AMBITROL™ Inhibited Glycol-based Coolants

Engineering and operating guide

DOW®

Contents

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Introduction

AMBITROL™ coolants: Specially inhibited to help prevent corrosion damage and keep your engines running longer with minimal maintenance.

Chances are that if your stationary engines are old, maintenance problems are surfacing with increasing regularity. But even if you've invested in new machinery, keeping your entire system operating is always a top priority.

You pay attention to lubricants, fuel economy, and station efficiency, but unless an engine fails due to coolant-related problems, little thought is given to the efficiency of the heat transfer system.

Yet, even a small buildup of scale or corrosion in critical areas can greatly inhibit heat transfer and lead to serious thermal problems and engine failure.

The family of AMBITROL™ high-performance inhibited coolants from Dow is specifically designed to protect your machinery investment and help assure long-term operating efficiency.

Coolant function

The purpose of a coolant is to remove excess heat from an engine to maintain the proper operating temperature. Water does this perfectly well, but, unfortunately, water also freezes and is corrosive. The freezing problem is solved by adding an appropriate concentration of glycol and the corrosion problem is solved by providing a corrosion inhibitor package to protect all common industrial metals. Add to these features the benefits of elevated boiling point, protection from scale formation, non-fouling, low foaming, low hazard, and long fluid life and you begin to see why AMBITROL™ coolants are so important to maintaining a good cooling system.

Problems with other coolant systems

Heat transfer problems often occur because improperly inhibited aqueous or glycol-based coolants are used. These coolant systems can't provide the long-term protection against scale or corrosion that industrially inhibited ethylene glycol and propylene glycol coolants like AMBITROL™ products can offer.

In fact, serious problems can result from the use of untreated or inadequately treated water, ineffectively inhibited antifreeze solutions, or antifreeze brands that are chemically incompatible. AMBITROL™ coolants can solve these and other related problems.

AMBITROL™ coolants vs. inhibited glycols

A supplier who takes a glycol, adds some corrosion inhibitor and maybe some water is not necessarily qualified to adequately protect your coolant system. The coolant product you purchase must have a proven corrosion inhibitor package and be supported by a comprehensive analysis program, global technical service, convenient local representatives, and a long-term commitment to servicing the industrial coolant user. You will find that AMBITROL™ coolants fulfill all these requirements.

AMBITROL™ coolants vs. automobile antifreeze

The inhibitors in AMBITROL™ products are designed specifically for heavy industrial engines, while those in automotive antifreeze are not. As more aluminum is used in automobile engines to lessen weight, more silicates are added to the antifreeze to prevent corrosion of the aluminum. The silicates in automobile antifreeze form a coating on aluminum and other coolant surfaces to provide corrosion protection to aluminum. Unfortunately, this silicate coating also cuts down heat transfer efficiency.

Over time, these silicates tend to form gels or scale that can restrict the flow through the slower circulating systems of large stationary engines. Ultimately, silicate gels can create hard-to-remove scale that prevents proper heat transfer within the engine. The result is engine overheating which can lead to engine failure.

In addition to silicates, the automobile antifreeze usually contains oxidizing corrosion inhibitors like molybdates or nitrites which protect metal surfaces from corrosion by forming a resistant metal oxide film. Unfortunately, these oxidizers also degrade glycol. By changing out automotive antifreeze every two to three years you can minimize these problems for your auto coolant system.

AMBITROL™ coolants vs. water-inhibitor systems

Water-inhibitor coolants are relatively inexpensive – at least initially. But if you don't have good quality water available in large quantities, the contaminants in the water can cause damaging scale buildup and fouling from microbial growth.

You won't have this problem with AMBITROL™ NTF or FL coolants because they are diluted with deionized water.

Another problem AMBITROL™ coolants help you avoid is corrosion due to low inhibitor levels in the aqueous system.

Finally, even the deep South is occasionally gripped by frigid weather. Water-inhibitor systems cannot guarantee you total freeze protection during these unpredictable cold waves. On the other hand, AMBITROL™ coolants provide unsurpassed freeze protection.

AMBITROL™ coolants vs. alcohol and water

There are very few coolant systems left which rely on ethanol or methanol for freeze protection and for good reason. The alcohols have low flash points and present a fire safety hazard. And because of their high volatility, the alcohols are often vented, reducing their concentration and freeze protection. Additionally, ethanol offers no corrosion protection.

The unique advantages of AMBITROL™ products

As you've seen, inhibited glycol coolants such as AMBITROL™ products are improved to automotive antifreeze, water-inhibitor systems, and alcohol-water systems in stationary engines.

Dow's special inhibitors and additives in AMBITROL™ products combine to give you an excellent coolant. And AMBITROL™ products come to you with technical support and distributor service to provide the most comprehensive, high-value coolant package available.

40 years of experience

Dow has more than 40 years of experience in providing glycol-based coolants for all types of engines. We have the technical expertise to produce coolants specifically designed to help keep your engine running without damage, and at the lowest long-term cost possible.

We have also spent years establishing our technical support group – a group that understands your needs and can respond to your challenges quickly and accurately.

A proven combination of inhibitors and additives

AMBITROL™ coolants give advanced protection against corrosion and the effects of cavitation in wet-sleeve stationary engines. That's because AMBITROL™ products incorporate a high-quality inhibitor package without silicates. As a result, there is no gel or scale buildup.

In addition, AMBITROL™ coolants can be reinhibited to keep the glycol base in optimal condition, inhibiting buildup of corrosive degradation by-products.

AMBITROL™ coolants are supplied free of corrosive ions, such as chlorides or sulfates, which make corrosion protection more difficult and accelerate glycol degradation.

All this translates into greater heat transfer efficiency, fewer maintenance problems, and longer engine life.

Eliminate excessive fluid loss and reinhibit with ease

AMBITROL™ coolants are available in concentrated and prediluted solutions. Their low vapor pressure eliminates excessive fluid loss, even at high temperatures. This gives you predetermined, consistent coolant quality – as well as minimum coolant make-up.

Even more important, AMBITROL™ coolants can be kept in optimum condition by the addition of AMBITROL™ inhibitors. So, coolant life is extended and long-term costs are reduced.

Can be used in a wide variety of applications

AMBITROL™ products are used primarily in large stationary engines, such as those running compressors to transmit natural gas and other products through pipeline distribution systems. However, AMBITROL™ coolants are also commonly used in the following:

- Small field compression units
- Two-cycle stationary engines or engines operating at 750 rpm or less
- Engine generator sets that produce electricity for nuclear or conventional power plants, hospitals, shopping centers, or installations where standby power is required
- Utility combustion air preheaters
- Utilities using LPG bath heaters
- Industrial stationary engines without aluminum cooling systems

In fact, AMBITROL™ products can be used in many heat transfer applications – wherever the heat transfer fluid must provide protection against freezing, have low vaporization losses at high operating temperatures, and offer protection against corrosion and fouling of the system.

The family of AMBITROL™ coolants offers a wide variety of heat transfer fluids

AMBITROL™ coolants are specially formulated to meet the severe and fluctuating year-round operating requirements of large, heavy-duty stationary engines.

Choose between ethylene glycol- or propylene glycol-based coolants

The line of AMBITROL™ coolants includes ethylene glycol- and propylene glycol-based products. Both types of AMBITROL™ coolants have long histories of successful use in gas transmission service and related applications.

The primary differences between ethylene glycol- and propylene glycol-based coolants are viscosity and toxicity. Ethylene glycol-based coolants are less viscous than their propylene glycol counterparts, particularly at temperatures below 0°F (-l8°C). Therefore, they generally provide slightly better heat transfer efficiency and low temperature performance and may be preferred for many gas transmission applications.

Due to their low acute oral toxicity, AMBITROL™ Inhibited Propylene Glycol-based Coolants are recommended for applications where incidental contact with drinking water or ground water is possible, or where regulatory guidelines on ethylene glycol make the use of propylene glycol coolants preferable. Propylene glycol-based coolants are also especially effective in reducing cavitation erosion damage to cylinder liners of wet-sleeve stationary engines.

Table 1: Product descriptions of AMBITROL™ Inhibited Ethylene Glycol-based Coolants

	AMBITROL™ CN Coolant	AMBITROL™ FL 50 Coolant	AMBITROL™ FL 40 Coolant	AMBITROL™ FL 30 Coolant
Composition (% by volume) ethylene glycol	96	50	40	30
Color	Blue-green	Red	Red	Red
Specific gravity at 60°/60°F	1.131	1.078	1.063	1.048
pH of solutions	NA	9.3	9.3	9.3
Reserve alkalinity (min)	11.0	11.0	11.0	11.0
Flash point, °F (P.M.C.C.[1])	232	None	None	None
Fire point, °F (C.O.C.[2])	250	None	None	None
Freezing point, °F	-3	-35	-13	-3
Boiling point, °F	317	225	222	220
Density (lb/gal)	9.43	8.98	8.87	8.75

[1]Pensky-martens closed cup
[2]Cleveland open cup

Table 2: Product descriptions of AMBITROL™ Inhibited Propylene Glycol-based Coolants

	AMBITROL™ CN Coolant	AMBITROL™ FL 50 Coolant	AMBITROL™ FL 40 Coolant	AMBITROL™ FL 30 Coolant
Composition (% by volume) propylene glycol	96	50	40	30
Color	Blue	Yellow	Yellow	Yellow
Specific gravity at 60°/60°F	1.055	1.048	1.040	1.031
pH of solutions	NA	9.5	9.5	9.5
Reserve alkalinity (min)	11.0	11.0	11.0	11.0
Flash point, °F (P.M.C.C.[1])	214	None	None	None
Fire point, °F (C.O.C.[2])	220	None	None	None
Freezing point, °F	-60	-29	-7	8
Boiling point, °F	310	222	219	216
Density (lb/gal)	8.80	8.73	8.68	8.61

[1]Pensky-martens closed cup
[2]Cleveland open cup

AMBITROL™ CN Coolant concentrate

An ethylene glycol-based concentrate, AMBITROL™ CN Coolant should be diluted with distilled (or deionized) water to concentrations ranging from 30-60% by volume, depending upon the degree of freeze protection desired. Solutions above 60% reduce the heat transfer capacity of the system, whereas solutions with concentrations below 30% may not provide adequate freeze or corrosion protection.

AMBITROL™ FL 50, FL 40, and FL 30 Coolants

These completely formulated, prediluted coolants are based on ethylene glycol, deionized water, and a complete inhibitor system. AMBITROL™ FL Coolants are desirable when high quality dilution water is unavailable or when the convenience and accuracy of a prediluted product is desired.

AMBITROL™ NTC Coolant concentrate

AMBITROL™ NTC Coolant is a propylene glycol-based concentrate that is miscible and chemically compatible with AMBITROL™ CN Coolant. Before installation, it should be diluted to a concentration between 30% and 60% by volume to obtain the appropriate level of freeze and corrosion protection.

AMBITROL™ NTF 50, NTF 40, and NTF 30 Coolants

These fully inhibited, prediluted propylene glycol-based coolants are analogs of the AMBITROL™ FL Coolants and exhibit the same dilution advantages.

Inhibitor packages

From time to time, it may be necessary to replenish the inhibitor in the system. This analysis is provided at no additional charge as part of the routine analysis program offered by Dow. Recommendations will be made by your technical representative as appropriate to ensure your system is optimally maintained. If needed, inhibitor packages can be purchased to replenish the inhibitor without having to replace the coolant already in the system.

Dow's free, yearly analytical service ensures corrosion protection and cuts coolant costs

The Dow analytical service is an exclusive system set up to analyze customer samples of AMBITROL™ coolants. This trouble-shooting service thoroughly analyzes the condition of a customer's AMBITROL™ coolant, reports the results, and makes recommendations for any needed fluid adjustments. By properly maintaining AMBITROL™ coolants, our customers have regularly achieved useful fluid life exceeding 20 years. Long fluid life and the avoidance of downtime cost, maintenance, and disposal costs make AMBITROL™ coolant a great value.

Why you need it

If you are like many people who use typical glycol-based coolants, you change the coolant frequently before the glycol loses its corrosion protection.

The problem is: You really don't know the exact condition of your coolant, or what it may be doing to your stationary engines. You can measure freeze protection, but you need more information.

That's why Dow offers a free annual analytical service for every system using 500 gallons or more of AMBITROL™ coolants.

From the sample you send, Dow will determine the state of your AMBITROL™ coolant. And we'll tell you what to do to keep your system protected so you won't have to worry about worn out glycol in your cooling system.

Quite simply, AMBITROL™ coolant with the Dow analytical service is the best solution to the problem of changing coolant too often ... or, not often enough.

Analysis conducted by the service includes evaluation of coolant:

- Color
- Appearance
- Glycol level and type
- Glycol degradation products
- Freeze point
- pH
- Reserve alkalinity
- Inhibitor types and levels
- Water quality
- Ion contamination

Once your coolant samples have been analyzed, our findings are reported to you clearly and professionally in a complete written report. Included are our recommendations of actions you'll want to take to keep your system protected. Dow technical representatives are also available to discuss specific findings with you in detail.

Baseline testing

After an AMBITROL™ coolant has been newly installed in an engine and circulated for 24 hours, a sample should be extracted and placed in the sample bottle. This sample is then sent along with a completed information sheet to the address provided on the kits.

The baseline information assures the customer that the coolant has been properly installed and that all levels of the coolant components are within established parameters. In addition, the ongoing, annual analysis begins with this important initial analysis. All future computer analysis is based on this information, so it is imperative that the initial record be as complete and accurate as possible.

A separate Installation Data Sheet should be filled out for each engine's cooling system. The program at Dow is set up to analyze individual coolant systems in those companies that have large stationary engines in multiple locations. Also, when an initial sample is sent for testing, make sure to request enrollment into the analytical program for AMBITROL™.

Dow's continuing analytical testing program

Once the analytical service begins, customers enrolled in the analytical program for AMBITROL™ are sent Thermal Fluids Sampling Kits once a year in the spring. These kits permit easy and accurate labeling of fluid samples and safe shipment of samples to Dow for analysis.

Before a sample is drawn, the coolant should be circulated for at least 30 minutes to ensure that a representative sample is analyzed. The labels on the bottles must be filled out completely and accurately. Be sure to indicate on the label the name of the station where the engine is located and the name of the person or persons to whom the report(s) should be sent.

After the samples are tested, the results are analyzed and reported back to the customer. The report lists the current conditions and indicates where action, such as reinhibition, is necessary. Any unusual or potentially damaging coolant conditions are also noted. Furthermore, the analysis is compared to previous analysis on the system to note any significant change in coolant condition. The laboratory for AMBITROL™ coolants maintains a history on each system for a period of ten years.

Dow's analytical test program for engine coolants reflects the importance Dow places on providing customers with the most complete information needed to protect their engines. We have committed significant resources to this analytical program because our customers have found it to be an invaluable service.

Submission of coolant samples

When submitting coolant samples to Dow for analytical testing, be sure to affix a fully completed label to each sample bottle according to the following:

Unit sampled – Give more information than "glycol sample" or "AMBITROL™ FL Coolant." Identify unit by engine number or other designation when possible.

Company and station name – Give your company name and location.

Attention – Specify station superintendent or person to whom the report is to be sent.

Station address, city, state, zip – Your mailing address. Results can be emailed to as many as five contacts by listing each contact's accurate email address.

Dow thermal fluids sampling kit

On-site testing and analysis

Some customers may prefer to monitor coolant properties themselves. Others may have small systems which do not qualify for the Dow analytical program. The following assistance is provided for these customers:

Glycol concentration and freeze point

Freeze points of both ethylene glycol- and propylene glycol- based coolants can be measured using a portable refractometer. After the freeze point is known, the concentration can be determined using the data shown in Table 5 for AMBITROL™ CN or FL, and Table 6 for AMBITROL™ NTC or NTF.

Fluid appearance testing

You can determine the condition of your fluid by examining its appearance. Any drastic variation from the initial fluid specifications (such as a black or dark-grey color) presence of an oily layer, burnt odor, or any heavy sludge in the fluid may indicate the need for fluid replacement.

pH level testing

Control of pH between 8.0 to 10.0 is important to minimize corrosion and glycol degradation. Use a narrow range pH paper, such as pHydrion control paper with a 7.2 to 8.8 pH range, to read your pH level.

A pH tester can also measure alkalinity or acidity and give you an indication of the reserve alkalinity or inhibitor level of the fluid. The pH should fall between 8.0 and 10.0. Adjustments can be made by using a 50% solution of sodium hydroxide or potassium hydroxide if the pH is approaching the acidic range (below 8.0). Typically, one gallon of a 50% solution of sodium hydroxide should be added per 1,000 gallons of system capacity to ensure proper pH adjustment. If pH is very low, additional adjustment may be required.

General system design and equipment considerations

The following is a general discussion of system design and other engineering considerations related to the use of AMBITROL™ coolants. For more information regarding a specific system problem or question, contact Dow's Technical Service and Development staff for assistance.

Materials of construction

Standard system materials can be used with AMBITROL™ coolants. Steel, cast iron, copper, brass, bronze, solder, and most plastic piping materials are all generally acceptable. AMBITROL™ coolants can also be used with aluminum at temperatures below 150°F (65°C). At temperatures above 150°F (65°C), use of aluminum is not recommended because the inhibitors will not fully protect aluminum components in the system. Galvanized steel is not recommended because the zinc will react with the inhibitor in the fluids, causing precipitate formation, depletion of the inhibitor package, and removal of the protective zinc coating, particularly above 100°F (38°C). Precipitation can also lead to localized corrosion.

Typically, the same types of packing or mechanical seals used for water may be used with solutions of AMBITROL™ coolants. Packing and seal manufacturers should be consulted for materials appropriate to your application and operating temperature.

Solutions of AMBITROL™ coolants are also compatible with most plastics and elastomers. Generally, any material that can be used with uninhibited glycols may be used with AMBITROL™ coolants. Before using a particular elastomer, check with the manufacturer to determine the suitability of the material over the anticipated temperature and pressure ranges.

If the use of coatings is desired (for example, to protect the vapor space of an expansion tank) several options are available. Suitable coatings include novalac-based vinyl ester resins (e.g., DERAKANE™ 470-36 Vinyl Ester Resin), high bake phenolic resins, polypropylene, and polyvinylidene fluoride. To ensure that the coating is suitable for a particular application and temperature, the coating manufacturer should be consulted.

Bypass filters are recommended for removal of foreign solids. This is especially important if the quality of solution water does not conform to recommendations on page 12 of this guide. Precipitates and sludge deposited by solution water can lead to localized corrosion. Filters (typically 10 micron) made of non-absorbent cotton, fiber, or cellulose type media have been used successfully.

Using dissimilar metals in a system is not recommended because galvanic corrosion may result. This type of corrosion can occur in electrolytic solutions when dissimilar metals (referencing the galvanic series in sea water) are in contact with, or near, each other (aluminum directly connected to copper is an example). Solutions of AMBITROL™ coolants are better than plain water, but still cannot protect against galvanic corrosion of dissimilar metals electrically coupled in a system. Electrical isolation eliminates galvanic corrosion concerns.

Operating temperature

AMBITROL™ Inhibited Glycol-based Coolants have an effective operating temperature range of -50°F to 275°F (-45°C to 121°C). At temperatures below -50°F (-45°C), increased viscosity can make the use of these coolants impractical unless larger pumps are installed.

At the upper end of the operating range for AMBITROL™ coolants, a maximum bulk temperature of 275°F (121°C) is recommended. Film temperatures should not exceed 300°F (150°C).

AMBITROL™ coolants can tolerate brief temperature excursions up to 100°F (38°C) above the maximum recommended temperatures. However, extended exposure of the coolants to temperatures in excess of the maximum operating temperature will result in accelerated degradation of the glycol and inhibitor systems.

In addition, the pressure at all points in the system should be at least 5 psi greater than the vapor pressure exerted by the coolant to avoid localizing boiling and resulting precipitation.

At temperatures above 150°F (65°C), the system must be closed to avoid rapid oxidation of the glycol, inhibitor depletion, and subsequent increased corrosion.

Expansion factor

Like any fluids, solutions of AMBITROL™ coolants expand as temperature increases. Therefore, expansion tanks must be sized appropriately. To determine the volume of expansion, use the following formula:

$$\frac{\rho(T_{LOW}) - \rho(T_{HIGH})}{\rho(T_{HIGH})} \times \text{volume} = \frac{\text{expansion}}{\text{volume}}$$

Where,

$\rho(T_{LOW})$ = The density at the lowest anticipated temperature.

$\rho(T_{HIGH})$ = The density at the highest anticipated temperature.

Density data for AMBITROL™ coolants are given on pages 26-27.

One method for sizing an expansion tank is to use the determined expansion volume to calculate the total size of the tank. A typical tank size would allow the coolant to fluctuate between the levels associated with 15% and 80% full. The tank size is calculated from:

Expansion volume/0.65 = Tank size

When using this method, ensure that the minimum amount of coolant in the tank will provide the net positive suction head (NPSH) of the pump if the tank is a portion of the source head.

An alternative method of sizing the tank is to determine the volume of the system and specify a large enough tank to accommodate the entire coolant volume at maximum temperature. This method allows the system to be drained to the expansion tank for maintenance. Industrial users of AMBITROL™ coolants will typically use this procedure.

Also note that, as temperatures drop below the freeze point of a glycol solution, ice crystals begin to form. This causes the solution to expand and the slush to flow to the available expansion volume. The lower the temperature is, the greater the expansion. This expansion should be used for expansion tank sizing.

However, when it becomes cold enough for glycol crystals to form, the volume of the solution will contract. At very low temperatures, the entire mass freezes and contracts.

Line and bath heater applications

Dow recommends using NORKOOL™ Industrial Coolants in line and bath heater applications. Typically, these heaters use a gas "fire tube" to heat the fluid to 180°F (82°C) which in turn transfers heat to warm product gas or fluids. Because these heaters normally utilize natural fluid convection to circulate the fluid, film temperatures at the fire tube (particularly during start-up) can become quite high causing glycol degradation. Units with forced circulation alleviate this situation.

Line and bath heaters are also commonly vented to the atmosphere from the fluid reservoir. This can lead to water vapor loss which increases the glycol concentration and lessens heat transfer efficiency. Water saver units can prevent this from happening. Vented units will also breathe in air which accelerates glycol degradation.

Because of the increased demands on the fluids used in line and bath heaters, it is recommended that regular fluid evaluation and maintenance be part of line and bath heater operation.

Cavitation erosion

Certain wet sleeve stationary engines are prone to cavitation pitting of their cylinder liners, which is caused by the collapse of water vapor bubbles that form at the cylinder liner surface because of localized coolant boiling. The boiling is a result of liner vibration that causes alternating areas of low pressure (boiling) and high pressure (collapse). Dow recommends using NORKOOL™ Industrial Coolants in systems that are prone to cavitation. Contact your Dow technical representative for more information.

Preparing systems for the addition of AMBITROL™ coolants

Existing systems

In existing systems, all lines and materials should be cleaned and flushed thoroughly before charging the system with AMBITROL™ coolant. This is especially important if coolant previously in the system is incompatible with the new inhibited glycol coolant. A Dow technical service representative can help you determine the compatibility of other fluids with AMBITROL™ coolants.

If a fluid containing silicates (such as automotive antifreeze) was previously used, it may be necessary to clean silicate residues from the system.

It is also important to remove all rust, scale, and sediment in the system. Traces of chlorine should be removed – whether from old coolant or residue from acid cleaner – because chlorides can contribute to corrosion. For large systems, or where corrosion is already evident, consult a professional industrial cleaning organization.

For heavily fouled or corroded systems, an optimum cleaning procedure includes the use of an inhibited acid followed by neutralization and phosphorization. This procedure is quite involved and should be done by a company experienced in industrial cleaning. If chemical cleaning is used, it is important that all traces of the cleaning agent be removed, and the system be thoroughly flushed with water. Dow offers NORKOOL™ Cleaner, NORKOOL™ Degreaser and Surface Modifier N244 for scale removal and safe cleaning for cooling systems. Please contact your Dow representative for additional information.

New systems

New systems are typically coated with oil, grease, or a protective film during fabrication, storage, or construction. Dirt, solder flux, and welding and pipe scale can also cause problems. Therefore, thorough cleaning of new systems is recommended. A single pass of NORKOOL™ Cleaner, and NORKOOL™ Degreaser, with a final rinse containing Surface Modifier N244 will prepare the system for the addition of the new coolant.

Water quality considerations

If the local water used to dilute concentrated coolant products (such as AMBITROL™ CN Inhibited Ethylene Glycol-based Coolant and AMBITROL™ NTC Inhibited Propylene Glycol-based Coolant) does not meet certain purity standards, engine contamination, damage, and even failure can result.

For local water to be acceptable, individual levels of chlorides, sulfates, calcium, and magnesium should be less than 25 ppm, or total hardness below 100 ppm. Unfortunately, in many areas of the country, one or more of these minerals may exceed these maximum limits.

AMBITROL™ coolants contain a proprietary additive that significantly reduces the potential of fouling or scale deposition due to the use of high-hardness water. However, Dow continues to recommend the use of demineralized water since the anti-scale additive does not neutralize the negative effects of chloride or sulfate ions.

Extremely hard water with high levels of magnesium and calcium can form deposits and scale that reduce heat transfer capabilities and can lead to engine damage. High levels of chlorides or sulfates will lead to greatly increased metal corrosion.

Chloride ions in water accelerate pitting of cast iron and steel components in cooling systems. These ions can also attack protective oxide films on metal parts. At the same time, chloride ions reduce the effectiveness of corrosion inhibitors and increase depletion rates.

Like chloride ions, sulfates in the water supply increase pitting on cast iron and steel parts. When combined with high calcium and magnesium levels, sulfates also contribute to the formation of hard scale that can reduce heat transfer efficiency and cause engine damage.

Calcium bicarbonates are another cause of serious problems in stationary engines because they tend to thermally decompose into mono-carbonate form: calcium carbonate. This calcium carbonate is deposited on cooling system surfaces, resulting in reduced heat transfer efficiency and even plugging of radiator tubes. Problems with high levels of calcium bicarbonate contamination are particularly prevalent in the Central Plains states, although moderate levels of this contamination are found in water in most areas of the U.S.

Table 3: Corrosion test results/weight loss in milligrams (mils penetration per year)

	Water	Propylene glycol	AMBITROL™ NTC Coolant	Ethylene glycol	AMBITROL™ CN Coolant
Copper	2 (0.08)	4 (0.16)	1 (0.12)	4 (0.16)	3 (0.12)
Solder	99 (3.14)	1,095 (34.7)	1 (0.030)	1,780 (56.5)	4 (0.13)
Brass	5 (0.23)	5 (0.20)	2 (0.16)	11 (0.46)	3 (0.12)
Mild steel	212 (9.69)	214 (9.80)	1 (0.04)	974 (44.5)	1 (0.04)
Cast iron	450 (21.2)	345 (16.2)	3 (0.15)	1,190 (55.7)	3 (0.13)
Aluminum	110 (13.2)	15 (1.80)	+2 (+0.26)	165 (19.8)	4 (0.44)

Samples with a "+" showed weight gain.
ASTM D-1384 – 190°F (88°C) for 2 weeks. 30% by volume glycol, air bubbling.

How AMBITROL™ inhibited fluids protect against corrosion

AMBITROL™ Inhibited Glycol-based Coolants contain specially formulated industrial inhibitor packages that are effective in preventing corrosion of metals commonly used in process heat transfer equipment. These inhibitors prevent corrosion of metal in two ways.

First, they passivate the surface of metals, reacting with the surface to prevent acid from attacking it. Unlike inhibitors used in some other coolants, Dow inhibitors perform this passivation process without fouling heat transfer surfaces. The inhibitors in automotive antifreeze, on the other hand, contain silicates that coat heat transfer surfaces with a thick silicate gel that reduces heat transfer.

Second, the inhibitors in AMBITROL™ coolants buffer any acids formed as a result of glycol oxidation. All glycols produce organic acids as degradation products. This degradation is accelerated in the presence of oxygen and/or heat. Left in solution, such acids lower pH and contribute to corrosion. Properly formulated inhibitors like those found in AMBITROL™ coolants neutralize these acids.

The standard ASTM D-1384 corrosion test is a screening test that measures the relative corrosion protection provided by different solutions on standard metals under standard test conditions. The data in Table 3 show relative corrosion rates for AMBITROL™ coolants compared to uninhibited ethylene glycol, propylene glycol, and plain water. The data indicate that solutions of AMBITROL™ coolants fall well within the generally accepted corrosion limits considered adequate under this test. Rates in excess of 0.5 mpy (2.5 mpy for aluminum) are generally evidence of inadequate corrosion protection (since it is only a screening test, ASTM D-1384 may not be indicative of performance in an actual system).

The presence of excessive amounts of contaminants, such as chlorides, sulfates, and/or ammonia, could contribute to system corrosion not evident in these tests. For example, excessive concentrates of chloride ions will result in the formation of iron chloride. With any available oxygen, iron chloride will react to form iron oxide which is insoluble. The resulting deposition of precipitant forms an area where under-deposit corrosion can occur. This corrosion will be further accelerated by the presence of chlorides and cannot be eliminated through the use of a non-chromate-based inhibitor. This underscores the importance of dilution water quality discussed on page 12.

How to install AMBITROL™ coolants

AMBITROL™ CN and AMBITROL™ NTC Coolants are concentrated glycol coolants and must be diluted with high quality water. Coolant solutions must be at least 30% AMBITROL™ CN or NTC Coolant in order to provide adequate corrosion protection. However, the solution must not contain more than 60% concentrate or heat transfer efficiency is lost.

Dilution can be done prior to installation or, as is often the case, the amount of AMBITROL™ CN or NTC Coolant required to provide the desired freezing point may be put into the cooling system first. Water is then added to fill the system, and the solution is circulated for 24 hours to ensure complete mixing. Note that any flush water remaining in the system should be taken into account when introducing and diluting AMBITROL™ coolants. It is not unusual to have "hold-up" of up to 20% of the total system volume, although 10% is more common.

Determining the desired level of freeze protection

The following is an example of how to determine the desired level of freeze protection:

Assume the system has a total coolant capacity of 1,000 gallons, and a freezing point of -10°F (-23°C) is desired. Using Table 5 on page 17-18, it is apparent that a 41% by volume solution of AMBITROL™ CN Coolant is needed to obtain freeze protection at this temperature. Therefore, the system needs 410 gallons of AMBITROL™ CN Coolant and 590 gallons of distilled or deionized water. Similar calculations can be done for AMBITROL™NTC Coolant using Table 6 on page 19.

Solutions of AMBITROL™ FL and AMBITROL™ NTF Pre-diluted Coolant are already completely formulated and ready-to-use, so dilution with water is not required. Just add AMBITROL™ FL or AMBITROL™ NTF Coolant to the system after all flush water is removed. Small amounts of water in the system will not usually affect the corrosion-inhibiting properties of either coolant.

Efficiency vs. concentration

To obtain maximum heat transfer efficiency while achieving adequate freeze protection, avoid using excess concentrations of AMBITROL™ coolants in water. Generally when the coolant is used for freeze protection, the specified concentration should yield a freeze point about 5°F (-15°C) lower than the lowest ambient temperature. It is rarely necessary to use concentrations higher than 50% to 55% glycol in water. The less glycol used, the higher the relative heat transfer efficiency of the solution.

For optimum corrosion protection, the concentration of AMBITROL™ Coolant in water should provide at least 30% (by volume) glycol. If operation at lower concentrations is desired, consult your Dow technical service representative for information regarding inhibitor adjustment.

Procedures for reinhibiting AMBITROL™ coolants

Inhibitor should be added only when analysis indicates that its level is low. For those receiving the Dow free analytical service, the amount of inhibitor to add to the system will be specified in the analytical report.

For those not receiving Dow's analytical computer reports, the relative inhibitor levels can be determined and if the coolant tests low, you can consult a Dow technical representative for the correct amount to add.

Follow these steps once you've determined the amount of inhibitor that must be added:

1. Run the system for several hours to mix the coolant solution thoroughly.
2. Shut the system down and wait until it is below 200°F (93°C) before opening the system.
3. Open the system cautiously, especially if it is under pressure. If necessary, drain enough coolant from the system to accommodate the amount of inhibitor being added.
4. Add the required amount of inhibitor and run the system to completely mix the solution.

A NOTE OF CAUTION: Dow's inhibitor is not designed for use with water or uninhibited ethylene glycol-water solutions. Nor should it be added to other inhibited glycol-water systems unless prior analysis indicates that the different inhibitors are compatible.

Low temperature considerations

Ethylene glycol (EG) and propylene glycol (PG) solutions do not have sharply defined freezing points like water. For these fluids, the freezing point is defined as the temperature at which crystals first form. As the temperature is lowered gradually, slushes form followed by increasing viscosity until the whole system solidifies.

In solutions with up to 60% EG, the first crystals to form are ice. In solutions with 60-80% EG, slushes form which remain fluid even at very low temperatures. In fact, the freezing point cannot be accurately determined because of super-cooling and high viscosities. However, in solutions with EG concentrations from 80-100%, the freezing points can again be determined, and the first crystals to form are solid EG (see Figure 5, page 32).

Figure 5 shows the freezing point line of solutions containing from 0-60% PG. With concentrations above 60% PG, crystallization is either very difficult or does not occur at all under low temperatures. Instead of freezing, these solutions become increasingly viscous and finally set up like glass.

Freezing points and pour points

The fluidity of glycol-water mixtures below their freezing points is sometimes described by pour point. The pour point is taken at 5°F (-15°C) above the temperature at which no movement is observed when a container with the liquid is rapidly inverted.

The relationship between freezing points and pour points is shown in Figure 6 (page 34) for solutions of both AMBITROL™ CN and AMBITROL™ NTC Coolants.

Solutions of AMBITROL™ NTC Coolant (PG-based) have lower pour points than solutions of AMBITROL™ CN Coolant having the same freezing point. However, Figure 5 (page 32) shows that for a given concentration (0-60%), solutions of AMBITROL™ NTC Coolant (PG-based) have slightly higher freezing points than solutions of AMBITROL™ CN Coolant (EG-based).

Procedure for adjusting freezing point

The reports for each sample of AMBITROL™ Coolant indicate both the concentrations of glycols present and the freezing point of the solution. If a lower freezing point is required, the concentration of glycol must be increased accordingly (see Figure 5, page 32). The same information can be obtained from Tables 5 or 6 (pages 17-19).

Use the formula below to determine the amount of solution to drain and the number of gallons of AMBITROL™ CN or NTC Coolant to add to increase the glycol concentration:

$$A = \frac{V(D - P)}{96 - P}$$

Note: 96 = The glycol concentration of AMBITROL™ CN and NTC Coolants. To decrease the glycol concentration, the following formula should be used to determine the volume to drain and replace with high-quality water:

$$A = \frac{V(D - P)}{96 - P}$$

If the system has adequate capacity to add AMBITROL™ CN or NTC Coolant without having to drain some of the existing fluid, the following formula can be used to determine the quantity of concentrate to add (A). This will increase the glycol concentration from P to D.

$$A = \frac{V(D - P)}{96 - P}$$

Where,

A = The quantity, in gallons, of AMBITROL™ CN or NTC Coolant, or water to be added to the system. This is also equal to the quantity, in gallons, of the solution that must be drained from the system (except for last formula).

V = The total quantity of fluid in the system, in gallons.

D = The volume percent of ethylene glycol or propylene glycol desired in the system.

P = The volume percent of ethylene glycol or propylene glycol presently in the system.

Safety, handling, storage, and disposal of AMBITROL™ coolants

Toxicology

For complete product toxicological information for AMBITROL™ coolants, request Safety Data Sheets (SDS) from Dow. These sheets provide the most up-to-date health and safety considerations related to the use of these products and should be consulted prior to using the products.

Flammability

When mixed with water, AMBITROL™ coolants are not flammable because they have no measurable flash point (pensky-martens closed cup) in concentrations up to 80% glycol. Undiluted AMBITROL™ NTC Coolant has a flash point of 225°F (107°C) (pensky-martens closed cup). Undiluted AMBITROL™ CN Coolant has a flash point of 232°F (111°C) (tag closed cup). It is possible to ignite solutions of glycol if enough water has been vaporized and the concentration of glycol increases to greater than 80%.

Storage

Storage of AMBITROL™ coolants presents no unusual problems. The materials do not readily solidify, have high flash points, and can be handled without posing a hazard to health. As a precaution, however, sparks or flames should be avoided during transfer or processing operations because undiluted glycols can be ignited. Tank truck shipments can be emptied into storage tanks or clean drums.

Tank storage

Ordinary steel tanks are normally satisfactory for storage of AMBITROL™ coolants. However, during extended storage, slight discoloration may occur from iron contamination. Rusting may occur in the vapor space because there is no inhibitor where condensation occurs and oxygen is present. This problem can be minimized by closing any vent to the tank to limit oxygen intake. If this is not possible, see page 12 for a discussion of the coatings suitable for protection of vapor space in tanks.

Insulation and heat are required for storage of AMBITROL™ coolants at low temperatures. This will prevent freezing or pumping problems due to high viscosity. Maintaining temperatures above 10°F (-12°C) is usually sufficient to avoid such problems.

Drum storage

AMBITROL™ coolants may be stored in the drums in which shipment is made. Because glycols are hygroscopic, it is important to keep the material in the drum from absorbing water. Drums should be stored inside a heated building when temperatures below 10°F are anticipated. This will assure that the glycol is in a liquid form when needed.

Environmental considerations

The biochemical oxygen demand (BOD) for both ethylene glycol and propylene glycol approaches the theoretical oxygen demand (ThOD) value in the standard 20-day test period. This indicates that these materials are biodegradable and should not concentrate in common water systems. The possibility of spills in lakes or rivers, however, should be avoided since rapid oxygen depletion may have harmful effects on aquatic organisms. Extensive testing of the effects of ethylene glycol and propylene glycol on aquatic organisms has shown the materials to be practically non-toxic (LC 50 > 100 mg/L) with LC 50s > = 10,000 mg/L for fathead minnow, rainbow trout, and daphnia magna.

Spill, leak, and disposal procedures

Using appropriate safety equipment, small spills may be soaked up with common absorbent material. For large spills, the fluid should be pumped into suitable containers located in diked areas. Residual material should be cleaned up with water. Concentrate should be handled according to local, state, and federal regulations.

Salvage

Some distributors of AMBITROL™ coolants are equipped to reclaim and/or dispose of spent or contaminated fluids. Occasionally, where regulations permit, diluted spent fluids that are not otherwise contaminated can be disposed of in local sewage treatment facilities, provided those facilities are advised and prepared for such disposal in advance. Aerobic bacteria easily oxidize the fluids to carbon dioxide and water within the usual 20-day test period. Dow does not normally provide a disposal service for used or contaminated glycol-based coolants.

Recycle

Dow can provide assistance to customers wishing to recycle their used coolant. Customers interested in pursuing this option should contact their coolant distributor or your Dow technical representative.

Table 4: Biochemical oxygen demand (BOD) for ethylene glycol and propylene glycol

BOD	Parts oxygen/parts ethylene glycol	Parts oxygen/parts propylene glycol
5 day	0.78	1.16
10 day	1.06	1.18
20 day	1.15	1.45
ThOD	1.29	1.68

Physical properties and engineering data for AMBITROL™ coolants

Pages 17 through 35 provide physical properties and engineering data for AMBITROL™ coolants. Included is information on viscosity, thermal conductivity, specific heat, vapor pressure, density, and pressure drop. This information is useful to engineers, designers, operators, and maintenance personnel involved in solving problems related to heat transfer.

Table 5: Typical freezing and boiling points of aqueous solutions of AMBITROL™ CN Ethylene Glycol-based Coolant

Wt % ethylene glycol	Vol % ethylene glycol	Wt % AMBITROL™ CN Coolant	Vol % AMBITROL™ CN Coolant	Freezing point, °F	Boiling point, °F @ 760 mm HG	Refractive index 22°C	Specific gravity 60/60°F
0.0	0.0	0.0	0.0	32.0	212	1.3328	1.000
5.0	4.4	5.2	4.6	29.4	213	1.3378	1.007
10.0	8.9	10.5	9.3	26.2	214	1.3428	1.015
15.0	13.6	15.7	14.2	22.2	215	1.3478	1.022
20.0	18.1	20.9	19.0	17.9	216	1.3530	1.030
21.0	19.2	22.0	20.1	16.8	216	1.3540	1.032
22.0	20.1	23.0	21.0	15.9	216	1.3551	1.034
23.0	21.0	24.1	22.0	14.9	217	1.3561	1.035
24.0	22.0	25.1	23.0	13.7	217	1.3572	1.037
25.0	22.9	26.2	24.0	12.7	218	1.3582	1.038
26.0	23.9	27.2	25.0	11.4	218	1.3593	1.039
27.0	24.8	28.3	26.0	10.4	218	1.3603	1.041
28.0	25.8	29.3	27.0	9.2	219	1.3614	1.043
29.0	26.7	30.4	28.0	8.0	219	1.3624	1.045
30.0	27.7	31.4	29.0	6.7	220	1.3635	1.046
31.0	28.7	32.5	30.2	5.4	220	1.3646	1.047
32.0	29.6	33.5	31.0	4.2	220	1.3656	1.048
33.0	30.6	34.6	32.0	2.9	220	1.3667	1.049
34.0	31.6	35.6	33.1	1.4	220	1.3678	1.051
35.0	32.6	36.6	34.1	-0.2	221	1.3688	1.052
36.0	33.5	37.7	35.1	-1.5	221	1.3699	1.054
37.0	34.5	38.7	36.1	-3.0	221	1.3709	1.056
38.0	35.5	39.8	37.2	-4.5	221	1.3720	1.057
39.0	36.5	40.8	38.2	-6.4	221	1.3730	1.058
40.0	37.5	41.9	39.3	-8.1	222	1.3741	1.060
41.0	38.5	42.9	40.3	-9.8	222	1.3752	1.061
42.0	39.5	44.0	41.4	-11.7	222	1.3763	1.063
43.0	40.5	45.0	42.4	-13.5	223	1.3774	1.064
44.0	41.5	46.1	43.5	-15.5	223	1.3785	1.066

– continued

Table 5: Typical freezing and boiling points of aqueous solutions of AMBITROL™ CN Ethylene Glycol-based Coolant – *continued*

Wt % ethylene glycol	Vol % ethylene glycol	Wt % AMBITROL™ CN Coolant	Vol % AMBITROL™ CN Coolant	Freezing point, °F	Boiling point, °F @ 760 mm HG	Refractive index 22°C	Specific gravity 60/60°F
45.0	42.5	47.1	44.5	-17.5	224	1.3796	1.067
46.0	43.5	48.2	45.5	-19.8	224	1.3807	1.069
47.0	44.5	49.2	46.6	-21.6	224	1.3817	1.071
48.0	45.5	50.2	47.6	-23.9	224	1.3828	1.072
49.0	46.6	51.3	48.8	-26.7	224	1.3838	1.074
50.0	47.6	52.4	49.8	-28.9	225	1.3849	1.075
51.0	48.6	53.4	50.9	-31.2	225	1.3859	1.077
52.0	49.6	54.5	51.9	-33.6	225	1.3869	1.078
53.0	50.6	55.5	53.0	-36.2	226	1.3879	1.079
54.0	51.6	56.4	54.0	-38.8	226	1.3890	1.081
55.0	52.7	57.6	55.2	-42.0	227	1.3900	1.082
56.0	53.7	58.6	56.2	-44.7	227	1.3910	1.083
57.0	54.7	59.7	57.3	-47.5	228	1.3921	1.084
58.0	55.7	60.7	58.3	-50.0	228	1.3931	1.085
59.0	56.8	61.8	59.5	-52.7	229	1.3942	1.087
60.0	57.8	62.8	60.5	-54.9	230	1.3952	1.088
65.0	62.8	68.0	65.8	< -60.0	235	1.4003	1.095
70.0	68.3	73.3	71.5	< -60.0	242	1.4055	1.102
75.0	73.6	78.5	77.1	< -60.0	248	1.4107	1.108
80.0	78.9	83.8	82.6	-52.2	255	1.4159	1.114
85.0	84.3	89.0	88.3	-34.5	273	1.4208	1.119
90.0	89.7	94.2	93.9	-21.6	285	1.4255	1.126
95.0	95.0	99.5	99.5	-3.0	317	1.4300	1.130

Typical properties not to be construed as specifications.
Note: Generally, for an extended margin of protection, you should select a temperature in this table that is at least 5°F (-15°C) lower than the expected lowest ambient temperature. Inhibitor levels should be adjusted for solutions of less than 30% glycol. Contact Dow for information on specific cases or further assistance.

Table 6: Typical freezing and boiling points of aqueous solutions of AMBITROL™ NTC Propylene Glycol-based Coolant

Wt % propylene glycol	Vol % propylene glycol	Wt % AMBITROL™ NTC Coolant	Vol % AMBITROL™ NTC Coolant	Freezing point, °F	Boiling point, °F @ 760 mm HG	Refractive index 22°C	Specific gravity 60/60°F
0.0	0.0	0.0	0.0	32.0	212	1.3328	1.000
5.0	4.8	5.2	5.0	29.1	212	1.3383	1.005
10.2	9.6	10.5	10.0	26.1	212	1.3438	1.011
15.0	14.5	15.7	15.1	22.9	212	1.3495	1.016
20.0	19.4	20.9	20.3	19.2	213	1.3555	1.021
21.0	20.4	22.0	21.3	18.3	213	1.3567	1.022
22.0	21.4	23.0	22.4	17.6	213	1.3579	1.023
23.0	22.4	24.0	23.4	16.6	213	1.3591	1.024
24.0	23.4	25.1	24.5	15.6	213	1.3603	1.025
25.0	24.4	26.1	25.5	14.7	214	1.3615	1.026
26.0	25.3	27.2	26.5	13.7	214	1.3627	1.027
27.0	26.4	28.2	27.6	12.6	214	1.3639	1.028
28.0	27.4	29.3	28.6	11.5	215	1.3651	1.029
29.0	28.4	30.3	29.7	10.4	215	1.3663	1.030
30.0	29.4	31.4	30.7	9.2	216	1.3675	1.031
31.0	30.4	32.4	31.8	7.9	216	1.3687	1.032
32.0	31.4	33.5	32.8	6.6	216	1.3698	1.034
33.0	32.4	34.5	33.9	5.3	216	1.3710	1.035
34.0	33.5	35.5	35.0	3.9	216	1.3721	1.036
35.0	34.4	36.6	36.0	2.4	217	1.3733	1.037
36.0	35.5	37.6	37.1	0.8	217	1.3744	1.038
37.0	36.5	38.7	38.2	-0.8	217	1.3756	1.038
38.0	37.5	39.7	39.2	-2.4	218	1.3767	1.039
39.0	38.5	40.8	40.3	-4.2	218	1.3779	1.040
40.0	39.6	41.8	41.4	-6.0	219	1.3790	1.040
41.0	40.6	42.9	42.4	-7.8	219	1.3802	1.041
42.0	41.6	43.9	43.5	-9.8	219	1.3813	1.042
43.0	42.6	45.0	44.5	-11.8	219	1.3825	1.042
44.0	43.7	46.0	45.7	-13.9	219	1.3836	1.043
45.0	44.7	47.0	46.7	-16.1	220	1.3847	1.044
46.0	45.7	48.1	47.8	-18.3	220	1.3858	1.045
47.0	46.8	49.1	48.9	-20.7	220	1.3870	1.046
48.0	47.8	50.2	50.0	-23.1	221	1.3881	1.046

– continued

Table 6: Typical freezing and boiling points of aqueous solutions of AMBITROL™ NTC Propylene Glycol-based Coolant – *continued*

Wt % propylene glycol	Vol % propylene glycol	Wt % AMBITROL™ NTC Coolant	Vol % AMBITROL™ NTC Coolant	Freezing point, °F	Boiling point, °F @ 760 mm HG	Refractive index 22°C	Specific gravity 60/60°F
49.0	48.9	51.2	51.1	-25.7	221	1.3892	1.047
50.0	49.9	52.3	52.2	-28.3	222	1.3903	1.048
51.0	50.9	53.3	53.2	-31.0	222	1.3914	1.048
52.0	51.9	54.4	54.3	-33.8	222	1.3924	1.049
53.0	53.0	55.4	55.4	-36.7	223	1.3935	1.050
54.0	54.0	56.5	56.5	-39.7	223	1.3945	1.051
55.0	55.0	57.5	57.5	-42.8	223	1.3956	1.052
56.0	56.0	58.5	58.5	-46.0	223	1.3966	1.054
57.0	57.0	59.6	59.6	-49.3	224	1.3977	1.054
58.0	58.0	60.6	60.6	-52.7	224	1.3987	1.055
59.0	59.0	61.7	61.7	-56.2	224	1.3998	1.055
60.0	60.0	62.7	62.7	-59.9	225	1.4008	1.056
65.0	65.0	68.0	68.0	< -60.0	227	1.4058	1.058
70.0	70.0	73.2	73.2	< -60.0	230	1.4104	1.059
75.0	75.0	78.4	78.4	< -60.0	237	1.4150	1.060
80.0	80.0	83.6	83.6	< -60.0	245	1.4193	1.060
85.0	85.0	88.9	88.9	< -60.0	257	1.4235	1.059
90.0	90.0	94.1	94.1	< -60.0	270	1.4275	1.057
95.0	95.0	99.3	99.3	< -60.0	310	1.4315	1.055

Typical properties not to be construed as specifications.
Note: Generally, for an extended margin of protection, you should select a temperature in this table that is at least 5°F (-15°C) lower than the expected lowest ambient temperature. Inhibitor levels should be adjusted for solutions of less than 30% glycol. Contact Dow for information on specific cases or further assistance.

Vapor pressure and boiling point

As liquids vaporize, pressure is exerted which increases as temperature increases. Aqueous solutions of AMBITROL™ products have vapor pressures lower than water and boiling points above water. However, aqueous solutions of AMBITROL™ products have vapor pressures close to that of water because of the water in the solution. Actually, the vapor pressure of the glycol by itself is much less.

As a result, solutions of AMBITROL™ products will tend to lose water by evaporation as temperature rises above the dew point. Because glycols are hygroscopic (attract water molecules), the fluids pick up water molecules from the air and dilute the solution (lowering the boiling point) as the temperature drops below the dew point. Closed systems, of course, reduce this potential problem.

Total pressure should be kept under 600 mm Hg. Figures 1 and 2 let you calculate total pressure using solution temperature and concentration. If you are exceeding 600 mm Hg total pressure, you will need to increase the glycol concentration, or consider a closed system.

Figure 1: Total pressures over aqueous solutions of AMBITROL™ Ethylene Glycol-based Coolants

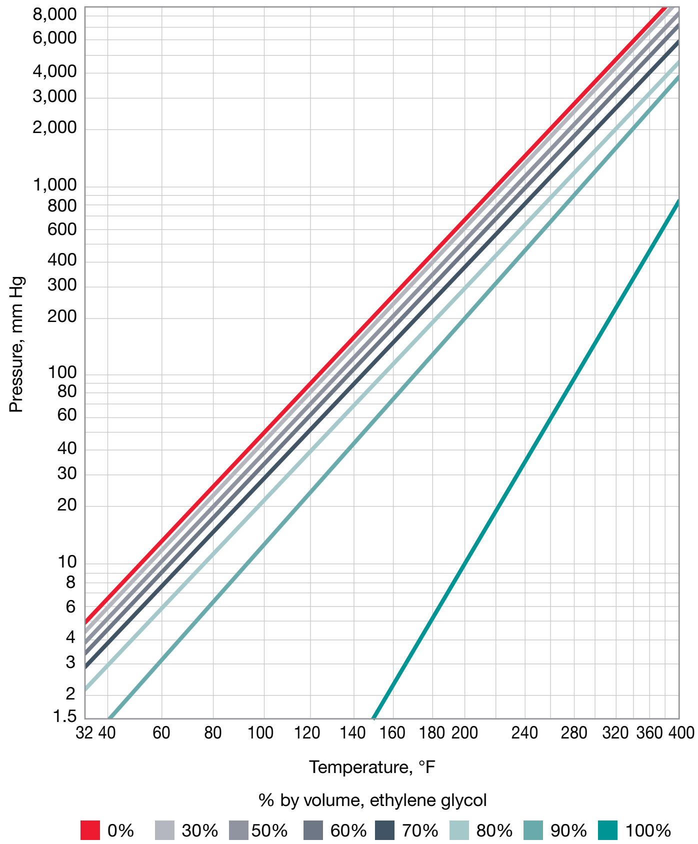
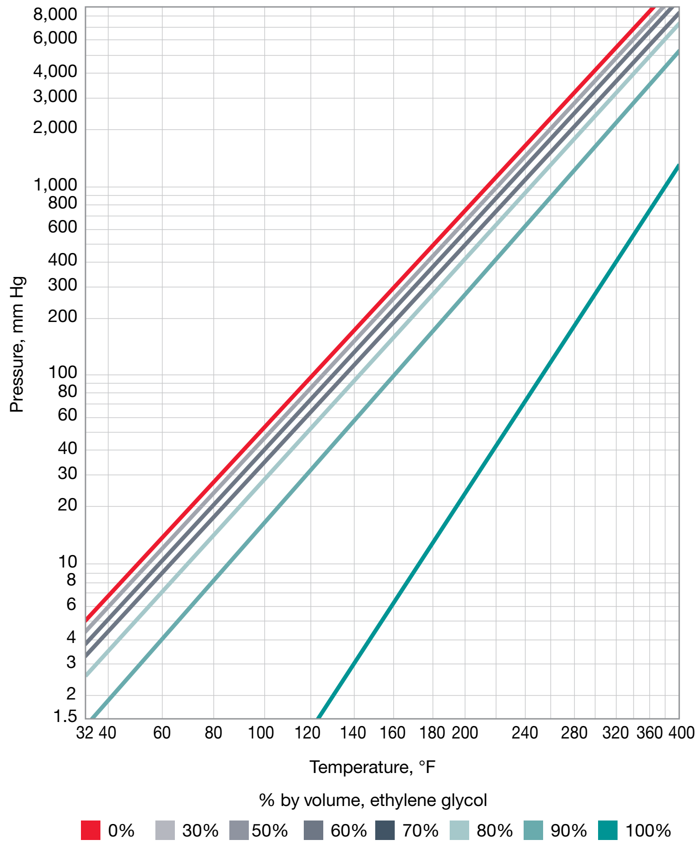


Figure 2: Total pressures over aqueous solutions of AMBITROL™ Propylene Glycol-based Coolants



Viscosity

Viscosity is the measure of the property of a fluid that resists the force tending to cause the fluid to flow. In a way, then, it is a measure of the internal friction of a fluid. As viscosity increases, the tendency to flow decreases. Viscosities of AMBITROL™ products vary directly with concentration and inversely with temperature. The tables generated here are important when viscosity information is required for pumping or piping calculation, or for the calculation of heat transfer efficiency factors. Typically measured in centipoise, this can be easily converted to centistokes by dividing the number of centipoise by the density of the solution in grams per milliliter at a given temperature.

Table 7: Viscosities (cps) of aqueous solutions of AMBITROL™ CN Coolant

Temp °F	Volume percent ethylene glycol									
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%
-30	–	–	–	–	–	–	89.67	128.79	185.22	–
-20	–	–	–	–	–	40.38	60.46	89.93	131.32	284.48
-10	–	–	–	–	–	27.27	42.05	63.50	91.88	169.83
0	–	–	–	–	13.76	19.34	30.08	45.58	65.04	107.77
10	–	–	–	6.83	10.13	14.26	22.06	33.31	46.89	71.87
20	–	–	3.90	5.38	7.74	10.85	16.56	24.79	34.48	49.94
30	–	2.16	3.14	4.33	6.09	8.48	12.68	18.77	25.84	35.91
40	1.53	1.82	2.59	3.54	4.91	6.77	9.90	14.45	19.71	26.59
50	1.30	1.56	2.18	2.95	4.04	5.50	7.85	11.31	15.29	20.18
60	1.12	1.35	1.86	2.49	3.38	4.55	6.33	8.97	12.05	15.65
70	0.98	1.18	1.61	2.13	2.87	3.81	5.17	7.22	9.62	12.37
80	0.86	1.04	1.41	1.84	2.46	3.23	4.28	5.88	7.79	9.93
90	0.76	0.93	1.24	1.60	2.13	2.76	3.58	4.85	6.38	8.10
100	0.68	0.83	1.11	1.41	1.87	2.39	3.03	4.04	5.28	6.68
110	0.61	0.75	0.99	1.25	1.64	2.08	2.58	3.40	4.41	5.58
120	0.55	0.68	0.90	1.11	1.46	1.82	2.23	2.88	3.73	4.71
130	0.51	0.62	0.81	1.00	1.30	1.61	1.93	2.47	3.17	4.01
140	0.46	0.57	0.74	0.90	1.17	1.43	1.69	2.13	2.72	3.45
150	0.43	0.53	0.68	0.82	1.05	1.28	1.49	1.86	2.35	2.98
160	0.39	0.49	0.63	0.75	0.95	1.15	1.32	1.63	2.05	2.60
170	0.37	0.46	0.58	0.68	0.87	1.04	1.18	1.43	1.80	2.28
180	0.34	0.43	0.54	0.63	0.79	0.94	1.06	1.27	1.58	2.01
190	0.32	0.40	0.50	0.58	0.73	0.85	0.95	1.14	1.40	1.79
200	0.30	0.37	0.47	0.54	0.67	0.78	0.86	1.02	1.25	1.60
210	0.28	0.35	0.43	0.50	0.61	0.71	0.78	0.92	1.12	1.43
220	0.27	0.33	0.41	0.46	0.57	0.66	0.72	0.83	1.01	1.29
230	0.25	0.32	0.38	0.43	0.53	0.60	0.66	0.76	0.91	1.16
240	0.24	0.30	0.36	0.40	0.49	0.56	0.61	0.69	0.83	1.06
250	0.23	0.29	0.34	0.38	0.45	0.52	0.56	0.63	0.75	0.96

= Above atmospheric boiling point

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Table 8: Viscosities (cps) of aqueous solutions of AMBITROL™ NTC Coolant

Temp °F	Volume percent propylene glycol									
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%
-30	–	–	–	–	–	–	497.57	864.87	1363.75	3555.22
-20	–	–	–	–	–	156.08	298.75	493.93	820.58	1819.72
-10	–	–	–	–	–	95.97	182.96	291.28	495.68	983.05
0	–	–	–	–	40.99	61.32	114.90	177.73	303.94	558.32
10	–	–		13.44	27.17	40.62	74.19	112.20	190.41	332.02
20	–	–	5.36	9.91	18.64	27.83	49.29	73.22	122.30	205.91
30	–	2.80	4.23	7.47	13.20	19.66	33.68	49.32	80.66	132.67
40	1.53	2.28	3.41	5.75	9.63	14.28	23.65	34.22	54.64	88.51
50	1.30	1.89	2.79	4.52	7.22	10.65	17.05	24.41	37.99	60.93
60	1.12	1.60	2.32	3.61	5.55	8.13	12.59	17.86	27.10	43.16
70	0.98	1.38	1.95	2.94	4.36	6.34	9.51	13.38	19.79	31.37
80	0.86	1.20	1.66	2.43	3.50	5.04	7.34	10.25	14.79	23.35
90	0.76	1.05	1.43	2.04	2.86	4.08	5.77	8.00	11.29	17.75
100	0.68	0.93	1.25	1.73	2.37	3.35	4.62	6.37	8.79	13.76
110	0.61	0.83	1.10	1.49	2.00	2.79	3.76	5.15	6.97	10.86
120	0.55	0.75	0.97	1.30	1.71	2.36	3.11	4.23	5.62	8.71
130	0.51	0.68	0.87	1.14	1.49	2.02	2.61	3.53	4.60	7.09
140	0.46	0.62	0.78	1.01	1.30	1.75	2.22	2.98	3.82	5.85
150	0.43	0.57	0.71	0.90	1.16	1.53	1.91	2.54	3.22	4.89
160	0.39	0.52	0.64	0.82	1.03	1.35	1.66	2.19	2.75	4.13
170	0.37	0.48	0.59	0.74	0.93	1.20	1.45	1.91	2.37	3.52
180	0.34	0.44	0.54	0.68	0.85	1.08	1.29	1.69	2.07	3.04
190	0.32	0.41	0.50	0.62	0.78	0.97	1.15	1.50	1.82	2.64
200	0.30	0.38	0.46	0.58	0.72	0.88	1.04	1.34	1.61	2.31
210	0.28	0.36	0.43	0.54	0.67	0.81	0.94	1.21	1.45	2.04
220	0.27	0.34	0.40	0.50	0.62	0.74	0.86	1.10	1.31	1.82
230	0.25	0.32	0.38	0.47	0.59	0.69	0.79	1.00	1.19	1.63
240	0.24	0.30	0.36	0.45	0.55	0.64	0.73	0.92	1.09	1.47
250	0.23	2.28	0.34	0.42	0.52	0.59	0.68	0.85	1.00	1.33

= Above atmospheric boiling point

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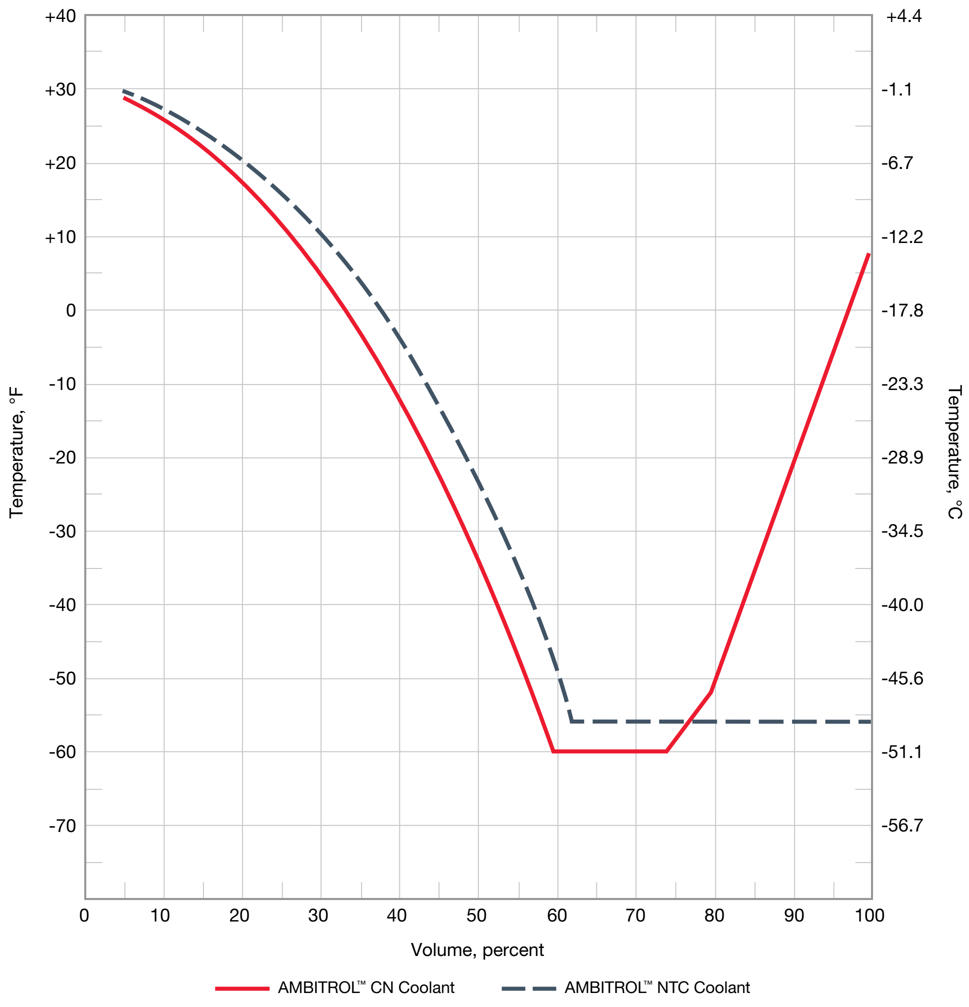
Freezing point

The freezing points for glycols are the temperatures at which ice crystals first form. Below these temperatures, a slushy solution of glycol ice crystals and liquid will still permit flow and provide coolant protection. However, as the temperature decreases, the slush becomes more and more viscous until solid freezing takes place.

Figure 3: Freezing points of aqueous solutions of AMBITROL™ products



Comparison of densities for aqueous solutions of AMBITROL™ CN and NTC Coolants

Density is a measure of weight-per-unit volume of mass. This relationship typically changes with varying temperatures and concentrations. For example, the densities of a solution of AMBITROL™ NTC Coolant may be the same for two concentrations. So, density alone is not a reliable measure for determining the concentration of a solution of AMBITROL™ NTC Coolant. In contrast, density can be used alone to determine the concentration of a solution of AMBITROL™ CN Coolant, providing that the temperature of the solution is known.

The data plotted here show the densities of given solutions, but it may also be necessary to know the specific gravities of the solutions at certain temperatures. The specific gravity is obtained by dividing the density of the glycol or glycol-water solution by the density of water. Because densities and specific gravities vary with temperature, however, it is necessary to indicate the temperature of both the glycol and the water.

Specific gravities can, therefore, be expressed at given temperatures as follows:

AMBITROL™ CN Coolant at "X"°F/"Y"°F =

$$\frac{\text{Density of AMBITROL™ at "X"°F}}{\text{Density of water at "Y"°F}}$$

For example, the specific gravity of 50% (by volume) solution of ethylene glycol (the density of which is 67.20 lb/ft^3 at 60°F [15°C]) is found by dividing this value by 62.34 lb/ft^3 (the density of water at 60°F [15°C]). So we have:

$$\text{Specific gravity at 60/60ºF} = \frac{67.20\ \text{lb/ft}^3}{62.34\ \text{lb/ft}^3} = 1.078$$

Using the specific gravity for solutions of AMBITROL™ from Tables 5 and 6 (pages 17 and 19), the density of the solution can be determined using these conversions:

Specific gravity x 1 = gm/ml

Specific gravity x 62.34 = lb/ft^3

Specific gravity x 8.334 = lb/gal

Finally, volume changes caused by heating or cooling the glycol solutions may be determined by comparing the density change over the temperature range. For example, the volume change of a 50% ethylene glycol solution between 70°F (21°C) and 140°F (60°C):

$$\frac{67.05\ \text{lb/ft}^3}{65.75\ \text{lb/ft}^3} = 1.0198 \text{ or } 2.0\% \text{ vol increase}$$

Table 9: Densities (lb/ft³) of aqueous solutions of AMBITROL™ CN Coolant

Temp °F	Volume percent ethylene glycol									
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%
-30	–	–	–	–	–	–	69.03	69.90	70.75	–
-20	–	–	–	–	–	68.05	68.96	68.82	70.65	71.45
-10	–	–	–	–	–	67.98	68.87	69.72	70.54	71.33
0	–	–	–	–	66.97	67.90	68.78	69.62	70.43	71.20
10	–	–	–	65.93	66.89	67.80	68.67	69.50	70.30	71.06
20	–	–	64.83	65.85	66.80	67.70	68.56	69.38	70.16	70.92
30	–	63.69	64.75	65.76	66.70	67.59	68.44	69.25	70.02	70.76
40	62.42	63.61	64.66	65.66	66.59	67.47	68.31	69.10	69.86	70.59
50	62.38	63.52	64.56	65.55	66.47	67.34	68.17	68.95	69.70	70.42
60	62.34	63.42	64.45	65.43	66.34	67.20	68.02	68.79	69.53	70.23
70	62.27	63.31	64.33	65.30	66.20	67.05	67.86	68.62	69.35	70.04
80	62.19	63.19	64.21	65.17	66.05	66.90	67.69	68.44	69.15	69.83
90	62.11	63.07	64.07	65.02	65.90	66.73	67.51	68.25	68.95	69.62
100	62.00	62.93	63.93	64.86	65.73	66.55	67.32	68.05	68.74	69.40
110	61.84	62.79	63.77	64.70	65.56	66.37	67.13	67.84	68.52	69.17
120	61.73	62.63	63.61	64.52	65.37	66.17	66.92	67.63	68.29	68.92
130	61.54	62.47	63.43	64.34	65.18	65.97	66.71	67.40	68.05	68.67
140	61.39	62.30	63.25	64.15	64.98	65.75	66.48	67.16	67.81	68.41
150	61.20	62.11	63.06	63.95	64.76	65.53	66.25	66.92	67.55	68.14
160	61.01	61.92	62.86	63.73	64.54	65.30	66.00	66.66	67.28	67.86
170	60.79	61.72	62.64	63.51	64.31	65.05	65.75	66.40	67.01	67.58
180	60.57	61.51	62.42	63.28	64.07	64.80	65.49	66.12	66.72	67.28
190	60.35	61.29	62.19	63.04	63.82	64.54	65.21	65.84	66.42	66.97
200	60.13	61.06	61.95	62.79	63.56	64.27	64.93	65.55	66.12	66.65
210	59.88	60.82	61.71	62.53	63.29	63.99	64.64	65.24	65.81	66.33
220	59.63	60.57	61.45	62.27	63.01	63.70	64.34	64.93	65.48	65.99
230	59.38	60.31	61.18	61.99	62.72	63.40	64.03	64.61	65.15	65.65
240	59.10	60.05	60.90	61.70	62.43	63.10	63.71	64.28	64.81	65.29
250	58.82	59.77	60.62	61.40	62.12	62.78	63.39	63.94	64.46	64.93

= Above atmospheric boiling point

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Table 10: Densities (lb/ft³) of aqueous solutions of AMBITROL™ NTC Coolant

Temp °F	Volume percent propylene glycol									
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%
-30	–	–	–	–	–	–	67.05	67.47	68.38	68.25
-20	–	–	–	–	–	66.46	66.93	67.34	68.13	68.00
-10	–	–	–	–	–	66.35	66.81	67.20	67.87	67.75
0	–	–	–	–	65.71	66.23	66.68	67.05	67.62	67.49
10	–	–	–	65.00	65.60	66.11	66.54	66.89	67.36	67.23
20	–	–	64.23	64.90	65.48	65.97	66.38	66.72	67.10	66.97
30	–	63.38	64.14	64.79	65.35	65.82	66.22	66.54	66.83	66.71
40	62.42	63.30	64.03	64.67	65.21	65.67	66.05	66.35	66.57	66.44
50	62.38	63.20	63.92	64.53	65.06	65.50	65.87	66.16	66.30	66.18
60	62.34	63.10	63.79	64.39	64.90	65.33	65.68	65.95	66.04	65.91
70	62.27	62.98	63.66	64.24	64.73	65.14	65.47	65.73	65.77	65.64
80	62.19	62.86	63.52	64.08	64.55	64.95	65.26	65.51	65.49	65.37
90	62.11	62.73	63.37	63.91	64.36	64.74	65.04	65.27	65.22	65.09
100	62.00	62.59	63.20	63.73	64.16	64.53	64.81	65.03	64.95	64.82
110	61.84	62.44	63.03	63.54	63.95	64.30	64.57	64.77	64.67	64.54
120	61.73	62.28	62.85	63.33	63.74	64.06	64.32	64.51	64.39	64.26
130	61.54	62.11	62.66	63.12	63.51	63.82	64.06	64.23	64.11	63.98
140	61.39	61.93	62.46	62.90	63.27	63.57	63.79	63.95	63.83	63.70
150	61.20	61.74	62.25	62.67	63.02	63.30	63.51	63.66	63.55	63.42
160	61.01	61.54	62.03	62.43	62.76	63.03	63.22	63.35	63.26	63.13
170	60.79	61.33	61.80	62.18	62.49	62.74	62.92	63.04	62.97	62.85
180	60.57	61.11	61.56	61.92	62.22	62.45	62.61	62.72	62.68	62.56
190	60.35	60.89	61.31	61.65	61.93	62.14	62.29	62.39	62.39	62.27
200	60.13	60.65	61.05	61.37	61.63	61.83	61.97	62.05	62.10	61.97
210	59.88	60.41	60.78	61.08	61.32	61.50	61.63	61.69	61.81	61.68
220	59.63	60.15	60.50	60.78	61.00	61.17	61.28	61.33	61.51	61.38
230	59.38	59.89	60.21	60.47	60.68	60.83	60.92	60.96	61.21	61.08
240	59.10	59.61	59.91	60.15	60.34	60.47	60.55	60.58	60.91	60.78
250	58.82	59.33	59.60	59.82	59.99	60.11	60.18	60.19	60.61	60.48

= Above atmospheric boiling point

Specific heat

The specific heat of a substance is the amount of energy required to raise one gram of a substance one degree centigrade. This value is expressed as Btu/lb/°F or cal/g/°C. At room temperature 22°F (-5°C), the specific heat of water is about 1.0. The specific heats of glycol vary with the temperature as shown here. As you might suspect, the specific heat of a glycol solution increases with increasing water concentration.

Table 11: Specific heat (Btu/lb•°F) of aqueous solutions of AMBITROL™ CN Coolant

Temp °F	Volume percent ethylene glycol									
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%
-30	–	–	–	–	–	–	0.680	0.625	0.567	–
-20	–	–	–	–	–	0.739	0.686	0.631	0.574	0.515
-10	–	–	–	–	–	0.744	0.692	0.638	0.581	0.523
0	–	–	–	–	0.799	0.749	0.698	0.644	0.588	0.530
10	–	–	–	0.849	0.803	0.754	0.703	0.651	0.595	0.538
20	–	–	0.897	0.853	0.808	0.759	0.709	0.657	0.603	0.546
30	–	0.940	0.900	0.857	0.812	0.765	0.715	0.664	0.610	0.553
40	1.004	0.943	0.903	0.861	0.816	0.770	0.721	0.670	0.617	0.561
50	1.001	0.945	0.906	0.864	0.821	0.775	0.727	0.676	0.624	0.569
60	1.000	0.947	0.909	0.868	0.825	0.780	0.732	0.683	0.631	0.576
70	0.999	0.950	0.912	0.872	0.830	0.785	0.738	0.689	0.638	0.584
80	0.998	0.952	0.915	0.876	0.834	0.790	0.744	0.696	0.645	0.592
90	0.998	0.954	0.918	0.880	0.839	0.795	0.750	0.702	0.652	0.600
100	0.998	0.957	0.922	0.883	0.843	0.800	0.756	0.709	0.659	0.607
110	0.998	0.959	0.925	0.887	0.848	0.806	0.761	0.715	0.666	0.615
120	0.998	0.961	0.928	0.891	0.852	0.811	0.767	0.721	0.673	0.623
130	0.999	0.964	0.931	0.895	0.857	0.816	0.773	0.728	0.680	0.630
140	0.999	0.966	0.934	0.898	0.861	0.821	0.779	0.734	0.687	0.638
150	1.000	0.968	0.937	0.902	0.865	0.826	0.785	0.741	0.694	0.646
160	1.001	0.971	0.940	0.906	0.870	0.831	0.790	0.747	0.702	0.654
170	1.002	0.973	0.943	0.910	0.874	0.836	0.796	0.754	0.709	0.661
180	1.003	0.975	0.946	0.913	0.879	0.842	0.802	0.760	0.716	0.669
190	1.004	0.978	0.949	0.917	0.883	0.847	0.808	0.766	0.723	0.677
200	1.005	0.980	0.952	0.921	0.888	0.852	0.813	0.773	0.730	0.684
210	1.007	0.982	0.955	0.925	0.892	0.857	0.819	0.779	0.737	0.692
220	1.008	0.985	0.958	0.929	0.897	0.862	0.825	0.786	0.744	0.700
230	1.010	0.987	0.961	0.932	0.901	0.867	0.831	0.792	0.751	0.708
240	1.012	0.989	0.964	0.936	0.905	0.872	0.837	0.799	0.758	0.715
250	1.014	0.992	0.967	0.940	0.910	0.877	0.842	0.805	0.765	0.723

= Above atmospheric boiling point

Table 12: Specific heat (Btu/lb•°F) of aqueous solutions of AMBITROL™ NTC Coolant

Temp °F	Volume percent propylene glycol									
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%
-30	–	–	–	–	–	–	0.741	0.680	0.615	0.542
-20	–	–	–	–	–	0.799	0.746	0.687	0.623	0.550
-10	–	–	–	–	–	0.804	0.752	0.693	0.630	0.558
0	–	–	–	–	0.855	0.809	0.758	0.700	0.637	0.566
10	–	–	–	0.898	0.859	0.814	0.764	0.707	0.645	0.574
20	–	–	0.936	0.902	0.864	0.820	0.770	0.713	0.652	0.583
30	–	0.966	0.938	0.906	0.868	0.825	0.776	0.720	0.660	0.591
40	1.004	0.968	0.941	0.909	0.872	0.830	0.782	0.726	0.667	0.599
50	1.001	0.970	0.944	0.913	0.877	0.835	0.787	0.733	0.674	0.607
60	1.000	0.972	0.947	0.917	0.881	0.840	0.793	0.740	0.682	0.615
70	0.999	0.974	0.950	0.920	0.886	0.845	0.799	0.746	0.689	0.623
80	0.998	0.976	0.953	0.924	0.890	0.850	0.805	0.753	0.696	0.631
90	0.998	0.979	0.956	0.928	0.894	0.855	0.811	0.760	0.704	0.639
100	0.998	0.981	0.959	0.931	0.899	0.861	0.817	0.766	0.711	0.647
110	0.998	0.983	0.962	0.935	0.903	0.866	0.823	0.773	0.718	0.656
120	0.998	0.985	0.965	0.939	0.908	0.871	0.828	0.779	0.726	0.664
130	0.999	0.987	0.967	0.942	0.912	0.876	0.834	0.786	0.733	0.672
140	0.999	0.989	0.970	0.946	0.916	0.881	0.840	0.793	0.740	0.680
150	1.000	0.991	0.973	0.950	0.921	0.886	0.846	0.799	0.748	0.688
160	1.001	0.993	0.976	0.953	0.925	0.891	0.852	0.806	0.755	0.696
170	1.002	0.995	0.979	0.957	0.929	0.896	0.858	0.812	0.762	0.704
180	1.003	0.996	0.982	0.961	0.934	0.902	0.864	0.819	0.770	0.712
190	1.004	0.998	0.985	0.964	0.938	0.907	0.869	0.826	0.777	0.720
200	1.005	1.000	0.988	0.968	0.943	0.912	0.875	0.832	0.784	0.729
210	1.007	1.002	0.991	0.971	0.947	0.917	0.881	0.839	0.792	0.737
220	1.008	1.003	0.994	0.975	0.951	0.922	0.887	0.845	0.799	0.745
230	1.010	1.005	0.996	0.979	0.956	0.927	0.893	0.852	0.806	0.753
240	1.012	1.007	0.999	0.982	0.960	0.932	0.899	0.859	0.814	0.761
250	1.014	1.009	1.002	0.986	0.965	0.937	0.905	0.865	0.821	0.769

= Above atmospheric boiling point

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Thermal conductivity

Energy loss is a surface phenomenon. Thermal conductivity is a measure of the rate at which a substance (in this case, AMBITROL™ Coolant Fluids) can conduct heat away from a surface of a given size above ambient temperature. Water (deionized) has the highest thermal conductivity.

Table 13: Thermal conductivity (Btu/(hr•ft²)(°F/ft) of aqueous solutions of AMBITROL™ CN Coolant

Temp °F	Volume percent ethylene glycol									
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%
-30	–	–	–	–	–	–	0.178	0.167	0.158	–
-20	–	–	–	–	–	0.193	0.181	0.170	0.160	0.151
-10	–	–	–	–	–	0.197	0.184	0.172	0.161	0.152
0	–	–	–	–	0.216	0.200	0.186	0.174	0.163	0.153
10	–	–	–	0.238	0.220	0.204	0.189	0.176	0.164	0.154
20	–	–	0.264	0.243	0.224	0.207	0.191	0.178	0.166	0.155
30	–	0.294	0.269	0.247	0.227	0.210	0.194	0.180	0.167	0.156
40	0.328	0.300	0.274	0.251	0.231	0.212	0.196	0.182	0.169	0.157
50	0.335	0.305	0.279	0.255	0.234	0.215	0.198	0.183	0.170	0.158
60	0.341	0.311	0.284	0.259	0.237	0.218	0.200	0.185	0.171	0.159
70	0.347	0.316	0.288	0.263	0.240	0.220	0.202	0.186	0.172	0.160
80	0.352	0.320	0.292	0.266	0.243	0.223	0.204	0.188	0.173	0.161
90	0.358	0.325	0.296	0.269	0.246	0.225	0.206	0.189	0.174	0.161
100	0.362	0.329	0.299	0.272	0.248	0.227	0.208	0.190	0.175	0.162
110	0.367	0.333	0.302	0.275	0.251	0.229	0.209	0.192	0.176	0.163
120	0.371	0.336	0.305	0.277	0.253	0.230	0.210	0.193	0.177	0.163
130	0.374	0.339	0.308	0.280	0.255	0.232	0.212	0.194	0.178	0.164
140	0.378	0.342	0.311	0.282	0.256	0.233	0.213	0.195	0.179	0.165
150	0.381	0.345	0.313	0.284	0.258	0.235	0.214	0.196	0.180	0.165
160	0.384	0.347	0.315	0.285	0.259	0.236	0.215	0.197	0.180	0.166
170	0.386	0.349	0.316	0.287	0.261	0.237	0.216	0.197	0.181	0.166
180	0.388	0.351	0.318	0.288	0.262	0.238	0.217	0.198	0.181	0.167
190	0.389	0.352	0.319	0.289	0.263	0.239	0.218	0.199	0.182	0.167
200	0.391	0.353	0.320	0.290	0.263	0.240	0.218	0.199	0.182	0.168
210	0.391	0.354	0.321	0.291	0.264	0.240	0.219	0.200	0.183	0.168
220	0.392	0.355	0.321	0.291	0.265	0.240	0.219	0.200	0.183	0.168
230	0.392	0.355	0.322	0.291	0.265	0.241	0.219	0.200	0.183	0.169
240	0.392	0.355	0.322	0.291	0.265	0.241	0.219	0.200	0.184	0.169
250	0.392	0.354	0.321	0.291	0.265	0.241	0.220	0.201	0.184	0.169

= Above atmospheric boiling point

Table 14: Thermal conductivity (Btu/(hr•ft²)(°F/ft) of aqueous solutions of AMBITROL™ NTC Coolant

Temp °F	Volume percent propylene glycol									
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%
-30	–	–	–	–	–	–	0.171	0.159	0.147	0.137
-20	–	–	–	–	–	0.188	0.174	0.160	0.148	0.137
-10	–	–	–	–	–	0.191	0.176	0.161	0.148	0.136
0	–	–	–	–	0.211	0.194	0.178	0.162	0.149	0.136
10	–	–	–	0.235	0.215	0.196	0.179	0.163	0.149	0.136
20	–	–	0.262	0.239	0.218	0.199	0.181	0.164	0.150	0.136
30	–	0.293	0.267	0.243	0.222	0.201	0.183	0.165	0.150	0.135
40	0.328	0.299	0.272	0.247	0.225	0.204	0.184	0.166	0.150	0.135
50	0.335	0.304	0.277	0.251	0.227	0.206	0.186	0.167	0.150	0.135
60	0.341	0.310	0.281	0.254	0.230	0.208	0.187	0.168	0.150	0.134
70	0.347	0.315	0.285	0.258	0.233	0.210	0.188	0.168	0.151	0.134
80	0.352	0.319	0.289	0.261	0.235	0.211	0.189	0.169	0.151	0.134
90	0.358	0.323	0.292	0.263	0.237	0.213	0.190	0.169	0.151	0.133
100	0.362	0.327	0.295	0.266	0.239	0.214	0.191	0.170	0.151	0.133
110	0.367	0.331	0.298	0.268	0.241	0.215	0.192	0.170	0.151	0.132
120	0.371	0.334	0.301	0.270	0.243	0.217	0.193	0.170	0.150	0.132
130	0.374	0.338	0.304	0.272	0.244	0.218	0.193	0.170	0.150	0.131
140	0.378	0.340	0.306	0.274	0.245	0.218	0.194	0.171	0.150	0.131
150	0.381	0.343	0.308	0.276	0.246	0.219	0.194	0.171	0.150	0.130
160	0.384	0.345	0.309	0.277	0.247	0.220	0.194	0.171	0.150	0.130
170	0.386	0.347	0.311	0.278	0.248	0.220	0.195	0.171	0.149	0.129
180	0.388	0.348	0.312	0.279	0.249	0.221	0.195	0.170	0.149	0.129
190	0.389	0.350	0.313	0.280	0.249	0.221	0.195	0.170	0.148	0.128
200	0.391	0.351	0.314	0.280	0.249	0.221	0.194	0.170	0.148	0.127
210	0.391	0.351	0.314	0.280	0.249	0.221	0.194	0.169	0.147	0.127
220	0.392	0.352	0.314	0.280	0.249	0.220	0.194	0.169	0.147	0.126
230	0.392	0.352	0.314	0.280	0.249	0.220	0.193	0.168	0.146	0.125
240	0.392	0.351	0.314	0.280	0.249	0.220	0.193	0.168	0.146	0.125
250	0.392	0.351	0.314	0.279	0.248	0.219	0.192	0.167	0.145	0.124

= Above atmospheric boiling point

Engineering data for determining heat transfer

This section contains helpful information about film coefficients and pressure drop in pipes for aqueous solutions of AMBITROL™ CN and AMBITROL™ NTC Coolants and for water.

Film coefficients

The overall film coefficient (U) must be determined in order to evaluate the heat transfer surface required in the system. The overall heat transfer coefficient may be expressed by the following equation:

$q = UA\Delta t_{LM}$

Because solutions of AMBITROL™ coolants have heat transfer properties different from those of plain water, they typically have lower film coefficients under equivalent flow conditions. This may affect the design and operation of the system, depending on factors such as the heat transfer coefficient of the material being heated or cooled.

The overall film coefficient is influenced by the fluid film heat transfer rates on each side of the tube (h and h_o), and the resistance through the tube wall (r_f) and the fouling factor (r_w). In terms of these individual factors, the following equation can be written:

$1/U = 1/h_i + 1/h_o + r_w + r_f$

If one film coefficient is small and the other very large, the smaller coefficient provides the major resistance to heat flow. The overall film coefficient for the equipment is very nearly equal to the smaller of the "controlling" film coefficients. This is the usual situation for AMBITROL™ coolants where air flow on the outside of a fin fan cooler has a much lower heat transfer coefficient than does AMBITROL™ coolants and, therefore, controls the overall coefficient.

Liquid film coefficients for 50% solutions of AMBITROL™ CN and AMBITROL™ NTC Coolants are shown in Figures 4 and 5.

Figure 4: Liquid film coefficients for 50% volume AMBITROL™ NTC Coolant inside pipes and tubes (turbulent flow only)

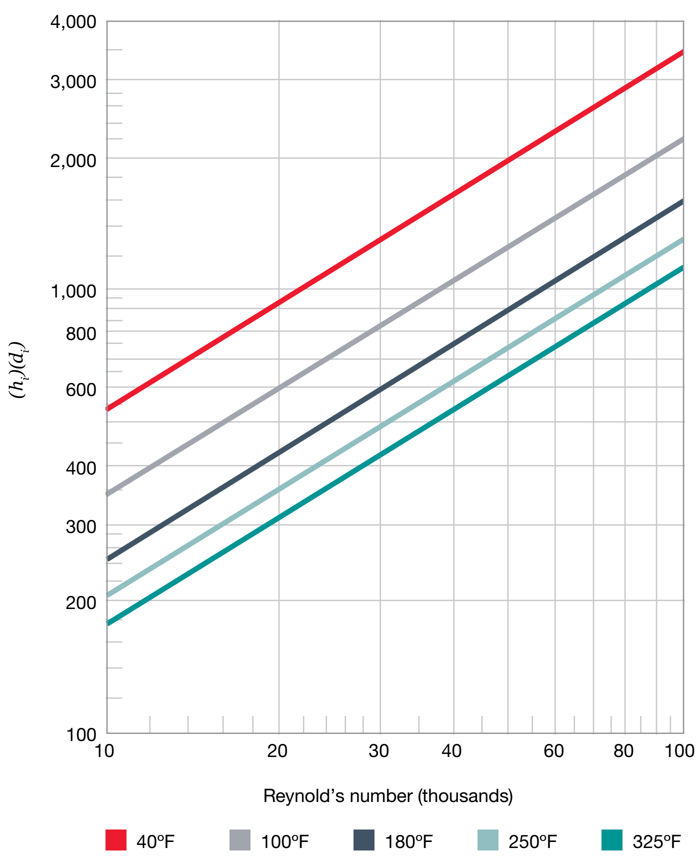
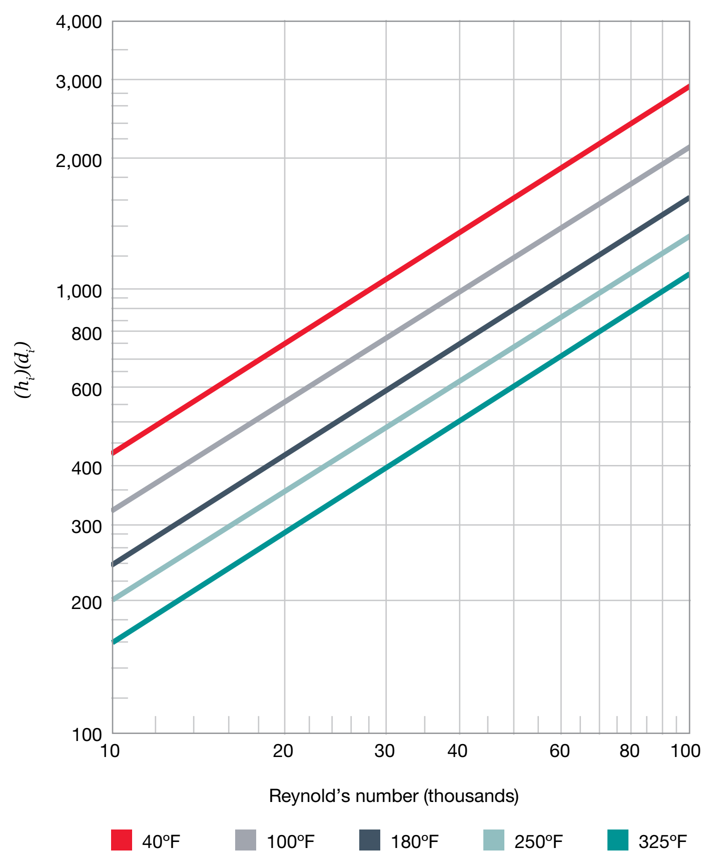


Figure 5: Liquid film coefficients for 50% volume AMBITROL™ CN Coolant inside pipes and tubes (turbulent flow only)



These film coefficients are based on the Sieder and Tate correlating equation:

$Nu = 0.027\ Re^{0.8}\ PR^{0.33}\ (\mu/\mu_w)^{0.14}$

Where,

$Re = 300\ dG/\mu = 300\ dv\rho/\mu$

$Pr = C_p\ \mu/k$

$Nu = hd/12\ k$

The film coefficients in this brochure are based on the assumption that:

$(\mu/\mu_w)^{0.14} = 1$

This correlation holds only for turbulent flow and should not be used for reynolds numbers less than 10,000.

Table 15: Nomenclature and symbols

Symbol	Meaning	Unit
A	Heat transfer surface area	ft^2
Cp	Specific heat	Btu/lb•°F
d	Diameter	inch
f	Friction factor	ft^2/in^2
G	Mass velocity	lb/sec•ft^2
h	Average film coefficient	Btu/(hr•ft^2•°F)
k	Thermal conductivity	Btu/(hr•ft^2)(°F/ft)
Q	Flow rate	gal/min
q	Heat flow	Btu/hr
r	Tube resistance	(hr•ft^2•°F)/Btu
U	Overall heat transfer coefficient	Btu/(hr•ft^2•°F)
v	Fluid velocity	ft/sec
Nu	Nusselt number	–
Pr	Prandtl number	–
ΔP	Pressure drop	psi
Δt_{LM}	Log mean temperature difference	°F
μ	Viscosity (cps × 2.42) = lb/(hr•ft)	lb/(hr•ft)
ρ	Density	lb/ft^3
Re	Reynolds number (122.85 Qρ/dμ)	Dimensionless

Table 16: Subscripts

Symbol	Meaning
f	Fouling
i	Inside
o	Outside
w	Wall

Pressure drop

When a fluid flows over a stationary or moving surface, the pressure of the fluid decreases along the surface due to friction. This is called the pressure drop of the system. The Darcy equation for pressure drop of fluids in turbulent flow is:

$P_{100} = 0.1294 f \rho v^2/d = 0.0216 f \rho Q^2/d^5$

Values of f may be obtained from f versus reynolds number plotss given in standard texts.

Figure 6: Pressure drop vs. flow rate of 50% volume AMBITROL™ NTC Coolant

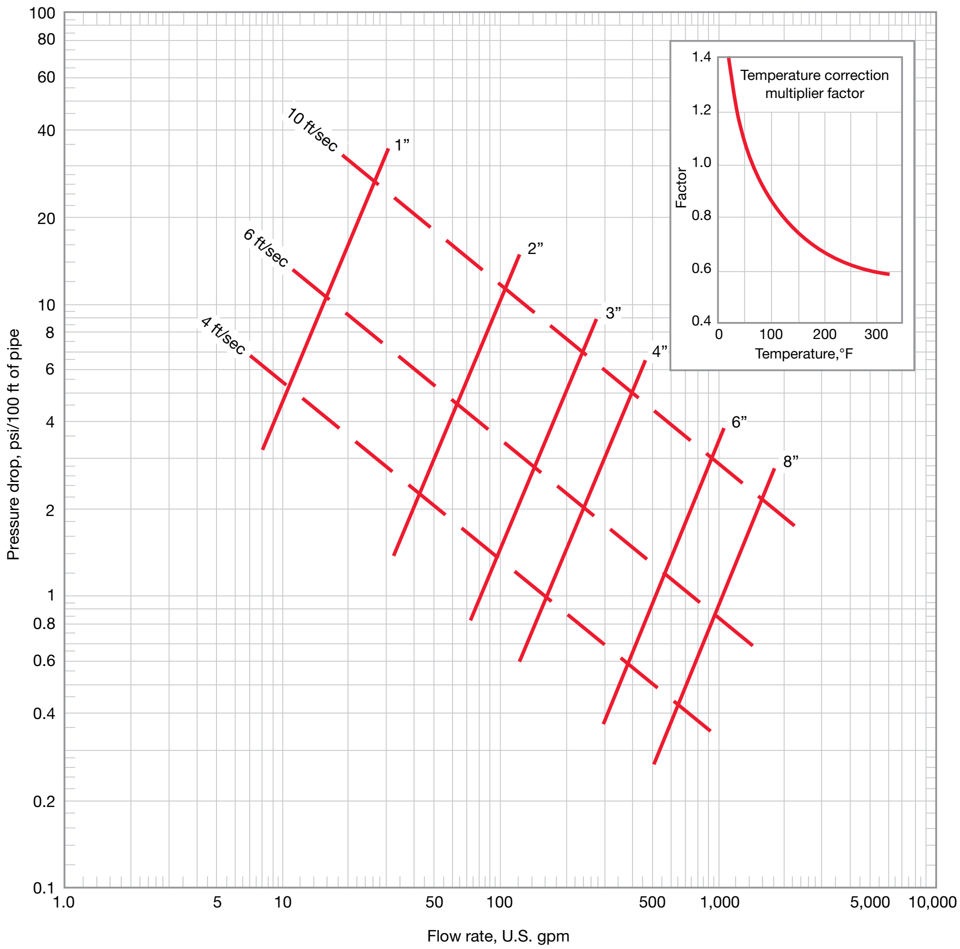
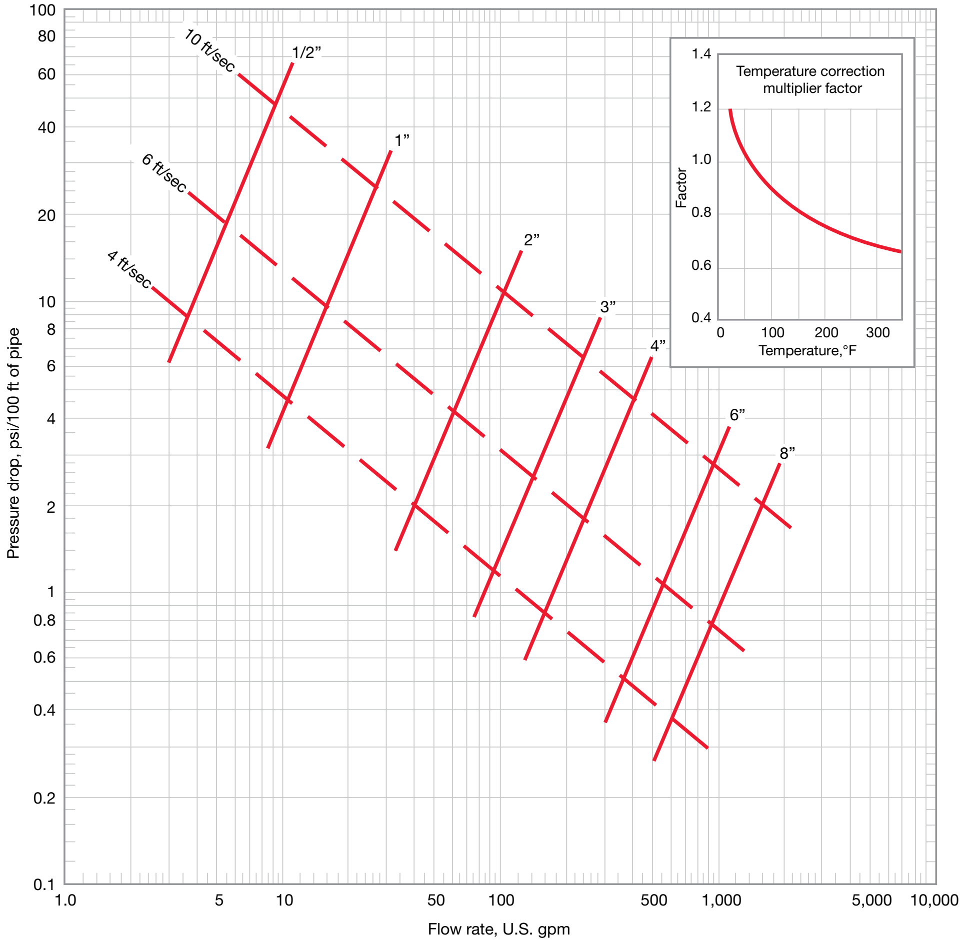


Figure 7: Pressure drop vs. flow rate of 50% volume AMBITROL™ CN Coolant



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