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 coolant 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 Coolants used in DECS loops which comes into direct contact with computer components. Topics covered in this guide are: a brief introduction to DOWFROST™ LC Coolants, typical product specifications, system design and preparation guidelines, dilution water quality information, plus detailed engineering data including density, viscosity, specific heat and thermal conductivity. If you would like additional product information, please contact Dow toll free at 1-800-447-4369.

2.0 Properties of DOWFROST™ LC Coolants

2.1 Appearance and description

DOWFROST™ LC Coolants are dyed a fluorescent yellow-green color. The addition of this dye helps to identify the location of a possible leak within a system. Coolant in the system should remain relatively clear with a fluorescent yellow-greenish color and no evidence of cloudiness or suspended solids as it operates. The appearance of cloudiness or suspended solids normally indicates problems with corrosion (incompatible material) or is the result of mixing the DOWFROST™ LC with poor quality dilution water. DOWFROST™ LC Coolants which are in use for an extended length of time may not exhibit the same bright color and can appear more brown or black in color.

DOWFROST™ LC 25 and DOWFROST™ LC 55 Coolants are pre-diluted mixtures at concentrations of 25% and 55% by volume of glycol, respectively. DOWFROST™ LC 25, containing 25% propylene glycol, represents the minimum allowable concentration since concentrations below 25% will support biological oxidation of the glycol. Propylene glycol is highly bio-degradable when diluted with water below 15% by volume of glycol and will support bio-oxidative degradation at concentrations between 15% and 25% by volume of glycol.

2.2 Propylene Glycol quality

In order to provide effective long-term corrosion protection of DECS, the HTF must be made from highly purified propylene glycol that meets United States Pharmacopeia (USP) specifications in addition to containing appropriate corrosion inhibitors (acceptable pH and reserve alkalinity). Products which do not meet USP specifications may have higher amounts of impurities which may impart strong odors and cause excessive foaming. No amount of additional corrosion inhibitors or additives can negate or undo the potentially harmful effects of unwanted impurities. DOWFROST™ LC 25 and DOWFROST™ LC 55 are made from Dow PURAGUARD™ USP grade propylene glycol and contain industrial strength corrosion inhibitors, pH buffers and stabilizers as well as a fluorescent yellow dye specifically designed for operation within DECS systems while facilitating system leak detection.

2.3 Physical and chemical properties

As concentration of propylene glycol in water increases, several other physical properties change rather significantly along with the Freezing point including osmotic pressure, viscosity, thermal conductivity, specific heat, and specific gravity.

Similar changes will be observed for the other physical properties as concentration of propylene glycol increases and these adversely impact heat transfer and pressure drop. Therefore, it is recommended to utilize DOWFROST™ LC Coolant at a concentration of at least 25% (to guard against bio-fouling) but no higher than what is needed for freeze protection purposes and no higher than 55% for minimize the impact on heat transfer and pressure drop.

Table 1. Typical product specifications† of DOWFROST™ LC 25 and DOWFROST™ LC 55 Coolants

Fluid parameter	DOWFROST™ LC 25	DOWFROST™ LC 55
Propylene glycol concentration (vol%)	25	55
Freezing point	-14°F -10°C	-40°F -40°C
pH	8.0-10.5	8.0-10.5
Reserve alkalinity (mL)	>6.0	>6.0
Thermal conductivity at 50°C (W/mK)	0.485	0.336
Specific heat at 50°C (kJ/kg-K)	3.94	3.43
Viscosity at 20 oC (mPa sec) at 50 oC (mPa sec)	 2.5 1.1	 8.2 2.6
Volume expansion from -40 to 90°C (%)	5.2%	7.7%
Boiling point at 760 mmHg (°C)	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 Coolant

°C	Density (kg/m^3)	Specific heat (kJ/kg K)	Thermal conductivity (W/mK)	Viscosity (mPa sec)	Vapor pressure (kPa)
-5	1042.5	3.81	0.425	6.48	0.004
0	1041.0	3.82	0.432	5.23	0.006
5	1039.4	3.83	0.438	4.27	0.009
10	1037.6	3.84	0.444	3.52	0.012
15	1035.7	3.85	0.450	2.94	0.017
20	1033.7	3.87	0.456	2.48	0.023
25	1031.5	3.88	0.462	2.12	0.031
30	1029.3	3.89	0.467	1.82	0.042
35	1026.9	3.90	0.472	1.59	0.055
40	1024.4	3.92	0.476	1.39	0.072
45	1021.7	3.93	0.481	1.23	0.093
50	1019.0	3.94	0.485	1.10	0.119
55	1016.1	3.95	0.488	0.99	0.152
60	1013.1	3.97	0.492	0.891	0.191
65	1010.0	3.98	0.495	0.81	0.239
70	1006.8	3.99	0.497	0.74	0.297
75	1003.4	4	0.5	0.681	0.367
80	999.9	4.01	0.502	0.629	0.45

†Typical properties, not to be construed as specifications.

Table 3. Physical properties† of DOWFROST™ LC 55 Coolant

°C	Density (kg/m^3)	Specific heat (kJ/kg K)	Thermal conductivity (W/mK)	Viscosity (mPa sec)	Vapor pressure (kPa)
-40	1090.8	2.98	0.28	607	
-35	1089.2	3.01	0.283	382	
-30	1087.5	3.03	0.287	243	
-25	1085.7	3.06	0.291	157	0.001
-20	1083.7	3.08	0.294	103	0.001
-15	1081.7	3.11	0.298	69.8	0.002
-10	1079.5	3.13	0.302	48.1	0.002
-5	1077.2	3.16	0.305	34	0.004
0	1074.9	3.18	0.309	24.6	0.005
5	1072.4	3.21	0.312	18.1	0.007
10	1069.8	3.23	0.315	13.7	0.01
15	1067.0	3.26	0.318	10.5	0.015
20	1064.2	3.28	0.321	8.23	0.02
25	1061.3	3.30	0.324	6.55	0.027
30	1058.3	3.33	0.327	5.3	0.036
35	1055.1	3.35	0.329	4.35	0.048
40	1051.8	3.38	0.332	3.62	0.062
45	1048.5	3.40	0.334	3.05	0.081
50	1045.0	3.43	0.336	2.6	0.104
55	1041.4	3.45	0.338	2.23	0.132
60	1037.7	3.48	0.339	1.94	0.167
65	1033.9	3.50	0.341	1.71	0.209
70	1030	3.53	0.342	1.51	0.26
75	1025.9	3.55	0.343	1.35	0.32
80	1021.8	3.58	0.344	1.21	0.395

†Typical properties, not to be construed as specifications.

2.4 Dilution water

DOWFROST™ LC Coolants may be diluted with water in order to enhance the temperature range of performance although it is not recommended to further dilute DOWFROST™ LC 25 as the minimum recommended concentration for use is 25% by volume of glycol. The water used for blending must be distilled, de-ionized, or equivalently purified water. Failure to use acceptably purified water can cause corrosion and fouling issues. Purified water means, at a minimum, it meets the following requirements.

Table 4. Dilution water quality requirements

Parameter	Acceptable limit
Total Chlorides (as Cl-)	<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 micro-mhos/cm
pH	5 < pH < 9

While de-ionized water can be aggressive towards many metals, it is acceptable for use when blended with DOWFROST™ LC.

2.5 Glycol concentration and Freezing point

The installed solution of DOWFROST™ LC Coolant 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, the DOWFROST™ LC shall not be diluted less than 25% by volume as propylene glycol. Dilution water meeting the quality requirements defined in 2.4 must be used when adjusting concentration. Over-dilution of glycol-based fluids reduces the effectiveness of the corrosion inhibitors and also allows for bio-degradation of the glycol by bacteria or fungi which can be inadvertently introduced to the system from dilution water or air vents.

The propylene glycol concentration and, therefore, Freezing point can be determined by measuring refractive index and consulting the Table 4. DOWFROST™ LC 25 Coolant contains 25% propylene glycol, by volume, while DOWFROST™ LC 55 contains 55% propylene glycol, by volume.

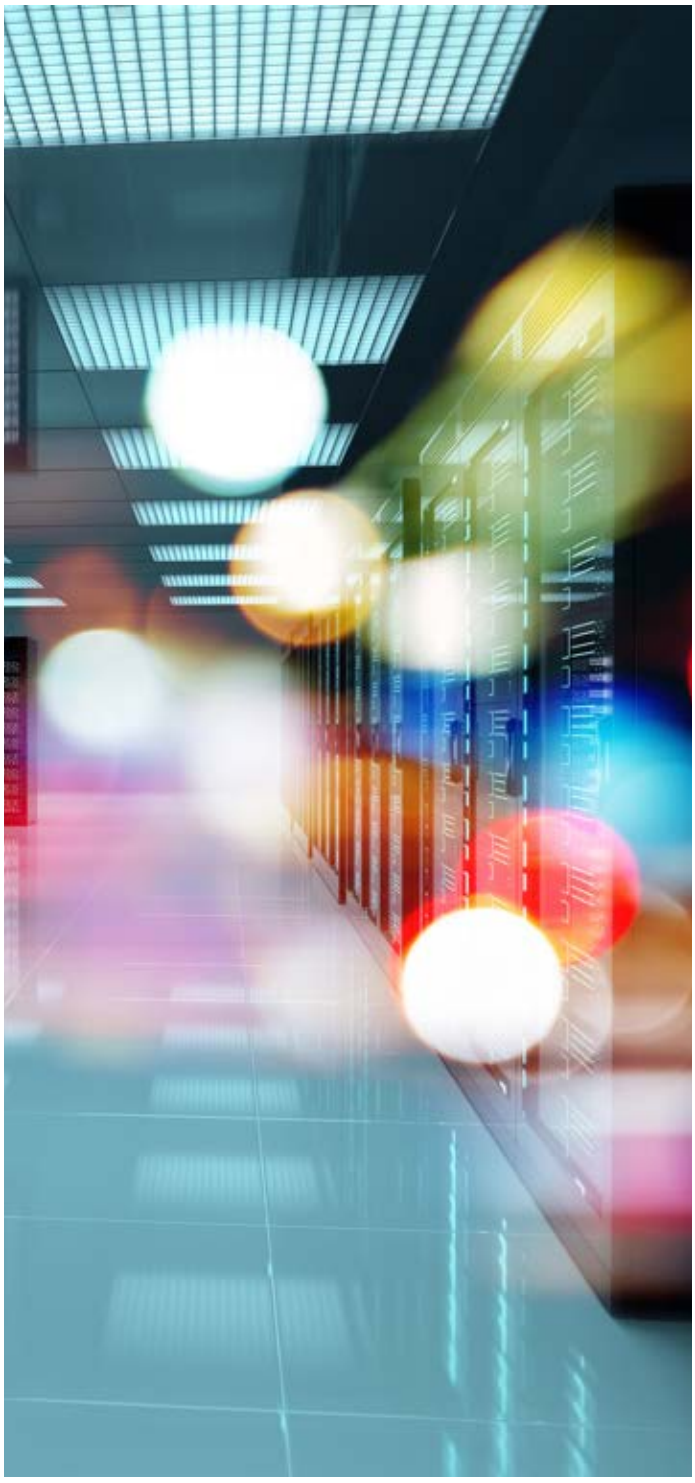
Table 5. Freezing points† of DOWFROST™ LC Coolant on Glycol concentration and refractive index

Freezing point		Propylene Glycol		Refractive index
°F	°C	Wt %	Vol %	22°C
19.2	-7.1	20.0	19.4	1.3555
14.7	-9.6	25.0	24.4	1.3615
9.2	-12.7	30.0	29.4	1.3675
2.4	-16.4	35.0	34.4	1.3733
-6.0	-21.1	40.0	39.6	1.3790
-16.1	-26.7	45.0	44.7	1.3847
-28.3	-33.5	50.0	49.9	1.3903
-42.8	-41.6	55.0	55.0	1.3956
-59.9	-51.5	60.0	60.0	1.4008

†Typical properties, not to be construed as specifications.

2.6 Electrical conductivity

The necessary use of corrosion inhibitors, pH buffers, stabilizers and other additives specifically designed for DECS HTFs like DOWFROST™ LC will impart higher electrical conductivity (lower electrical resistivity) than is commonly seen for water. Typical electrical conductivity values for DOWFROST™ LC HTF will exceed 2,500 micro-mhos/cm.



3.0 System design considerations

3.1 General

It is recommended that all system components and materials in contact with a DOWFROST™ LC Coolants heat transfer fluid be verified for compatibility at the minimum and maximum expected exposure temperatures.

3.2 Propylene Glycol quality

The DECS heat transfer fluid must be capable of providing long term corrosion protection of common metals used for DECS including carbon steel, stainless steel, copper, copper alloys and brazes up to bulk fluid temperatures of 90°C.

Glycol based HTFs can undergo oxidation and thermal degradation forming acidic glycol compounds as the HTF is exposed to air and heat during normal operation. 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 25 and 55 Coolants are specifically formulated for these applications.

3.3 Elastomers and plastics

The DECS HTF must demonstrate long term chemical compatibility with common elastomers and polymers used, including EPDM, PTFE, HDPE, PP, up to bulk fluid temperatures of 90°C (194°F). The compatibility of the DOWFROST™ LC Coolant with specific elastomeric or plastic materials used for tanks, piping, tubing, pumps, valves, gaskets, mechanical pump seals, valve packings, O-rings, etc. must be verified by the component material supplier before use. Substantial variation exists for specific elastomers with respect to maximum allowable exposure temperatures.

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

3.4 Chemical compatibility of wetted materials

Table 6. DOWFROST™ LC 25 and DOWFROST LC 55 Wetted Materials List

Material name	Compatibility with DOWFROST™ LC 25 and 55
Acrylonitrile butadiene rubber (NBR)	Caution: Most compositions of this polymer are not recommended above 40°C
Aluminum and alloys	Not recommended above 60°C or if copper or copper alloys are also present
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
Polyoxymethylene (POM)	Not recommended above 30°C
Ethylene Propylene Diene Monomer (EPDM)	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: Most 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: Some compositions of this polymer are not recommended above 40°C
Stainless steel, solution treated and passivated	Acceptable up to at least 90°C

4.0 System preparations

4.1 System flushing

In cases where fabrication debris or particulates such as pipe scale, weld slag, solder flux, etc. are present, it is recommended that the system be flushed with purified water immediately prior to installation of DOWFROST™ LC Coolant to remove loose solids. If chemical cleaning is used, it is important to consult a company experienced in industrial cleaning. All traces of the cleaning agent should be removed and the system thoroughly flushed with water.

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 of 2.4 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 Coolant 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 By-pass 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 like 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 the DECS HTF must be collected from the DECS after installation and circulation of the HTF 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 actually present in the DECS. Regular testing of additional samples, at least once per year, should be conducted to verify that the fluid is still capable of providing acceptable protection of system components.

5.2 Fluid identification and appearance

Visual appearance of DECS HTF samples conveys important information. Conducting a regular check of fluid appearance, between 3 months and at least once per year, is highly recommended. Clear, bright colored fluorescent yellow-green DOWFROST™ LC Coolants, with no cloudiness and no solids indicates the fluid is in acceptable condition. Cloudiness or the presence of solids indicate a problem has occurred with the heat transfer fluid. If the fluid shows signs of unacceptable appearance it should be replaced.

5.3 Refractive Index or Freezing point (Concentration)

A hand-held refractometer can be used to verify refractive index or Freezing point (concentration) of the DOWFROST™ LC Coolant has not changed. The refractive index of DOWFROST™ LC should remain the same as when initially installed. Fluids having a refractive index below 1.3620, which corresponds to 25% concentration by volume, should be adjusted higher by adding more DOWFROST™ LC 55, or in cases where the appearance is also unacceptable the fluid should be replaced. DECS HTF having a refractive index above 1.400, which corresponds to 60% concentration by volume, should be adjusted by adding water which meets the purity requirements 2.1, or in cases where the appearance is also unacceptable the fluid should be replaced.

5.4 DOWFROST™ LC Coolant pH

DOWFROST™ LC 25 and DOWFROST™ LC 55 Coolants which have a pH within the range of 8.0 to 10.5 is considered to be in an acceptable condition. Fluid which has a pH outside this range, particularly if the appearance is unacceptable, should be replaced immediately. Handheld pH meters, or pH paper calibrated to 0.1 units within a pH range of 7 to 11, can be used to verify whether the DOWFROST™ LC has an acceptable pH.

5.5 Reserve alkalinity

DOWFROST™ LC 25 and DOWFROST™ LC 55 Coolants should have Reserve Alkalinity (RA) greater than 5.0 mL when tested according to ASTM D1121 and should be replaced when RA fails below this limit. Reserve Alkalinity corresponds to the level of corrosion inhibitors and failure to maintain adequate concentration may cause excessive corrosion.

5.6 Degradation products

DOWFROST™ LC Coolants will degrade when exposed to heat and air (oxygen) during system operation. Fluid degradation compounds will accumulate over time and will deplete the corrosion inhibitors and stabilizers used in the fluid. This is natural and unavoidable. Every heat transfer 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. Fluid pH will decrease below 8.0 and may cause excessive corrosion or fouling of DECS components. It is recommended that the HTF be changed out when fluid conditions are outside the normal operating ranges to ensure consistent heat removal in the DECS.

5.7 Degradation products

When DOWFROST™ LC Coolant 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.

It is recommended that a system nameplate encased in clear plastic be affixed with the following information to assist with fluid maintenance: date the DOWFROST™ LC Coolant was installed, description of the HTF (DOWFROST™ LC 25 or LC 55 and any water dilution), volume of fluid installed and a copy of the Safety Data Sheet (SDS).

6.0 Conditions to avoid

6.1 Excessive fluid temperature

The maximum recommended bulk fluid temperature for DOWFROST™ LC Coolants is 195°F (90°C) whereas the lowest operating temperature is normally considered ~0oF (-20oC) due to the viscosity increase at this temperature. Freeze protection down to -40°F (-40°C) can be obtained using DOWFROST™ LC 55 Coolant.

Operation above the maximum recommended fluid temperature limits will cause excessive degradation of the PG and will compromise the expected lifetime of the DOWFROST™ LC and will adversely affect the performance of the DECS.

6.2 Excessive aeration

Excessive turbulence in an expansion tank vented to atmosphere or other situations where the DOWFROST™ LC Coolant is exposed to copious amounts of air should be avoided. 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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