

the conduit

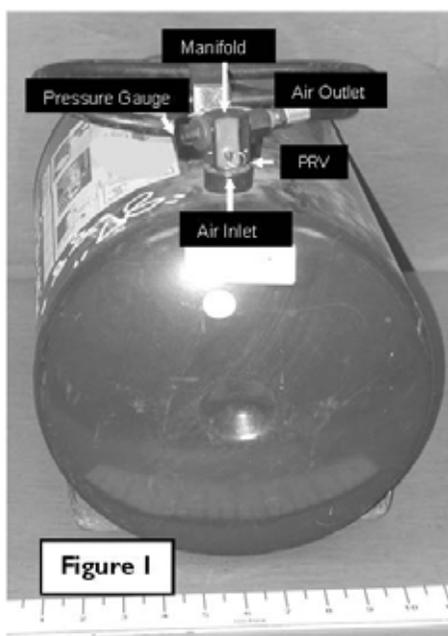
Summer 2005

How Long is it Safe to Keep a Portable Air Carrier?

By: Peter Ellis

A POPULAR COMMODITY

Portable Air Carriers (PACs) are light-weight steel air receiving tanks (ranging in volume from six to about thirty gallons and charged to 125-psig with compressed air for service station compressors) and used for everything from inflating tires to rubber boats to driving pneumatic tools. The first PACs were introduced in 1978. Global production was between one million and ten million units per year in 2002, and no one knows how many PACs are in service today.



Some states require that PACs sold within their jurisdiction be "Code" PACs; that the tanks conform to the requirements of the ASME Pressure Vessel Code and bear "U-Stamps." Other States permit "Non-code" PACs like the one shown in Figure 1. Both Code and Non-Code tanks use the same manifold design threaded into a 1/2-NPT socket welded to the shell of the PAC Tank. The manifold accommodates a pressure gauge ranging from 0-psig to 160-psig with the zone above 125-psig marked "danger," an ASME pressure relief valve, a Shrader valve allowing filling from a service station compressor, and hose with a Shrader fitting to dispense the compressed air. A code version of the tank would have a threaded inspection port in the center of each head as well as a drain plug underneath the tank. Table 1 shows that while some non-code PACs are made from thinner steel than code tanks, many non-code units are made with steel thickness conforming to Code requirements.

A GROWING CONCERN

By 2002, at least twelve instances of catastrophic rupture (Figure 2 and Figure 3) were known to have occurred in PACs manufactured prior to 1991. In each case, the catastrophic rupture occurred while

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the portable air carrier was being pressurized.

In response, one major manufacturer requested that M&M Engineering determine why PACs manufactured before 1991 were failing catastrophically and evaluate the potential risk of catastrophic failure with increasing PAC age.

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CAUSE OF CATASTROPHIC RUPTURE

The cause of rupture was determined to be internal corrosion along the bottom or 6 o'clock axis of the PAC tanks. The corrosion occurs because, unlike commercial grade compressed air, the air from service station compressors, particularly the coin-operated variety, contains compression condensate (water). M&M Engineering concluded that pin-hole leaking, the most common failure mode, occurred when the corrosion included significant pitting. In contrast the tank would catastrophically rupture when the corrosion was more uniform in nature.

MODELING THE PROBABILITY OF CATASTROPHIC RUPTURE

M&M Engineering developed an empirical extreme-values model from which the probabilities of catastrophic rupture of different diameter PACs with various thicknesses of carbon steel sheet were calculated. Calculations were made based on corrosion rates developed by inserting electrical resistance atmospheric corrosion sensors into actual PACs and containing distilled water simulating condensate, and monitoring the



Figure 3

Table 1. Shell Thickness of Portable Air Carriers					
Nominal Wall Thickness		Tank Diameter			
(MSG)	(in)	6-in	10-in	12-in	14-in
11	0.1196				
12	0.1046				
13	0.0897				
14	0.0747				
Code:					
	Meets ASME Code Requirements				
	Does Not Meet ASME Code Requirements				
	Not used for construction of this diameter of air receiver				

corrosion rate over 100 days. Monte-Carlo simulations were then run to determine a statistical probability of catastrophic failure.

How Safe Is Safe Enough?

Figure 4 (facing page) shows the service years in which the probability of any given PAC undergoing catastrophic rupture.

To put these probabilities of catastrophic rupture in perspective, the following events have probabilities of occurrence between one in one-million and one in a 100,000.

- The following events have probabilities of occurrence of one in ten-million to one in one-million
- Winning the lottery on the purchase of a single ticket in a year
- Throwing sevens eight times in a row with a pair of dice.
- Getting twenty to twenty-three consecutive heads (or tails) in a coin toss.

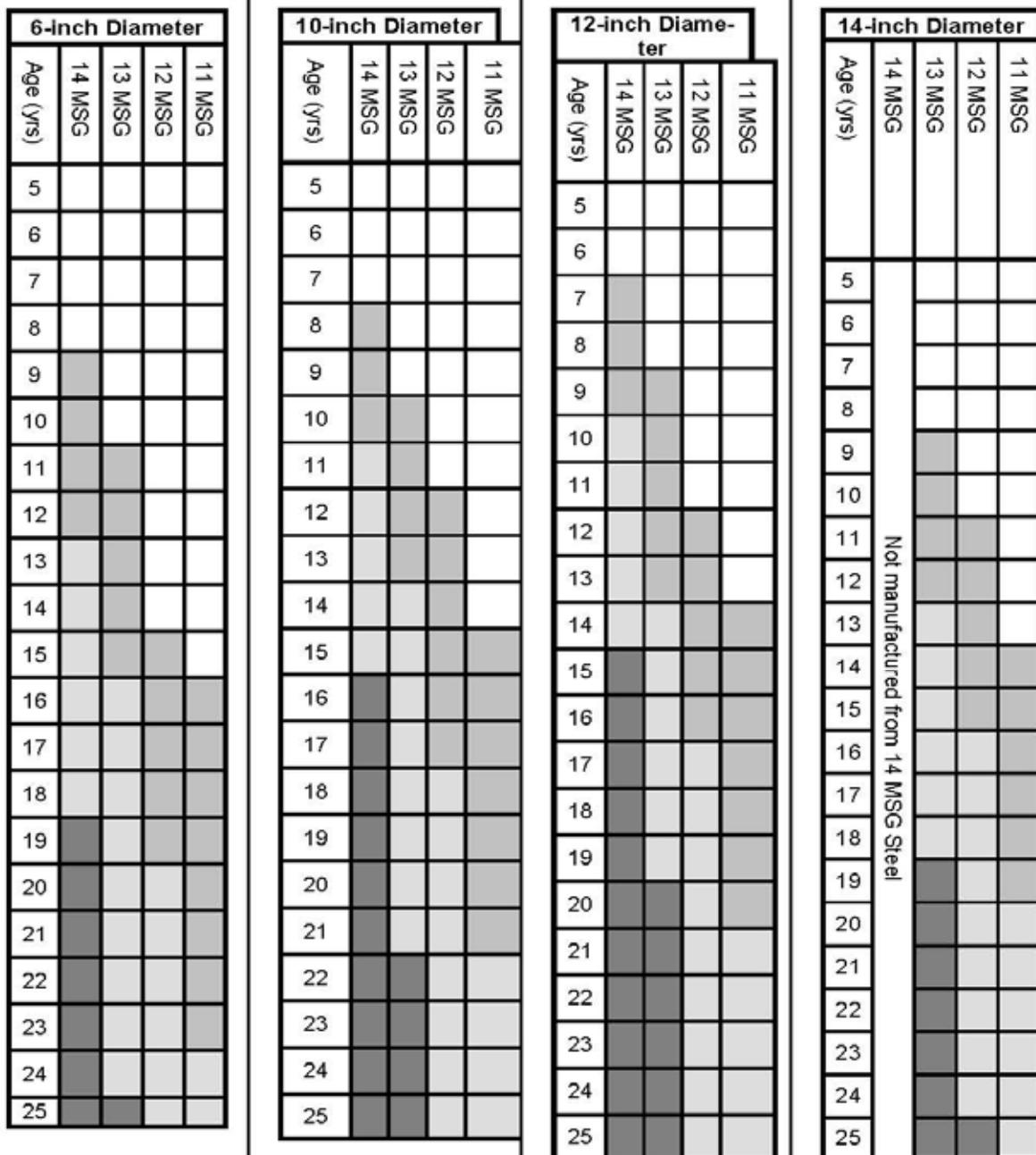
Some manufacturers are now marking their PACs for destruction on the seventh anniversary of manufacture.



- Being killed by lightning in the United States in a single year
- Throwing Sevens seven times in a row on a pair of dice
- Getting seventeen to nineteen consecutive heads (or tails) in a coin toss.

Figure 4.

Probability of Catastrophic PAC Failure Due To Internal Corrosion



Probability of Catastrophic Failure



Caustic in Boilers — Free and Otherwise

By David Daniels

The presence of a solid alkali, whether sodium hydroxide or sodium phosphate, is common in almost all industrial boilers and many utility boilers. In coordinated phosphate treatment, a very common phosphate control strategy, the presence of “free caustic” has always been a negative. Yet in Great Britain, caustic alone was used for many years to treat many CEGB boilers.

The question of free caustic in the boiler has surfaced again in the newest boiler water treatment strategy put forth by EPRI—that encourages the pH of the boiler be raised to the point where about 1-ppm of “free” caustic is present in the boiler water.

So is caustic in a boiler good or bad?

A Historical Perspective

Many years ago, treatments using a combination of caustic and phosphate were devised for boilers operating on softened water makeup with significant silica concentration and a significant potential for hardness contamination in the feedwater. The caustic served three functions: it helped maintain a stable magnetite layer, minimize silica carryover, and buffer against drops in boiler pH caused by contamination.

Cracking was found in riveted steam drums and the crevice between the drum and rolled tubes that was attributed to caustic that concentrated in the crevices created by the rivets and tube/ drum interface. Caustic was also

associated with an under-deposit corrosion mechanism that caused gouging in waterwalls. (We now know that a number of chemicals can concentrate under-deposits and cause gouging and corrosion in waterwall tubes.)

When the problems with caustic cracking surfaced in the 1930s, one obvious answer was to eliminate caustic from the boiler water treatment. A treatment based on the addition of trisodium phosphate alone was proposed in 1943 by Purcell and Whirl. This became known as coordinated phosphate control.

In 1954, research showed that even solutions of trisodium phosphate could produce caustic as they interacted with magnetite in a laboratory autoclave. Based on that finding, a new treatment program was developed using a blend of disodium phosphate and trisodium phosphate with a sodium to phosphate ratio between 2.2 and 2.6. This became known as a congruent phosphate treatment and was the standard in the industry for many years. It is still widely and successfully used by many industrial and utility boilers.

When the first supercritical boilers were manufactured, a new treatment was required. Since all the water in the boiler was converted to steam, only volatile chemicals could be added to the boiler. This treatment was called all-volatile treatment or AVT. Ammonia was typically used to increase the pH of the feedwater and a volatile oxygen scavenger was used, often hydrazine. Also, the feedwater needed to be ultrapure demineralized water otherwise

deposits would accumulate in the boiler and on the turbine. To maintain high purity feedwater, plants used demineralized makeup and condensate polishers to handle minor contamination from, for example, a small condenser tube leak.

When AVT was introduced, many drum boilers also gave it a try. Unfortunately their feedwater often was not sufficiently pure. As it turns out, ammonia under boiler conditions is molecular and does not hydrolyze with water and therefore cannot protect the boiler against contaminants. Therefore, a boiler on AVT has no protection against acidic contamination regardless of what the pH of a cooled boiler sample might be. The result was that many of these boilers suffered hydrogen damage failures resulting in multiple catastrophic failures and often the replacement of large amounts of tubing. Many units kept using phosphate.

Hideout

Higher pressure boilers, particularly those operating above 2400-psig, had trouble maintaining phosphate residuals during high load conditions. The phosphate residual would disappear or “hideout” regardless of how much was added to the boiler. Also, the pH of the boiler would continue to rise above the recommended 2.2 to 2.6 ratio, prompting the plants to add more acidic phosphate salts such as monosodium phosphate in an attempt to bring the pH down. When load was dropped, the pH fell and phosphates that had been “hiding out” reappeared with a vengeance.

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For many boilers phosphate hideout has gone from being a nuisance to being a real problem. Sodium iron phosphate compounds, particularly maracite, have been associated with a gouging type of damage that is

60% had seen gouging that was attributed to phosphate. Some gouging damage has been so severe that major tube replacement has been required.

level was between 0.1-ppm and 2.0-ppm. Since no phosphate limit is specified, the equilibrium point could be much higher than 2.0, particularly on boilers that operate at 1800-psig or lower.

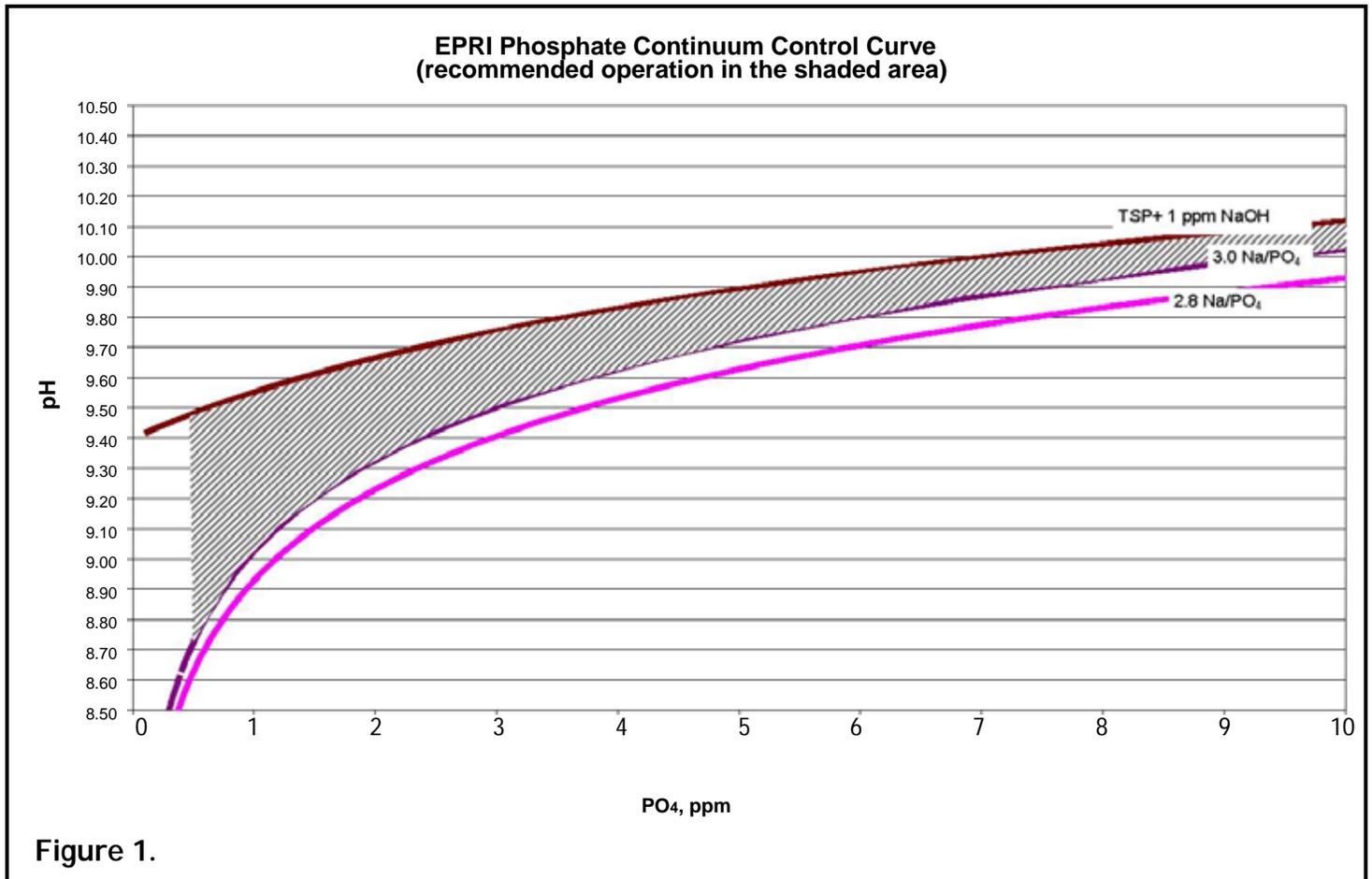


Figure 1.

often referred to as acid phosphate attack. The name implies the addition of "acidic" phosphate compounds such as monosodium phosphate, or acidic conditions in the boiler, but research has shown that repeated dissolution and precipitation of sodium iron phosphate compounds can generate very acidic localized deposits even if blends of disodium phosphate and trisodium phosphate are fed to the boiler. One survey in the early 90s showed that 90% of the units using congruent phosphate treatment had some degree of hideout and over

Equilibrium Phosphate Treatment (EPT) was developed by Jan Stodola at Ontario Hydro in response to units that were having difficulty with phosphate hideout. In the original version of EPT used by Ontario Hydro, sufficient trisodium phosphate and caustic is added to maintain solid alkali in the boiler water such that the pH of boiler is between 9.0 and 9.6 for 2600-psig boiler. EPT does not specify a phosphate control range; instead, it requires that each unit determine its own equilibrium point for phosphate. For many boilers, this

Initially, EPRI adopted the EPT philosophy seeing it as an additional phosphate treatment regime and placed it on the pH/phosphate control chart along with the other phosphate treatments. Many utilities moved to EPT to get away from problems with phosphate hideout. As they did, the number of hydrogen damage failures increased. Evidently, as with the AVT experience, there was once again insufficient alkalinity in the boiler water to combat trace amounts of contamination.

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2005 HRSG Users Group Annual Meeting

The annual meeting of the HRSG Users Group was held April 11-13 at the Saddlebrook Resort Conference Center, near Tampa, Florida. Once again the conference attendance was more than 300 with 160 companies represented from 10 different countries.

This is a conference where everyone is a speaker and has a chance to ask and answer questions. With the vast collection of experience in the room, including representatives from the equipment manufacturers, you're sure to not only get the correct technical answer, but also to hear how others have solved the same problem in the past.

In addition to the open Question and Answer periods, there were four formal discussions on Flow Accelerated Corrosion, Tube Leaks, Attemperation, and Control Logic. A good discussion of Flow Accelerated Corrosion (FAC) came out of Barry Dooley's presentation. It seems that design and materials have minimized FAC in newer units, but the problems are still prevalent in some designs, particularly where an oxygen scavenger is used.

It was great to see how much emphasis is placed by so many of the plants on proper lay-up of the units when they are off line for extended periods.

Mark your calendars now for the 2006 Meeting in Colorado Springs, March 13-15. Check the HSRG Users Group website at www.hrsgusers.org for details.

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Where are we now?

The current EPRI recommendations for high level phosphate treatment are shown in Figure 1 (previous page). It allows a small amount of caustic in the boiler. Current limits extend from a sodium:phosphate ratio of 2.8 to 3.0+1ppm caustic. This is combined with the recommendation that only trisodium phosphate be used as a source of phosphate to treat a boiler. The recommended phosphate concentration is still low, typically less than 10-ppm, but with a higher sodium:phosphate ratio, the capacity to neutralize small amounts of acidic contaminants is improved.

Industrial boilers can benefit from the EPRI guidelines even if they operate at lower pressures (<1200-psig). If they use demineralized water makeup, the congruent phosphate treatment program should work well for these boilers; add only trisodium phosphate as a phosphate source. Sodium hydroxide can also be used but only to maintain the pH in the 3.0 + 1ppm NaOH range. Excessive sodium hydroxide in the boiler is not needed and may be harmful.

Calendar of Events

14th Annual Southwest Chemistry Conference

Scottsdale, Arizona

July 26-28

For Info:

Mark.Yarbrough@pwenergy.com

International Conference on the Interaction of Organics and Organic Cycle

Treatment Chemicals with Water, Steam and Materials

Stuttgart, Germany

October 4-6

For info: www.organics2005.com

International Water Conference

Orlando, FL

October 10-13

For info: www.eswp.com

The best boiler water chemical treatment is still high purity feedwater. If the feedwater is clean, the boiler stays clean and clean boilers are easier to treat.



This past April, over 300 attended the HRSG User Group Conference in Tampa, Florida.

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