YORK
BY JOHNSON CONTROLS

CHILLER MATERIALS APPLICATION GUIDE FOR VARIOUS WATER QUALITIES

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IMPORTANT!

READ BEFORE PROCEEDING!

GENERAL SAFETY GUIDELINES

This equipment is a relatively complicated apparatus. During rigging, installation, operation, maintenance, or service, individuals may be exposed to certain components or conditions including, but not limited to: heavy objects, refrigerants, materials under pressure, rotating components, and both high and low voltage. Each of these items has the potential, if misused or handled improperly, to cause bodily injury or death. It is the obligation and responsibility of rigging, installation, and operating/service personnel to identify and recognize these inherent hazards, protect themselves, and proceed safely in completing their tasks. Failure to comply with any of these requirements could result in serious damage to the equipment and the property in which it is situated, as well as severe personal injury or death to themselves and people at the site.

This document is intended for use by owner-authorized rigging, installation, and operating/service personnel. It is expected that these individuals possess independent training that will enable them to perform their assigned tasks properly and safely. It is essential that, prior to performing any task on this equipment, this individual shall have read and understood the on-product labels, this document and any referenced materials. This individual shall also be familiar with and comply with all applicable industry and governmental standards and regulations pertaining to the task in question.

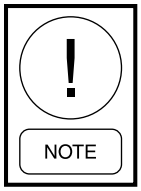
SAFETY SYMBOLS

The following symbols are used in this document to alert the reader to specific situations:

Indicates a possible hazardous situation which will result in death or serious injury if proper care is not taken.

Identifies a hazard which could lead to damage to the machine, damage to other equipment and/or environmental pollution if proper care is not taken or instructions and are not followed.

Indicates a potentially hazardous situation which will result in possible injuries or damage to equipment if proper care is not taken.



Highlights additional information useful to the technician in completing the work being performed properly.

External wiring, unless specified as an optional connection in the manufacturer's product line, is not to be connected inside the control cabinet. Devices such as relays, switches, transducers and controls and any external wiring must not be installed inside the micro panel. All wiring must be in accordance with Johnson Controls' published specifications and must be performed only by a qualified electrician. Johnson Controls will NOT be responsible for damage/problems resulting from improper connections to the controls or application of improper control signals. Failure to follow this warning will void the manufacturer's warranty and cause serious damage to property or personal injury.

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DISCLAIMER

Johnson Controls offers the following component material recommendations for chiller applications. These recommendations vary in cost and degree of protection and are meant to be used as guidelines for material selection to reduce the risk of failure. These recommendations are based on water quality specifications that meet the parameters mentioned throughout this document. Water quality falling outside these parameters may fall under a different water quality category or may need to be further analyzed by a water quality expert.

This document may be subject to change at any time.

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INTRODUCTION

Water quality is a term used to describe the chemical, physical and biological characteristics of water, usually in respect to its suitability for a particular purpose. As customers utilize increasingly lower quality sources for chiller water, such as treated sewage effluent and sea water, chiller material selection becomes even more critical. This document has been designed to provide a water and material chemical compatibility. The values shown on the corresponding tables represent an individual chemical parameter for each chemical compound. This document was not designed to address water or tube side fouling.

Chillers are most often designed with an evaporator (where heat is removed from a building in a “closed” chilled water loop) and a water cooled condenser (where heat is rejected to an “open” cooling tower loop).

Under most conditions, the reliability of the evaporator “closed” loop design is easily controlled by conventional chemical water treatment. It is also true that the “open” condenser loop, when supported with proper water treatment, can provide many years of reliable service with the industry standard copper tubes and carbon steel waterboxes and tubesheets.

However, in some applications, the water cooled condenser “open” loop design may require additional attention. The source water may have higher scaling or corrosive tendencies. There may be acid or caustic contaminates in the air or make-up water to a cooling tower. In lieu of a cooling tower, the heat may be rejected to river water, pond water or sea water. In these applications, chemical water treatment alone may not be sufficient to assure long-term reliability.

When designing or specifying a special treatment system or special materials of construction, the assistance of a specialist, either a consultant or a representative from a treatment company who is fully aware of the special requirements of the local conditions, is recommended.

Ultimately, it is the responsibility of a professional specifying the equipment to select materials that are appropriate for the application based on site-specific water quality assessment. However, the information that follows can be used as a guideline to aid in the selection of chiller materials. Johnson Controls offers these guidelines to material selections based on four categories of water quality commonly found to be used today (Treated Fresh Water, Low Chloride TSE, High Chloride TSE and Brackish or Sea Water).

TREATED FRESH WATER (FILTERED)

Typcially includes potable water, well water, treated industrial water, lake/ pond water, and river water.

Johnson Controls considers Treated Fresh Water to be water that meets the water quality specification in the table provided below. Water quality that does not meet the specification may be defined by a different water quality category, or may need further analysis by a water treatment expert before defining the application guidelines.

TABLE 1 - WATER QUALITY SPECIFICATION FOR TREATED FRESH WATER (FILTERED)

PARAMETER [1]	MAKE-UP WATER [2]	CONCENTRATED COOLING TOWER WATER [3,4]
pH	7.0 - 8.8	7.0 - 8.8
Total Suspended Solids, ppm	< 2.0	< 10
Total Dissolved Solids, ppm	1000	< 2500
Total Alkalinity, ppm as $CaCO_3$	< ~400 at 1.5 cycles	< 600
Total Hardness (Ca + Mg), ppm as $CaCO_3$	< ~600 (allows 1.5 COC in cooling tower)	100 - 800
Iron, ppm as Fe	< 0.02	< 2.0
Copper, ppm as Cu	< 0.01	< 0.1
Chloride, ppm as Cl	< 200 at 1.5 cycles	< 300
Sulfate, ppm as SO_4	< 200 at 1.5 cycles	< 300
Silica, ppm as SiO_2	< 100 at 1.5 cycles	< 150
Phosphate, ppm as PO_4	0 - 4.00	[PO_4] must be below the maximum allowable concentration for the chemical treatment program
Phosphonate, ppm as P_2O_5	0 - 4.00	[Phosphonate] must be below the maximum allowable concentration for the chemical treatment program
Chlorine, free, ppm as Cl	0.1 - 0.5	0.2 - 1.0 [5]
Ammonia, ppm as NH_3	0	< 1
Sulfides, ppm as SO_2	0	0
TOC (mg/L)	< 2	requires good feed control of oxidizing biocide
Aerobic Bacteria, CFU/ml	< $1x10^2$	< $1x10^3$
Anaerobic Bacteria, CFU/ml	0	0
Coliform, (counts per 100/ml)	0	< 1
E-Coli, (counts per 100/ml)	0	0
BOD (mg/L)	0	0
COD (mg/L)	0	0

1. Individual chemical parameter. If not shown above, contact the Chiller Applications group. If any parameter exceeds the levels set forth in the table above, move to the next water quality specification for material recommendations or contact Chiller Applications group. See Glossary for definitions.
2. Make up water concentration levels may change based on number of cycles.
3. Cooling water will require chemical additives or a non-chemical water treatment device or a combination of both. Once through systems may not require chemical treatment, but still need to meet the parameters listed above.
4. Water that will be utilized for condenser heat exchanger.
5. Chlorine, free [Clfree]= 2.0 ppm may be required in systems with high nutrient loading and/or drift

Component Recommendations for Treated Fresh Water (filtered)

The recommendations made below are to offer various levels of protection against:

- Corrosion
- Erosion
- Deposition
- Microbiological fouling

TABLE 2 - HEAT EXCHANGER TUBES

RECOMMENDATION	MATERIAL	WALL THICKNESS	LIFE EXPECTANCY	PRESSURE DROP	KW/TON	CHILLER FIRST COST
#1 (Baseline)	Copper	0.025	Baseline	Baseline	Baseline	Baseline
#2	Copper	0.028				
or						
0.035	↑	---	---	↑		
#3	90/10 CuNi	0.028				
or						
0.035	↑↑	---	↑	↑↑		

↑ = slight increase ↑↑ = significant increase

Recommendation #1: Copper tube, 0.025 wall thickness, internally enhanced

This tube is available as a standard option. Copper tubes offer reliable operation and maximum chiller efficiency. Proper water treatment processes must be followed to ensure reliable operation.

Recommendation #2: Copper tube, 0.28 or 0.035 wall thickness, internally enhanced

A thicker wall tube is an upgrade. There is a slight increase in cost. However, thicker tubes offer a longer life expectancy and reduced risk of variations to water treatment chemistry.

Recommendation #3: 90/10 CuNi tube, 0.028 or 0.035 wall thickness, internally enhanced

A 90/10 CuNi alloy tube is a further upgrade for corrosion protection in treated fresh water. This option would be a significant increase in cost compared to the baseline recommendation. However, 90/10 CuNi tubes offer longer corrosion life and lower risk of variations to water treatment chemistry.

Tubesheets

Recommendation: Carbon Steel

This is Johnson Controls' standard offering. With properly maintained water chemistry, carbon steel is an appropriate material option for reliable operation.

Protective coatings are not recommended with proper water treatment.

Waterboxes

Recommendation: Carbon Steel

This is Johnson Controls' standard offering. With properly maintained water chemistry, carbon steel is an appropriate material option for reliable operation.

Protective coatings are not recommended with proper water treatment.

Couplings/ Plugs

Recommendation: Carbon Steel

This is Johnson Controls' standard offering and is an appropriate material option.

Thermowells

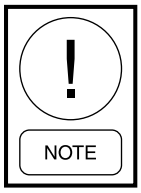
Recommendation: Copper

This is Johnson Controls' standard offering and is an appropriate material option.

Anodes

Recommendation: None

Most treated fresh water applications do not require the use of anodes for industry-standard levels of corrosion protection. However, anodes can be provided for additional corrosion protection if recommended by a water treatment expert.



Anodes will be provided as standard if any coatings are requested to protect against corrosion should coating holidays occur.

Flow Switches

Recommendation: Johnson Controls' standard stainless steel flow switches are appropriate for chiller applications that use treated fresh water.

LOW CHLORIDE TSE (TREATED SEWAGE EFFLUENT)

Johnson Controls considers Low Chloride Treated Sewage Effluent to be water that meets the water quality specification in the table provided below. Water quality that does not meet the specification may be defined by a different water quality category, or may need further analysis by a water treatment expert before defining the application guidelines.

- Chemical and/or mechanical treatment is required if the water quality cannot support the specification.
- If the TSE water supplier has a water quality specification, then only one sample is initially required to evaluate material compatibility.
- If the TSE water supplier does NOT have a water quality specification, then a minimum of three (3) water samples are required to ensure compatibility. These samples must be taken on three separate days preferably in three different seasons.

The notes above are for an initial water quality evaluation. Continued water sampling and treatment are required to maintain water quality within the parameters listed below.

TABLE 3 - WATER QUALITY SPECIFICATION FOR LOW CHLORIDE TSE

PARAMETER [1]	MAKE-UP WATER [2]	CONCENTRATED COOLING TOWER WATER [3,4]
pH	7.0 - 8.8	7.0 - 8.8
Total Suspended Solids, ppm	< 2.0	< 20
Total Dissolved Solids, ppm	-	< 2500
Total Alkalinity, ppm as $CaCO_3$	< ~400 at 1.5 cycles	< 600
Total Hardness (Ca + Mg), ppm as $CaCO_3$	< ~500 at 1.5 cycles	100 - 800
Iron, ppm as Fe	< 0.2	< 2.0
Copper, ppm as Cu	< 0.01	< 0.1
Chloride, ppm as Cl	< 200 at 1.5 cycles	< 300
Sulfate, ppm as SO_4	< 200 at 1.5 cycles	< 300
Silica, ppm as SiO_2	< 100 at 1.5 cycles	< 150
Phosphate, ppm as PO_4	0 - 10.00	[PO_4] must be below the maximum allowable concentration for the chemical treatment program
Phosphonate, ppm as P_2O_5	0 - 10.00	[Phosphonate] must be below the maximum allowable concentration for the chemical treatment program
Chlorine, free, ppm as Cl	0.1 - 0.5	0.2 - 1.0 [5]
Ammonia, ppm as NH_3	< 3	< 1 [6]
Sulfides, ppm as SO_2	0	0
TOC (mg/L)	< 5	requires good feed control of oxidizing biocide
Aerobic Bacteria, CFU/ml	< $1x10^3$	< $1x10^3$
Anaerobic Bacteria, CFU/ml	0	0
Coliform, (counts per 100/ml)	0	0
E-Coli, (counts per 100/ml)	0	0
BOD (mg/L)	0	0
COD (mg/L)	0	0

1. Individual chemical parameter. If not shown above, contact Chiller Applications group. If any parameter exceeds the levels set forth in the table above, move to the next water quality specification for material recommendations or contact Chiller Applications group. See Glossary for definitions.
2. Make up water concentration levels may change based on number of cycles.
3. Cooling water will require chemical additives or a non-chemical water treatment device or a combination of both. Once through systems may not require chemical treatment, but still need to meet the parameters listed above.
4. Water that will be utilized for condenser heat exchanger.
5. Chlorine, free [Clfree] = 2.0 ppm may be required in systems with high nutrient loading and/or exposure to drift.
6. Ammonia concentration levels are lower in tower water as some will evaporate to the atmosphere.

Component Recommendations for Low Chloride TSE

The recommendations made below are to offer various levels of protection against:

- Corrosion
- Erosion
- Deposition
- Microbiological fouling

TABLE 4 - HEAT EXCHANGER TUBES

RECOMMENDATION [2]	MATERIAL	WALL THICKNESS	LIFE EXPECTANCY	PRESSURE DROP	KW/TON	CHILLER FIRST COST
Baseline [1]	Copper	0.025	Baseline	Baseline	Baseline	Baseline
#1	304 Stainless Steel	0.028	↑	↓↓	↑	↑
#2	Titanium	0.028	↑↑	↓↓	↑↑	↑↑

↑ = slight increase ↑↑ = significant increase

1. Copper tubes are shown in the table above for baseline comparison purposes only. Copper tubes are not suitable for Low Chloride TSE applications.
2. If ammonia in cooling water is consistently below 1 ppm, 70/30 copper/nickel alloy may be suitable for Low Chloride TSE applications. Further evaluation would be required.

Recommendation #1: 304 Stainless Steel

304 stainless steel is an appropriate option for tube material to offer reliable operation.

Recommendation #2: Titanium

Titanium is an upgrade in tube material and is the best option to provide the longer life expectancy. Titanium is very resistant to corrosion and erosion; however, it is a higher cost option.

It is highly recommended that the waterboxes and tubesheets are clad or coated due to the high potential for galvanic corrosion.

Tubesheets

Recommendation #1: Carbon Steel

This is Johnson Controls' standard offering. With appropriate water treatment and consistent make-up water quality, carbon steel is an appropriate material option for reliable operation.

Recommendation #2: Carbon Steel with Epoxy Coating

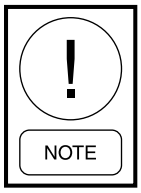
Epoxy coating is available as an option for tubesheet protection. Epoxy coating adds an additional layer of protection against corrosion/erosion that can lengthen the service life of the tubesheet. Coatings are subject to wear and tear and should be inspected annually and maintained as required.

Recommendation #3: Carbon Steel with Ceramic Coating

Ceramic Coating is considered another appropriate option for tubesheet protection, which provides more durable, built-up layers of protection, to ensure longer service life and a better level of protection against corrosion/erosion. Coatings are subject to wear and tear and should be inspected annually and maintained as required.

Recommendation #4: Carbon Steel with Cladding

Cladding offers the best protection from corrosion/erosion. It is the highest up-front cost, but is virtually maintenance free and offers the longest service life. Stainless steel cladding must be used if stainless steel tubes are selected. Titanium cladding must be used if titanium tubes are selected.



Cladding or coating of tubesheets is highly recommended with the use of titanium tubes due to the high potential for galvanic corrosion that exists between carbon steel and titanium.

Waterboxes

Recommendation #1: Carbon Steel

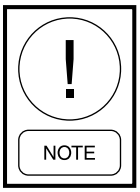
This is Johnson Controls' standard offering. With appropriate water treatment and consistent make-up water quality, carbon steel is an appropriate material option for reliable operation.

Recommendation #2: Carbon Steel with Epoxy Coating

Epoxy coating is available as an option for waterbox protection. Epoxy coating adds an additional layer of protection against corrosion/erosion that can lengthen the service life of the waterbox, provided the coatings are inspected annually and maintained as required. Anodes will be provided as standard if any coatings are requested to protect against corrosion should coating holidays occur.

Recommendation #3: Carbon Steel with Ceramic Coating

Ceramic coating is considered another appropriate option for waterbox protection, which provides more durable, built-up layers of protection, to ensure longer service life and a better level of protection against corrosion/erosion. Coatings are subject to wear and tear and should be inspected annually and maintained as required. Anodes will be provided as standard if any coatings are requested to protect against corrosion should coating holidays occur.



Coating of waterboxes is highly recommended with the use of titanium tubes due to the high potential for galvanic corrosion that exists between carbon steel and titanium.

Couplings/ Plugs

Recommendation #1: Carbon Steel

This is Johnson Controls' standard, lowest cost offering and is an appropriate material option.

Recommendation #2: Stainless Steel 304 or 316

Stainless steel is considered to be a better material option, with greater corrosion resistance. Stainless steel is a higher cost option.

Recommendation #3: Monel

Monel is the best option to ensure reliable operation.

Thermowells

Recommendation #1: Carbon Steel

Recommendation #2: Stainless Steel 304 or 316

Stainless steel is a better material option, with greater corrosion resistance. Stainless steel is also a higher cost option.

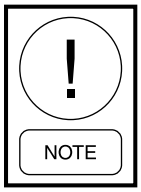
Recommendation #3: Monel

Monel is the best option to ensure reliable operation.

Anodes

Recommendation: Zinc

Zinc anodes are a recommended option for an additional level of protection.



Anodes will be provided as standard if any coatings are requested to protect against corrosion should coating holidays occur.

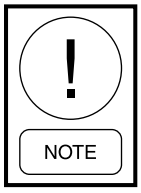
Flow Switches

Recommendation: Johnson Controls' standard stainless steel flow switches are appropriate for chiller applications that use Low Chloride TSE.

Other chiller components

Recommendation: Any chiller components that require condenser water for cooling, Johnson Controls recommends that closed loop evaporator water be used for cooling these components, such as:

- Unit mounted Variable Speed
- Unit mounted Solid State Starter
- TEWAC (Totally Enclosed Water-Air Cooled) motor heat exchangers
- Shell & tube heat exchangers used for oil cooling



Under most conditions, the reliability of the evaporator "closed" loop design is easily controlled by conventional chemical water treatment.

HIGH CHLORIDE TSE (TREATED SEWAGE EFFLUENT)

Johnson Controls considers High Chloride Treated Sewage Effluent to be water that meets the water quality specification in the table provided below. Water quality that does not meet the specification may be defined by a different water quality category, or may need further analysis by a water treatment expert before defining the application guidelines.

Water Quality Specification for High Chloride TSE:

- Chemical and/or mechanical treatment is required if the water quality cannot support the specification.
- If the TSE water supplier has a water quality specification, then only one sample is required to evaluate material compatibility.
- If the TSE water supplier does NOT have a water quality specification, then a minimum of three (3) water samples are required to ensure compatibility. These samples must be taken on three separate days preferably in three different seasons.

The notes above are for an initial water quality evaluation. Continued water sampling and treatment are required to maintain water quality within the parameters listed below.

TABLE 5 - WATER QUALITY SPECIFICATION FOR HIGH CHLORIDE TSE

PARAMETER [1]	MAKE-UP WATER [2]	CONCENTRATED COOLING TOWER WATER [3,4]
pH	7.0 - 8.8	7.0 - 8.8
Total Suspended Solids, ppm	< 2.0	< 20
Total Dissolved Solids, ppm	-	[Dissolved Solids] must be below the solubility limits for scale formation
Total Alkalinity, ppm as $CaCO_3$	< ~400 at 1.5 cycles	< 600
Total Hardness (Ca + Mg), ppm as $CaCO_3$	< ~500 at 1.5 cycles	100 - 800
Iron, ppm as Fe	< 0.2	< 2.0
Copper, ppm as Cu	< 0.01	< 0.1
Chloride, ppm as Cl	> 200 at 1.5 cycles	[Cl] must be below the solubility limit for the chemical treatment program
Sulfate, ppm as SO_4	> 200 at 1.5 cycles	[SO_4] must be below the solubility limit for the chemical treatment program
Silica, ppm as SiO_2	< 100 at 1.5 cycles	< 150
Phosphate, ppm as PO_4	0 - 10.00	[PO_4] must be below the maximum allowable concentration for the chemical treatment program
Phosphonate, ppm as P_2O_5	0 - 10.00	[Phosphonate] must be below the maximum allowable concentration for the chemical treatment program
Chlorine, free, ppm as Cl	0.1 - 0.5	0.2 - 1.0 [5]
Ammonia, ppm as NH_3	< 3	< 1 [6]
Sulfides, ppm as SO_2	0	0
TOC (mg/L)	< 5	requires good feed control of oxidizing biocide
Aerobic Bacteria, CFU/ml	< $1x10^3$	< $1x10^3$
Anaerobic Bacteria, CFU/ml	0	0
Coliform, (counts per 100/ml)	0	0
E-Coli, (counts per 100/ml)	0	0
BOD (mg/L)	0	0
COD (mg/L)	0	0

1. Individual chemical parameter. If not shown above, contact Chiller Applications group. If any parameter exceeds the levels set forth in the table above, move to the next water quality specification for material recommendations or contact Chiller Applications group. See Glossary for definitions.
2. Make up water concentration levels may change based on number of cycles.
3. Cooling water will require chemical additives or a non-chemical water treatment device or a combination of both. Once through systems may not require chemical treatment, but still need to meet the parameters listed above.
4. Water that will be utilized for condenser heat exchanger.
5. Chlorine, free [Clfree] = 2.0 ppm may be required in systems with high nutrient loading and/or drift.
6. Ammonia concentration levels are lower in tower water as some will evaporate to the atmosphere.

Component Recommendations for High Chloride TSE

The recommendations made below are to offer various levels of protection against:

- Corrosion
- Erosion
- Deposition
- Microbiological fouling

TABLE 6 - HEAT EXCHANGER TUBES

RECOMMENDATION	MATERIAL	WALL THICKNESS	LIFE EXPECTANCY	PRESSURE DROP	KW/TON	CHILLER FIRST COST
Baseline[1]	Copper	0.025	Baseline	Baseline	Baseline	Baseline
#1	Titanium	0.028	↑↑	↓↓	↑	↑↑

↑ = slight increase ↑↑ = significant increase

1. Copper tubes are shown in the table above for baseline comparison purposes only. Copper and copper alloy tubes are not suitable for High Chloride TSE applications.

Recommendation: Titanium

Titanium is the only tube option to ensure reliable operation. Applications using water with high Chloride levels must utilize titanium tubes.

Tubesheets

Recommendation #1: Carbon Steel with Ceramic Coating

Ceramic Coating is considered another appropriate option for tubesheet protection, which provides more durable, built-up layers of protection, to ensure longer service life and a better level of protection against corrosion/erosion. Coatings are subject to wear and tear and should be inspected annually and maintained as required.

Recommendation #2: Carbon Steel with Titanium Cladding

Titanium cladding is considered the best option for tubesheet protection to ensure the longest service life.

Cladding offers the best protection from corrosion/erosion. It is virtually maintenance free and offers the longest service life.

Waterboxes

Recommendation: Carbon Steel with Ceramic Coating

Ceramic Coating is an appropriate option for watebox protection to ensure reliable operation and protection against corrosion/erosion. Coatings are subject to wear and tear and should be inspected annually and maintained as required.

Anodes will be provided as standard if any coatings are requested to protect against corrosion should coating holidays occur.

Couplings/ Plugs

Recommendation: Monel

Monel is the best option to ensure reliable operation.

Thermowells

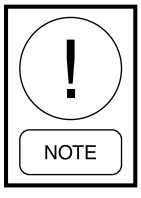
Recommendation: Monel

Monel is the best option to ensure reliable operation.

Anodes

Recommendation: Zinc

Zinc anodes are a recommended option for an additional level of protection against corrosion.



Anodes will be provided as standard if any coatings are requested to protect against corrosion should coating holidays occur.

Flow Switches

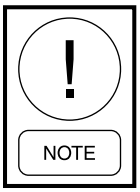
Recommendation: Titanium

Titanium is the best option to ensure reliable operation.

Other chiller components

Recommendation: Any chiller components that require condenser water for cooling, Johnson Controls recommends that closed loop evaporator water be used for cooling these components, such as:

- Unit mounted Variable Speed
- Unit mounted Solid State Starter
- TEWAC (Totally Enclosed Water-Air Cooled) motor heat exchangers
- Shell & tube heat exchangers used for oil cooling



Under most conditions, the reliability of the evaporator "closed" loop design is easily controlled by conventional chemical water treatment.

FILTERED BRACKISH OR SEAWATER

Johnson Controls considers Filtered Brackish or Seawater to be water that meets the water quality specification in the table provided below. Water quality that does not meet the specification may be defined by a different water quality category, or may need further analysis by a water treatment expert before defining the application guidelines.

TABLE 7 - WATER QUALITY SPECIFICATION FOR FILTERED BRACKISH OR SEAWATER

PARAMETER [1]	MAKE-UP WATER [2]	CONCENTRATED COOLING TOWER WATER [3,4]
pH	6.5 - 8.8	< 9.0
Total Suspended Solids, ppm	< 2.0	< 10
Total Dissolved Solids, ppm	< 50,000	[Dissolved Solids] must be below the solubility limits
Total Alkalinity, ppm as $CaCO_3$	200 - 350	< 525
Total Hardness (Ca + Mg), ppm as $CaCO_3$	450 - 650	< 975
Iron, ppm as Fe	< 0.02	< 2.0
Copper, ppm as Cu	< 0.01	< 0.1
Chloride, ppm as Cl	1000 - 28,000	[Cl] must be below the solubility limit for the chemical treatment program
Sulfate, ppm as SO4	1000 - 4,000	[SO_4] must be below the solubility limit for the chemical treatment program
Silica, ppm as SiO_2	< 100 at 1.5 cycles	< 150
Phosphate, ppm as PO_4	< 0.5	Phosphate-based corrosion inhibitors are seldom added.
Phosphonate, ppm as P_2O_5	< 0.5	Phosphonate-based corrosion inhibitors are seldom added.
Chlorine, free, ppm as Cl	0.1 - 0.5	0.2 - 1.0 [5]
TOC (mg/L)	< 2	Requires good feed control of oxidizing biocide
Ammonia, ppm as NH_3	0 7	< 1 [6]
Sulfides, ppm as SO_2	0	0
Aerobic Bacteria, CFU/ml	< $1x10^2$	< $1x10^3$
Anaerobic Bacteria, CFU/ml	0	0
Coliform, (counts per 100/ml)	0	0
E-Coli, (counts per 100/ml)	0	0
BOD (mg/L)	0	0
COD (mg/L)	0	

1. Individual chemical parameter. If not shown above, contact Chiller Applications group. If any parameter exceeds the levels set forth in the table above, move to the next water quality specification for material recommendations or contact Chiller Applications group. See Glossary for definitions.
2. Make up water concentration levels may change based on number of cycles.
3. Cooling water will require chemical additives or a non-chemical water treatment device or a combination of both. Once through systems may not require chemical treatment, but still need to meet the parameters listed above.
4. Water that will be utilized for condenser heat exchanger.
5. Chlorine, free [Clfree] = 2.0 ppm may be required in systems with high nutrient loading and/or drift.
6. Limit applies to CuNi tubes only. No limit for titanium.
7. Make-up water with even trace amounts of ammonia is considered to be polluted. Refer to the High Chloride TSE water category of this document for recommended chiller material selections.

Component Recommendations for Filtered Brackish or Seawater:

The recommendations made below are to offer various levels of protection against:

- Corrosion
- Erosion
- Deposition
- Microbiological fouling

TABLE 8 - HEAT EXCHANGER TUBES

RECOMMENDATION	MATERIAL	WALL THICKNESS	LIFE EXPECTANCY	PRESSURE DROP	KW/TON	CHILLER FIRST COST
Baseline [1]	Copper	0.025	Baseline	Baseline	Baseline	Baseline
#1	70/30 CuNi	0.035	↑	↓	↑	↑
#2	Titanium	0.028	↑↑	↓↓	↑	↑↑

↑ = slight increase ↑↑ = significant increase
1 Copper tubes are shown in the table above for baseline comparison purposes only. Copper tubes are not suitable for sea water applications.

Recommendation #1: 70/30 CuNi

70/30 CuNi is an appropriate option for tube material to offer reliable operation.

Recommendation #2: Titanium

Titanium is an upgrade in tube material and is considered the best option to provide the longest life expectancy. Titanium is very resistant to corrosion and erosion; however, it is the highest cost option.

Tubesheets

Recommendation #1: Carbon Steel with Ceramic Coating

Ceramic Coating is considered another appropriate option for tubesheet protection, which provides more durable, built-up layers of protection, to ensure longer service life and a better level of protection against corrosion/erosion. Coatings are subject to wear and tear and should be inspected annually and maintained as required.

Recommendation #2: Carbon Steel with Cladding

Cladding is a better option for tubesheet protection. Cladding offers the best protection from corrosion/erosion. It is the highest up-front cost, but is virtually maintenance free and offers the longest service life.

70/30 CuNi cladding must be used if 70/30 CuNi tubes are selected.

Titanium cladding must be used if titanium tubes are selected.

Waterboxes

Recommendation: Carbon Steel with Ceramic Coating

Ceramic Coating is an appropriate option for waterbox protection to ensure reliable operation and protection against corrosion/erosion. Coatings are subject to wear and tear and should be inspected annually and maintained as required.

Anodes will be provided as standard if any coatings are requested to protect against corrosion should coating holidays occur.

Couplings/ Plugs

Recommendation: Monel

Monel is an appropriate option to ensure reliable operation.

Thermowells

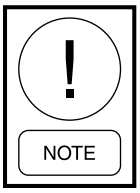
Recommendation: Monel

Monel is an appropriate option to ensure reliable operation.

Anodes

Recommendation: Zinc

Zinc anodes are a recommended option for an additional level of protection.



Anodes will be provided as standard if any coatings are requested to protect against corrosion should coating holidays occur.

Flow Switches

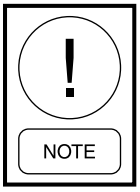
Recommendation: Titanium

Titanium is an appropriate option to ensure reliable operation.

Other chiller components

Recommendation: Any chiller components that require condenser water for cooling, Johnson Controls recommends that closed loop evaporator water be used for cooling these components, such as:

- Unit mounted Variable Speed
- Unit mounted Solid State Starter
- TEWAC (Totally Enclosed Water-Air Cooled) motor heat exchangers
- Shell & tube heat exchangers used for oil cooling



Under most conditions, the reliability of the evaporator "closed" loop design is easily controlled by conventional chemical water treatment.

GLOSSARY

BOD (Biochemical Oxygen Demand) - The measure of biological organisms, such as algae or bacteria (i.e. Chloroform), in a body of water.

Ceramic Coating - A liquid ceramic polymer composites that can be used to resurface and protect all wet areas on fluid flow components from aggressive erosion/corrosion attack. Typically applied to the tubesheets and/or the inside of the waterboxes. Coatings are subject to wear and tear and should be inspected annually and maintained as required.

COD (Chemical Oxygen Demand) - The measure of inorganic contaminates, such as nitrite, that will react to oxygen in the water.

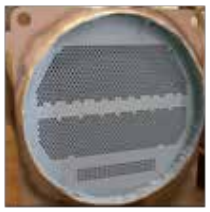
Cladding - This is the process of covering one material with another. Typically, an exotic metal or metal/alloy (chosen to be used for protection) will be used to cover a steel component, most often a tubesheet or the inside of a waterbox. Cladding is a higher up-front cost, but virtually maintenance free.

Copper - The industry standard for heat exchanger tubes. Copper offers the best in thermal conductivity and is a good material for workability, which allows for a greater range of tube internal and external enhancement configurations. This typically results in the highest chiller capacity and highest heat transfer. All tubes are suitable for 300 psi waterside DWP.

Copper Nickel (CuNi) - A copper/nickel alloy often used for heat exchange tubes. Most commonly offered as 90/10 and 70/30 (% copper / % nickel), these alloys typically offer an increased level of protection at the sacrifice of capacity, efficiency, and cost.

COC (Cycles or Cycles of Concentration) - Cycles of concentration represents the accumulation of dissolved minerals in the recirculating cooling tower water as it is evaporated from the cooling tower. Draw-off (or blow down) is used principally to control the buildup of these minerals. Staining and scale build up may result from the precipitation of the dissolved solids.

Epoxy Coating - A protective coating that can be applied to the inside of waterboxes, tubesheets or both. Epoxy coating provides limited protection against corrosion. Coatings are subject to wear and tear and should be inspected annually and maintained as required.



Galvanic Corrosion - A process that degrades metals electrochemically. This corrosion occurs when two dissimilar metals are placed in contact with each other in the presence of an electrolyte, such as salt water, forming a galvanic cell. The resulting electrochemical potential then develops an electric current that electrolytically dissolves the less noble material.

Holidays - a discontinuity or break in a coating, exposing the bare base metal underneath.

Monel - Monel is a nickel alloy, primarily composed of nickel and copper, with some iron and other trace elements.

Sacrifical Anodes - Sacrificial anodes serve as an electrode through which electric current flows into a polarized electrical device capturing charged materials in water therefore reducing corrosion.

Titanium - A very durable material that is extremely resistant to corrosion and erosion. Titanium will offer the highest reliability, but at the highest price and decreased heat transfer. Tube configurations are limited as titanium does not have very good workability and is difficult to enhance.

TOC (Total Organic Carbon) - This is the amount of carbon bound in an organic compound and is often used as a non-specific indicator of water quality or cleanliness of equipment.

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