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WASTE CHILL RECOVERY HEAT EXCHANGERE.

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Abstract Waste chill recovery (WCR) heat exchangers Industrial waste heat is the energy that is generated in industrial processes which is not put into any practical use and is lost, wasted and dumped into the environment. Recovering the waste heat can be conducted through various waste heat recovery technologies to provide valuable energy sources and reduce the overall energy consumption. In this paper, a comprehensive review is made of waste heat recovery methodologies and state of the art technologies used for industrial processes. By considering the heat recovery opportunities for energy optimisation in the steel and iron, food, and ceramic industries, a revision of the current practices and procedures is assessed. The research is conducted on the operation and performance of the commonly used technologies such as recuperators, regenerators, including furnace regenerators and rotary regenerators or heat wheels, passive air preheaters, regenerative and recuperative burners, plate heat exchangers and economisers and units such as waste heat boilers and run around coil (RAC). Techniques are considered such as direct contact condensation recovery, indirect contact condensation recovery, transport membrane condensation and the use of units such as heat pumps, heat recovery steam generators (HRSGs), heat pipe systems, Organic Rankin cycles, including the Kalina cycle, that recover and exchange waste heat with potential energy content. Furthermore, the uses of new emerging technologies for direct heat to power conversion such as thermoelectric, piezoelectric, thermionic, and thermo photo voltaic (TPV) power generation techniques are also explored and reviewed. In this regard, the functionality of all technologies and usage of each technique with respect to their advantages and disadvantages is evaluated and described.

INTRODUCTION

With the growing trend of increases in fuel prices over the past decades as well the rising concern regarding global warming, engineering industries are challenged with the task of reducing greenhouse gas emissions and improving the efficiency of their sites.
In this regard, the use of waste heat recovery systems in industrial processes has been key as one of the major areas of research to reduce fuel consumption, lower harmful emissions and improve production efficiency.
Industrial waste heat is the energy that is generated in industrial processes which is not put into any practical use and is wasted or dumped into the environment. Sources of waste heat mostly include heat loss transferred through conduction, convection and radiation from industrial products, equipment and processes and heat discharged from combustion processes. Heat loss can be classified into high temperature, medium temperature and low temperature grades. Waste Heat Recovery (WHR) systems are introduced for each range of waste heat to allow the most optimum efficiency of waste heat recovery to be obtained.
High temperature WHR consists of recovering waste heat at temperatures greater than 400 °C, the medium temperature range is 100–400 °C and the low temperature range is for temperatures less than 100 °C . Usually most of the waste heat in the high temperature range comes from direct combustion processes, in the medium range from the exhaust of combustion units and in the low temperature range from parts, products and the equipment of process units .
It is estimated that the UK industrial sector consumes as much as 17% of the overall UK economy's energy consumption and generates about 32% of the UK's heat-related CO_2 emissions. From this value and as can be seen from , 72% of the UK industrial demand is from industrial thermal processes of which 31% is classified as low temperature process heat and almost 20% of that or 40 TWh /yr is estimated to have potential for industrial waste heat recovery . It is found that the most energy consuming industries in the UK are cement, ceramic, iron and steel, refineries, glassmaking, chemicals, paper and pulp and food and drink. These industries together contribute about 50 bn/yr to the UK's economy. This indicates that improving energy efficiency through waste heat recovery models can help UK businesses to reduce the operating costs of their businesses, improve the energy efficiency of their sites and reduce the UK's industrial CO_2 emissions.

2. WCR Technology

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. 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 "counter flow" 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.

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%.

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.

LITERATURE SURVEY:

1 In December 1990 R.Z. Wang*, J.Y. Wu, Y.X. Xu, W. Wang, have presented that A heat regenerative adsorption refrigerator using spiral plate heat exchangers as absorbers’ and an adsorption heat pump for air conditioning using plate ®n heat exchangers or plate shell and tube type heat exchangers as absorbers have been developed and researched. Experimental research results are shown. The activated carbon methanol adsorption pair is used for the two kinds of adsorption systems. With a heat source temperature of 1008C, the refrigerator achieved a refrigeration power density of more than 2.6 kg ice per day per kg activated carbon with a co-efficient of performance (COP) of 0.13, and the heat pump achieved 150 W/kg activated carbon for air cond - itioning with a COP of about 0.4.

2 In December 1997 The U.S. Department of Energy, have presented that the WCR heat exchanger can be the 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,

3 In March 1998 R. Z. WANG , J. Y. WU AND W. WANG, have presented A heat regenerative adsorption refrigerator using spiral plate heat exchangers as absorbers and an adsorption heat pump for air conditioning using plate In heat exchangers as absorbers have been developed and researched, experimental research results are shown. The activated carbon methanol adsorption pair is used for the two adsorption systems, which yield a refrigeration power density of more than 2)6 kg ice per day per kg activated carbon and 150Wkg~1 activated carbon for air conditioning, respectively.

4.In February 20016. Wen Wang A.O. Dieng*, R.Z. Wang, have presented that the primary objective of this review is to provide fundamental understandings of the solar adsorption systems and to give useful guidelines regarding designs parameters of adsorbent bed reactors, and the applicability of solar adsorption both in air- conditioning and refrigeration with the improvement of the coefficient of performance. Solar adsorption heat pump and refrigeration devices are of significance to meet the needs for cooling requirements such as air-conditioning and ice-making and medical or food preservation in remote areas. They are also noiseless, non-corrosive and environmentally friendly. For these reasons the research activities in this sector are still increasing to solve the crucial points that make these systems not yet ready to compete with the well-known vapor compression system. There is an increasing interest in the development and use of adsorption chillers due to their various economic and impressive environmental benefits, enabling solar energy or waste heat to be used for applications such as district networks and cogeneration plants. Compared to adsorption systems 39 that require heat sources with temperatures above 100°C (zeolite– water systems, activated carbonmethanol systems) or conventional compressor chillers, a silica gel/water adsorption refrigerator uses waste heat with temperature below 100°C. This creates new possibilities for utilizing low temperature energy.

5. In May 2003 B.B. Saha, S. Koyama, T. Kashiwagi, A. Akisawa, K.C. Ng, H.T. Chua, have presented that Over the past few decades there have been considerable efforts to use adsorption (solid/vapour) for cooling and heat pump applications, but intensified efforts were initiated only since the imposition of international restrictions on the production and utilization of CFCs and HCFCs. In this paper, a dual-mode silica gel–water adsorption chiller design is outlined along with the performance evaluation of the innovative chiller. This adsorption chiller utilizes effectively low temperature solar or waste heat sources of

temperature between 40 and 95 C. Two operation modes are possible for the advanced chiller. The first operation mode will be to work as a highly efficient conventional chiller where the driving source temperature is between 60 and 95C. The second operation mode will be to work as an advanced three stage adsorption chiller where the available driving source temperature is very low (between 40 and 60 _C). With this very low driving source temperature in combination with a coolant at 30C, no other cycle except an advanced adsorption cycle with staged regeneration will be operational. The drawback of this operational mode is its poor efficiency in terms of cooling capacity and COP.

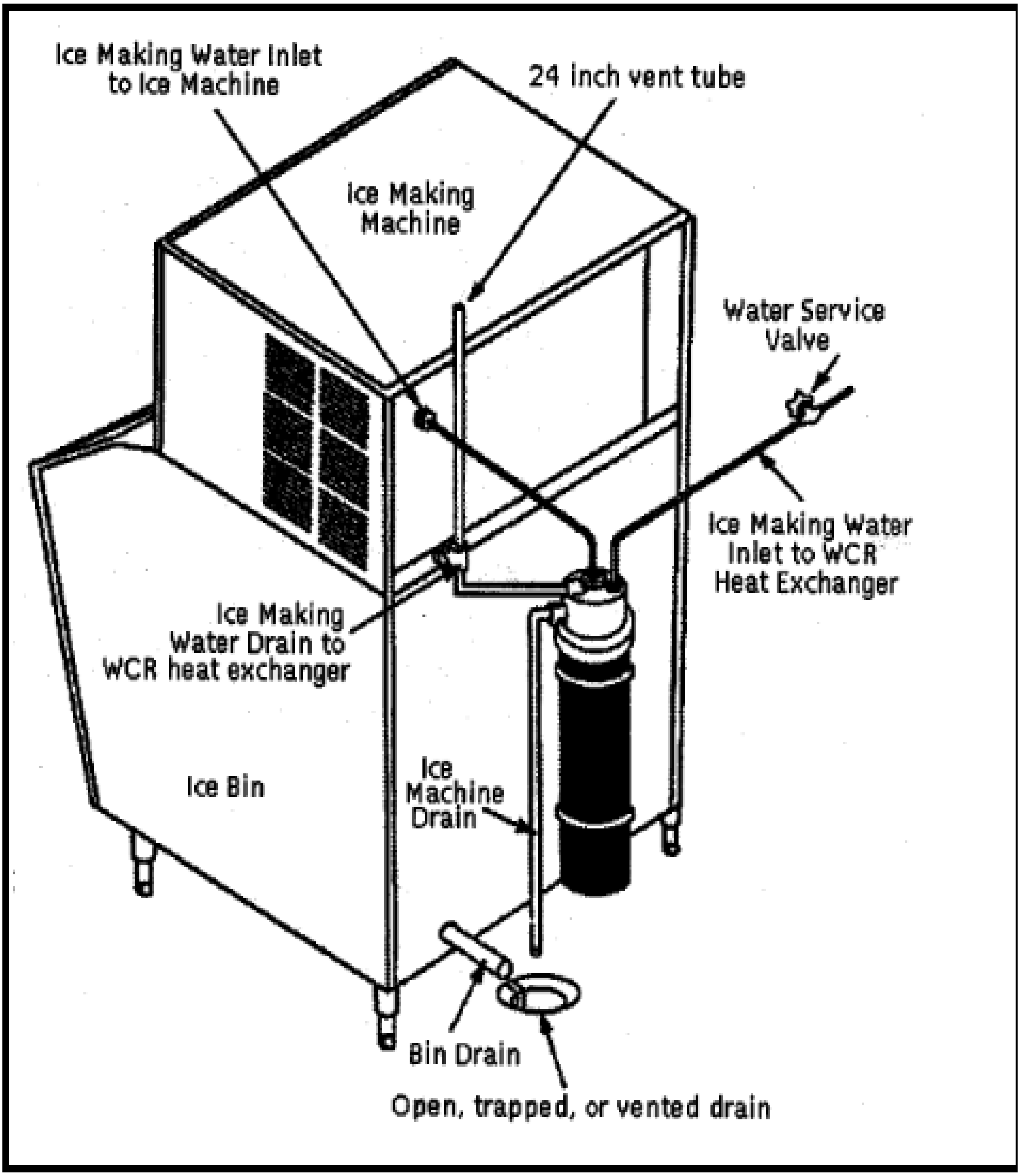
OBJECTIVES:

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 .Primary objective of this review is to provide fundamental understandings of the solar adsorption systems and to give useful guidelines regarding designs parameters of adsorbent bed reactors, and the applicability of solar adsorption both in air-conditioning and refrigeration with the improvement of the coefficient of performance. Solar adsorption heat pump and refrigeration devices are of significance to meet the needs for cooling requirements such as air-conditioning and ice-making and medical or food preservation in remote areas. They are also noiseless, non-corrosive and environmentally friendly. For these reasons the research activities in this sector are still increasing to solve the crucial points that make these systems not yet ready to compete with the well-known vapor compression system.

SUMMARY OF REVIEW:-

The WCR heat exchanger can be 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. The increased production rate may be the most valuable impact to users with inadequate ice making capacity. Reducing the cooling load on the ice maker should result in less "wear and tear," resulting in lower maintenance costs and longer equipment life 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. 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.



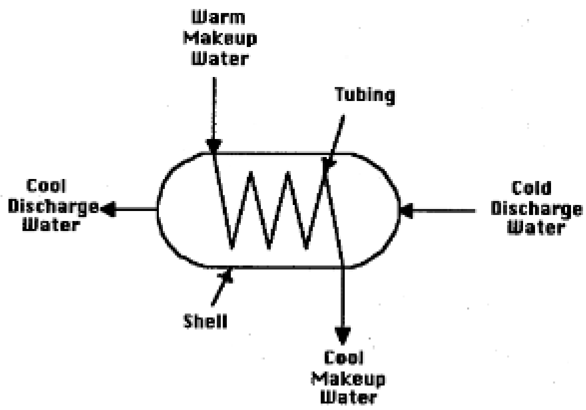


Figure 1. WCR Heat Exchanger Concept

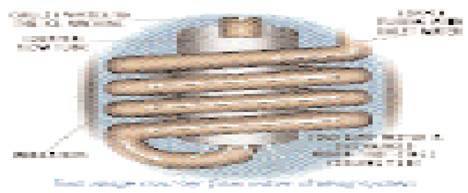


Figure 2. Maximicer WCR Heat Exchanger

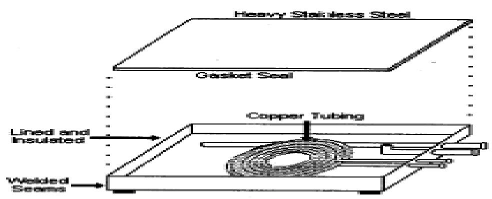


Figure 3. Fast Ice WCR Heat Exchanger

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