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Executive Summary

This report is intended to analyze the workings of the NHL regulation rink to be installed in the Sears Centre. Ice-rink operation measures are a critical portion of this facilities operations cost. Value engineering suggestions will be supplied to aid CCO Entertainment in the day to day up keep of the arena facility.

Report Sections include:

- **Ice-System Overview**
  - *System Design Conditions*
  - *Typical Slab placement Construction*

- **Ice-System Operations**
  - *Brief review of Refrigeration principals for Cold and Warm Brine Refrigerant Solution*
  - *Ice-Surface Formation Procedure*

- **Ice-System Value Engineering Assessments**
  - *Cost Reduction Measures proposed for facilities operations*

The system will be installed by a leading ice-rink contractor (CIMCO) in conjunction with an ice-demineralizer supplier (Jet Ice). CIMCO-Jet Ice has produced over 20 projects for indoor ice sports facilities. Basic installation processes require substantial completion of building enclosure before initial testing. A key aspect to note is that heating of the underslab rink condition is necessary for preservation of the floor base. If this condition isn't obtain, substantial heaving produced by a pseudo "Freeze-Thaw" cycle could permanent damage the slab beyond recovery. A costly replacement could hamper arena operations and impact facilities operations and minimize revenues produced by leased events.

Highlighted Suggestions for operations reduction include:

- *Operations and Maintenance Improvements*
- *Lighting Improvements*
- *Ice-Resurfacing Improvements*
- *Refrigeration Systems Improvements*
- *Heating, Dehumidification and Ventilation Improvements*

If used appropriately, the proposed suggestions will reduce the annual operations budget by $ 25,800. Operations reduction have a potential to have a direct impact on the facilities payback period, in addition to reducing the time required for recapturing full building construction costs.

Ice-Rink Analysis for Value Engineering suggestion in Sears Centre Facilities Operations & Energy Costs Reduction

Ice-System Overview:

Ice construction is the most important aspect of the Sears Centre. The ice-rink could be viewed as the primary purpose for building construction. Part of the arena construction package is adherence to ice-distribution installation procedure typically used on National Hockey League ice rink and ice surfaces. Plans call for installation of (1) 85'-0" x 200'-0" NHL/ NCAA regulation ice rink with R 28'-0" Radii. This system can be classified as a mix use Ammonium (NH_3), 35 % (by volume) Ethylene Glycol/ Calcium Carbonate, closed loop brine system. (2) Brine circuits form the primary rink freeze and melt operations. Similar to typical sports facilities, the ArenaPak refrigerant supply and distribution system is located in the Northeast Event level mechanical room. (1) 4'-6" Under slab trench is used to distribute (2) 10" diameter cold brine supply and return headers and (2) 3" diameter warm brine supply and return headers. Trench extends to (1) 6' x 6' valve box on the north border of the ice-rink and (1) 3' x 3' trench box on the south terminus ice-rink.
Equally important to the analysis of rink operations is value engineering procedures in rink maintenance which can potentially reduce facilities energy use and operations cost. Specific measures will be made referenced to with proposed costs savings.

Identify needs of system
System Design:

- *Refrigeration capacity* — *160 tons of refrigeration*
- *Design Capacity* — *17° F to 15° F*
- *Saturated evaporator temperature* — *5° F*
- *Condensing Temperature* — *95° F*
- *Primary Refrigerant* — *Ammonium NH_3*
- *Secondary Refrigerant* — *35 % (by volume) Ethylene Glycol*
- *Water Deminarilizer* — *Jet-Ice Dimineralizer (20 gpm)*

System Design Pressures: *High* ***250 [psig*]*** *System Operating Pressures:* *High* ***181.1[psig] @ 95° F***	*System Design Pressures:* *Low* ***250 [psig]*** *System Operating Pressures:* *Low* ***19.6 [psig] @ 5° F***

Ice-Rink Analysis

How an ice-distribution system works
Identify system components

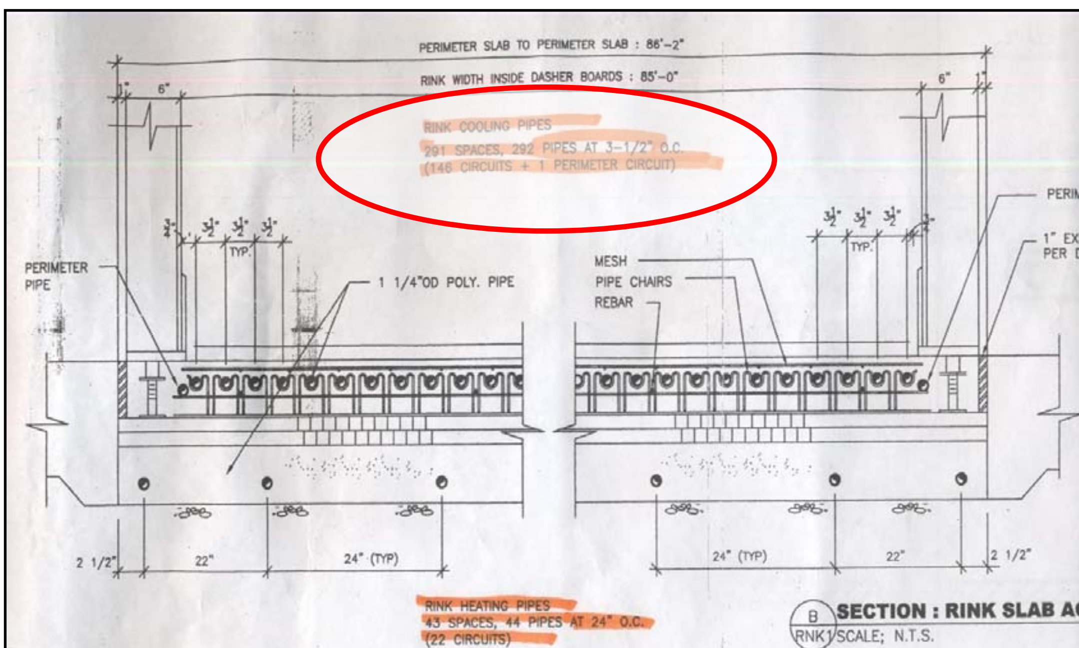
Equipment Schedule

- (2) Mycom N8WB compressors
- CIMCO CB0604 Shell & Tube Heat Exchanger *(Warm Brine Heat Exchanger)*
- CIMCO 24" Ø x 10'-0" Chiller w/ 24" Ø x 9'-0" Surge Drum *(Cold Brine Chiller)*
- EVAPCO ATC-280 *(Evaporative Condenser Unit)*
- Armstrong 4030 8x6x10 Cold Brine Pumps
- Armstrong 4030 3x2x6 Warm Brine Pump
- Armstrong Jacket Glycol Cooling Pump
- 937 US gallon Ammonium Absorption Water Tank
- 130 US gallon Cold Brine Expansion Tank
- 80 US gallon Warm Brine Expansion Tank
- 10 US gallon Glycol Expansion Tank
- 53 US gallon Refrigerant Mixing Tank

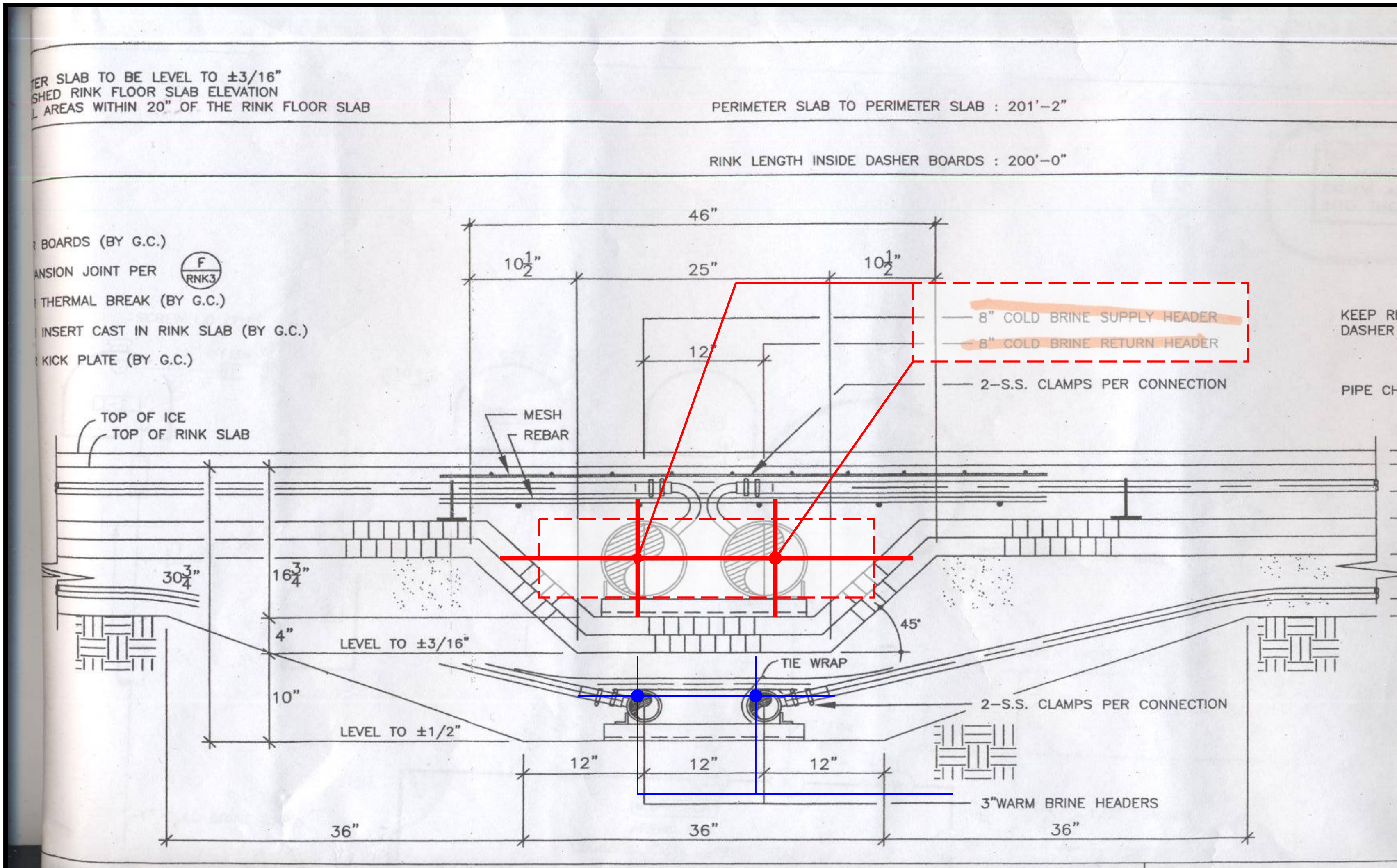
System Distribution:

Brine Piping via Schedule 40/ ASTM 53B ERW Steel varying diameter

Brine Type	Main/Header Material	Main Diameter (inches)	Header Diameter (inches)	Number of Circuits	Distribution Material	Diameter Size (inches)
Cold S.R	SCH 40 Stl.	10	8	147	Poly Pipe	1-1/4"
Warm S.R	SCH 40 Stl.	3	3	22	Poly Pipe	1-1/4"



Ice-Rink Floor Profile:



Ice-Rink Floor Construction (Sequence from bottom up):

- 1-1/2" Thick Ice Surface
- 6" 5,000 psi Thick Reinforced Concrete Rink Slab level to +/- 3/16" c/w
- 6x6 W2.9x2.9 Weld wire mesh above rink pip with 6" overlaps
- 1-1/4" OD Polyethylene rink pipes space @ 3-1/2" o.c.
- #4 Rebar at 12" (Bottom Layer) and 10-1/2" (Top Layer) on center each way. Below rink pipes with 15" overlaps tied together with loop-type wires at every intersection along the diagonal starting at every third rebar intersection along the length of the rink with bottom layer parallel to rink chairs (installed prior to floor pipe) and top layer parallel to pipe and top loaded into pipe chairs (installed after floor pipe)
- Mesh wired to pipe chairs every 12" along pipe chairs and around perimeter of each mesh sheet and to rebar below as required to hold all reinforcing in place, all tie wires to be bent away from rink pipe
- To loaded pipe chairs with base plate spaced at 3'-0" o.c. Overlap chairs by one pipe at the end of each chair
- 6 mil poly vapor barrier with 12" overlapping joints
- 4" DOW HI-60 Insulation or equivalent to be installed (2 Layers of 2" insulation with 6" staggered and overlapping joints)
- 7" thick (1'-2" and 1-5" lift) clean sand or screening compacted to 95% standard density and level to +/- 3/16"
- 1-1/4" OD Polyethylene heating pips spaced 24" o.c.
- Adequately drained subgrade and/ or 95% standard density granular backfill, level to +/- 1"

Purpose of (Two-Brine Paths):

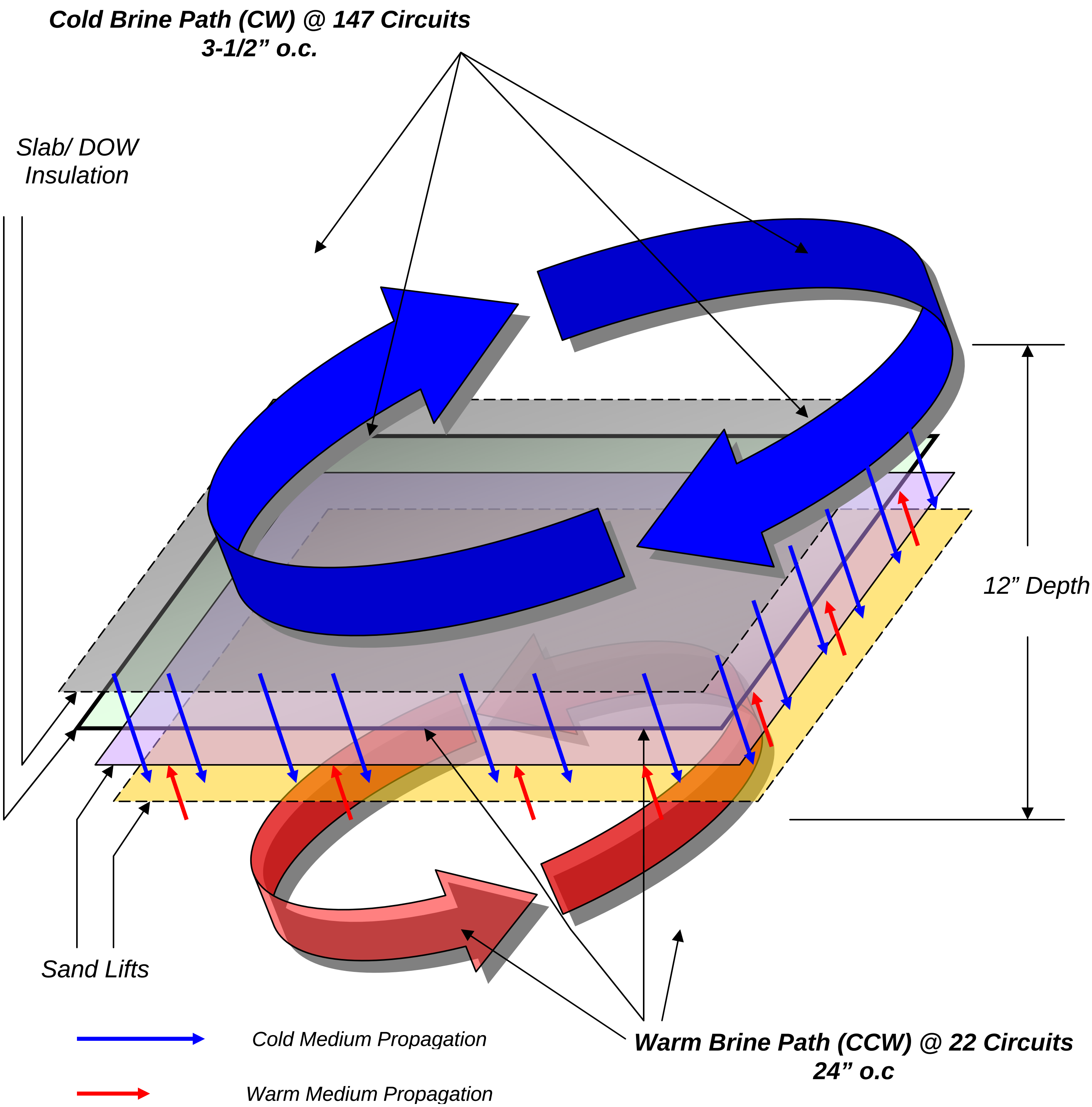
- *Brine Path #1*

"Brine Path # 1" consist of the super-cooled refrigerant mixture (Ammonium (NH_3), 35 % (by volume) Ethylene Glycol/ Brine mixture) which is used to provide a cooled base for ice formation on the event slab. Circuited network is embedded in the concrete base slab and runs clockwise to provide required cooling distribution.

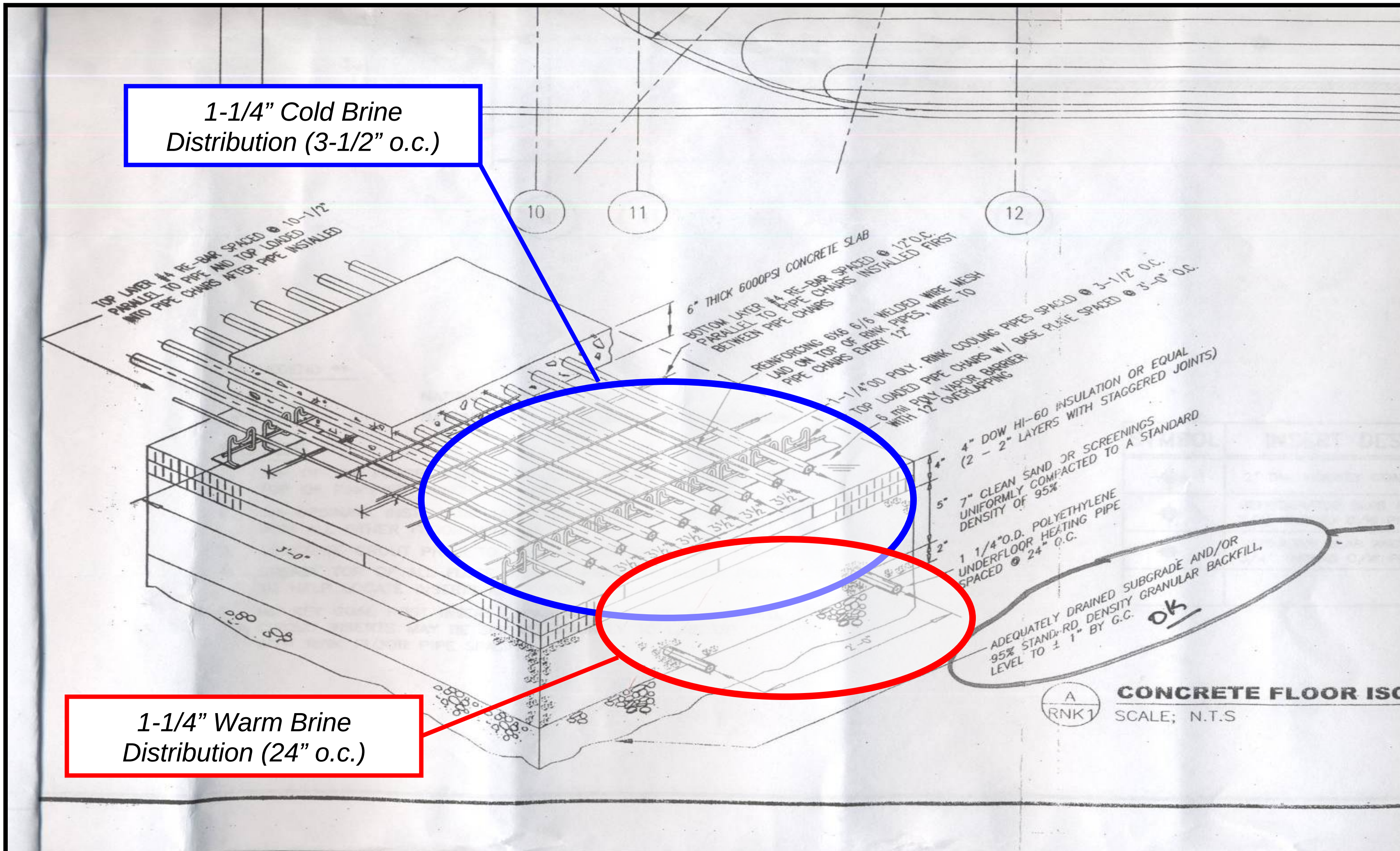
- *Brine Path # 2*

"Brine Path # 2" consist of a warmed brine mixture medium that is distributed beneath the insulation providing a warming condition which will protect the concrete slab against a frost-thaw, ground heave occurrence. Circuited network is embedded in the sand-lifts beneath the ground insulation and runs a counter-clockwise path to prevent heat neutralization of the incremented area.

Brine Path Graphic:

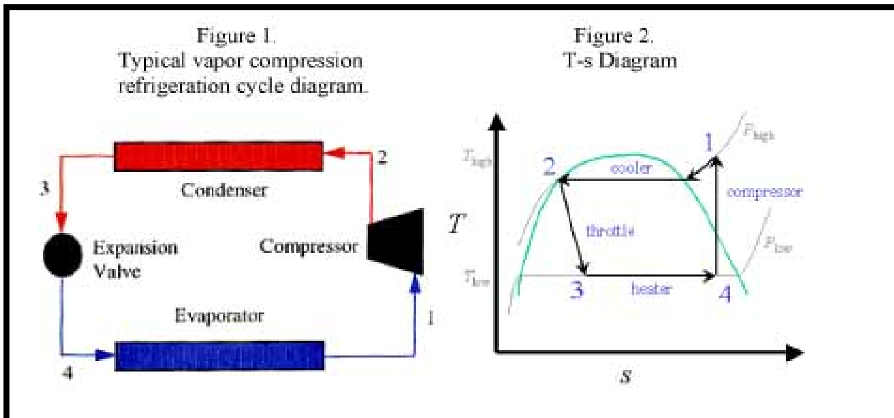


Ice-Floor Schematic:



How an ice-distribution system works

Ice-System Operations: *Review Basic Refrigeration Cycle*
Flow Diagram –"Basic Refrigeration Cycle"/ Cold and Warm Brine Path



*Brief Summary of **"Cold Brine"** Refrigeration Principle:*

Defined as "the transfer of heat from a lower temperature region to a higher temperature in adjacent surrounding", refrigeration is the basic principle to ice-rink operations. An ideal vapor-compression cycle uses a working refrigerant (*Ammonium (NH_3), 35 % (by volume) Ethylene Glycol)* as a working fluid to absorb and reject heat. Referring to the previous diagram: (It is important to note that the cold and warm brine solution cycles operate

(Inlet 1/ Start of Refrigeration Circuit)

- *(Ammonium (NH_3), 35 % (by volume) Ethylene Glycol/ Brine mixture) Ammonium solution leaves water absorption tank to mix with glycol solution from expansion tank. Once two mixtures mix, combination mixture will interact with "cold brine" solution. Composite solution enters (2) MYCOM N8W8 compressors as a saturated vapor*

(During Compression/ Point 1 – 2)

- *(Ammonium (NH_3), 35 % (by volume) Ethylene Glycol/ Brine mixture)-Q_{in} increases in temperature by absorbing heat from surroundings that will be cooled and becomes a saturated vapor at "peak" heat (To improved absorption characteristics of refrigerant)*

(Point 2 - 3)

- *(Ammonium (NH_3), 35 % (by volume) Ethylene Glycol/ Brine mixture)-Q_{out} as a heated vapor passes through the EVAPCO ATC-280 unit condenser section of the closed circuit and exchanges heat with the surrounding, thus re-cooling the refrigerant solution as a saturated liquid. [Potential for heat re-use]*

[Possible heat transfer to warm brine mixture beneath floor insulation/ embedded in sand layers]

<u>(Refrigerant Expansion/ Point 3 – 4)</u>

- (*Ammonium (NH_3), 35 % $_{(by\ volume)}$ Ethylene Glycol/ Brine mixture)-Q_{out} passes through an expansion valve causing a decrease in temperature and pressure of refrigerant solution. (Chilled liquid)*

<u>(Point 4 – 1/ Complete Refrigeration Circuit)</u>

- (*Ammonium (NH_3), 35 % $_{(by\ volume)}$ Ethylene Glycol/ Brine mixture)-Q_L re-enters EVAPCO ATC-280 unit after absorbing heat from the ice-floor slab while creating a cooled slab condition necessary for freezing of water layers (sheet ice) (completing one closed circuit run embedded in (6") 5,000 psi concrete ice slab) as a saturated vapor before re-entering (2) MYCOM N8W8 compressors to began the process anew.*

*Brief Summary of **"Warm Brine"** = Refrigeration Principle in reverse:*

<u>(Point 1 – 4 Start of Warm Brine Circuit)</u>

- *"Warm" Brine solution leaves Compressor unit as a heated vapor, prior to being pumped through distribution network beneath rink insulation embedded in sand layers*

<u>(Re-warming of Brine Solution)</u>

- *"Warm" Brine solution absorbs cool medium transferred through 4" DOW HI-60 insulation later, resulting in a lower temperature*
- *"Warm" Brine solution enters EVAPCO ATC-280 Unit after absorbing cooled medium from slab and rink floor insulation*

<u>(Warm Brine Expansion/ Point 4 – 3)</u>

- *"Warm" Brine solution passes through expansion valve at reversed setting as a saturated liquid to increase in temperature and pressure*

<u>(Point 3 – 2)</u>

- *"Warm" Brine solution – Q_{in} receives heat from surrounding environment, re-heating brine solution to a saturated vapor (in purest form) [Possible Heat Transference from Cold Brine operations]*

<u>(Point 2 – 1)</u>

- *"Warm" Brine solution" enters Evaporative condenser to condense into liquid form at slightly lower temperature*

<u>(Point 4 – 1/ Completion of "Warm" Brine Cycle)</u>

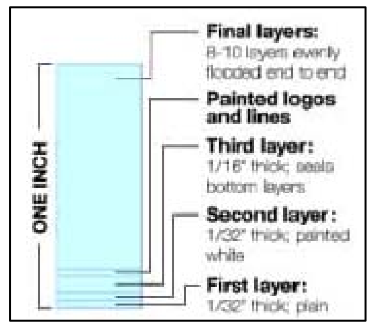
- *"Warm" Brine solution enters compressor at reverse setting to become super-heated as a vapor before beginning the process anew.*

The formation and placement of an Ice-Surface:

Floor Preparation:

Chiller cools the brine refrigerant to 15°F
System supplies 9,000 gal of cold brine to freeze an NHL regulation rink surface
Cold brine is pumped into embedded pipes in the bearing slab
Cold brine is used to maintain a floor prep temperature just below Fahrenheit freezing 32°F

Ice Surface Formation:



(1) It takes 12,000 – 15,000 gallons to form a Hockey rink surface
(2) Crew spays first and second layers on using a spray truck (Layer 1 = 1/32" Thick & Layer 2 = 1/32" Thick/ Second layer applied after freezing of first layer
(3) Crew paints the frozen second layer
(4) Crew spay applies third layer (Layer 3 = 1/16") as a sealant for the first two painted layers
(5) Crew supplies the remaining layers (10.5" / 10,000 galloons) @ rates 8.33 gpm to 10 gpm
(6) Complete freezing occurs before application of new layer
(7) Suggested Ice surface 24°F to 26°F

Ice-Resurfacing:

Standard Ice Resurfacing Rates

(#) Resurfacers	Bucket Capacity *(1 Bucket = 2,600 lbs of snow or 3 gallons)*	MPH	Time of (1) complete Rink Resurface (min)
1	3	9 to 10	[6 to 7] / 8 Passes
2	6	9 to 10	3/ 8 Passes

Typically a bucket is filled to ¾ capacity during resurfacing
(80 to 100 gallons of water) used for rink surfaces between periods
Life expectancy of propane powered ice-resurfacers:

5 seasons x (8 months / season) = 40 months
Propane resurfacer costs: $55,000 per unit

Value Engineering Operations Suggestions:

Operation and Maintenance Improvements

Increase Ice Temperature

- Sheet ice constantly absorbs heat from its surroundings. Heat absorption naturally decreases as the temperature in the ice goes up. As a result the refrigeration system must work to remove the heat that the ice sheet absorbs, its energy use also decreases proportionately when the ice sheet temperature can be slightly increased

- Ice sheet integrity is the case that governs the temperature controls in a sports facility. Temperature controls are typically set conservatively low values as a measure to preserve the condition of the ice sheet. Depending on a refrigeration systems schedule practical measures of increasing the temperature of the ice surface during facility down time may reduce yearly operations costs. Annual energy costs savings from increasing average temperature 1°F range from $ 800 to $1,600 for facilities of similar type and use

Reduce Ice Sheet Thickness

- Control and reduction of ice thickness can also reduce energy cost while providing consistent ice quality. Reducing ice sheet thickness for main sheets by ¼" will maintain an adequate surface support during re-surfacing procedures.

- Increasing coolant and slab temperatures will save energy through efficient use of refrigeration systems. Typical annual costs savings of a ½" surface reduction are between $ 145 - $ 300.

Reduce Refrigeration System Head Pressure Controls

- The refrigeration system keeps ice sheet cold by re-circulating refrigerant in a closed loop network. Once used in system, refrigerants absorb heat from under ice sheet and deposits heat medium to external source via condensation. In order for heat to flow from the refrigerant in the condenser, refrigerant must have a high temperature and pressure. This condition is known as head pressure, and is generated in the systems (2) compressors. Compressors use significant electrical energy during operations, if head pressure was reduced, energy usage and system wear on compressor components could be minimized. Refrigeration systems with expansion valves can operate properly at a pressure of 175 psig. The current operating pressure is 181.5 psig, by reducing 6.5 psig annual savings generated can reached between $ 292.50 and $ 468.00 annually

Lighting Improvements

Ice Sheet Lighting Recommendations

The level of illumination required for sports lighting depends on the following tasks:

- General Nature of Tasks
- Speed of action
- Skill of Players
- Number of Spectators
- Field of Distance

Recommended values from the Illuminating Engineering Society can be used for deciding the amount of foot candles or lux to apply to an ice surface

Activity	Foot candles
Pro Hockey	100
Amateur Hockey	50
Recreational Hockey	20
Figure Skating	15
Curling	10 – 20
Recreational Skating	10

The current requested foot candle value for the Sears Centre ice surface is 300 foot candles, for television purposes. If the present foot candle requirement could be reduced by 5% a significant reduction in the arena's power bill will result in kwH savings.

Resurfacing Improvements

De-mineralized Flood Water Treatment

A moderately busy ice rink with an average of 6-resurfacings a day will use approximately 1,000 gallons of water per day. Only heated city water can be used in the construction of the standard ice-surface. If dematerialized flood water is introduced in the refrigeration system, the hot water requirement is eliminated.

Water De-mineralization can be achieved two ways

(1) Ion-Exchange
(2) Reverse Osmosis

Current Demineralization System used in refrigeration Operations for Sears Centre:

- Jet-Ice Ion-Exchange system with a design capacity of 250,000 grains at a 20 gpm flow rate

Demineralization System Comparisons:

Demineralizers	Installation Costs	Operations Cost/ 1000 gal.
Ion-Exchange	$ 24,000	$ 12 - $ 15
Reverse Osmosis Filtration	$ 18,000	$ 3 - $ 5

If either system is installed the temperature of the ice sheet can be slightly raised to accommodate the reduction of energy needed to freeze pure water when compared to water with dissolve solids and heavier densities.

Electric Ice Resurfacer Analysis

Resurfacer	Purchase Costs	Operational Cost
Propane Powered	$ 55,000	$ 1,620/ yr (propane)
Electric Tethered	$ 72,000	$ 420/ yr (electric)
Electric Battery	$ 75,000	$ 420/ yr (electric)

Cost Comparisons over 40 months

Propane: $ 55,000 + [$1,620 (40/12)] = $ 109,000
Elect.(T) $ 72,000 + [$ 420(40/12)] = $ 73,400
Elect.(B) $ 75,000 + [$ 420(40/12)] = $ 76,400
Savings with Electric Tether: $ 35,600
Savings with Electric Battery: $ 32,600

- *Additional benefit of electric powered ice-resurfacer, reduction in CO & CO_2 deposits in facility*

Automatic Flood Water Full Shut-off Nozzle

- Arenas can conserve water and energy by installing a simple, inexpensive automatic shut off nozzle to the end of a flood hose.
- Measure can save excess H_2O spillage on ice-surface filling

Refrigeration Systems Improvements

Reclaiming Waste Heat from the Refrigeration System

- Waste heat generated by ice sheet refrigeration is a cost effective method of energy use reduction if captured.
- Re-used heat can be stored in heating apparatus/ Heating Tower for later use
- Reclaimed heat can be used to heat water or air to a temperature of 90°F ≤ Temp
  (1) Reclaimed heat uses:
  (2) Heating Arena air
  (3) Heating Hot water service
  (4) Melting Snow in snow melt pit (from ice re-surfacing operations), which can be distilled before using in irrigation system during summer seasons
  (5) Additionally warming brine in frost heave prevention operations

Heating, Dehumidification and Ventilation Improvements

Low Emissivity Reflective Ceiling

Reducing the amount of heat that ice sheet surface absorbs will result in lower energy bills in addition to improved ice quality.

Infrared radiation can account for more than 35% of the total cooling load of an ice sheet.
Refrigeration system workings varies from day to day depending on outdoor temperatures
Installation of a barrier between the ceiling and the ice sheet can effectively stop infrared radiation
Two methods of barrier installation
Low emissivity paints
Low emisivity fabrics

Infrared Reduction Method	Installation Costs	Year Pay back
Low Emissivity Paint	$ 22,000 - $ 100,000	$ 4,000
Low Emissivity Fabric	$ 23,000 - $ 28,000	$ 11,500

Conclusions:

By utilizing the value engineering suggestions the yearly operational savings achieved are:

Operations & Maintenance Improvements	**$ 1,237.50**
Increase Ice Temperature	$ 800.00
Reduced Ice-Thickness	$ 145.00
Reduction in Head Pressure	$ 292.50
Resurfacing Improvements	**$ 20,562.00**
Reverse Osmosis Deminarilizer	$ 9,882.00
Electric Resurfacer	$ 10,680.00
Ventilation Improvements	**$ 4000.00**
Low Emissivity Paints	$ 4,000.00

Total Savings Annual (O&M, Resurface Impv., Vent Impv.) = $ 25,800

Over a 10 (yr) period VE savings = $ 257,995