



# PIPE CORROSION — IT'S NOT JUST ABOUT RUSTY PIPES

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Jim has been involved with industrial refrigeration for more than 35 years. He began as a plant operator, then joined a contracting company and has worked in contracting for most of those 35 years. For the past six years, I have worked in the design of refrigerated distribution facilities, food processing plants and other applications that involve refrigeration.

He has been an active member of RSES for 35 years and completed the training course and passed the Certified Mechanics Test. He completed a two year apprenticeship program as a plant operator and worked for five years as a chief operator. He is a member of RETA and currently serve as DFW Chapter President, works with the Certification Committee and is a member of the national Board of Directors.

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# Corrosion: Not Just Rusty Pipes

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For the RETA National Conference  
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## Corrosion: Not Just Rusty Pipes

When we think of corrosion what do we think of, rusty pipes and vessels. That is right; we are talking about rusty stuff. But we want to look a little deeper and not only talk about what causes it, but how does it really affect the performance of the piping system. We are not going to talk too much about vessels; they have other issues that I really do not want to address in this paper. We are going to concentrate on piping, not just rusty pipes but what other issues may be created by “rusty pipes.”

My interest in corrosion came from visits to plants and seeing pipe in an advanced state of deterioration, see below. I had to think, “It looks bad; but is it really bad or can the rust be knocked off, and the pipe repainted?” Well, that what we are going to discuss. As I do in evaluating systems, I am not going to reach any conclusions; you make the decision based on the evidence.





First, of course, we have to talk a little science. What is Corrosion?

There are papers and books about it; all day seminars on how to prevent it; organizations dedicated to it; Federal Specifications that define, analyze, tell how to prevent it; and a lot of other highly interesting and important information about Corrosion. Believe it or not almost anything can corrode, including glass and ceramics. Usually we think of ferrous metal that is exposed to the elements or that is in a wet environment rusting and corroding. In general for rust to occur there must be a flow of ions. Believe it or not, what occurs to create rust is somewhat similar to what occurs in a typical battery, there is a flow of electrons from one area to another. For this to occur there must be an anode, a cathode, an electrolyte, and an electrical path. The anode, cathode and electrical path are inherent in the pipe used to construct an industrial refrigeration system. When we think of corrosive substances we usually think of acids, and alkalis, and salts, but the last component needed for corrosion, the electrolyte, is water that accumulates in the insulation or on exposed piping and vessels. If other chemicals combine with the water, the electrolytic strength can be increased, which in turn increases the speed of corrosion.

I do not want to spend a lot time talking about the science of corrosion, but there is one form of corrosion I would like to mention, Poultrice Corrosion. This is one my favorite because it conjures up memories of some of my relatives back in the hills of Southern Ohio. This is a term that the automotive industry is familiar with. We old timers, most of us anyway, know what a poultice is; it is type of compress that is use for home cures. A lump of herbs or some other blend of remedies is moistened and place on a wound or affected area. The idea is to keep the compress in contact with the wound or affected area. In corrosion this is facilitated when a clump of dirt or debris; or other moisture retaining material gets into an area and is wetted. In the case of a car by road water or at the car wash. The electrolyte is maintained and the corrosion process is enhanced. Think about it, in our industry where might we experience this type of condition? Does this seem to be a lot like what happens under wet insulation? A piping system, especially on a high temperature system, that has had a failure of the vapor barrier system is the perfect laboratory for poultice corrosion.

Pipe that is subjected to temperature cycling such as a defrost relief piping, (see Figure 1) is of particular concern because it corrodes at a much greater rated than pipe in a constant temperature application. So it needs to receive additional preparation and maintenance to ensure that it does not deteriorate at a rate that is not acceptable.

Oddly enough, piping that is encased with ice does not seem to experience this problem. In my experience I have seen pipe that is twenty years old, encased in ice for fifteen years and when the insulation is removed it is like new; see Figure 1 and Figure 2. In one system the existing thirteen year old piping encased in ice looked better then the new piping being tied into it. I do not, however, recommend letting piping become encased in ice, this can create other issues of a serious nature like stress on the building structure.

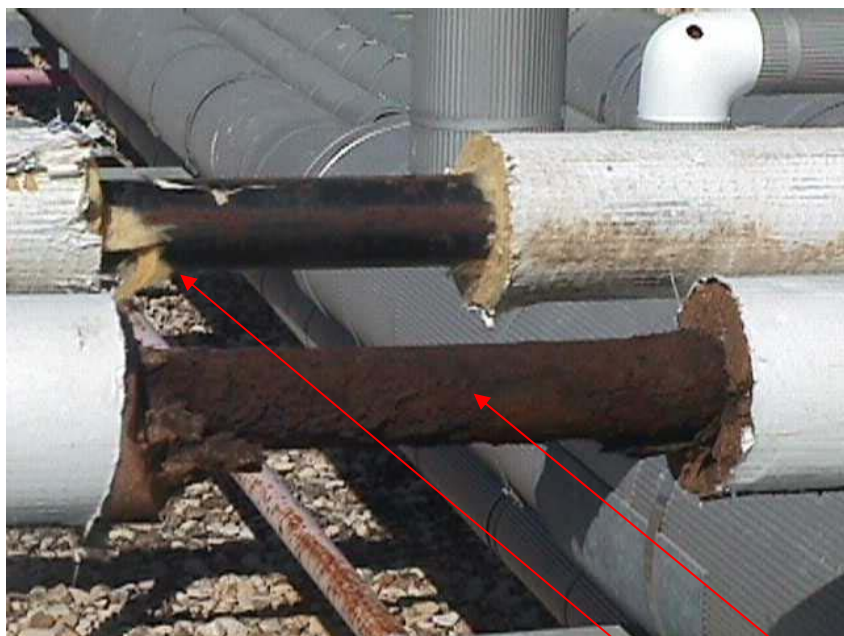


Figure 1

DEFROST RELIEF PIPING

LOW TEMP SUCTION



Figure 2

One other type of corrosion worth a mention before we move on is galvanic corrosion. Typically, dissimilar metal connections are not found in industrial refrigeration applications, particularly in ammonia systems. However, in systems using aluminum coils, copper coils, or copper pipe dissimilar metal connections can occur. When this does occur, corrosion can be accelerated. The corrosion is usually localized to the immediate area of the dissimilar metal connection. Copper cannot be used in ammonia systems, but may be used in large HCFC and HFC systems.

The compounds that are used in some insulation, such as chloride, chlorine compounds, and sulfur accelerate the corrosion process when they leach out and combine with the water in the insulation. The materials that are used to insulate pipe, and to provide vapor barrier must be carefully selected not only for their thermal and vapor resistant property; but also considering the compounds used in manufacturing. Some very good insulations have extremely adverse effects on the piping material.

Another major consideration for insulation is the water absorption characteristics. An insulation that has a high insulating value but a high water absorption value is less desirable than an insulation with a lower insulating value and low water absorption value. With the products available on the market today there is no reason you cannot have good insulation value and good water absorption characteristics in a single product.

The major problem with corrosion is that it reduces the base metal. Steel molecules are lost from the area of the cathode and combine with oxygen to form an oxide that is deposited in the area of the anode. This loss of material causes pitting in the pipe material. So the question becomes, how much of the original thickness can be lost before the pipe may fail? Another question is what is the more critical consideration, pressure containment or structural strength?

Certainly it is very important to keep the refrigerant inside the pipe, so we must be sure that the pipe has adequate strength to resist the pressure without bursting. Fortunately, the pipe wall thickness can be quite thin and still be capable of containing the pressure. The reality is that typically, the pressures experienced in most refrigeration systems are relatively low. As an example assume:

- The refrigerant is ammonia
- 6" pipe, SA 53 B seamless, schedule 40 with a nominal wall thickness of .28
- A 25% corrosion/erosion allowance = .07" loss of material over the useful life of the pipe
- System design pressure 250 psig (the piping system has to be designed to match the pressure of the vessel to which it is connected)
- It is used in the suction line, +20°F at 33.5 PSIG

Based on ASME B31.5, the pipe has an allowable stress of 15,000 PSI.

The calculated minimum allowable wall thickness is **.12"** based on the following calculations:

$$t_m = t + c \quad (\text{equation 1})$$

$t_m$  = minimum thickness required

$t$  = pressure design thickness from equation 2

$c$  = (for internal pressure) sum in inches of the corrosion and erosion allowances

$$t = \frac{PD_o}{2S} \quad (\text{equation 2})$$

$P$  = internal design pressure

$D_o$  = outside diameter of pipe in inches

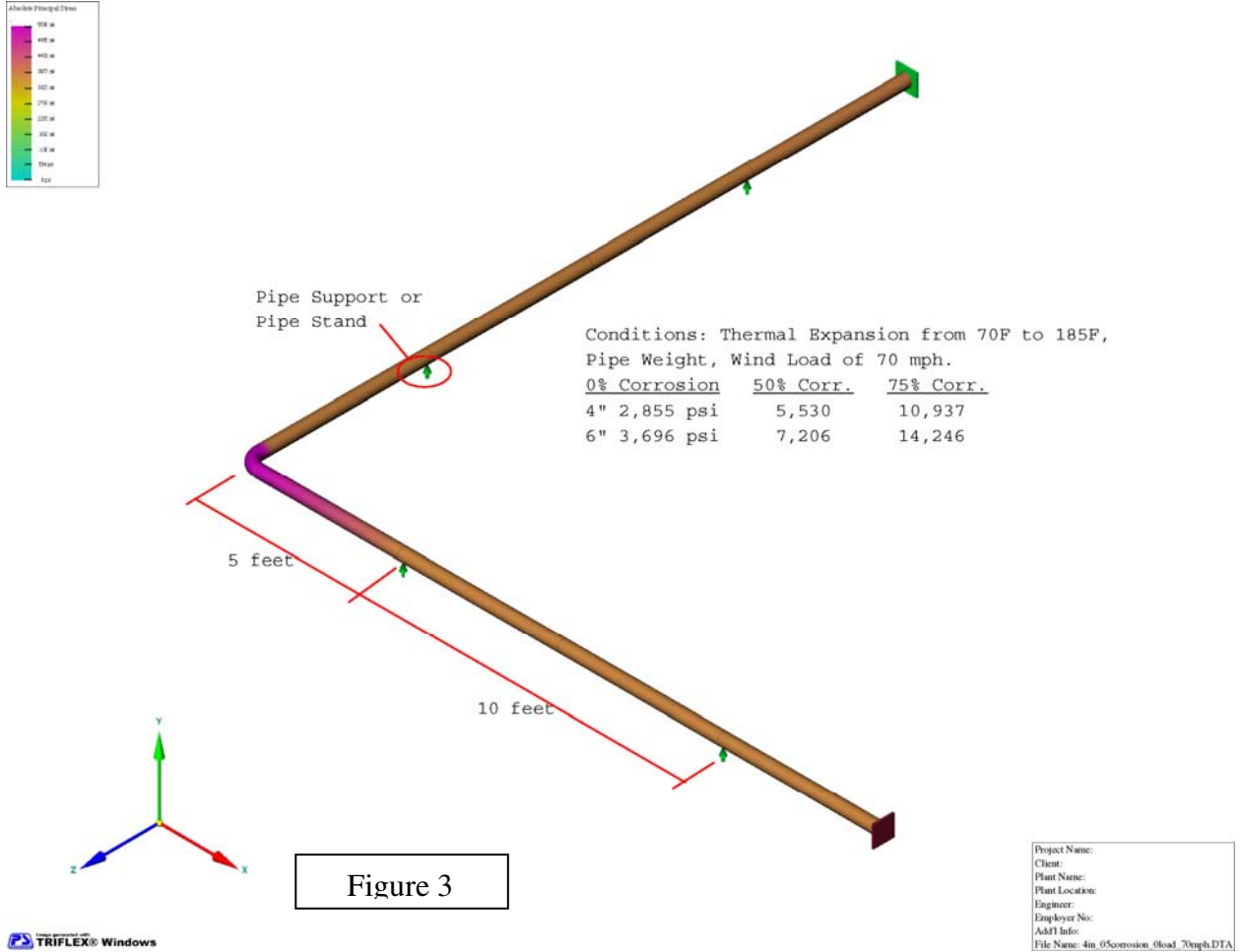
$S$  = applicable allowable hoop stress

So as you can see in the example above, the wall thickness can be fairly thin and still be adequate to contain the pressure. But you have to consider do you want to be face to face with 250 or 300 psig of ammonia with less than 1/8" thick pipe separating you? For my money, I don't think so! So what other consideration have to be given to the strength of pipe?

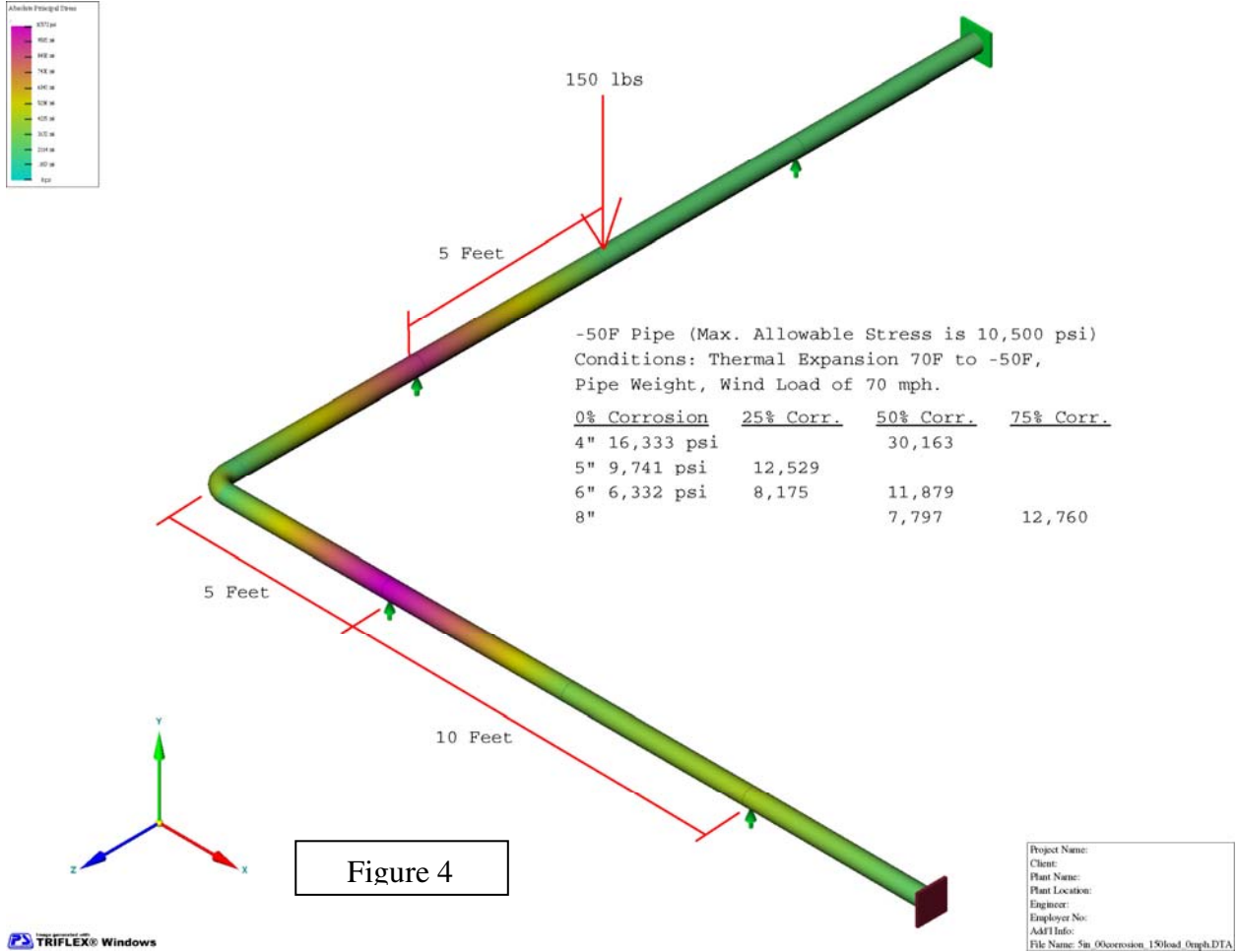
Two other factors I would like to consider are: the structural strength of the pipe; and consideration of pressure containment strength based on Standard B31 G1991.

Rarely is the structural strength considered in piping designed. When it is considered it can be a little concerning. I want to give you a couple of example of typical applications in piping systems. Keep in mind that although the pipe is beyond the allowable stress it most likely will not fail. It is, however, out of code and if it should fail for some reason it would put the owner in a difficult to defend position in the event of injury or property damage.

Example 1, see figure 3, is for a typical discharge line that is exposed to a relatively high wind load and no external load. The maximum allowable stress is 15,000 psi. Based on the pipe analysis below the pipe should be replaced if the remaining material is 75% without further consideration. Typically, when operators or owners see losses of 50% they start become nervous



Example 2, see figure 4, is for a low temperature pipe that is exposed to no wind load and has an external load of 150 pound applied. It can be seen that the 4" pipe falls outside the allowable stress even with no corrosion and thus is out of code. This can be remediated by decreasing the distance between the pipe supports or using a heavier schedule pipe.



Example 3, see figure 5, is for a discharge line that is exposed to 70 MPH wind load and has an external load of 150 pound applied. It can be seen that the 3" and 4" pipe falls outside the allowable stress even with no corrosion and thus is out of code. This can be remediated by decreasing the distance between the pipe supports or using a heavier schedule pipe. The 3" – 5" fails with 25% loss of material and steps need to be taken to reduce the stress.

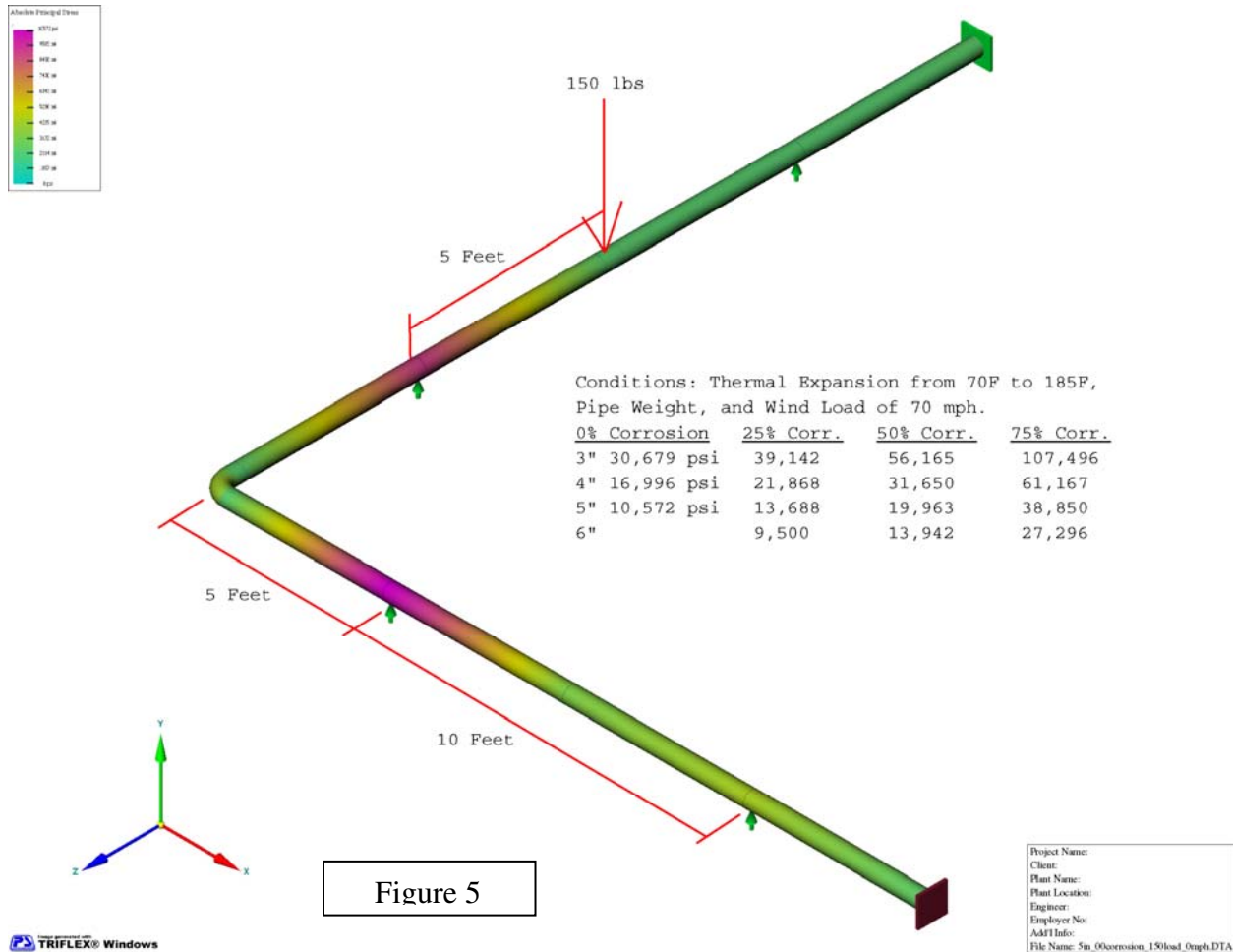


Figure 5

From the above examples it can be seen that the structural strength of the piping, the distance between supports, imposed load and the schedule of the pipe need to be considered in designing the piping system. Also, it can be seen that corrosion rapidly reduces the structural strength of the pipe. In reality the pipe may not fail but remember it is out of code and if it does fail there is a liability issue.

ASME B31 G provides calculations derived through actual testing to calculate the remaining strength of corroded pipe. This standard provides consideration of not only depth of corrosion, but the extent of the corrosion along the length of the pipe. There are three methods provided to determine the remaining strength: by using the calculations provided, by using the tabulated

tables derived from the calculations, or to set up a computer program that does the calculations, the program data is provided at the end of the standard. By using one of the three methods, it can be determined what the maximum extent of the corrosion can be. If this maximum length is exceeded the Maximum Allowable Operating Pressure (MAOP) must be reduced. Below is a typical print out of a spread sheet using the program from ASME B31 G:

#### ASME B31G-1991 PIPE CORROSION EVALUATIONS

Required Inputs:

Nominal Pipe Size	6”
Pipe Schedule	40
Measured Corrosion Depth	.22”
Length of Corroded Area	24”
Nominal wall thickness =	.28”

Outputs:

Max. Allowable Length of Corrosion = 0.699”

PIPE MAY BE OPERATED SAFELY AT MAOP PSIG

**MAOP must be reduced due to Pipe Corrosion**

Notes:

1) Assumes SA53 Grade B or SA106 Grade B pipe steel

Source:

ASME B31-G-1991 Appendix A

Manual for Determining the Remaining Strength of Corroded Pipelines  
(A Supplement to ASME B31 Code for Pressure Piping)

#### ASME B31G-1991 PIPE CORROSION EVALUATIONS

Required Inputs:

Maximum Allowable Operating Pressure (MAOP) 300 psi

Outputs:

Length of Corroded Area 24.00 in

**Safe MAOP 254 psig**

PIPE MAY BE OPERATED SAFELY AT MAOP PSIG

Notes:

1) Assumes SA53 Grade B or SA106 Grade B pipe steel

Source:

ASME B31-G-1991 Appendix A

Manual for Determining the Remaining Strength of Corroded Pipelines  
(A Supplement to ASME B31 Code for Pressure Piping)

**CONCLUSION**

When we look at a piping system we have to consider that there is more to rusty pipes than ugly appearance. The corrosion is an indication that the pipe is losing strength. I say this gently, it is also an indication of poor maintenance practices. But more must be considered than just brushing off the rust, and painting the pipe; the remaining life and strength must be investigated. While the pipe may not be in danger of failing, that cannot be determined until it is properly evaluated. Certainly, no owner wants the liability of operating a system outside the code. That is part of what has to be determined by proper evaluation. Also, it must be considered that the condition of the piping is an element of plant Mechanical Integrity and must be maintained like any other part of the system.

The underlying theme of this paper is: Pay attention to the condition of the piping, and vessels and valves, just as you pay attention to room temperatures and oil levels. Keep in mind, you are operating a refrigeration **SYSTEM** and each component is important to continued safe and efficient operation.