ORNL/TM-2021/2350

03.02.02.45: ICE: Energy Efficiency Improvements in Ice Related Processes – Materials and methods

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November 2021

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ORNL/TM-2021/2350

Buildings and Transportation Sciences Division

MATERIALS AND METHODS USED IN ICE MAKING PROCESSES

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November 2021

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UT-BATTELLE LLC
for the
US DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

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EXECUTIVE SUMMARY

A detailed survey of ice mold and evaporator metal surfaces, physical structures, operational conditions, materials of construction, design of different equipment was reviewed and analyzed. The key objective was to identify different ice related processes' materials, structures, and operating conditions for designing, optimizing, and applying advance materials to lower ice adhesion strength to be investigated in this project.

Residential ice makers with daily capacity in the range of 3 to 25 pounds were reviewed. Typical configurations in this class include domestic refrigerators and standalone tabletop portable ice makers. Commercial ice makers on the other hand vary in capacities from 35 to 500 pounds per day for medium scale applications in the food service industry while the industrial scale production varies in the range of 10,000 to 40,000 pounds per day, mostly for applications in shipping, food, and medical industries.

Key attributes reviewed in this study include:

- Power consumption
- Make and model
- Mold/evaporator material
- Ice harvesting mechanism
- Daily capacity
- End-use application

Depending on the application, primary shapes of the manufactured ice included cube, crescent, cylindrical, sphere, flake, tube, rectangular block, and clear cubes.

Principal ice harvesting mechanisms included exposure of the ice mold to either a heating element or hot refrigerant while some older machines use hot water, albeit a smaller percentage in practice. Additionally, mechanical twist action of the smaller domestic refrigerator ice trays is utilized when the capacity is around 3 pounds per day. Power consumption of these appliances range from 200 W to 50 kW, depending on the scale of the machine.

Based on the conducted survey, several ice fabrication mold materials were identified, as listed below:

- Aluminum coated with heat cured epoxy
- Aluminum alloy 3003
- Nickel plated copper
- Teflon Polytetrafluoroethylene (PTFE)
- Delrin plastic, Polyoxymethylene
- Stainless steel 304 (SS 304)
- Stainless steel 316 (SS 316)
- Carbon steel

1. OBJECTIVE

The primary objective of this project is to develop an energy efficient methodology to dispense ice from the ice maker mold. Ice is an important commodity both as a direct use product and as a nuisance in day-to-day refrigeration related equipment. It is utilized: as an energy storage medium at industrial scale, in the food service industry, in domestic household refrigeration, and in supermarkets. Ice making is an energy intensive process, where ~ 30% of this energy is exclusively consumed during the dispensing process which involves mold heating for dislodging the ice followed by re-cooling of the thermal mass to attain the desired temperature for the subsequent cycle. The key approach in this project is to help dislocate the ice layer using advanced materials to lower ice adhesion strength. Application of such materials requires a good understanding of various materials and methodologies utilized in residential, commercial, and industrial equipment. Hence a survey of ice mold and evaporator metal surfaces, physical structures, operational conditions, materials of construction, and design of different equipment was conducted. The key objective was to identify different ice related processes' materials and structures for designing, optimizing, and applying the advanced materials to be investigated in this project.

2. SURVEY APPROACH

A comprehensive survey of different classes of equipment utilized in all sectors, viz. residential, commercial, and industrial applications was conducted. Initial review of peer reviewed publications provided sparse information on this subject; hence a wide variety of alternative sources were consulted – original equipment manufacturers' (OEMs) sales and technical representatives, available user manuals and product descriptions, miscellaneous online reports, and other open access literature.

3. MATERIALS AND PROCESSES

Based on the comprehensive survey, commercially available equipment has been classified in to four primary categories, as described below:

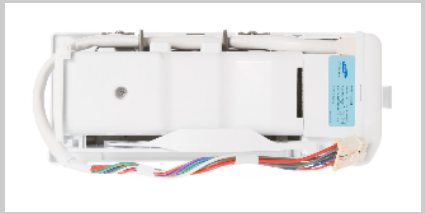
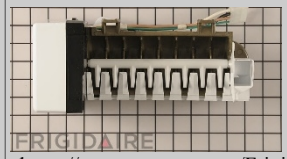
1. Residential ice makers with daily capacity in the range of 3 to 25 pounds. Typical configurations in this class include domestic refrigerators and standalone tabletop portable ice makers
2. Commercial ice makers with capacities in the range of from 35 to 500 pounds per day for medium scale applications in the food service industry
3. Industrial scale production in the range of 10,000 to 40,000 pounds per day, mostly for applications in shipping, food, and medical industries
4. Miscellaneous equipment encompassing dry ice manufacturing

Key attributes reviewed in this study include:

- Power consumption
- Make and model
- Mold/evaporator material
- Ice harvesting mechanism
- Daily capacity
- End-use application

An overview of all these attributes is delineated in tables 1-4 below:

3.1 RESIDENTIAL EQUIPMENT

Make	Model	Size/ Watts	Capacity	Application	Material	Harvest mechanism	Picture/Source
GE  	WR30X10097 (for models GFSS6KEXSS, GFSS6KKYSS;)	200W	3 lb/day	Household refrigeration	Aluminum coated with a heat-cured Epoxy clear coat	Mold body heater underneath ice maker	https://products.geappliances.com/appliance/gea-support-search-content?contentId=16978 
Whirlpool, Maytag, Kitchenaid, Amana 	WPW10190929 (for model ED2KVEXVB01, MBF2556KEQ11, KFCS22EVMS00)		3 lb/day	Household refrigeration	Coated aluminum	Heating element	 
Kenmore/Frigidaire 	W10251081 for model 106.78202891		3 lb/day	Household refrigeration	Aluminum alloy 3003	Heating element	 https://www.amazon.com/Frigidaire-241983201-Refrigerator-Equipment-Manufacturer/dp/B00FKIO6UM

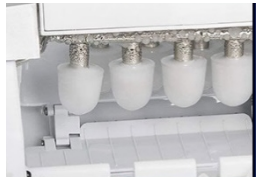
Make	Model	Size/ Watts	Capacity	Application	Material	Harvest mechanism	Picture/Source
Samsung 	DA97-07365G (for RF26, RF42, RFG29 series models)		5 lbs/day	Household refrigeration	Coated Aluminum 3003	Heating element	 https://theniftyhouse.com/how-to-remove-ice-maker-from-samsung-refrigerator/
Magic Chef, Crownful, Igloo, Frigidaire 	MCIM22/ICEB33SL/EFIC108	150-350 Watts	26 - 35 lb/day	Portable ice maker	Stainless steel or Nickel-plated copper tubes	Hot refrigerant	 
Newair 	IM200SS, Clearice40	250-400 Watts	24-40 lb/day	Portable ice maker	Stainless steel or Nickel-plated copper grid/tray	hot refrigerant	
Frigidaire 	EFIC115-SS	400 Watts	48 lb/day	Free standing ice maker	Stainless steel or Nickel-plated copper tubes	Hot refrigerant	

Figure 1: Residential class ice making equipment – materials, methods, capacity, and energy consumption

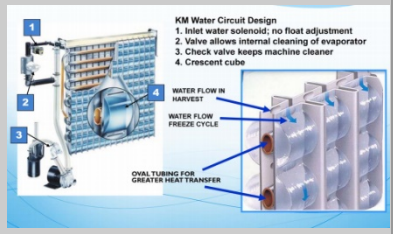
3.2 COMMERCIAL EQUIPMENT

Make	Model	Size/ Watts	Capacity	Application	Material	Harvest mechanism	Picture/Source
Whirlpool/ Kitchenaid 	WUI95X15HZ		25 lb/day	Free standing ice maker	Nickel-plated copper grid/tray	Hot refrigerant and heating element	 https://www.whirlpool.com/kitchen/refrigeration/refrigerators/ice-makers/p.15-inch-icemaker-with-clear-ice-technology.wui95x15hz.html
GE 	UNC15	750 Watts	56 LB/DAY	Free standing ice maker	Nickel plated copper or stainless-steel tube	Hot refrigerant	
Maxx Ice 	MIM265H	7.14 kWh/ 100 lb	250 lb/day	Commercial food service	Nickel-plated copper tray /grid	Hot refrigerant	  https://cdn.shopify.com/s/files/1/0047/1095/7102/t/6/assets/MIM250265HSpecs-1614619776371.pdf

Make	Model	Size/ Watts	Capacity	Application	Material	Harvest mechanism	Picture/Source
Koolmore 	CIM-315	1.2 kW	315 lb/day	Commercial food service	Nickel plated copper tray /grid	Hot refrigerant	 https://images.thdstatic.com/catalog/pdfImages/d9/d9144b35-b46d-4ce4-935b-abdfe920ff8b.pdf
Snooker/Norpole 	SK-529/NPCIM500M	1.5 - 1.7kW	500 lb/day	Commercial food service	Nickel plated copper or stainless steel tray /grid	Hot refrigerant	 https://images.thdstatic.com/catalog/pdfImages/72/72375b6f-8a7f-423c-a8ee-fa40b464fd82.pdf https://images.thdstatic.com/catalog/pdfImages/c9/c93c3e1d-d6f1-4ed1-928f-849bfa215313.pdf

Figure 2: Commercial class ice making equipment – materials, methods, capacity, and energy consumption

3.3 INDUSTRIAL EQUIPMENT

Make	Model	Size/Watts	Capacity	Application	Material	Harvest mechanism	Picture/Source
Arctic Temp 	4000SC	20,000 lb/day	40-50 kW	Industrial cube ice maker	Double walled stainless steel tubes	Hot refrigerant	https://whiteswarehouse.net/product/13906/ ; https://holiday-ice.com/img/4000SC.pdf 
Northstar 	Model 40	20.7 ton/day		Industrial ice flake machine (1.5-2mm thick ice flakes)	stainless steel or carbon steel cylindrical surface	Mechanical scraping arm	https://www.northstarice.com/uploads/pdf/ns-ice-maker-brochure-english.pdf 
Hoshizaki 	KM-1900SRH	1857 lb/day	4.09 kwh/100 lbs	Industrial crescent cubed ice	Double-sided stainless-steel surface	Hot refrigerant	https://whiteswarehouse.net/product/km-1900srh-urc-22f-ice-maker-remote-cooled/; https://secure.hoshizakiamerica.com/TechSupport/techtips/pdf/training/KM_Seq.pdf; 

Make	Model	Size/Watts	Capacity	Application	Material	Harvest mechanism	Picture/Source
Clinebell/Polar Temp/US Icemachine/Tamutom 	CI-4/IBM300/Comey	10-50 lb block, 12-60 blocks/cycle		Ice block machine	Stainless steel container	Hot fluid dip	

Figure 3: Industrial class ice making equipment – materials, methods, capacity, and energy consumption

3.4 MISCELLANEOUS EQUIPMENT

Make	Model	Size/Watts	Capacity	Application	Material	Harvest mechanism	Picture/Source
Bel-Art™ SP Scienceware™ Frigimat™ Dry Ice Maker	Bel-Art™ F388740000/EMD	10 blocks per cycle		Dry ice maker			 https://www.fishersci.com/shop/products/bel-art-scienceware-frigimat-dry-ice-maker-1/S90141
Thermco™ DI800 - Dry Ice Machine	Thermco™ THDI800	1 lb block		Dry ice maker	Delrin plastic	Heating element	 https://www.fishersci.com/shop/products/di800-dry-ice-machine/04500330

Figure 4: Miscellaneous ice making equipment – materials, methods, capacity, and energy consumption

4. CONCLUSIONS

Depending on the application, primary shapes of the manufactured ice include cube, crescent, cylindrical, sphere, flake, tube, rectangular block, and clear cubes. Principal ice harvesting mechanisms include exposure of the ice mold to either a heating element or hot refrigerant while some older machines use hot water, albeit a smaller percentage in practice. Additionally, mechanical twist action of the smaller domestic refrigerator ice trays is utilized when the capacity is around 3 pounds per day. Power consumption of these appliances range from 200 W to 50 kW, depending on the scale of the machine.

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- Nickel plated copper
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- Delrin plastic, Polyoxymethylene
- Stainless steel 304 (SS 304)
- Stainless steel 316 (SS 316)
- Carbon steel

However, two most popular materials of choice are either austenitic alloys (316 and 304) or nickel-plated copper.