



The Cold Front

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IN THIS ISSUE

- Closed Refrigerant Circuit for Screw Compressor Oil Cooling 1-6
- Upcoming Ammonia Classes 2
- Noteworthy 2
- PSM Auditing Course 7
- Benchmarking Study Invitation 8

CLOSED REFRIGERANT CIRCUIT FOR SCREW COMPRESSOR OIL COOLING

Thermosiphon oil cooling (TSOC) is a popular choice for screw compressor oil cooling. An alternative approach to traditional thermosiphon design is to provide one or more dedicated evaporative condensers in a closed-loop refrigerant circuit to meet the oil cooling heat rejection load. Tropicana Products' new world-class machinery room in Bradenton, FL is one example of a successful implementation of this concept.

This article examines the closed refrigerant circuit oil cooling approach in detail. We begin with a brief background on oil cooling methods followed by a description of the approach. We conclude the article with design and operational considerations.

BACKGROUND

With the current state of technology, oil cooling is an integral and necessary part of industrial refrigeration screw compressor operation. Screw compressors rely on oil to lubricate, seal, quiet, clean, and cool the compressor's rotors and bearings during operation. Because the oil is in direct contact with the refrigerant being compressed, it will increase in temperature as it absorbs a portion of the refrigerant's "heat of compression". To prevent the oil from overheating, some means of cooling the oil is required.

The techniques available for screw compressor oil cooling can be split into two categories: internal and external. *Internal* oil cooling involves cooling the oil within the compressor at some stage during the compression process. The most common internal oil cooling approach is "liquid injection", which involves expanding high-pressure liquid refrigerant directly into the body of the compressor to cool the oil. In liquid injection oil cooling, the oil supply temperature is controlled by metering the flow of the high pressure liquid refrigerant to maintain a desired discharge temperature (typically 130°F). Alternatively, oil can be cooled *external* to the compressor using a separate heat exchanger. The medium that cools the oil can be water, glycol, or refrigerant. Water for oil cooling could originate from an evaporative condenser sump or if water use is not an issue, once-through cooling. Glycol-cooled oil cooling systems are configured as closed-loop systems with a dedicated fluid cooler

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located outdoors (**Figure 1**). The most common approach for *external* oil cooling relies on the use of a refrigerant in a thermosiphon arrangement.

Although *internal* oil cooling offers low first-cost, ease of design, and installation, *external* thermosiphon oil cooling (TSOC) is quickly becoming the preferred choice for screw compressor oil cooling. Compared to *internal* oil cooling, *external* oil cooling has lower operating and maintenance costs as well as extended screw compressor life. Several compressor manufacturers are reporting that today, TSOC oil cooling is specified in more than 50% of their new compressor sales.

Traditional TSOC designs position an elevated *thermosiphon pilot receiver* in-line between the condenser outlets and the high-pressure receiver (**Figure 2**). Liquid from the pilot receiver falls by gravity to feed individual oil coolers [IIAR Piping Handbook, 2000] through the TSOC supply lines. The warmer oil gives up its heat to evaporate the high-pressure liquid refrigerant supplied to the oil coolers. The vapor generated by the evaporation

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September 15-19, 2003 Madison, WI

Introduction to Ammonia Refrigeration

October 8-10, 2003 Madison, WI

Ammonia Refrigeration Piping

October 27-29, 2003 Madison, WI

Intermediate Ammonia Refrigeration

December 3-5, 2003 Madison, WI

See <http://www.irc.wisc.edu/training/> for more information.



Figure 1: Glycol fluid cooler (left) for screw compressor external glycol oil cooler (right).



Noteworthy



- In February, we welcomed [Sargento Foods](#) as the newest IRC Member Company. Click [here](#) for the press release.
- Check out the coverage of the [2003 IRC Research & Technology Forum in Process Cooling & Equipment](#). Click [here](#) for the article.
- Send items of note for next newsletter to Todd Jekel, tbjekel@wisc.edu.

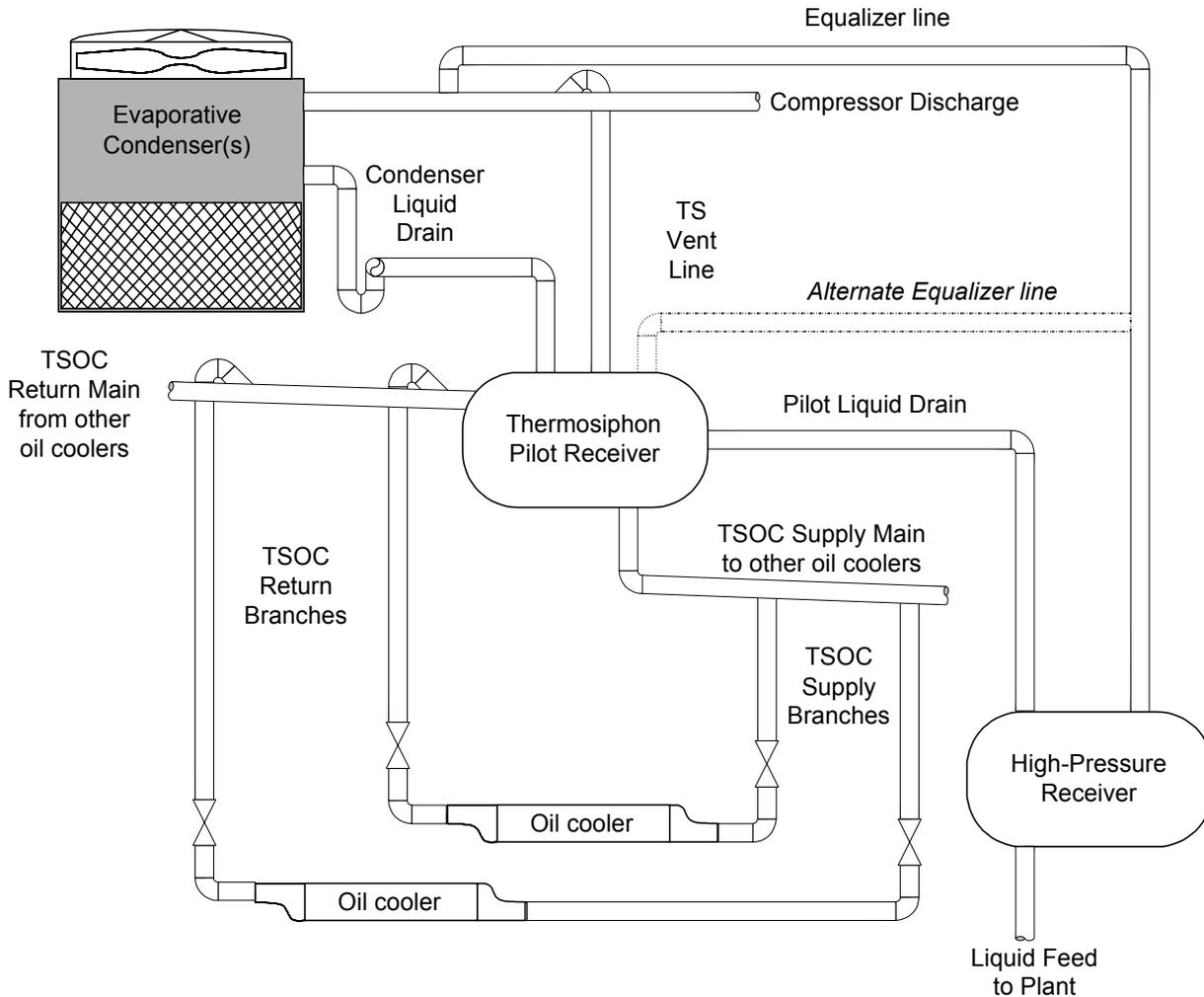


Figure 2: Traditional TSOC piping (Not to scale).

process, along with any unboiled high-pressure liquid refrigerant entrained and carried over from the oil coolers, migrates back to the pilot receiver through the TSOC return lines. In the pilot receiver, liquid separates from the vapor for supply back to the oil coolers. Vapor is relieved to the condenser inlet where the heat from the oil cooling process is rejected to the outside environment. Any high-pressure liquid draining from the condensers that exceeds the amount required to feed the oil coolers overflows to the system's high-pressure receiver.

CLOSED REFRIGERANT CIRCUIT TSOC HEAT REJECTION

An alternative approach to the traditional design of high-side piping and equipment for thermosiphon oil cooling involves dedicating a closed circuit refrigerant loop with separate evaporative condenser(s) that operate only to meet the oil cooling heat rejection load as shown in **Figure 3**. Like the closed-loop glycol fluid cooler system (**Figure 1**), the dedicated TSOC system is also a closed-loop. The dedicated TSOC differs in that the working fluid is now a

refrigerant that undergoes a change of phase rather than a glycol that changes temperature

When to consider

When should a dedicated refrigerant circuit for thermosiphon oil cooling be considered? There are several points of opportunity to evaluate the feasibility of this approach for your systems and plants. A system expansion is always a great opportunity to take a step back and consider what could be done, in the context of the expansion, to improve the system safety, reliability, operability, safety, and productivity. Some companies have formed energy SWAT teams. These teams can evaluate the dedicated TSOC refrigerant circuit as one approach to improve the efficiency of refrigeration system through reduced operational costs for heat rejection. There are other advantages beyond the efficiency and operational issues that can justify the use of a dedicated evaporative condenser for thermosiphon oil cooling. Let's look at some advantages and disadvantages.

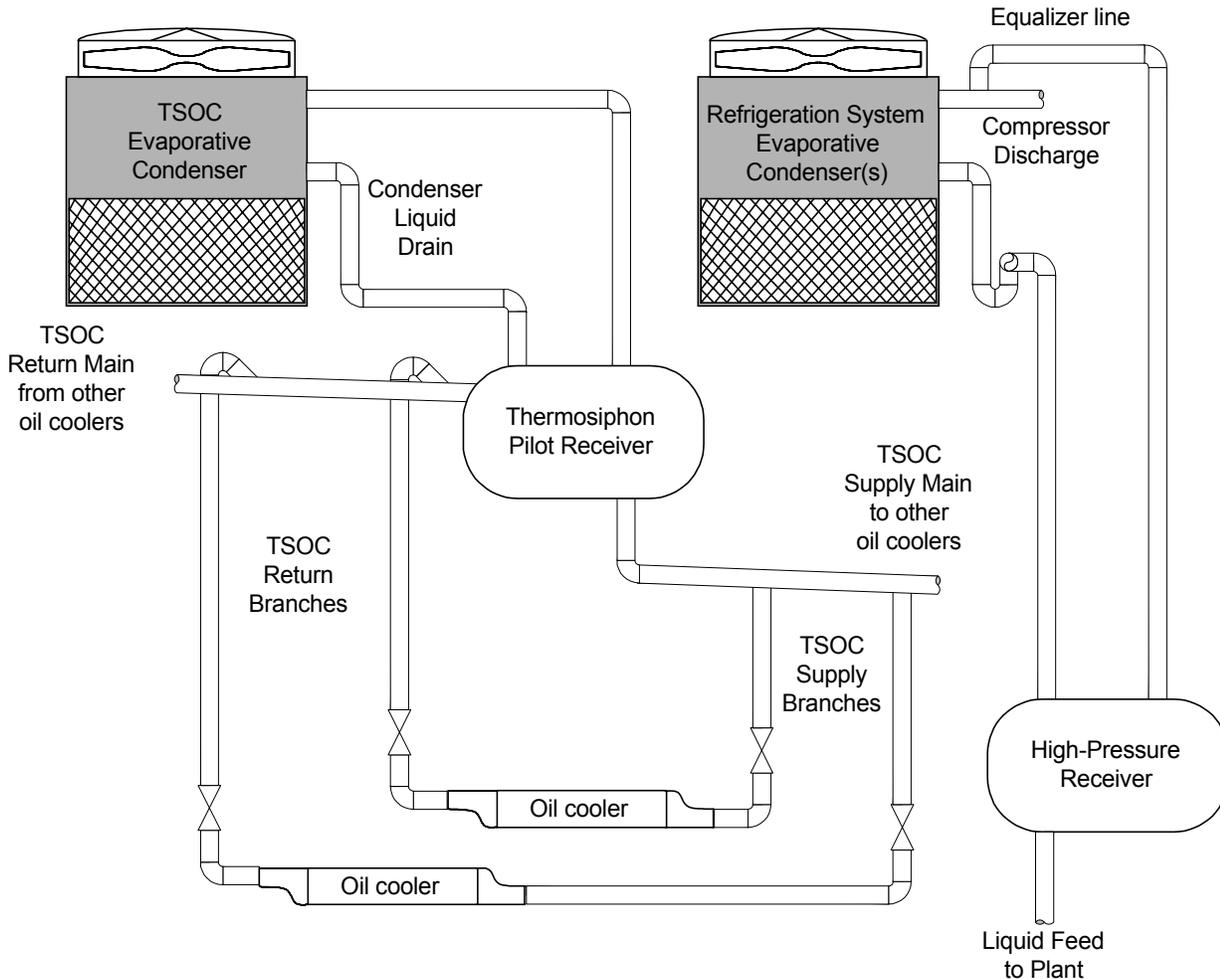


Figure 3: Closed refrigerant circuit TSOC piping (Not to scale).

Pros and Cons

The advantages of a closed-loop refrigerant circuit for thermosiphon oil cooling include:

- Improved refrigeration system efficiency and reduced operating costs for oil cooling loads
- Reduced maintenance by maintaining an oil-free refrigerant circuit for feeding oil cooler heat exchangers
- Simplification of high-pressure receiver equalizer piping and thermosiphon relief vent line piping
- Troubleshooting high-side operational issues is simplified

The disadvantages of segregating heat rejection for oil cooling are:

- Overcoming the “We’ve never done it that way before” attitude
- Provisions for redundant oil cooling

OPERATIONAL CONSIDERATIONS

Control

In our short courses, technical papers, and guidebooks, we have repeatedly talked about the benefits of lowering or “floating” head pressure in industrial refrigeration systems. However, for a closed-circuit oil cooling system, reducing the condensing pressure does not minimize energy use. Consider an oil cooling heat rejection system designed to accommodate the full-load oil cooling requirements with a saturated refrigerant temperature of 95°F (181 psig). *How should that refrigerant circuit be controlled for efficient operation during off-design hours?*

Since the oil cooling circuit is now segregated from the refrigeration system’s high-side, we can focus on how it can be controlled for efficient operation. It is important to recognize that, unlike the rest of the refrigeration

system, a dedicated oil cooling refrigeration circuit does not have compressors connected that would benefit from reduced “head pressure”. So if the oil cooling heat rejection system is designed for full-load oil cooling with a circuit pressure of 181 psig (95°F saturation), then maintaining a set point pressure in the oil cooling circuit at 181 psig (95°F) will accomplish the peak heat rejection without overuse of condenser fan energy. The lower the refrigerant set point pressure in the TSOC circuit, the greater the fan energy consumption. This simple operating set point strategy can be extended by re-setting the circuit set point pressure upward as the oil cooling load decreases; however, it is important to monitor the oil supply temperatures to ensure each operating compressor has adequate oil cooling.

In Northern climates, design conditions are only one aspect of operation, *what about operation during wintertime?* The importance of wintertime operation is heightened when the oil-cooling load decreases during cold weather due to reduced compressor discharge pressures and reduced refrigeration load. Typically, oil cooling loads are correlated with ambient weather conditions in application such as distribution centers, cold-storage warehouses, storage terminals, and other applications with weather dependant loads. In cold climates, consider locating the pilot receiver in the engine room to maintain the TSOC refrigerant circuit pressure above 103 psig (65°F saturation temperature) so oil within the coolers will remain warm enough to flow freely during compressor shutdowns. Avoid cycling water

pumps during ambient temperature conditions near freezing (32°F) because the magnitude of evaporative condenser capacity change associated with wet vs. dry operation (particularly with the high saturated condensing temperatures expected in the sub-system) can create control loop stability problems.

Condenser fan control for the thermosiphon circuit is an important aspect of this sub-system. Condenser control can be enhanced by installing a variable frequency drive(s) (VFD) on the condenser fan(s). This allows more precise control of the thermosiphon circuit refrigerant pressure to its set point while minimizing fan energy use. VFDs will also reduce the energy associated with oil cooling heat rejection during off-design conditions. Off-design conditions are a reduction in oil cooling load due either to reduced refrigeration load or ambient wet-bulb. As implied earlier, the condenser fans on the thermosiphon circuit need to be modulated to maintain the thermosiphon pilot receiver pressure at its control set point. Nominally, the circuit set point will be 181 psig; however, the pilot receiver pressure can be reset upward as the oil cooling load decreases.

Reliability and Redundancy

Redundancy or reliability is important to consider in the design and operation of an oil cooling system. *Will the refrigeration system need to be available 24 hrs per day, 7 days per week and 365 days per*

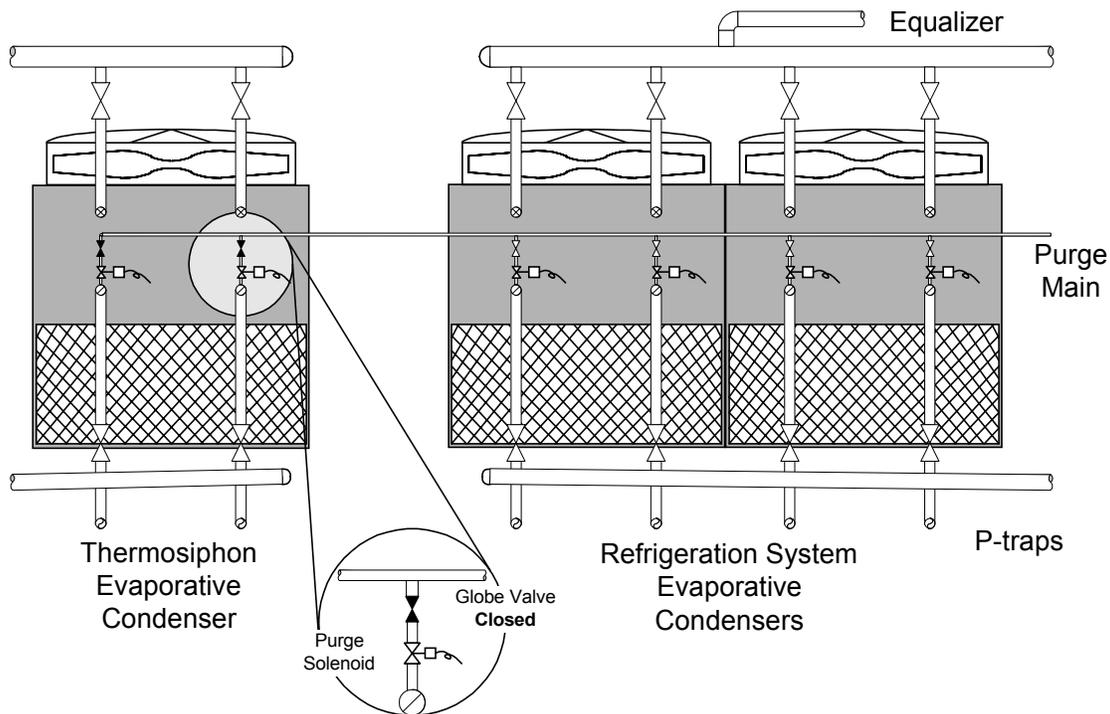


Figure 4: Purger considerations (Not all valves shown).

year? How will the oil cooling arrangement support system operation in the event that the one or more of the oil cooling condensers require service? There are several ways of achieving redundancy for enhanced oil cooling reliability including: **1.** provide alternate oil cooling source, such as liquid injection, on one or more compressors; **2.** provide condenser flexibility by specifying more than one condenser to meet oil cooling loads at design conditions; **3.** a combination of #1 and #2; or **4.** provide the ability to cross-connect the oil cooling circuit with the condensers used in the main refrigeration system for heat rejection. The cross-connection option for redundancy requires that the pilot receiver be connected to the refrigeration system condensers and high-pressure receiver as shown in **Figure 2**.

Purging

Automatic purgers are used in industrial refrigeration systems using ammonia for removing non-condensable gases to maintain efficient system operation. Typically, foul gas, drawn from individual purge points located at the top of each condenser heat exchanger outlet, is piped to a foul gas main connected to one or more purgers (**Figure 4**). In a dedicated thermosiphon oil cooling circuit, two purging-related issues need to be addressed: **1.** how is it accomplished, and **2.** when should it be done.

How? With a dedicated oil-cooling refrigerant circuit, the set point pressure of the oil-cooling condenser will generally be higher than the refrigeration system condensing (head) pressure. If the purge points for the oil cooling condensers are on a common purge main with the refrigeration system, the pressure difference between the two systems presents a problem. When the oil cooling circuit operates at a pressure higher than the system condensing pressure, the purge solenoids for the system may be forced open whenever a purge solenoid in the oil cooling circuit opens. To avoid this problem, we recommend one of two alternatives: **1.** purge points from the two heat rejection systems be segregated onto separate foul gas mains, or **2.** isolate each of the thermosiphon evaporative condenser purge points using the stop valve at the purge point (**Figure 4**). These recommendations allow for operation of the oil cooling condenser at a higher pressure than the system condensers without back-flowing foul gas from the thermosiphon to the purge connections on the refrigeration system condensers.

When? Since a dedicated TSOC circuit will not accumulate non-condensables during operation, it is advisable to take those purge points out of the purge "rotation" except immediately after startup and servicing that requires line breaking.

Sub-system Charging

Charging of the oil cooling refrigerant circuit can be an iterative process. Because there will not be any oil cooling load during the initial start-up, liquid refrigerant will tend to fill the liquid supply piping, oil coolers and individual oil cooler return piping branches to the level in the pilot. Once operational, the return branch piping to the pilot will only be partially filled with liquid on the active oil coolers. It is important to closely monitor the liquid level in the pilot receiver after initial startup to avoid overfilling the pilot. A high liquid level will result in turbulent conditions in the vapor space of the pilot during operation.

Reserve liquid in the pilot is less important in a dedicated thermosiphon system because the oil cooler circuit is a fixed charge and the oil coolers are not "sharing" liquid with the entire refrigeration system. However, a nominal liquid level in the pilot receiver is needed to ensure that liquid can be fed to each oil cooler supply branch lines without starving any branches.

If the cross-connect option (discussed previously for redundancy) is chosen, the thermosiphon system can be charged directly from main refrigeration system using the cross-connect piping.

Oil Management

In a traditional thermosiphon system, oil carry-over in the discharge line from screw compressors can possibly accumulate in the refrigerant-side of oil coolers. Draining oil from the refrigerant side of oil coolers is time consuming and presents considerable safety risks. With a dedicated refrigerant circuit for oil cooling, the refrigerant supply to oil coolers can be maintained oil free, thereby, eliminating the need to manage or drain oil from the oil coolers.

CONCLUSION

A thermosiphon refrigerant circuit and condenser dedicated to oil cooling for screw compressors is an alternative to traditional thermosiphon configuration that offers reduced operational costs, simplified troubleshooting, and eliminates oil from the refrigeration side of the oil cooler. In addition to presenting the concept, considerations for operation, maintenance, and redundancy were briefly covered.

If you have questions or comments on this article, please contact [Todd Jekel](mailto:Todd.Jekel@wisc.edu) at (608) 265-3008 or tbjekel@wisc.edu.

Process Safety Management Audits

June 18-20, 2003

Madison, WI

Demand Forces Overflow Offering

Due to the demand for EPD's *Auditing PSM Systems* course initially offered in January 2003, we have scheduled a repeat "overflow" course for June. Don't miss this opportunity to "raise the bar" on your plant's process safety management programs.

What Have Past Attendees Said About This Course?

"This is one of the most thorough, energetic, well-paced, and valuable content seminars I've ever attended!"
Phil Froncek, Agrilink Foods

"Very nicely laid out and thorough. The program was timely and will help us assure a safer workplace."
Jeff Vorpahl, Packerland Packing

"Good tools to proceed with for conducting our audits and program improvements."
Paul Brunette, Kraft Canada

Learn Sound Principles and Practices

Attend this course and learn sound principles and practices for conducting effective PSM compliance audits. Compliance audits of PSM systems are one of the most effective means of continuously improving your plant's PSM program. Perform quality audits and reap the benefits of enhanced safety and more reliable "cold".

Boost Your Understanding

The workshop format of this course will help **you** conduct high-performance, effective process safety management systems audits. Our goals in offering this course are to help you

- understand a range of approaches for conducting PSM compliance audits
- assess and allocate required resources to conduct effective audits
- continuously improve PSM programs, and
- continuously improve the reliability and deliverability of "cold" as a result of conducting a compliance audit

Upon completion of the course, you will understand

- a wide range of audit types
- techniques for conducting effective PSM audits
- strategies for staffing and executing audits
- approaches for turning your audit results into PSM program improvements

Attend and Benefit

This course has been designed for

- PSM coordinators
- managers responsible for safety
- refrigeration personnel (operators, mechanics and supervisory staff)
- audit team members
- managers concerned with the reliability and dependability of "cold"
- others who want to learn more about enhanced refrigeration system safety and reliability

Take Home Valuable Compliance Audit Tools

As an attendee, you will receive a complete set of course notes. In addition, you will receive a CD-ROM with valuable tools for conducting compliance audits at your facility.

Download a complete brochure including a course outline and registration materials by clicking [here](#).

Benchmarking Refrigeration System Performance

Is your refrigeration plant energy efficient? How do you know?

Improving the energy efficiency of refrigeration systems can provide significant economic and operational benefits. Unfortunately, very little information is currently available to identify systems with above- or below-average energy use. The Industrial Refrigeration Consortium (IRC) has initiated a research effort to develop benchmark data to help refrigeration plant personnel assess their facilities' energy costs relative to other plants.

The IRC is currently seeking plants to take part in this research project. In exchange for furnishing monthly energy use and load data, participating organizations will gain preferred access to the benchmarking results, including:

- *Prepublication copies* of the final report (published reports will not be released for 18 months following completion of the work)
- Written *status reports* and telephone conference calls on work in progress
- *Special assistance* from investigators to resolve energy analysis questions
- Optional *custom analysis* of your plants' energy use

For more information, or to learn how to participate, download the [project description](#) from our website at www.irc.wisc.edu.

IT'S NOT TOO LATE!

Join the IRC in 2003

The IRC's mission is *to improve the safety, reliability, efficiency, and productivity of industrial refrigeration systems*. Our vision is *to make continuous progress toward improving the safety, productivity, and efficiency of the systems and technologies that form the foundation of the industrial refrigeration industry*.

Does your company have needs in the areas of education, technical assistance or strategic planning for refrigeration? If so, please contact us to see how joining the IRC can benefit you and your company.

NEWSLETTER IDEAS WELCOMED!

If it is of interest to you, it is undoubtedly of interest to others.

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