per unit ice production

The water charged to the reservoir per unit of ice production should not be confused with total water consumption per unit of ice production. The latter figure is usually documented in the ice maker's user's manual and is also reported in the Air Conditioning and Refrigeration Institute's (ARI's) *Directory of Certified Automatic Commercial Ice-Cube Machines and Storage Bins* (ARI 1997) for equipment they have tested. The former figure will be less than the latter figure for ice makers with an overflow or combination purge/overflow charge and discharge mechanism. Reservoir volume can be easily determined by pouring a measured amount of water into the reservoir until full. Dividing by the amount of ice produced per harvest (should be documented in the ice maker user's manual) yields the appropriate ratio, which typically ranges from 1.2 to 1.8.

### makeup water temperature reduction

A reduction in makeup water temperature is the fundamental thermal objective of a WCR heat exchanger, but is very difficult to estimate. As previously discussed under *Application Screening,* a WCR heat exchanger can be expected to work best with purge-type ice makers, worst with overflow-type ice makers, with intermediate results for ice makers with a combination purge/overflow design. More specifically, the reduction in makeup water temperature is expected to be greatest for purge-type ice makers and least for overflow-type ice makers. For any type of ice maker, the reduction in makeup water temperature possible with a WCR heat exchanger increases with makeup water temperature. Higher makeup water temperatures increase the driving force controlling heat transfer within the WCR heat exchanger and the effective cooling capacity of the discharge water.

The reduction in makeup water temperature as a function of makeup water temperature was previously shown in Figure 4 for several ice makers equipped with a Maximicer WCR heat exchanger (similar data were not made available for the Fast Ice WCR heat exchanger). The following observations are made:

- Water temperature reduction generally increases as makeup water temperature increases.

- Water temperature reduction is generally greater for the Manitowoc ice makers than the Hoshizaki or Cornelius ice makers.

- There is considerable variation in water temperature reduction for a given makeup water temperature, depending on the type of ice maker.

- The variation in water temperature reduction increases with makeup water temperature.

- No data were collected for overflow-type ice makers.

The Manitowoc and Cornelius ice makers are purge-type machines, while the Hoshizaki is a combination purge/overflow design. As expected, the average water temperature reduction reported for the two purge-type machines is greater than for the purge/overflow machine, but the limited data for Cornelius and Hoshizaki ice makers makes it risky to draw any firm conclusions. Furthermore, its not known what the purging frequency or filling period were for the two Hoshizaki machines or the ratio of reservoir water to ice for any of the machines. In short, Figure 2 can be used to estimate the "ballpark" impact of a WCR heat exchanger on the reduction in makeup water temperature, but there is considerable uncertainty in this key performance factor.

## ice maker COP

The ice maker "COP" translates the thermal energy savings from reducing the makeup water temperature into ice maker electrical energy savings and a reduction in thermal energy rejected at the condenser. The appropriate ice maker "COP" is defined as the ratio of total thermal load, including all sources of heat that must be rejected by the ice maker, to the sum of electric energy input to the compressor, condenser fan, and water pump during the ice-generation mode, with thermal load and electricity input measured in the same units.

Unfortunately, this measure of performance is not likely included in the ice maker owner's manual or readily available from the ice maker vendor. Ice maker performance is commonly quoted in terms of kWh per unit of ice production at prescribed test conditions. Unfortunately, this figure cannot be translated into the required "COP" figure without knowing the split between electricity consumption during the ice-making mode (which is affected by the WCR heat exchanger) and the ice-harvesting mode (which is not affected by the WCR heat exchanger) and the total thermal load. Fortunately, detailed thermal and electrical load estimates presented in A.D. Little (1996) for a typical ice maker show its "COP" to be about 1.7. While this figure will vary depending on ice maker design and ambient air conditions for systems with external condensers, the value of 1.7 is recommended for use in evaluating cost-effectiveness unless better data are available.

Ice maker and WCR heat exchanger data assumptions for the two case studies are presented in Table 3.

## Energy Savings

Annual energy savings are calculated by applying the assumptions presented in Tables 2 and 3 to equations 1-7. The month-by-month and annual energy savings are presented in Table 4. Ice maker energy savings occur for all applications, while HVAC energy savings occur if the ice maker condenser is inside the building. Note that when the building is in the heating mode, ice maker energy savings translate into HVAC fuel usage or increased heating energy costs. The case study results also show the significance of the HVAC energy savings in addition to the ice maker energy savings.

## Life-Cycle Cost

The purchase cost for a WCR heat exchanger applicable to a 1,000 lb/day ice maker is about $500, and includes the fittings likely to be required for installation. Hookup to the ice maker should take from 1 to 2 hours of a plumber's or refrigeration technician's time. Thus, the total installed cost is estimated to be about $550.

Other benefits claimed by WCR heat exchanger manufacturers are 1) increasing the hourly production capacity, which may avoid the need for a larger or additional machine or the need to purchase supplemental ice, and 2) lowering the compressor head pressure, which may lengthen machine life and/or reduce machine maintenance. These benefits may occur, but are generally less tangible, more uncertain, more site-specific, and more difficult to quantify than the energy savings benefits described above. Therefore, the dollar value of these benefits has not been included in the case studies. However, the increase in ice production capacity may be more valuable than the energy savings if the need to purchase a larger or additional machine or supplemental ice is avoided. The potential for longer machine life and/or less maintenance seems plausible, but the dollar value of these benefits is much more speculative.

WCR heat exchangers are passive devices (i.e., they have no moving parts). As a result, no components are expected to wear out or require adjustment. Periodic cleaning may be required, especially in applications with high

**Table 3. Case Study Ice Maker and WCR Heat Exchanger Assumptions**

| Month | Ice Production Capacity Factor | Ice Production lb (based on 1,000 lb/day machine) | Reservoir Water to Ice Ratio | Makeup Water Temperature Reduction, °F | Ice Maker COP |
|---|---|---|---|---|---|
| **Jan** | 0.4000 | 12,400 | 1.5 | 10 | 1.7 |
| **Feb** | 0.4333 | 12,133 | 1.5 | 7 | 1.7 |
| **Mar** | 0.4667 | 14,467 | 1.5 | 4 | 1.7 |
| **Apr** | 0.5000 | 15,000 | 1.5 | 7 | 1.7 |
| **May** | 0.5333 | 16,533 | 1.5 | 10 | 1.7 |
| **Jun** | 0.5666 | 17,000 | 1.5 | 13 | 1.7 |
| **Jul** | 0.6000 | 18,600 | 1.5 | 16 | 1.7 |
| **Aug** | 0.5667 | 17,567 | 1.5 | 19 | 1.7 |
| **Sep** | 0.5333 | 16,000 | 1.5 | 22 | 1.7 |
| **Oct** | 0.5000 | 15,500 | 1.5 | 19 | 1.7 |
| **Nov** | 0.4667 | 14,000 | 1.5 | 16 | 1.7 |
| **Dec** | 0.4333 | 13,433 | 1.5 | 13 | 1.7 |

**Table 4. Case Study Annual Energy Savings**

| Month | Ice Maker Electricity Savings, kWh | HVAC Electricity Savings, kWh | Total Electricity Savings, kWh | HVAC Fuel Usage, MMBtu | Ice Maker Electricity Savings, $ | HVAC Electricity Savings, $ | Total Electricity Savings, $ | HVAC Fuel Usage, $ | Net Energy Savings with Outside Condenser, $ | Net Energy Savings with Inside Condenser, $ |
|---|---|---|---|---|---|---|---|---|---|---|
| **Jan** | 32.06 | 0.00 | 32.06 | 0.37 | $1.92 | $0.00 | $1.92 | $1.66 | $1.92 | $0.26 |
| **Feb** | 21.96 | 0.00 | 21.96 | 0.25 | $1.32 | $0.00 | $1.32 | $1.14 | $1.32 | $0.18 |
| **Mar** | 14.96 | 14.96 | 29.92 | 0.00 | $0.90 | $0.97 | $1.87 | $0.00 | $0.90 | $1.87 |
| **Apr** | 27.15 | 28.19 | 55.33 | 0.00 | $2.44 | $2.82 | $5.26 | $0.00 | $2.44 | $5.26 |
| **May** | 42.74 | 46.16 | 88.91 | 0.00 | $3.85 | $4.62 | $8.46 | $0.00 | $3.85 | $8.46 |
| **Jun** | 57.13 | 64.28 | 121.41 | 0.00 | $5.14 | $6.43 | $11.57 | $0.00 | $5.14 | $11.57 |
| **Jul** | 76.94 | 90.32 | 167.26 | 0.00 | $6.92 | $9.03 | $15.96 | $0.00 | $6.92 | $15.96 |
| **Aug** | 86.29 | 97.07 | 183.36 | 0.00 | $7.77 | $9.71 | $17.47 | $0.00 | $7.77 | $17.47 |
| **Sep** | 91.00 | 98.28 | 189.28 | 0.00 | $8.19 | $9.83 | $18.02 | $0.00 | $8.19 | $18.02 |
| **Oct** | 76.14 | 79.06 | 155.20 | 0.00 | $4.57 | $5.14 | $9.71 | $0.00 | $4.57 | $9.71 |
| **Nov** | 57.91 | 57.91 | 115.82 | 0.00 | $3.47 | $3.76 | $7.24 | $0.00 | $3.47 | $7.24 |
| **Dec** | 45.15 | 0.00 | 45.15 | 0.52 | $2.71 | $0.00 | $2.71 | $2.34 | $2.71 | $0.37 |
| **Totals** | **629.42** | **576.24** | **1,205.66** | **1.14** | **$49.20** | **$52.31** | **$101.51** | **$5.14** | **$49.20** | **$96.37** |

concentrations of water impurities, but cleaning has not been an issue for users to date. Overall, uncertain cleaning costs are offset (more or less) by the uncertain benefits cited in the preceding paragraph.

The installed cost and energy savings data presented above were input into the NIST BLCC model (see Appendix A) to compare the life-cycle cost differences between an ice maker with and without a WCR heat exchanger. One comparison is based on the ice maker's condenser being inside the building, while the other is based on an outside condenser. BLCC output documenting the comparison is shown in Tables 5 and 6. Corresponding ECIP form data are presented in Appendix B. The results show the WCR heat exchanger to have a payback period of 6 years for an ice maker with an indoor condenser and 11 years for an outdoor condenser for the conditions assumed in Tables 2 and 3. **Please be cautioned that the payback period could be less than 1 year or greater than 100 years, depending on the site-specific conditions! Site-specific conditions must be evaluated before cost-effectiveness can be determined!**

# The Technology in Perspective

Care must be taken in evaluating the application of WCR heat exchangers to commercial ice makers. Differences in site conditions and ice maker design, plus differences in WCR heat exchangers offered by different vendors, have a significant impact on cost-effectiveness. Therefore, the accumulation of additional experience and independent testing by electric utilities and other organizations should make it easier to identify cost-effective applications in the future. Still, the potential benefits in certain applications are great enough that WCR heat exchangers should be considered in the Federal sector now.

## The Technology's Development

WCR from ice makers is not a novel concept. WCR equipment is commonly implemented in industrial ice-making systems, often in concert with water purification systems. WCR heat exchangers have periodically been applied to commercial ice makers in the past, according to several industry representatives, with mixed results. Problems with scaling were reported and/or the benefits were not adequate to justify the initial cost. No scaling problems have been reported as yet by users of either the Fast Ice or Maximicer WCR heat exchangers, but water purity and ice maker design and operating settings affecting water purging (key factors affecting the propensity for scaling) have rarely been recorded, so it is difficult to predict safe or unsafe application conditions. Maximicer has incorporated plastic parts to insulate the WCR heat exchanger from any stray electric currents that enhance precipitate formation. However, no consensus has been reached on the preferred WCR heat exchanger design, as indicated by the differences in the Fast Ice and Maximicer units.

## Technology Outlook

WCR heat exchangers for commercial-sized automatic ice makers are currently cost-effective in selected applications. Several factors affect cost-effectiveness. In general, cost-effectiveness is enhanced when 1) the annual demand for ice is relatively high, 2) the ice maker is operated in a "purge" mode (as described in *Application Screening*), 3) the average annual makeup water temperature is relatively high, 4) the ice maker's condenser is located indoors, and 5) the electricity rate is relatively high.

Thermal efficiency seems adequate in current WCR heat exchangers. Assuming that scaling remains a non-problem, the key factor that could be improved is first cost. Hopefully, mass production economies-of-scale and/or competition from multiple vendors will result in lower equipment costs in the future. Customer interest may also spark interest on the part of ice maker manufacturers to offer WCR heat exchangers as part of the original equipment. Several ice maker manufacturers indicated that energy efficiency generally ranks somewhere between fifth and tenth on the list of ice maker attributes that are important to their customers. Therefore, they have not been particularly interested in offering WCR heat exchangers or other energy-efficiency measures.

## Table 5. NIST BLCC Results for Ice Maker with Outside Condenser

```
****************************************************************************************************
                 *    N I S T  B L C C:  COMPARATIVE  ECONOMIC  ANALYSIS (ver. 4.3-96 )     *
****************************************************************************************************
                 PROJECT:  Waste Chill Recovery Heat Exchanger
                 BASE CASE:  Base1
                 ALTERNATIVE:  Outside Condenser

                 PRINCIPAL STUDY PARAMETERS:
                 ----------------------------
                 ANALYSIS TYPE:                  Federal Analysis—Energy Conservation Projects
                 STUDY PERIOD:                   7.00 YEARS (JAN 1997 THROUGH DEC 2003)
                 DISCOUNT RATE:                  3.8% Real (exclusive of general inflation)
                 BASE CASE LCC FILE:             BASE1.LCC
                 ALTERNATIVE LCC FILE:           WCR1.LCC

                              COMPARISON OF PRESENT-VALUE COSTS

                                                 BASE CASE:      ALTERNATIVE:      SAVINGS
                                                   Base1          outside cond     FROM ALT.
         INITIAL INVESTMENT ITEM(S):            ------------    -------------    ------------
         CASH REQUIREMENTS AS OF SERVICE DATE       $0              $550            -$550
                                                ------------    -------------    ------------
           SUBTOTAL                                 $0              $550            -$550
         FUTURE COST ITEMS:
         ENERGY-RELATED COSTS                      $292               $0             $292
                                                ------------    -------------    ------------
           SUBTOTAL                                $292               $0             $292
                                                ------------    -------------    ------------
         TOTAL P.V. LIFE-CYCLE COST                $292             $550            -$258

              NET SAVINGS FROM ALTERNATIVE Outside Cond COMPARED TO ALTERNATIVE Base1

                         Net Savings  =  P.V. of non-investment savings      $292
                                      -  Increased total investment          $550
                                                                           -------
                                         Net Savings:                       -$258

Note:  the SIR and AIRR computations include differential initial costs, capital replacement costs, and resale value (if any)
as investment costs, per NIST Handbook 135 (Federal and MILCON analyses only).

                              SAVINGS-TO-INVESTMENT RATIO (SIR)
                  FOR ALTERNATIVE Outside Cond COMPARED TO ALTERNATIVE Base1

                                   P.V. of non-investment savings
                        SIR   =   --------------------------------  =  0.53
                                   Increased total investment

                          ADJUSTED INTERNAL RATE OF RETURN (AIRR)
                  FOR ALTERNATIVE outside cond COMPARED TO ALTERNATIVE Base1
                        (Reinvestment rate =  3.80%; Study period =  7 years)

                                        AIRR =  -5.17%

                                 ESTIMATED YEARS TO PAYBACK

                           Simple Payback never reached during study period
                         Discounted Payback never reached during study period

                                   ENERGY SAVINGS SUMMARY

                   Energy      Units     -------- Annual Consumption --------    Life-Cycle
                    type                 Base Case    Alternative      Savings     Savings
                 ----------   -------   ----------   -----------     --------   ----------
                 Electricity    kWh        629            0            629        4,406
```

## Table 6. NIST BLCC Results for Ice Maker with Inside Condenser

```
**************************************************************************************************************
*      N I S T  B L C C:  COMPARATIVE  ECONOMIC  ANALYSIS (ver. 4.3-96 )      *
**************************************************************************************************************

                    PROJECT:  Waste Chill Recovery Heat Exchanger
                    BASE CASE:  Base2
                    ALTERNATIVE:  Inside Condenser

                    PRINCIPAL STUDY PARAMETERS:
                    ----------------------------
                    ANALYSIS TYPE:                 Federal Analysis—Energy Conservation Projects
                    STUDY PERIOD:                  7.00 YEARS (JAN 1997 THROUGH DEC 2003)
                    DISCOUNT RATE:                 3.8% Real (exclusive of general inflation)
                    BASE CASE LCC FILE:            BASE2.LCC
                    ALTERNATIVE LCC FILE:          WCR2.LCC

                              COMPARISON OF PRESENT-VALUE COSTS

                                              BASE CASE:    ALTERNATIVE:     SAVINGS
                                                Base2        inside cond    FROM ALT.
          INITIAL INVESTMENT ITEM(S):        ------------   ------------   ------------
          CASH REQUIREMENTS AS OF SERVICE DATE     $0           $550          -$550
                                             ------------   ------------   ------------
            SUBTOTAL                               $0           $550          -$550
          FUTURE COST ITEMS:
          ENERGY-RELATED COSTS                   $603            $31           $571
                                             ------------   ------------   ------------
            SUBTOTAL                             $603            $31           $571
                                             ------------   ------------   ------------
          TOTAL P.V. LIFE-CYCLE COST             $603           $581            $21

          NET SAVINGS FROM ALTERNATIVE Inside Cond COMPARED TO ALTERNATIVE Base2

                    Net Savings  =  P.V. of non-investment savings       $571
                                 -  Increased total investment           $550
                                                                       ------
                                    Net Savings:                          $21

Note:  the SIR and AIRR computations include differential initial costs, capital replacement costs, and resale value (if any)
as investment costs, per NIST Handbook 135 (Federal and MILCON analyses only).

                              SAVINGS-TO-INVESTMENT RATIO (SIR)
                     FOR ALTERNATIVE Inside Cond COMPARED TO ALTERNATIVE Base2

                                     P.V. of non-investment savings
                           SIR   =   ------------------------------  =  1.04
                                     Increased total investment

                           ADJUSTED INTERNAL RATE OF RETURN (AIRR)
                     FOR ALTERNATIVE inside cond COMPARED TO ALTERNATIVE Base2
                          (Reinvestment rate = 3.80%; Study period = 7 years)

                                        AIRR = -4.37%

                                 ESTIMATED YEARS TO PAYBACK

                                Simple Payback occurs in year 6
                              Discounted Payback occurs in year 7

                                   ENERGY SAVINGS SUMMARY

                Energy      Units   -------- Annual Consumption --------    Life-Cycle
                 type               Base Case   Alternative     Savings      Savings
             -----------  -------  ----------  ------------  ----------  -----------
              Electricity   kWh      1,206           0          1,206        8,440
             Natural Gas   MBtu          0           1             -1           -8
```

# Manufacturers

The two firms listed below are known to manufacture a waste chill recovery (WCR) heat exchanger device. Contact the manufacturers for more information regarding their products.

Maximicer
13740 Research Blvd, Suite K-5
Austin, Texas 78750
(512) 258-8801
(512) 258-8804 Fax
1-800-289-9098
email: ice@onr.com
http:/www.maximicer.com/

Fast Ice Products
Environmental Industries
International, Inc.
4731 Highway A1A, Suite #216
Vero Beach, Florida 32963
(561) 231-9772
(561) 231-9773 Fax
1-800-373-3423

# Who is Using the Technology

## Federal Sites

Bastrop Federal Correction Institution

## Non-Federal Sites

The WCR technology has been installed in many hotel, food, and convenience store locations. The following is a partial list of some WCR customers:

**Hotels and Motels -** Crown Plaza Hotels, Holiday Inn, Hyatt, La Quinta, Marriott Hotels, Omni Hotels, Radisson, Ramada Inn, and The Ritz - Carlton.

**Restaurants -** American Restaurant Partners, Pizza Hut, Long John Silvers, Metromedia Steak Houses, Ponderosa Steak House, Mr. Gatti's, Inc., Outback Steakhouse, Inc., PepsiCo, Inc., Taco Bell, Ryan's Family Steak Houses, Inc., S&A Restaurants, Inc., Steak and Ale, Bennigan's, ShowBiz Pizza Time, Inc., Chuck-E-Cheese's, Sonic Corp, Subway Sandwich Shops, Inc., The County Line, Inc., and Whataburger, Inc.

**School Districts/Universities -** Bastrop ISD, Texas, Belton ISD, Texas, Del Valley ISD, Texas, Gatesville ISD, Texas, Leander ISD, Texas, Marriott Food Services, Leander, Texas, Round Rock ISD, Texas, San Felipe Del Rio ISD, Texas, and Southwestern University.

**Hospitals -** Sid Peterson Memorial Hospital.

**Convenience Stores -** Diamond Shamrock, Diamond Shamrock Corner Mart, and The Water Jug.

# For Further Information

## Trade Associations

Air-Conditioning & Refrigeration Institute (ARI)
4301 N. Fairfax Dr., Suite 425,
Arlington, VA 22203
(703) 524-8800
(703) 528-3816 Fax

## User and Third Party Field and Lab Test Reports

Tennessee Valley Authority
1101 Market Street
Chattanooga, Tennessee 37402-2801
attn: Jim Folsom
423-751-7657

Southern California Edison
6090 N. Irwindale Avenue
Irwindale, CA 91702
attn: Sheila Hartley
1-800-336-2822

Madison Gas and Electric Company
133 South Blair Street
Madison, Wisconsin 53703
attn: Daniel J. Barker
608-252-5602

## Patents

| | |
|---|---|
| US Patent #4,881,378 | *(Fast Ice)* |
| US Patent #5,379,603 | *(Maximicer)* |
| US Patent #5,555,734 | *(Maximicer)* |

# References

ARI. 1997. *Directory of Certified Automatic Commercial Ice-Cube Machines and Storage Bins*. Air Conditioning and Refrigeration Institute. Arlington, VA

Arthur D. Little, Inc. 1996. *Energy Savings Potential for Commercial Refrigeration Equipment*. Cambridge, MA.

ASHRAE. 1996. *1996 ASHRAE Handbook: Equipment*. American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc. Atlanta, GA.

Colen, H.R. 1990. *HVAC Systems Evaluation*. R.S. Means Company, Inc. Kingston, MA.

# Appendixes

## Appendix A:  Federal Life-Cycle Costing Procedures and the BLCC Software

## Appendix B:  Life-Cycle Cost Analysis Summary: Energy Conservation Investment Program

# Appendix A

# Federal Life-Cycle Costing Procedures and the BLCC Software

Federal agencies are required to evaluate energy-related investments on the basis of minimum life-cycle costs (10 CFR Part 436). A life-cycle cost evaluation computes the total long-run costs of a number of potential actions, and selects the action that minimizes the long-run costs. When considering retrofits, sticking with the existing equipment is one potential action, often called the *baseline* condition. The life-cycle cost (LCC) of a potential investment is the present value of all of the costs associated with the investment over time.

The first step in calculating the LCC is the identification of the costs. *Installed Cost* includes cost of materials purchased and the labor required to install them (for example, the price of an energy-efficient lighting fixture, plus cost of labor to install it). *Energy Cost* includes annual expenditures on energy to operate equipment. (For example, a lighting fixture that draws 100 watts and operates 2,000 hours annually requires 200,000 watt-hours (200 kWh) annually. At an electricity price of $0.10 per kWh, this fixture has an annual energy cost of $20.) *Nonfuel Operations and Maintenance* includes annual expenditures on parts and activities required to operate equipment (for example, replacing burned out light bulbs). *Replacement Costs* include expenditures to replace equipment upon failure (for example, replacing an oil furnace when it is no longer usable).

Because LCC includes the cost of money, periodic and aperiodic maintenance (O&M) and equipment replacement costs, energy escalation rates, and salvage value, it is usually expressed as a present value, which is evaluated by

$$\text{LCC} = \text{PV(IC)} + \text{PV(EC)} + \text{PV(OM)} + \text{PV(REP)}$$

where PV(x) denotes “present value of cost stream x,”
IC is the installed cost,
EC is the annual energy cost,
OM is the annual nonenergy O&M cost, and
REP is the future replacement cost.

Net present value (NPV) is the difference between the LCCs of two investment alternatives, e.g., the LCC of an energy-saving or energy-cost-reducing alternative and the LCC of the existing, or baseline, equipment. If the alternative’s LCC is less than the baseline’s LCC, the alternative is said to have a positive NPV, i.e., it is cost-effective. NPV is thus given by

$$\text{NPV} = \text{PV}(\text{EC}_0) - \text{PV}(\text{EC}_1)) + \text{PV}(\text{OM}_0) - \text{PV}(\text{OM}_1)) + \text{PV}(\text{REP}_0) - \text{PV}(\text{REP}_1)) - \text{PV(IC)}$$

or

$$\text{NPV} = \text{PV(ECS)} + \text{PV(OMS)} + \text{PV(REPS)} - \text{PV(IC)}$$

where subscript 0 denotes the existing or baseline condition,
subscript 1 denotes the energy cost saving measure,
IC is the installation cost of the alternative (note that the IC of the baseline is assumed zero),
ECS is the annual energy cost savings,
OMS is the annual nonenergy O&M savings, and
REPS is the future replacement savings.

Levelized energy cost (LEC) is the breakeven energy price (blended) at which a conservation, efficiency, renewable, or fuel-switching measure becomes cost-effective (NPV >= 0). Thus, a project’s LEC is given by

$$\text{PV(LEC*EUS)} = \text{PV(OMS)} + \text{PV(REPS)} - \text{PV(IC)}$$

where EUS is the annual energy use savings (energy units/yr). Savings-to-investment ratio (SIR) is the total (PV) savings of a measure divided by its installation cost:

$$\text{SIR} = (\text{PV(ECS)} + \text{PV(OMS)} + \text{PV(REPS)})/\text{PV(IC)}.$$

Some of the tedious effort of life-cycle cost calculations can be avoided by using the Building Life-Cycle Cost software, BLCC, developed by NIST. For copies of BLCC, call the FEMP Help Desk at (800) 363-3732.

# Appendix B

# Life-Cycle Cost Analysis Summary: Energy Conservation Investment Program

### Energy/Water Life Cycle Cost Analysis Summary
### Outside Ice Maker Condenser

| | | |
|---|---|---|
| Installation: Sample | | Preparation Date: 06-26-1997 |
| Location: Sample | Region No. 4 | Project No. Sample |
| Project Title: Waste Chill Recovery Heat Exchanger | | Fiscal Year: 1997 |
| Base Date: JAN 1997 | BOD: JAN 1997[a] | Economic Life: 7 years |
| Discount rate: 3.80% | Prepared by: D.R Brown | |
| BLCC input data files: Project: MBASE1.DAT | Base Case: MWCR1.DAT | |

1. Investment

| | | | |
|---|---|---|---|
| A. | Construction Cost | $550 | |
| B. | SIOH | $0 | |
| C. | Design Cost | $0 | Funding Amount: |
| D. | Total Cost (1A + 1B + 1C) | $550 | $550 |
| E. | Salvage Value of Existing Equipment | $0 | |
| F. | Public Utility Company Rebate | $0 | Present Value:[b] |
| G. | Total Investment (1D - 1E - 1F ) | $550 | $550 |

2. Energy and Water Savings (+) or Cost (-)
Analysis Date Savings, unit costs, & discounted savings
Date of NISTIR 85-3273-X used for discount factors: october 1995

| Fuel | | Unit Cost $/MBtu (1) | Savings MBtu/Yr (2) | Annual Savings (3) | Discount Factor (4) | Discounted Savings (5) |
|---|---|---|---|---|---|---|
| A. | Electric | $22.854 | 2.1 | $49 | 5.950 | $292 |
| B. | Dist oil | $0.000 | 0.0 | $0 | 0.000 | $0 |
| C. | Resid oil | $0.000 | 0.0 | $0 | 0.000 | $0 |
| D. | Nat Gas | $0.000 | 0.0 | $0 | 0.000 | $0 |
| E. | Coal | $0.000 | 0.0 | $0 | 0.000 | $0 |
| F. | Demand Savings | | | $0 | 0.000 | $0 |
| G. | Subtotal | | 2.1 | $49 | | $292 |

| | | $/Mgal | Mgal/yr | Annual Savings | Discount Factor | Discounted Savings |
|---|---|---|---|---|---|---|
| H. | Water use | $0.00 | 0.0 | $0 | 0.000 | $0 |
| | Water disp | $0.00 | 0.0 | $0 | 0.000 | $0 |
| | Subtotal | | | $0 | | $0 |
| I. | Total | | | $49 | | $292 |

3. Non-Energy Savings (+) or Cost (-)

| | | | | |
|---|---|---|---|---|
| A. | Annually Recurring (+/-) | $0 | | |
| | (1) Discount Factor (Table A) | | 0.000 | |
| | (2) Discounted Savings/Cost (3A x 3A1) | | | $0 |

B. Non-Annually Recurring (+/-)

| | Item | Savings (+) Cost (-) (1) | Occurrence (from BOD) (2) | Factor (Table A-1) (3) | Discounted Savings or Cost (4) |
|---|---|---|---|---|---|
| d. | Total | $0 | | | $0 |

| | | |
|---|---|---|
| C. | Total Non-energy Savings (+)/Cost(-) (3A(2)+3Bd(4)) | $0 |
| 4. | First year savings (2I3 + 3A5 + 3Bd1/Yrs Economic Life) | $49 |
| 5. | Simple Payback Period (1G/4) | 11.21 years |
| 6. | Total Discounted Savings (2I5 + 3C) | $292 |
| 7. | Savings to Investment Ratio (SIR = 6 / 1G) | 0.53 |
| 8. | Adjusted Internal Rate of Return (AIRR) | -5.18% |

---

(a) BOD = Beneficial Occupancy Date (Service Date)
(b) Present value is less than actual cost when investment costs are incurred after base date.

# Energy/Water Life Cycle Cost Analysis Summary
# Inside Ice Maker Condenser

Installation: Sample
Location: Sample
Project Title: Waste Chill Recovery Heat Exchanger
Base Date: JAN 1997
Discount rate: 3.80%
BLCC input data files: Project: MBASE2.DAT

Region No. 4
BOD: JAN 1997[(a)]
Prepared by: D.R Brown
Base Case: MWCR2.DAT

Preparation Date: 06-26-1997
Project No. Sample
Fiscal Year: 1997
Economic Life: 7 years

1. Investment

| | | | |
|---|---|---|---|
| A. | Construction Cost | $550 | |
| B. | SIOH | $0 | |
| C. | Design Cost | $0 | Funding Amount: |
| D. | Total Cost (1A + 1B + 1C) | $550 | $550 |
| E. | Salvage Value of Existing Equipment | $0 | |
| F. | Public Utility Company Rebate | $0 | Present Value:[(b)] |
| G. | Total Investment (1D - 1E - 1F ) | $550 | $550 |

2. Energy and Water Savings (+) or Cost (-)
Analysis Date Savings, unit costs, & discounted savings
Date of NISTIR 85-3273-X used for discount factors: october 1995

| Fuel | | Unit Cost $/MBtu (1) | Savings MBtu/Yr (2) | Annual Savings (3) | Discount Factor (4) | Discounted Savings (5) |
|---|---|---|---|---|---|---|
| A. | Electric | $24.612 | 4.1 | $101 | 5.950 | $603 |
| B. | Dist oil | $0.000 | 0.0 | $0 | 0.000 | $0 |
| C. | Resid oil | $0.000 | 0.0 | $0 | 0.000 | $0 |
| D. | Nat Gas | $4.500 | -1.1 | -$5 | 6.071 | -$31 |
| E. | Coal | $0.000 | 0.0 | $0 | 0.000 | $0 |
| F. | Demand Savings | | | $0 | 0.000 | $0 |
| G. | Subtotal | | 3.0 | $96 | | $572 |

| | | $/Mgal | Mgal/yr | Annual Savings | Discount Factor | Discounted Savings |
|---|---|---|---|---|---|---|
| H. | Water use | $0.00 | 0.0 | $0 | 0.000 | $0 |
| | Water disp | $0.00 | 0.0 | $0 | 0.000 | $0 |
| | Subtotal | | | $0 | | $0 |
| I. | Total | | | $96 | | $572 |

3. Non-Energy Savings (+) or Cost (-)

| | | | | |
|---|---|---|---|---|
| A. | Annually Recurring (+/-) | $0 | | |
| | (1) Discount Factor (Table A) | | 0.000 | |
| | (2) Discounted Savings/Cost (3A x 3A1) | | | $0 |

B. Non-Annually Recurring (+/-)

| | Item | Savings (+) Cost (-) (1) | Occurrence (from BOD) (2) | Factor (Table A-1) (3) | Discounted Savings or Cost (4) |
|---|---|---|---|---|---|
| d. | Total | $0 | | | $0 |

| | | |
|---|---|---|
| C. | Total Non-energy Savings (+)/Cost(-) (3A(2)+3Bd(4)) | $0 |
| 4. | First year savings (2I3 + 3A5 + 3Bd1/Yrs Economic Life) | $96 |
| 5. | Simple Payback Period (1G/4) | 5.72 years |
| 6. | Total Discounted Savings (2I5 + 3C) | $572 |
| 7. | Savings to Investment Ratio (SIR = 6 /1G) | 1.04 |
| 8. | Adjusted Internal Rate of Return (AIRR) | 4.37% |

---

(a) BOD = Beneficial Occupancy Date (Service Date)
(b) Present value is less than actual cost when investment costs are incurred after base date.

# About the Federal Technology Alerts

The Energy Policy Act of 1992, and subsequent Executive Orders, mandate that energy consumption in the Federal sector be reduced by 30% from 1985 levels by the year 2005. To achieve this goal, the U.S. Department of Energy's Federal Energy Management Program (FEMP) is sponsoring a series of programs to reduce energy consumption at Federal installations nationwide. One of these programs, the New Technology Demonstration Program (NTDP), is tasked to accelerate the introduction of energy-efficient and renewable technologies into the Federal sector and to improve the rate of technology transfer.

As part of this effort FEMP is sponsoring a series of Federal Technology Alerts (FTAs) that provide summary information on candidate energy-saving technologies developed and manufactured in the United States. The technologies featured in the Technology Alerts have already entered the market and have some experience but are not in general use in the Federal sector. Based on their potential for energy, cost, and environmental benefits to the Federal sector, the technologies are considered to be leading candidates for immediate Federal application.

The goal of the Technology Alerts is to improve the rate of technology transfer of new energy-saving technologies within the Federal sector and to provide the right people in the field with accurate, up-to-date information on the new technologies so that they can make educated judgments on whether the technologies are suitable for their Federal sites.

Because the Technology Alerts are cost-effective and timely to produce (compared with awaiting the results of field demonstrations), they meet the short-term need of disseminating information to a target audience in a timeframe that allows the rapid deployment of the technologies—and ultimately the saving of energy in the Federal sector.

The information in the Technology Alerts typically includes a description of the candidate technology; the results of its screening tests; a description of its performance, applications and field experience to date; a list of potential suppliers; and important contact information. Attached appendixes provide supplemental information and example worksheets on the technology.

FEMP sponsors publication of the Federal Technology Alerts to facilitate information-sharing between manufacturers and government staff. While the technology featured promises significant Federal-sector savings, the Technology Alerts do not constitute FEMP's endorsement of a particular product, as FEMP has not independently verified performance data provided by manufacturers. Nor do the Federal Technology Alerts attempt to chart market activity vis-a-vis the technology featured. Readers should note the publication date on the back cover, and consider the Alert as an accurate picture of the technology and its performance at the time of publication. Product innovations and the entrance of new manufacturers or suppliers should be anticipated since the date of publication. FEMP encourages interested Federal energy and facility managers to contact the manufacturers and other Federal sites directly, and to use the worksheets in the Technology Alerts to aid in their purchasing decisions.

## Federal Energy Management Program

The Federal Government is the largest energy consumer in the nation. Annually, in its 500,000 buildings and 8,000 locations worldwide, it uses nearly two quadrillion Btu (quads) of energy, costing over $8 billion. This represents 2.5% of all primary energy consumption in the United States. The Federal Energy Management Program was established in 1974 to provide direction, guidance, and assistance to Federal agencies in planning and implementing energy management programs that will improve the energy efficiency and fuel flexibility of the Federal infrastructure.

Over the years several Federal laws and Executive Orders have shaped FEMP's mission. These include the Energy Policy and Conservation Act of 1975; the National Energy Conservation and Policy Act of 1978; the Federal Energy Management Improvement Act of 1988; and, most recently, Executive Order 12759 in 1991, the National Energy Policy Act of 1992 (EPACT), and Executive Order 12902 in 1994.

FEMP is currently involved in a wide range of energy-assessment activities, including conducting New Technology Demonstrations, to hasten the penetration of energy-efficient technologies into the Federal marketplace.

## For More Information

FEMP Help Desk
(800) 363-3732
International callers please use (703) 287-8391
Web site: http://www.eren.doe.gov/femp/

General Contacts

Ted Collins
New Technology Demonstration Program
Program Manager
Federal Energy Management Program
U.S. Department of Energy
1000 Independence Avenue, SW, EE-92
Washington, DC 20585
(202) 586-8017
Fax: (202) 586-3000
theodore.collins@hq.doe.gov

Steven A. Parker
Pacific Northwest National Laboratory
P.O. Box 999, MSIN: K5-08
Richland, Washington 99352
(509) 375-6366
Fax: (509) 375-3614
steven.parker@pnl.gov

Technical Contact

Daryl Brown
Pacific Northwest National Laboratory
P.O. Box 999, MSIN: K8-17
Richland, Washington 99352
(509) 372-4366
Fax: (509) 372-4370
daryl.brown@pnl.gov

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