

HEAT EXCHANGER INSPECTION METHODS

Inspecting furnace heat exchangers is sometimes not an easy task. Each heating season someone here at HVAC-Talk will ask “ Which is the best method?” Everyone is looking for an inspection method or test equipment that will find cracks or leaks 100 percent of the time. There isn't anyone method or tool that can be used on every style of heat exchanger. There are many areas on a heat exchanger that you can not get to for visual inspections while the heat exchanger is in the furnace. There are a variety of methods of inspecting or testing heat exchangers. Searching documents and internet sources the following is what I found on heat exchanger inspection methods and sources of information and training.

Refrigeration Service Engineer's Society's Service Application Manual (SAM) titled "Residential Gas Furnace Heat Exchanger Testing" Douglas DeWerth, P.E. American Gas Association (AGA) Laboratories under SAM number 630-92 9/86. The manual outlines and explains the many test methods that are used and have been used to inspect and test heat exchangers. This manual also goes into detail about the test equipment used in the 3 step method that the AGA developed. RSES members can view the SAM minus the photographs and diagrams at <http://www.rses.org>. If you are not a member or want to purchase a complete copy call RSES (800)297-5660 for availability and cost.

The American Gas Association developed a 3 step FURNACE HEAT EXCHANGER LEAKAGE TEST. Step 1 Visual inspection. Step 2 Burner flame deviation test. Step 3 injecting a nitrogen/methane gas mixture into the burner chamber. The heat exchanger outlet of the heat exchanger is plugged and a combustible gas detector is used to check for gas leakage on the exterior of the heat exchanger. A detailed fact sheet on the AGA test procedure is available at <http://www.aga.org/NR/rdonlyres/A156C36A-9324-4978-91B4-E78DB63DAD7D/0/8612FURNHEATEXCHNGLEAKTEST.pdf>

Inspecting Heat Exchangers

The first test step that the AGA Inspection test lists is the visual inspection of burner chamber area and exterior of heat exchanger. A variety of lights may be used for the inspection. I find that using a flashlight with high candlepower such a rechargeable MagLite as at the top does a superior job of illuminating cracks. Jet engine mechanics use high candled power lights called Jet Lites to inspect engine turbine blades to make cracks more visible.

FLASHLIGHTS



Flexible lights are good for getting a light right on a suspected area. Having a light almost on the crack will highlight the defect. Flex-A-Light from Sears or the inspection light from SnapOn Tools Stock#: GA481B



Sometimes you can even pickup odd looking lights such as this one that uses a rechargeable Makita battery.



Shining a light on the outside or the inside of the heat exchanger at the suspected area and examining the opposite side look for light penetration through the crack or perforation.

MIRRORS

Use a variety of mirrors. Small round and oval mirrors that have long telescoping reach are available at most welding supply stores. A large round mirror with long reach is also available through Sears. Large mirrors can be used for drum type heat exchangers.



For older heat exchangers have a mirror made at local glass shop 1/4" thick x 1-3/16" width x 24" length. A suitable carrying case can be made from 1-1/4" PVC pipe and fittings. Use a male threaded cap for one end. Install a small piece of foam such as rubatex in both ends. A tool plastic coating can be sprayed on the back side for protection and at one end for a hand grip.



The flame deviation test is the second listed AGA inspection step. Should the burner flame move when the circulator blower comes on it is an indication of a heat exchanger leak. If you do not locate a crack or perforation the heat exchanger seams may be leaking and the cause for the flame deviation, or the metal may have pinholes rusted through the wall.

The third AGA step is the methane/nitrogen gas injection method. J&N Associates formerly sold a Heat Exchanger Test (H.E.T.) Kit and HXG-2 Combustible Gas Detector for this third step. Though no longer available I thought I would include it.



Sensit HXG-2 Combustible Gas Detector



Sensit H.E.T. Kit came with regulator, hose, distribution wand, hole plugs, tracer gas and calibration gas for the HXG-2



The wand is a brass tube closed off at one end with several dispensing holes drilled into it.



There is a large cylinder of tracer gas which I understand is still available. One could therefore still order the tracer gas from J & N Associates and with a 7 cubic foot per hour regulator one could make their own tracer gas test kit to test to the AGA criteria.

Water Spray Test.

The water spray test is another alternative inspection method. Remove the furnace blower assembly, the fan/ limit and other electrical components to prevent damage. Spray the exterior of the heat exchanger with a water/soap solution 1 gallon water/ 1 tablespoon soap using a garden sprayer. Inspect the interior of heat exchanger with mirror and flashlight check for evidence of water indicating a crack, rust perforation or crimp leak.

Visible Defects developed an ultraviolet spray solution for this test. The UV spray is excellent for high lighting leaks on metals that may not contrast water only as well. The solution is sprayed on the exterior of the heat exchanger. The interior is then checked with the UV light. The UV glow shows cracks, rust holes, faulty seams and welds. Visible Defects also have a camera system. The lens head diameter is smaller than a dime.
<http://www.visibledefects.com>



Then there may be times you just need to pull the heat exchanger and fill it with water just to verify where the leak is at. This had to be done on a new secondary heat exchanger that I installed after the draft switch failed to prove draft. Found several rivets leaking.

Measuring for Carbon Monoxide (CO) in the plenum.

A CO detector cannot tell you if a heat exchanger is good. A CO detector can indicate a heat exchanger is cracked or perforated only if all of the following conditions occur simultaneously:

- a. The flame generates enough CO (lack of oxygen, excess fuel, high temperature).
- b. Enough exhaust gases are emitted from the heat exchanger crack or perforation.
- c. The exhaust gases from the crack are not diluted too much before coming in contact with the sensor. A cracked heat exchanger may leak CO in a small stream. You may measure high concentrations only an inch away.
- d. The heat exchanger is the only possible source for the CO detected.

Note: I have not tried this but have heard of some that will spray WD-40 or non flammable Gunk penetrating oil into the burner chambers (not the outside) of heat exchangers of furnaces with in shot burners to generate CO to see if CO will leak to the outside of the heat exchanger. I still have not tried this method. If you do a fire extinguisher might be a very good item to have on hand.

Using combustion meter measuring undiluted flue gases.



One sign of a cracked heat exchanger is a change of oxygen concentration in the flue gases of greater than one half percent oxygen, or a change in the carbon monoxide level greater than 25 parts per million (PPM). This change is measured by comparing readings before and after the circulation blower has turned on. For this test to be valid, CO levels must be present in the flue gas.

Check Bacharach's site [Checking for Cracked Heat Exchangers](http://www.bacharach-training.com/Tips/Cracked.htm)
<http://www.bacharach-training.com/Tips/Cracked.htm>

Magnehelic gauge test. Tape shut burner chamber openings or combustion air box and the flue outlet. Connect magnehelic gauge to inducer pressure sensing port. Operate the circulator blower. Movement of the gauge needle indicates leakage into the heat exchanger either from cracks, rust perforations or leaking seals or gaskets.



Photo courtesy of John Mills aka Baldloonie.

Vapco H.E.A.T. Spray, formulated for natural draft furnaces, catalog number HT-1Q. Spray into the blower compartment on opposite side of motor. If burner flame changes color there is a leak in the heat exchanger.

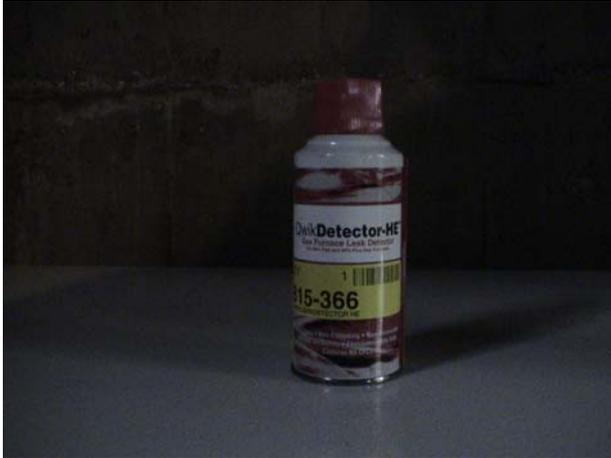


Vapco

<http://www.vapcoproducts.com/catalogPDF/2006prodcatalog.pdf>

page 23 of the catalog.

<http://qwik.com/qwik-detector.jsp> formulated for high efficiency furnaces
QwikDetector-HE PDF File http://qwik.com/qwikdetectorhe_instructions.pdf



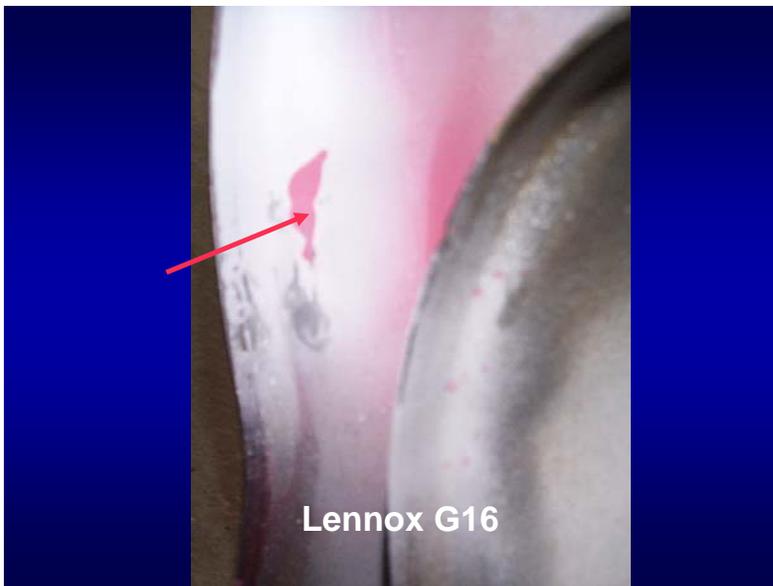
<http://qwik.com/qwik-detectornd.jsp> formulated for natural draft furnaces



Magna Flux Dye Penetrant. Using cleaner then penetrant and then cleaner over suspected area developer is then sprayed. Penetrant which has seeped into cracks, perforations or pinholes is pulled out by the developer agent. Full length of crack is seen not just what may be seen without this test. Magna Flux cleaner, developer, red penetrant and zyglo fluorescent penetrant is available through **welding supply stores**. It was originally developed by the military and has a mil standard labeled on the cans



Below is a photo of a Lennox G16 Dura Curve Heat Exchanger. The red arrow points to the location of the crack. The red penetrant is bleeding out of the crack onto the white developer. Cracks display as a line or a line of dots. Porosity shows as dots.



Smoke Candle and Puffer Test

The smoke candle is placed inside burner chamber and lit. You'll need a candle for each burner chamber. Evidence of smoke on the exterior of the heat exchanger indicates leakage.



Using a smoke puffer you can fill the burner chamber with smoke. Then turn the blower on. If the smoke sprays out and away from the burner opening you have a good indication of a leak in the heat exchanger.



Camera systems have some advantages over just using a mirror. You can gain access to some narrow openings. The inspection can also be recorded for later viewing by the home owner or for training other technicians. Before you buy a camera or optical scope things you might consider. Image quality can the lens be focused or has auto focusing to produce a clear viewable image? Recording capabilities. If you are not presently recording the inspection is there a possibility in the future that you may want to? Then consider a camera or scope that presently records or has the electronic connections to connect a recorder or digital camera. How small of an opening will you need to view through? Cameras and scopes have different size lens. Resolution of the image, high vs. low. If you are looking for cracks go with high resolution if you can afford it.

After deciding which features you need now you can now make a selection of a camera or scope system fits those needs.

Here are a couple sources for cameras are:

The Inspector

<http://www.shamrockindustries.com/shamweb/default.shtml>

This is a high resolution, auto focusing, true infrared camera system with a Duotone monitor. Uses a flash card to document inspection with the push of a button. This can later be downloaded to a computer.



IC Cam

http://www.rotobrush.com/products/product_catalog.aspx?catalogid=5&catalogname=Video_Inspection_Systems - *UPDATED!*



Abatement Technologies

http://www.abatement.com/residential/hvac_video.htm

Visible Defects

<http://www.visibledefects.com>

4 inch LCD Color monitor, audio video output for recording.



Optical boroscopes can also get you access to some narrow openings. Yet do not offer the ability to tape the inspected areas. This is original Testo View scope.



By super gluing a larger mirror to the Testo mirror you can improve the quality of the view.



Be sure to properly attach the mirror. The mirror support should be on the side of the head that has the large optical opening. The two smaller openings are the lights.



Testoview

<http://www.testo.com/testoview.htm>

The Testo 318-V Scope Auto focusing lens plus it has a video output jack for recording your views



The dime gives you a reference of how large the lens is.



To the left is a photo of that same dime taken from the screen of the 318-V

Rigid See Snake Micro
<http://www.ridgid.com/>



Below that same dime compared to the lens head
of the See Snake.



Below is that same dime on the view screen of the
See Snake.



Some furnaces such as the Lennox Pulse require that the heat exchanger to be pressure tested to determine if the heat exchanger is leaking beyond allowable limits. Use kit part number 74K96 available through Lennox Industries.



The kit comes with the pressure gauge fixture, plugs, instructions and a furnace wall patch plate. Additional patch plates available in a package of 5 using part number 16L98 can be ordered through Lennox. The plugs can also be used to block off standing tees on air conditioning drains so you can use a sludge sucker at the drain end to clear plugs.

The carrying case and inlay is something I did on my own to protect the gage assembly as well as provide quick inventory to insure that plugs are not left behind. This case was obtained through Sears.

Most failures on the Pulse occur at the solder joints at the condenser (secondary heat exchanger) outlet tube.

However failures can occur at other areas as this photo shows. The resonator can has a crack where the bubbles appear.



Here's an old timer's method for oil furnaces. According to the Timken Silent Automatic Oil Burner Serviceman's Guide, 1926 Edition:

A serviceman can easily check whether smoke is passing through the heat exchanger due to a crack is to shut off the burner and place a burning piece of TARPAPER in the combustion area. By then placing his nose next to a register if the smell of asphalt is detected in the home then there is probably a defective heat exchanger.

Here's a test that is recommended by someone in the land of natural gas, Alberta, Canada. It's called a sulfur test. We bring the unit up to full operating temp. then a small amount of sulfur is placed on a tiny collectors spoon which is fastened to a piece of soft 1/4" copper tubing about 15 and 22" long (I made 2 for different applications) and then inserted into the burner area. I let it burn in each chamber for about 15 seconds, moving it slowly back & forth, side to side. The amount of sulfur should do 3 or 4 chambers. NOTE: if you need additional sulfur, make sure you cool off the spoon in some water, or you'll have one stinky fire on your hands!! And don't lay the hot spoon on a linoleum floor or something until it cools off.

The principle being... if the exchanger is good, the rotten egg smell will be taken out of the home via the chimney, if it has a hole or crack anywhere in it, the smell will be distributed into the living space via the heating ducts, just like CO would be. I still monitor for CO with a digital 4 gas detection unit as an addition back-up, but as you have already heard, there are many conditions that can cause false or no readings at all.

The test is very cost effective, quick to perform, and quite reliable. Most HVAC companies around here use it. The sulfur is available at Pharmacy Drug Co. and at some Veterinarian places. It's bright yellow in color, and can be in powder or pellet form. It's called Precipitated Sulfur and sells for ~\$15.00 a lb. which lasts a long time.

Hint: try and be quick if you have to pull the spoon completely out past the heat shield to get it into the next chamber, so you don't smell up the area you are working in. It's pretty smelly stuff!

The following "Why Do Heat Exchangers Fail?" Courtesy of reprint by Steven J. Miles, Visible Defects LLC.

Why Do Heat Exchangers Fail?

An open letter to you, our valued customer:

Dear Friend,

I'm sorry that your heat exchanger has been condemned. I know that you didn't plan to have a broken furnace now.

You deserve the best trained and most professional service available. Our goal is to provide you with technicians that are on the cutting edge of current technology and diagnostic techniques.

Carbon Monoxide is highly toxic. Because of this danger, we have invested in new, patent pending technology that allows us to identify potentially hazardous furnaces much earlier and easier than ever before.

Diagnosing heat exchanger failures and other dangerous furnace conditions is part of the annual heating inspection that every industry organization and equipment manufacturer recommends.

We follow two industry guidelines when inspecting your heating system.

The first is the International Fuel Gas Code Annex H, it instructs us to "inspect the heat exchanger for cracks, openings, or excessive corrosion."

The second is the American Gas Association, they state that "any visible crack or hole discovered during this step is reason to **REQUIRE** replacement of the heat exchanger or furnace." Hopefully this guide will help you understand what was found during the inspection that was

performed on your equipment.

Thank you very much for trusting your family's safety and comfort to us. It is our primary concern at this time.

Heat Exchanger Q&A:

What is a Heat Exchanger?
What is a Chamber? How do they fail? Why do they fail?
How do you know?

What is a Heat Exchanger?

Your heat exchanger is a combination of one or more chambers or "cells" that heats the air in your home.

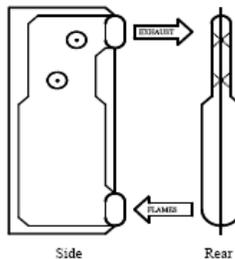
Your heat exchanger is designed as a barrier, its job is to contain a fueled fire, transmit the fire's heat to your living space, and vent the toxic exhaust gasses and by-products to the outdoors, without harming you or your family.

What is a Chamber or Cell?

Heat exchangers are made of one or more chambers called cells. Cells are formed from two fairly thin metal "shells," sealed around the edges, with two openings, one for the fire to enter, the other to exhaust the fire's toxic combustion gases.

How do they fail?

The most common failures are holes and cracks. Holes are usually caused by corrosion.



Cracks are usually caused by stresses that occur during the heating cycle.

Other defects include things like; defective draft diverters, front panels, gaskets, etc.

How do they fail?

Holes / Corrosion:

Moisture that has mixed with exhaust gases becomes acidic. When it comes into contact with the heat exchanger it will corrode the metal, until eventually, it penetrates the heat exchanger.

The moisture that causes the corrosion can come from different sources. The moisture content of the fuel, relative humidity in the home, air conditioner coils leaking, etc.

Fact: *(There is enough acidic moisture content in burning fuel to corrode bare metal quickly.)*

Cracks:

Your heat exchanger cells are made out of very thin metal. When the burners ignite, the heat causes them to expand slightly in every direction. When cooling off, they shrink to their normal size and shape.

Fact: *(You can literally hear the pinging noises as the metal in your system expands and contracts.)*

The stresses of constantly expanding and contracting, bending and flexing are usually concentrated in a small area. This continuous flexing back and forth, like bending a paper clip, eventually causes the metal to crack and the heat exchanger to fail an inspection.

How do you know?

There are many ways to inspect a heat exchanger, they include; Visual, Flame Disturbance, Dye Penetrant, and Tracer Gas.

Visual Inspection:

Inspecting the heat exchanger with a light and mirror.

Disadvantage: Some modern heat exchangers curve such that a visual inspection from the burner, and blower areas only reveals about 20% of the heat exchanger to inspection.

"Any visible crack or hole discovered during this step is reason for requiring replacement of the heat exchanger or furnace."
American Gas Assoc. (AGA)
(<http://www.aga.org>)

Flame Disturbance Test:

Inspect the burner box with a lit candle while the blower runs to check for any flame distortion that would indicate a hole or crack.

Disadvantage: The same as visual inspection. Some modern heat exchangers curve such that a candle inspection from the burner area, only reveals about 20% of the exchanger to inspection.

"Disturbance of the flame by the blower under this step is reason for requiring replacement of the heat exchanger or furnace."
(AGA)

Dye Penetrant Test:

A non-toxic fluorescent penetrating dye is sprayed on the "air side" of the heat exchanger. The inside or "combustion side" of the heat exchanger is then inspected, using an ultra violet flashlight for evidence of any leakage, seepage, or drips that would indicate a failure of the heat exchanger to separate the "air" and "combustion" sides of the heat exchanger.

Advantage: Allows cracks, holes, and defects, that cannot be seen by the naked eye, to be found by looking for the bright fluorescent dye penetrating inside of the heat exchanger.

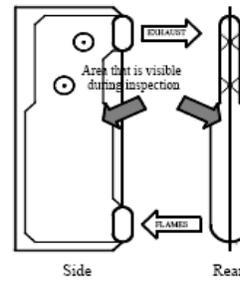
Disadvantage: Much more difficult and time consuming than visual or flame disturbance test. Penetrating dye may cause furnace to smell slightly the next time it comes on.

Tracer Gas Test:

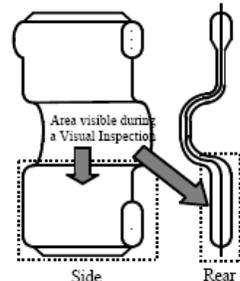
The heat exchanger cells are isolated and a tracer gas is discharged into the cell. A gas detector is then used to locate any tracer gas outside of the combustion chamber.

Advantage: Good for tubular type heat exchangers.

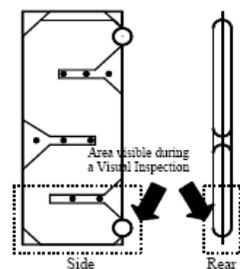
Disadvantage: Very time consuming, requires specialized and calibrated test equipment. Since tracer gas is lighter than air, it's only useful for finding holes in top third of the heat exchanger.



"Clamshell"



"Duracurve"
G8-G20



"Serpentine"

BOOKS

Want additional sources for heat exchanger testing and inspecting which include detailed methods and photographs of various heat exchangers showing locations of defects? Check the following.

Furnace Safety Consultant's

<http://www.furnacesafetyconsultants.shoppingcartplus.com/home.html>

Heat Exchanger Experts by Ellis Prach

<http://www.heatexchangerexperts.com>

Residential Furnace Heat Exchangers by Keith Prach if you can find the CD version has more photographic documentation.

http://www.inspectiondepot.com/Catalog/product_detail.php?PID=84

A Documentation Book of Furnace Heat Exchanger Failures 2007/2008 Edition

Shamrock Industries <http://www.shamrockindustries.com/shamweb/default.shtml>

Tim McElwain Gas Appliance Service Training and Consulting, 22 Griffith Drive, Riverside, Rhode Island 02915 phone 401.437.0557

An excellent book for combustion and carbon monoxide testing "Carbon Monoxide a Clear and Present Danger."

<http://www.escoinst.com>

TRAINING CLASSES

A training class on heat exchangers may sound rather mundane but you can learn a lot from a class. Some of the trainers such as Ellis Prach, Heat Exchanger Experts, brings numerous heat exchangers from a variety of furnaces, old and new.

Kansas City Building Institute

<http://www.kansasbuildingscience.com/inspect.htm>

Heat Exchanger Experts

<http://www.heatexchangerexperts.com/index.htm>

Furnace Safety Consultant's

<http://www.furnacesafetyconsultants.shoppingcartsplus.com/home.html>

Carbon monoxide is not the only thing to be concerned about from furnaces. Check this site about the toxicity of natural gas and other toxins.

<http://www.geocities.com/RainForest/6847/report1.html#6.0>

CONCLUSION

For those that want one single never fail method for inspecting heat exchangers. There is none. Think about it. Would you inspect a Pulse heat exchanger the same way as a clamshell heat exchanger, a clamshell heat exchanger the same way as a tubular heat exchanger? No you wouldn't nor should you. With equipment, knowledge and training you can become more proficient at inspecting heat exchangers.

Also check your local building codes. They may list further defects other than the ones listed requiring heat exchanger or equipment replacement.

Types of Heat Exchanger Failures

- Cracks.
- Rust perforations.
- Over 50 percent of the heat exchanger wall thickness has rusted away.
- Leaking heat exchanger seams.
- Loose or missing screws securing cells.
- Broken crimped rings
- Broken or leaking seals or gaskets, including cemented seals.
- Missing factory welds on seams.
- Clean out port gaskets missing or leaking.

As a service technician you need to locate defective heat exchangers you need to practice – practice - practice Bob Cousey, oops showing my age. Michael Jordan didn't become a great basketball player without practice. And you can't become proficient at inspecting heat exchangers without practice either.