DOWFROST™ LC Inhibited Propylene Glycol-Based Heat Transfer Fluid

Heat management and corrosion protection in liquid cooled data center applications

Engineering and Operating Guide

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1.0 Introduction

Continual advancement of micro-processor technology has led to increasingly higher heat loads incurred by datacom equipment cooling systems (DECS). As power density increases, conventional air cooling is no longer economically viable as the cost to operate air cooling equipment within a datacom center exceeds the cost of the equipment being cooled (over a typical three-year equipment life span). This has caused the industry to move toward liquid cooling of DECS. DOWFROST™ LC Heat Transfer Fluid (HTF) is specifically formulated for liquid cooled, direct-to-chip applications and provides your system with exceptional corrosion protection, even in high surface area copper components.

DOWFROST™ LC 25 or DOWFROST™ LC 55 can be used in these systems to provide freeze protection and limit corrosion to ensure long life of the system. The DECS may be supplied with fluid from an in-rack Cooling Distribution Unit (CDU) or supplied by an external CDU that services multiple racks.

This guide provides basic product performance information, engineering data and operating guidelines for DOWFROST™ LC Heat Transfer Fluids used in datacom equipment cooling system (DECS) loops. Topics covered in this guide are:

- Brief introduction to DOWFROST™ LC Heat Transfer Fluids
- Typical product specifications
- System design and preparation guidelines
- Fluid testing and maintenance
- Detailed engineering data

If you would like additional product information, please contact Dow at (800) 258-2436.

2.0 Properties of DOWFROST™ LC Heat Transfer Fluids

2.1 Appearance and description

DOWFROST™ LC Heat Transfer Fluids are dyed a fluorescent yellow-green color which helps to identify the location of any possible leaks within a system. Fluids which are in use for an extended length of time may not exhibit the same bright color and can be darker or less vibrant in appearance but should remain relatively clear with no evidence of cloudiness or suspended solids.

DOWFROST™ LC Heat Transfer Fluids are ready-to-use, propylene glycol-based heat transfer fluids which are available in concentrations of either 25% or 55% by volume of propylene glycol and should not be further diluted. Glycol-based heat transfer fluids should always be used at concentrations greater than 25% but no more than 60%. Diluting below 25% propylene glycol may put a system at risk for bacterial contamination as glycols are very biodegradable below this level. When glycol is maintained at a concentration of 25% or higher, the osmotic pressure of the solution is high enough to cause dehydration of bacteria and fungi, creating bio-static conditions.

2.2 Propylene glycol quality

In order to provide effective long-term corrosion protection of DECS, a heat transfer fluid must be made from highly purified propylene glycol that meets United States Pharmacopeia (USP) specifications in addition to containing appropriate corrosion inhibitors (providing acceptable pH and reserve alkalinity).

Propylene glycol that does not meet USP specifications may have higher levels of impurities which can impart strong odors and cause excessive foaming. The harmful effects of these unwanted impurities cannot be negated by the addition of corrosion inhibitors or additives. DOWFROST™ LC Heat Transfer Fluids are made from high purity Dow PURAGUARD™ USP/EP grade propylene glycol (>99.8% PG) and contain industrial strength corrosion inhibitors, pH buffers and stabilizers specifically designed for operation within datacom equipment cooling systems.

2.3 Physical and chemical properties

As the concentration of propylene glycol in water increases, several physical properties change considerably in addition to freeze point. These include:

- Osmotic pressure
- Viscosity
- Thermal conductivity
- Specific heat
- Specific gravity

As a result of increases in glycol concentration, heat transfer and pressure drop are adversely impacted. Therefore, it is recommended to use DOWFROST™ LC Heat Transfer Fluid at a concentration no higher than what is needed for freeze protection purposes to minimize the effect on heat transfer and pressure drop. Refer to Table 1 for freezing points of DOWFROST™ LC Heat Transfer Fluids.

Table 1. Typical product specifications† of DOWFROST™ LC 25 and DOWFROST™ LC 55 Heat Transfer Fluids

Fluid parameter	Units	DOWFROST™ LC 25	DOWFROST™ LC 55
Propylene glycol concentration	Volume %	25	55
Freezing point	°F	14°F	-40°F
	°C	-10°C	-40°C
pH		8.0-10.5	8.0-10.5
Reserve alkalinity	(mL)	>6.0	>6.0
Thermal conductivity	W/mK at 50°C	0.485	0.336
Specific heat at 50°C (kJ/kg-K)		3.94	3.43
Viscosity	20°C (mPa sec)	2.8	8.8
	50°C (mPa sec)	1.3	2.9
Volume expansion	% from -40 to 90°C	5.2%	7.7%
Boiling point	°C at 760 mmHg	101.4	105
Electrical conductivity	micromho/cm	>2,000	>2,000
Sulfate	ppm	<10	<10
Chloride	ppm	<5	<5
Total hardness	ppm as $CaCO_3$	<20	<20

†Typical properties, not to be construed as specifications.

Table 2. Physical properties† of DOWFROST™ LC 25 Heat Transfer Fluid

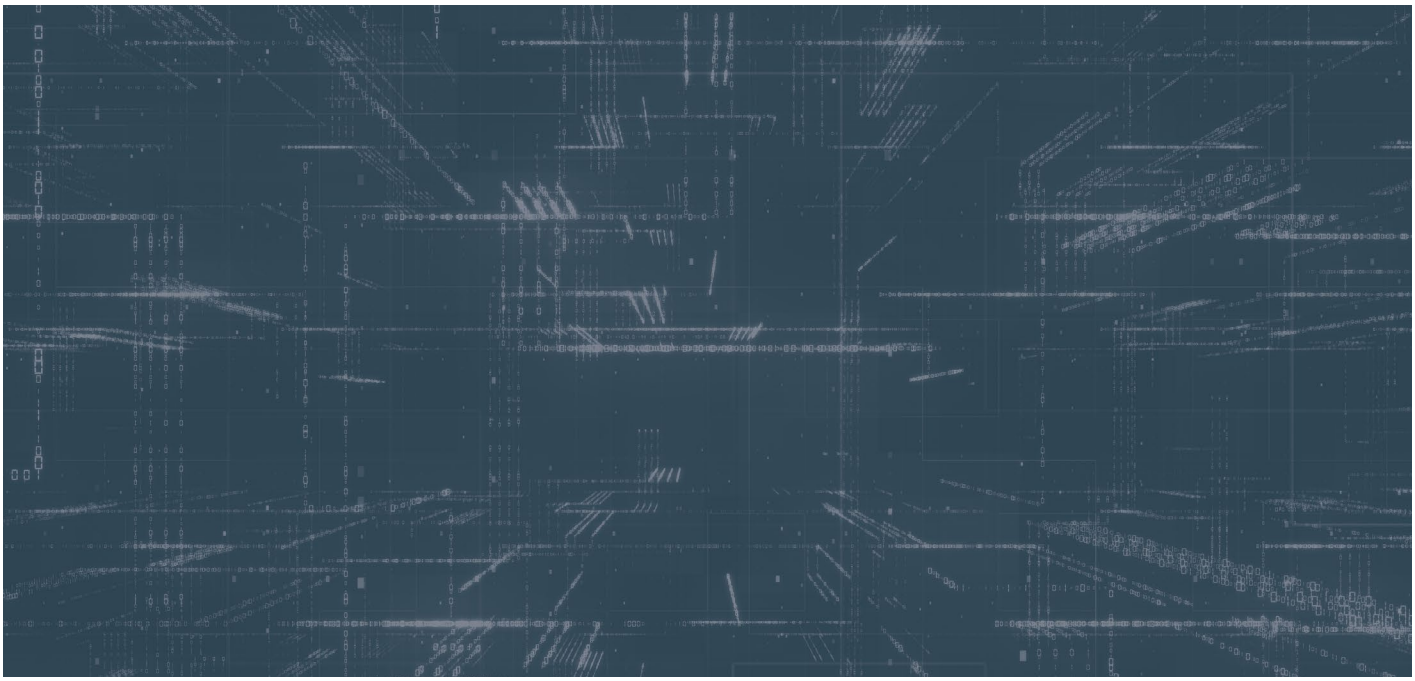
°C	Density (kg/m^3)	Specific heat (kJ/kg K)	Thermal conductivity (W/mK)	Viscosity (mPa sec)	Vapor pressure (kPa)
-5	1041.9	3.81	0.425	7.80	0.004
0	1040.5	3.82	0.432	6.32	0.006
5	1038.8	3.83	0.438	5.13	0.009
10	1036.9	3.84	0.444	4.17	0.012
15	1034.9	3.85	0.450	3.42	0.017
20	1032.7	3.87	0.456	2.84	0.023
25	1030.3	3.88	0.462	2.39	0.031
30	1027.8	3.89	0.467	2.05	0.042
35	1025.2	3.90	0.472	1.78	0.055
40	1022.5	3.92	0.476	1.58	0.072
45	1019.7	3.93	0.481	1.41	0.093
50	1016.8	3.94	0.485	1.27	0.119
55	1013.7	3.95	0.488	1.15	0.152
60	1010.6	3.97	0.492	1.04	0.191
65	1007.3	3.98	0.495	0.93	0.239
70	1003.9	3.99	0.497	0.83	0.297
75	1000.4	4.00	0.500	0.75	0.367
80	996.7	4.01	0.502	0.69	0.45

†Typical properties, not to be construed as specifications.

Table 3. Physical properties† of DOWFROST™ LC 55 Heat Transfer Fluid

°C	Density (kg/m^3)	Specific heat (kJ/kg K)	Thermal conductivity (W/mK)	Viscosity (mPa sec)	Vapor pressure (kPa)
-40	1085.9	2.98	0.280	1413.58	—
-35	1083.9	3.01	0.283	703.58	—
-30	1081.9	3.03	0.287	376.40	—
-25	1079.8	3.06	0.291	214.54	0.001
-20	1077.5	3.08	0.294	129.29	0.001
-15	1075.1	3.11	0.298	81.85	0.002
-10	1072.7	3.13	0.302	54.11	0.002
-5	1070.1	3.16	0.305	37.18	0.004
0	1067.4	3.18	0.309	26.42	0.005
5	1064.7	3.21	0.312	19.36	0.007
10	1061.8	3.23	0.315	14.57	0.01
15	1058.8	3.26	0.318	11.23	0.015
20	1055.7	3.28	0.321	8.84	0.02
25	1052.5	3.30	0.324	7.09	0.027
30	1049.2	3.33	0.327	5.79	0.036
35	1045.8	3.35	0.329	4.80	0.048
40	1042.2	3.38	0.332	4.03	0.062
45	1038.6	3.40	0.334	3.43	0.081
50	1034.9	3.43	0.336	2.95	0.104
55	1031.0	3.45	0.338	2.56	0.132
60	1027.1	3.48	0.339	2.24	0.167
65	1023.0	3.50	0.341	1.98	0.209
70	1018.9	3.53	0.342	1.76	0.26
75	1014.6	3.55	0.343	1.58	0.32
80	1010.2	3.58	0.344	1.42	0.395

†Typical properties, not to be construed as specifications.



2.4 Glycol concentration and freezing point

Installed fluid should have a freezing point which is at least 5°F (3°C) below the lowest anticipated temperature that the fluid will be exposed to in order to ensure free flow and system integrity during low temperature events. Regardless of required freezing point, DOWFROST™ LC 25 Heat Transfer Fluid should never be further diluted. Dilution below 25% propylene glycol allows for bio-degradation of the glycol by bacteria or fungi which can inadvertently be introduced to the system from dilution water or air vents. In general, it is not recommended to further dilute DOWFROST™ LC Heat Transfer Fluids because corrosion inhibitor and additive effectiveness will also be reduced.

The propylene glycol concentration and, therefore, freezing point can be determined on-site by measuring refractive index and referencing Table 4. Refractive index (RI) values are temperature dependent and may vary slightly depending on the condition of the fluid being tested.

The acceptable operating concentration for DOWFROST™ LC 25 Heat Transfer Fluid is between 24-27% propylene glycol, by volume, and for DOWFROST™ LC 55 Heat Transfer Fluid the acceptable operating range is between 53-57% propylene glycol.

Table 4. Freezing point and refractive index† versus glycol concentration for DOWFROST™ LC Heat Transfer Fluid

	Freezing point		Propylene Glycol		Refractive index	
	°F	°C	Wt %	Vol %	20°C	25°C
DOWFROST™ LC 25 Heat Transfer Fluid	15.6	-9.1	24	23.5	1.3622	1.3613
	14.7	-9.6	25	24.5	1.3634	1.3625
	13.7	-10.2	26	25.5	1.3646	1.3637
	12.6	-10.8	27	26.5	1.3658	1.3649
	11.5	-11.4	28	27.5	1.3670	1.3661
DOWFROST™ LC 55 Heat Transfer Fluid	-36.7	-38. 2	53	52.8	1.3949	1.3936
	-39.7	-39.8	54	53.8	1.3960	1.3947
	-42.8	-41.6	55	54.8	1.3971	1.3957
	-46.0	-43.3	56	55.9	1.3982	1.3968
	-49.3	-45.2	57	56.9	1.3993	1.3979

†Typical properties, not to be construed as specifications.

2.5 Dilution water

DOWFROST™ LC Heat Transfer Fluids should not be further diluted as they are ready-to-use fluids that are specifically formulated with suitable levels of inhibitors to provide long-term protection for DECS. Diluting with water will reduce inhibitor effectiveness which could pose serious corrosion or bio-fouling risks for a system.

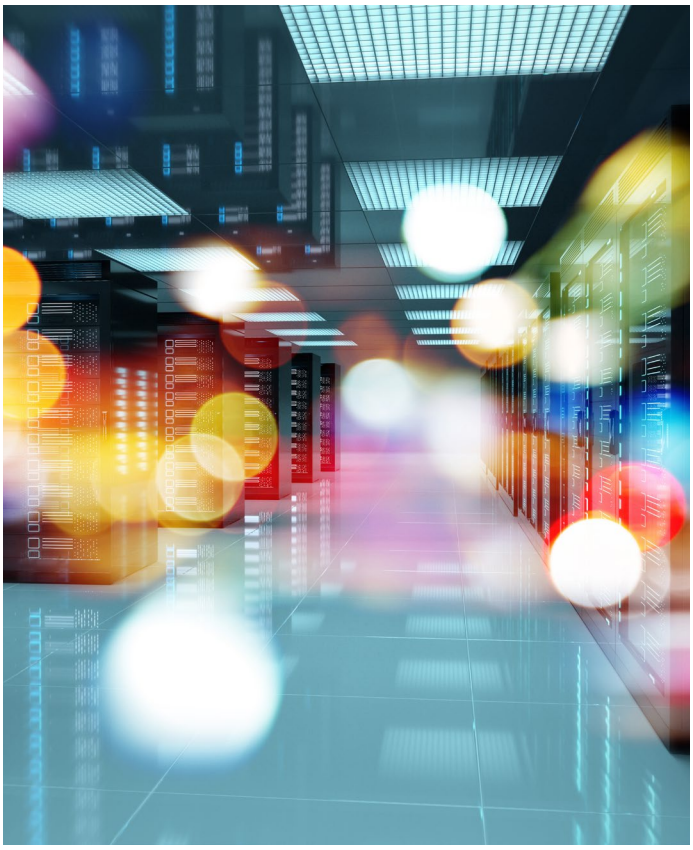
Although it is not recommended, if the heat transfer fluid must be diluted, for an unforeseen reason, only purified water (e.g., distilled, deionized, reverse osmosis) should be used. Failure to use purified water can lead to corrosion and fouling issues. Dilution water must meet the requirements in Table 5, at a minimum.

Table 5. Dilution water quality requirements

Parameter	Acceptable limit
Total Chlorides (as C^{l-})	<25 mg/L
Total Sulfates (as SO_4^{2-})	<25 mg/L
Total Hardness (as $CaCO_3$)	<50 mg/L
Total Iron (as Fe)	<1 mg/L
Electrical Conductivity	<50 micromhos/cm
pH	5 < pH < 9

2.6 Electrical conductivity

The necessary use of corrosion inhibitors, pH buffers, stabilizers and other additives specifically designed for datacom equipment cooling systems will impart higher electrical conductivity (lower electrical resistivity) than is commonly seen for water. Typical electrical conductivity values for DOWFROST™ LC Heat Transfer Fluid will exceed 2,000 micromho/cm.



3.0 System design considerations

3.1 General

It is recommended that all system components and materials in direct contact with DOWFROST™ LC Heat Transfer Fluids be verified for compatibility at the minimum and maximum expected exposure temperatures.

3.2 Metals

All heat transfer fluids used in a datacom equipment cooling system must be capable of providing long-term corrosion protection of common metals including carbon steel, stainless steel, copper, copper alloys and brazes up to bulk fluid temperatures of 90°C (194°F).

Glycol-based heat transfer fluids can experience oxidation and thermal degradation with exposure to heat and air during normal operation, leading to the formation of acidic compounds. These glycol degradation reactions are often catalyzed by metallic surfaces so it is critical that the additive package be specifically designed for these systems. DOWFROST™ LC Heat Transfer Fluids contain specially designed corrosion inhibitor packages that are designed for long-term protection in DECS applications.

Table 6. Corrosion Test* Results for DOWFROST™ LC 25 Heat Transfer Fluid

Metal	Units	Water	Propylene Glycol	DOWFROST™ LC 25 Heat Transfer Fluid
Copper	**mpy**	**0.08**	**0.16**	**0.03**
	weight loss, mg	2	4	0.6
Solder	**mpy**	**3.14**	**34.70**	**0.04**
	weight loss, mg	99	1095	0.8
Brass	**mpy**	**0.23**	**0.20**	**0.07**
	weight loss, mg	5	5	1
Mild Steel	**mpy**	**9.69**	**9.80**	**0.02**
	weight loss, mg	212	214	0.3
Cast Iron	**mpy**	**21.20**	**16.20**	**0.02**
	weight loss, mg	450	345	0.3
Aluminum	**mpy**	**13.20**	**1.80**	**0.31**
	weight loss, mg	110	15	2

*ASTM D1384 testing was performed at 190°F (88°C) for 2 weeks with constant air bubbling. Glycol solutions were tested at 30%, by volume of glycol.

Note: Rates in excess of 0.5 mils penetration per year (mpy), or 2.5 mpy for aluminum, are generally evidence of inadequate corrosion protection.

3.3 Elastomers and plastics

A DECS fluid must also demonstrate long-term chemical compatibility with common elastomers and polymers, up to bulk fluid temperatures of 90°C (194°F). The compatibility of DOWFROST™ LC Heat Transfer Fluids with specific elastomeric or plastic materials used for tanks, piping, tubing, pumps, valves, gaskets, mechanical pump seals, valve packings and o-rings must be verified by the component material supplier before use. Substantial variation exists for specific elastomers with respect to maximum allowable exposure temperatures. Table 6 should be used as a reference until compatibility has been verified.

Original Equipment Manufacturers (OEMs) of the DECSs may publish a "Wetted Materials List" which summarizes the types of materials which are compatible with various fluids. Consult with your OEM for specific information about acceptable materials.

3.4 Chemical compatibility of wetted materials

Table 7. DOWFROST™ LC 25 and DOWFROST LC 55 Wetted Materials List

Metals and metal alloys	Compatibility with DOWFROST™ LC Heat Transfer Fluids
Brass with <15% zinc	Acceptable up to at least 90°C
Brass, chrome plated	Acceptable up to at least 90°C
Brass, nickel plated	Acceptable up to at least 90°C
Carbon steel	Acceptable up to at least 90°C
Copper	Acceptable up to at least 90°C
Copper alloys: <15% zinc and lead free	Acceptable up to at least 90°C
Stainless steel, solution treated and passivated	Acceptable up to at least 90°C
Elastomers, plastics and other materials	**Compatibility with DOWFROST™ LC Heat Transfer Fluids**
Acrylonitrile butadiene rubber (NBR)	Caution: Most compositions of this polymer are not recommended above 40°C
Polyoxymethylene (POM)	Not recommended above 30°C
Ethylene Propylene Diene Monomer (EPDM)[1]	Acceptable up to at least 75°C
Fluoroelastomer (FKM)	Caution: Some compositions of this polymer are not recommended above 40°C
Fluorinated Ethylene Propylene (FEP)	Acceptable up to at least 90°C
Polyamide (PA)	Caution: Most compositions of this polymer are not recommended above 40°C
Polychloroprene (CR)	Caution: Some compositions of this polymer are not recommended above 40°C
Polyethylene (PE)	Acceptable up to at least 75°C
Polyphenylene Sulfide (PPS)	Acceptable up to at least 60°C
Polytetrafluoroethylene (PTFE)	Acceptable up to at least 90°C
Polypropylene (PP)	Acceptable up to at least 75°C
Polysulfone or Polyphenylsulfone (PSU, PPSU)	Acceptable up to at least 75°C
Silicone	Caution: Most compositions of this polymer are not recommended above 40°C

*High density polyethylene (HDPE), Loctite 567 (thread sealant), Poly ether ether ketone (PEEK) are also acceptable for use. Please confirm temperature rating with manufacturer.

[1]Initial data suggests that peroxide-cured EPDM is more robust than sulfur-cured EPDM.

4.0 System preparation

4.1 System flushing

In cases where fabrication debris or particulates such as pipe scale, weld slag and solder flux are present, it is recommended that the system be flushed with high purity water immediately prior to installation of DOWFROST™ LC Heat Transfer Fluid to remove loose solids. All flush water must be completely removed from the system before DOWFROST™ LC Heat Transfer Fluid is added so that the fluid is not inadvertently over-diluted. Refer to Table 5 for water quality requirements. If the system design does not allow for complete removal of flush water, it is recommended to flush with fresh DOWFROST™ LC Heat Transfer Fluid instead of water prior to final installation.

If chemical cleaning is used, it is important to consult a company experienced in industrial cleaning. The system must be thoroughly flushed with high purity water and the flush water removed prior to installation of DOWFROST™ LC Heat Transfer Fluid.

4.2 Hydrostatic testing and system volume measurement

Hydrostatic testing of DECS piping can be combined with system flushing. Suitable quality water meeting the requirements shown in Table 5 should be used. The addition of cleaning additives will not adversely affect hydrostatic testing.

The system volume can be estimated by metering in the amount of water needed to fill the system for flushing or hydrostatic testing. An estimation of volume based on piping and vessel sizes as indicated on engineering drawings or from actual measurements made in the field can also be used.

4.3 Piping

All piping materials must be known to be compatible with the DOWFROST™ LC Heat Transfer Fluid to minimize excessive corrosion or incompatibility of system components. Piping diameter must be large enough, as dictated by industry best practices, to avoid excessive flow velocity as well as excessive pressure drop. The selected concentration of DECS HTF will determine viscosity which will affect pressure drop through the DECS.

4.4 System vents

The DECS needs to be equipped with adequate venting to relieve trapped air at high points during initial filling with DOWFROST™ LC Coolant. Failure to remove air will lead to significant air entrainment problems which can impair heat transfer, increase likelihood of localized corrosion, and cause damage to internally flushed mechanical pump seals.

4.5 Bypass filters

Ideally, the DECS should be equipped with bypass filters to remove any solids or particulates which may form. Precipitates and other solids can lead to plugging or localized corrosion and can cause fouling of heat transfer surfaces. Filters made of non-absorbent cotton, or cellulose-type media having a pore size of 25 micron, should be used.

4.6 Spills

Small spills can be cleaned by using a suitable absorbent such as vermiculite or other floor drying sorbents. The absorbed material should be disposed of according to instructions on the MSDS. For large spills, the fluid should be recovered by diking and pumping into suitable containers which can then be properly disposed.

5.0 Fluid testing and maintenance

5.1 Representative samples and frequency of tests

A representative sample of DOWFROST™ LC Heat Transfer Fluid must be collected from the datacom equipment cooling system after installation, and circulation of the fluid for at least 24 hours, to establish a baseline. “Representative” means the sample has not been collected from a dead leg or areas of poor circulation and that it represents the bulk of what is present in the system. Afterward, it is recommended that a comprehensive analysis be completed annually to verify the fluid is still suitable for continued use. Refer to Table 8 for acceptable fluid characteristics.

5.2 Fluid identification and appearance

Visual appearance of a DOWFROST™ LC Heat Transfer Fluid sample conveys important information. Conducting a regular check of fluid appearance, at least once per year, is highly recommended. A brightly colored, fluorescent yellow-green fluid which is free from cloudiness and solids will typically indicate the fluid is in acceptable condition. Over time, an in-use fluid may start to appear darker in color or less vibrant, which is to be expected. Cloudiness, or the presence of solids, indicates a problem has occurred within the DECS. If the fluid shows signs of unacceptable appearance, it should be replaced.

5.3 Concentration and freezing point

A hand-held refractometer can be used to verify that the glycol concentration and freezing point of the fluid has not changed. The refractive index of DOWFROST™ LC Heat Transfer Fluid should remain nearly the same as when initially installed. Fluids having a refractive index outside of the ranges shown in Table 4 should be replaced.

5.4 Fluid pH

Fluids which have a pH within the range of 8.0 to 10.5 are considered to be in an acceptable condition. Fluids which are outside this range, particularly if the appearance is unacceptable, should be replaced immediately. Handheld pH meters, or pH paper calibrated to 0.5 units within a pH range of 7 to 11, can be used to verify whether the DOWFROST™ LC Heat Transfer Fluid has an acceptable pH. In general, the pH of a fluid will decrease, not increase, over time.

5.5 Reserve alkalinity

Reserve alkalinity (RA), or buffering capacity, for in-use DOWFROST™ LC Heat Transfer Fluids should be greater than 4.0 mL when tested according to ASTM D1121. Fluid replacement is recommended when RA falls below this limit. Reserve alkalinity correlates to the level of corrosion inhibitors and failure to maintain adequate concentration may cause lead to corrosion or fouling.

5.6 Degradation products

When exposed to heat and air during system operation, glycol-based heat transfer fluids will oxidize and degrade. These degradation compounds accumulate over time and deplete the corrosion inhibitors and stabilizers present in the fluid. This is natural and unavoidable. Every fluid reaches the end of its useful life when the level of degradation products is high enough to negate the effectiveness of the corrosion additives. When this happens, fluid pH will decrease below 8.0 and may lead to corrosion or fouling of DECS components. It is recommended that the fluid be replaced when conditions are outside the normal operating ranges to ensure consistent heat removal in the DECS.

5.7 Fluid lifetime and replacement

When DOWFROST™ LC Heat Transfer Fluid has reached the end of its useful life, it must be drained from the system and replaced with new material. There is no other practical way to remove the harmful impurities or degradation compounds that combine to cause corrosion, fouling or foaming problems for the system.

To assist with fluid maintenance, it is recommended that a system nameplate, encased in clear plastic and with the following information, be affixed to the system:

- Date of installation
- Description of the heat transfer fluid (DOWFROST™ LC 25 or DOWFROST™ LC 55)
- Volume of fluid installed
- Copy of the Safety Data Sheet (SDS)

Table 8. Acceptable quality characteristicsfor in-use DOWFROST™ LC Heat Transfer Fluids

Characteristic	Acceptable values	Test Method
Appearance	Yellow, clear, particulate free	Visual
Glycol Concentration	DOWFROST™ LC 25 - 24 to 28% PG, by weight DOWFROST™ LC 55 - 53 - 57% PG, by weight	ASTM D3321
Fluid pH	8.0-10.5	ASTM D1287
Reserve Alkalinity	>4 mL 0.1N HCl	ASTM D1121
Copper	< 2 ppm	ASTM D6130
Iron	< 2 ppm	ASTM D6130
Total Hardness	<100 ppm (as $CaCO_3$)	ASTM D6130
Chloride	< 25 ppm	ASTM D5827
Sulfate	< 25 ppm	ASTM D5827

6.0 Conditions to avoid

6.1 Excessive fluid temperature

The maximum recommended bulk fluid temperature for DOWFROST™ LC Heat Transfer Fluid is 90°C (194°F). Operation above the maximum recommended fluid temperature limits may accelerate fluid degradation and compromise the expected lifetime of the fluid as well as adversely affect the performance of the datacom equipment cooling system.

The lowest operating temperature is normally considered 0°F (-20°C) due to the viscosity increase at this temperature, however, freeze protection down to -40°F (-40°C) can be achieved using DOWFROST™ LC 55 Heat Transfer Fluid.

6.2 Excessive aeration

Excessive turbulence in an expansion tank that is vented to the atmosphere, or other situations where the fluid is exposed to an extensive amount of air, should be avoided as this can lead to air entrainment, foaming and increased oxidation of the glycol which may compromise the performance of the DECS.

A note about product safety

When considering the use of any Dow products in a particular application, you should review the latest Safety Data Sheets from Dow and ensure that they are intended for safe use. For other products mentioned in the text, you should obtain the current Material Safety Data Sheet and other available product safety information when reviewing and take necessary steps to ensure safety of use before handling. No chemical should be used as or in a food, drug, medical device or cosmetic, or in a product or process in which it may contact a food, drug, medical device or cosmetic until the user has determined the suitability and legality of the use. Since government regulations and use conditions are subject to change, it is the user's responsibility to determine that this information is appropriate and suitable under current, applicable laws and regulations. Dow requests that the customer read, understand and comply with the information contained in this publication and the current Safety Data Sheet(s). The customer should furnish the information in this publication to its employees, contractors and customers, or any other users of the product(s), and request that they do the same.

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