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Furnace High Velocity Thermocouple Traverses are performed to accomplish the following:

1. Quantify furnace exit gas temperatures.
2. Ascertain furnace temperature profile.
3. Quantify furnace Oxygen level.
4. Ascertain furnace Oxygen profile.

The HVT probe is typically inserted into the furnace at the Furnace Exit and at the Nose Arch Apex. Temperature at these locations can range between 1500°F and 2800°F requiring the HVT probe to be water-cooled. Water source at the HVT location should be 80 PSI and capable of delivering at least 30 gallons per minute of flow. Figure 1 --shown below-- illustrates the HVT probe design. Figure 2 -- illustrates typical HVT traverse locations on a 500 Mw coal fired unit.

Figure 1 – Water Cooled HVT Probe

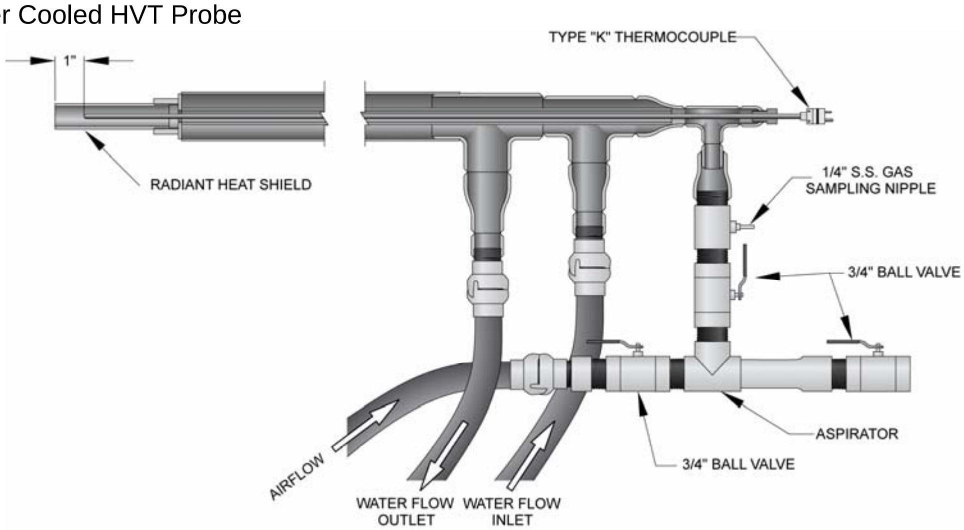
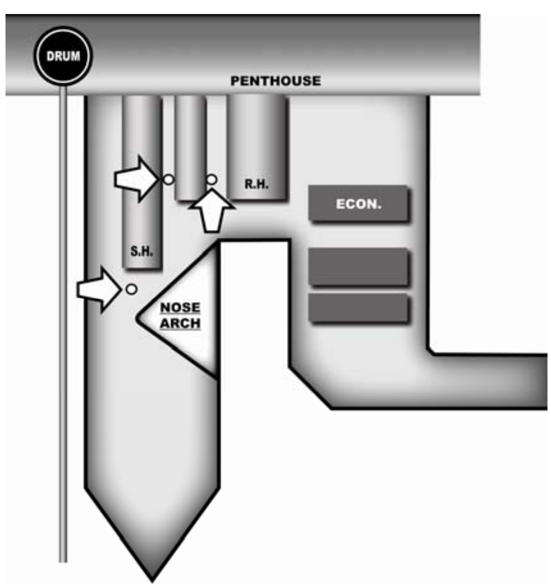


Figure 2 -- Typical HVT Traverse Test Planes



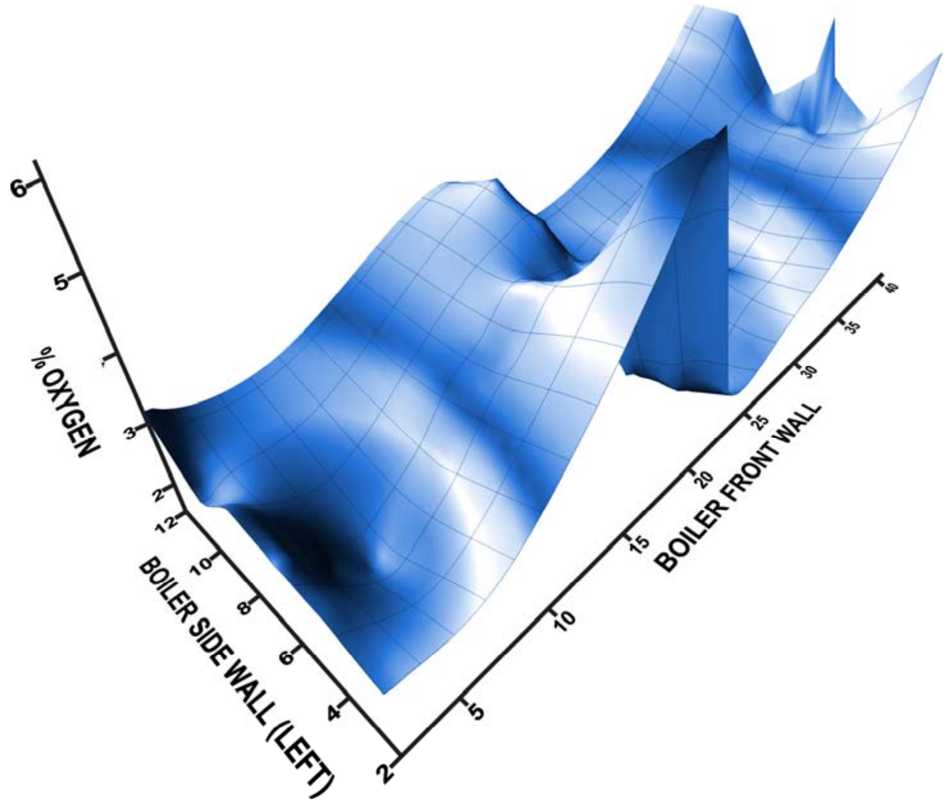
Diagnosis of Combustion Problems by Furnace HVT Traverse

The HVT traverse is, without a doubt, the single most important test in diagnosing combustion related problems. The HVT probe, by design, is intended to accurately measure gas temperature, but its greatest importance is the measurement of excess Oxygen. Steam generators over (10) years old have a common tendency toward high air in-leakage. Air in-leakage through the penthouse, nose arch dead air space, bottom ash hopper dead air spaces, expansion joints and the boiler setting are commonly assigned very low maintenance priority. These items are much more critical to unit performance than most realize. Further complication sometimes includes the lowering of excess air to reduce free Oxygen and subsequently reduce the formation of thermal NO_x to comply with emission levels stipulated by the Clean Air Amendment. Typically, excess Oxygen is controlled by an indication of Oxygen level at the economizer exit. High levels of air in-leakage through the areas previously mentioned dilute the flue gas with Oxygen prior to its measurement at the economizer exit. It is not uncommon to find total leakages between the furnace exit and the economizer exit in the 20% to 30% range. This results in indicated Oxygen of 3% to 4% at the economizer exit and 0% (reducing or sub-stoichiometric atmosphere) at the furnace exit. Temperature is rapidly depressed due to the high density of heating surface following the furnace exit. After the furnace exit, temperature usually falls below the ignition point of carbon very quickly. Without available free Oxygen, the carbon fails to combust prior to it's quenching below ignition temperature, resulting in high carbon in ash and high carbon monoxide levels.

Performing an HVT traverse to determine the presence of Oxygen at the furnace exit is a simple, cost effective and efficient method of ascertaining the magnitude of air in-leakage. The absence of an oxidizing atmosphere at the furnace exit is usually the result of high air in-leakage. High air in-leakage will result in increased dry gas loss due to the heat absorption of tramp air which did not pass across the air heaters. If excess air level is raised to obtain an oxidizing atmosphere in the furnace without reducing air in-leakage, higher than design draft losses will be incurred. High air in leakage will also cause the boiler exit temperature to appear falsely low. The “Tempering” effect of the cool ambient air in-leakage will lower indicated boiler exit gas temperature, when in fact, if corrected for leakage, exit gas temperature would be much higher. Numerous other complications are also the result of this condition, these are as follows:

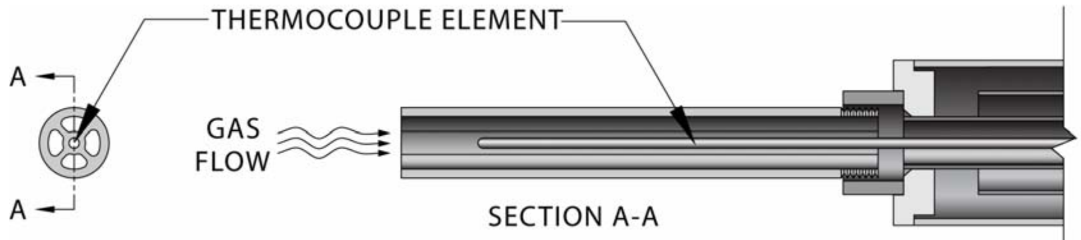
- Secondary or delayed combustion which elevates the combustion zone, reduces waterwall heat absorption and results in high furnace exit gas temperature.
- The resulting high furnace exit gas temperature combined with existence of a reducing atmosphere can lead to the following:
    - Decreased combustion efficiency.
    - Overheating of superheat and reheat tubes, which can eventually result in tube failure.
    - Combined with the effect of a reducing atmosphere, tube wastage and the subsequent tube thinning can result in future tube failures.
    - Aggravation of coal--ash corrosion.
    - Increased de-superheating spray flow.
    - Serious slagging and fouling of heating surfaces. Ash fusion temperatures are sometimes 250°F lower than oxidizing ash fusion temperatures. High exit temperatures combined with lower ash fusion temperatures facilitate a much higher proclivity towards heavy slagging and fouling.
- The resulting high furnace exit gas temperature combined with existence of a reducing atmosphere can lead to the following:
    - Increased cycle losses due to higher soot blowing frequency as a result of increased fouling and slagging of heating surfaces.
    - High boiler exit gas temperature which can lead to accelerated deterioration of air heater heating surface and possible degradation of precipitator performance.
- High leakage can result in reduction in available Induced Draft Fan capacity and subsequent de-rating of unit generation and availability.

Temperature and Oxygen profiles obtained by the HVT traverse can also be an indication of imbalances in air and fuel originating in the burner belt zone. Pulverizer fuel imbalances, combustion (secondary) air imbalance, closed air registers, plugged fuel lines, etc. are easily reinforced by the temperature and Oxygen profiles determined by a HVT traverse. It is also useful to compare side to side flyash Loss On Ignition (L.O.I.) and slagging tendencies with HVT Oxygen profiles. As an example, the figure below illustrates the Oxygen profile on a 500 Mw wall fired unit. The dip or cavity in Oxygen level correlates with an air register which was frozen in the closed position.

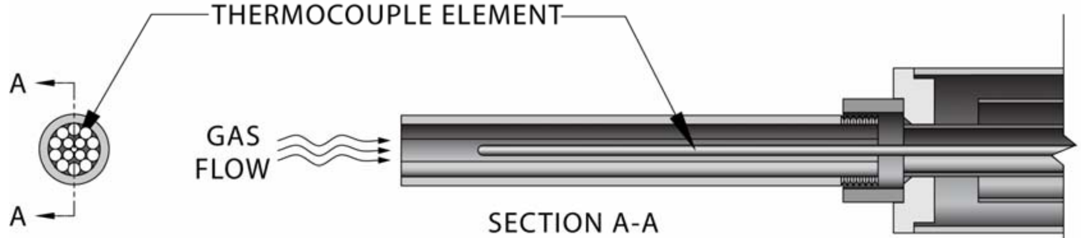


Accurate Determination of Furnace Exit Gas Temperature

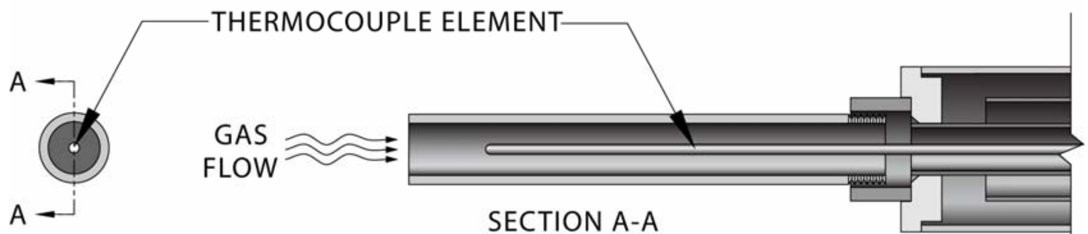
Accurate measurement of furnace flue gas temperature requires utilization of a shielded high velocity thermocouple. Bare thermocouples, infrared and other temperature measurement devices will not facilitate accurate measurement of flue gas temperature. New technologies such as acoustic pyrometers, which remain in the early stages of development, have shown some potential, but are not yet consistently reliable or practical. Temperatures measured by bare thermocouples are falsely low due the radiant heat emanated away from the thermocouple. HVT's, also identified by some as a "suction pyrometer", reduce this effect by aspirating flue gas at a high velocity across a shielded thermocouple junction. The multiple shielded thermocouple (MHVT) would eliminate the error between true gas temperature and temperature observed by the HVT. Use of a MHVT in a coal fired furnace is not practical. The small gas lanes of a MHVT radiation shield become fouled with slag, debris and ash in a very short time. A high degree of testing error is caused by high tendency of pluggage of the MHVT radiation shield. Based on our experiences over the years, we advocate the use of a single shielded high velocity thermocouple. Gas temperatures slightly lower than true gas temperature will be indicated by the single shielded HVT, however, pluggage of the radiation shield and the subsequent testing error is minimized when properly utilized. The figure below illustrates the single shielded and multiple shielded HVT radiation shields.



TYPE E BUREAU OF MINES
HIGH VELOCITY THERMOCOUPLE SHIELD ASSEMBLY



MULTIPLE SHIELD HIGH VELOCITY
THERMOCOUPLE SHIELD ASSEMBLY



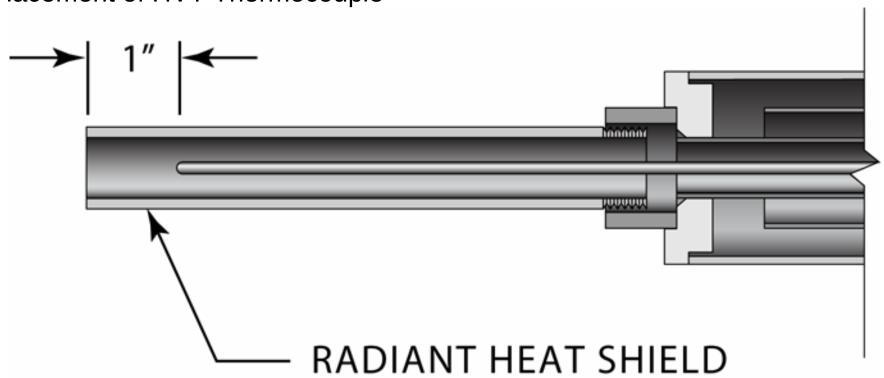
HIGH VELOCITY THERMOCOUPLE SHIELD ASSEMBLY

Performing a HVT Traverse

1. Water supply, water drain and air supply hoses will be required to use the HVT probe. The number and length of hoses required depends on the location of water sources, drains and air supply. 1” Ø hose is recommended for both the water supply and drain hose. A water source of 80 PSI and 30 gallon per minute <u>minimum</u> is required. Insufficient water pressure and flow may result in overheating of the HVT probe during the traverse. Overheating of the probe could damage or destroy the probe and possibly injure personnel using the probe. An air source of 90 PSI is required. Inadequate air pressure will result in lower than optimum aspirating rate which will indicate a lower than actual gas temperature.
2. Hoses should be connected to the probe and arranged in such a manner that easy movement of the probe around all test ports without tension or "kinking" of hoses is facilitated. Care should be taken not to use excessively long water inlet or drain hoses. Excessively long water hoses will result in increased restriction, reducing water flow through the probe.
3. Chicago fittings connecting the water and air hoses to the HVT probe must be wired or pinned together for safety. Water draining from the probe can be extremely hot at times, and if an air or water hose becomes detached during the traverse, injury to test personnel and/or damage to the HVT probe may result.

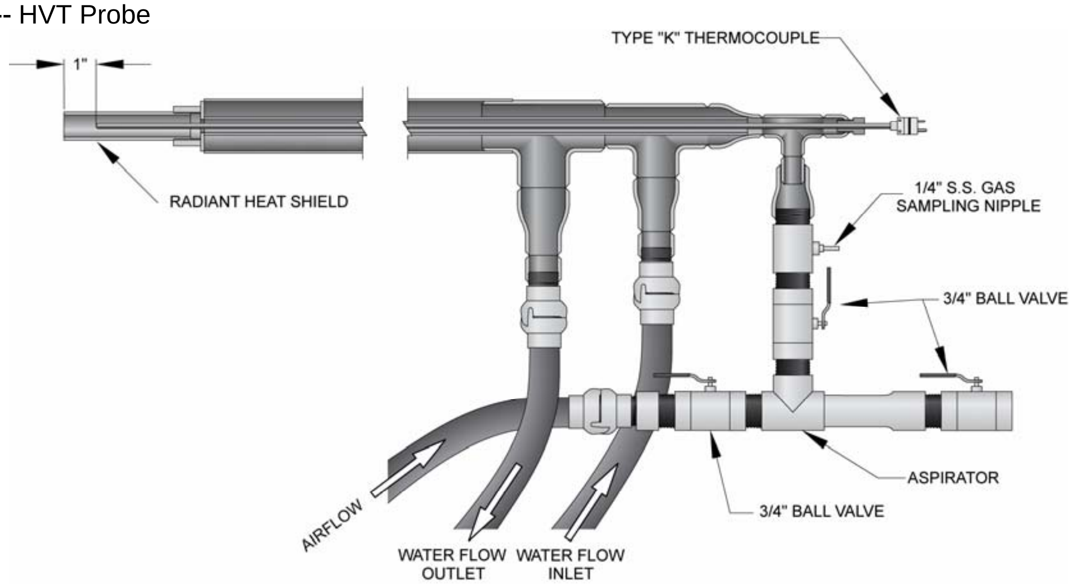
4. Mark the probe at 2' increments, starting from the tip of the radiation shield. Each of these points will be a traverse point where temperature and Oxygen are measured.
5. Ensure that the thermocouple is 1" from the tip of the radiation shield. The thermocouple should also be centered and not touching any part of the radiation shield. Figure 3 -- illustrates proper position of thermocouple in relation to the radiation shield.

Figure 3 -- Proper Placement of HVT Thermocouple

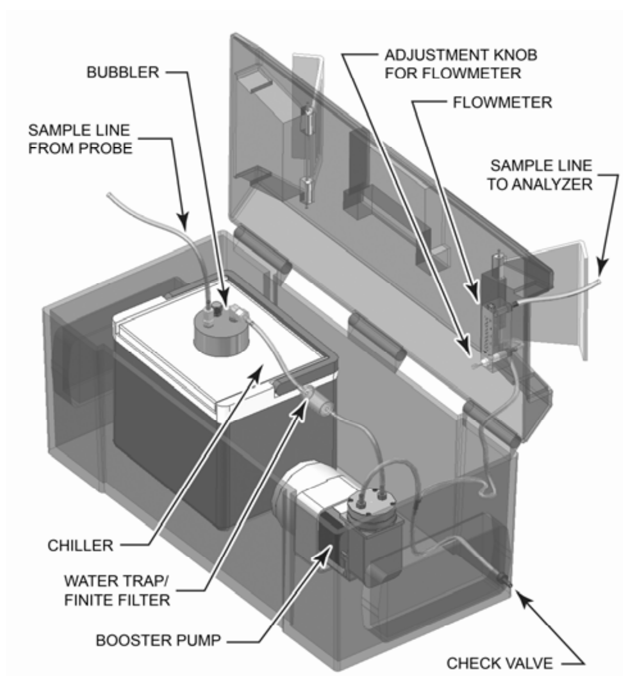


6. Before inserting the probe into the furnace, be confident that the water supply is of adequate pressure, turned on and water is flowing through the probe. Do this visually by verifying water is exiting the drain hose. The probe will quickly "melt down" as it is inserted without water flowing through the probe. It is suggested that the drain water flow be verified by filling a (5) gallon bucket with water flowing from the drain hose exit. (30) gallons per minute is desired, therefore, a (5) gallon bucket should be filled in (10) seconds.
7. Ensure that the compression fittings on the thermocouple are tight and all other fittings are gas tight. Threaded connections should be sealed with Teflon tape and leak free.
8. Clear the probe's sampling line and thermocouple passage. Do this by opening valves ❷ and ❸ , plugging the outlet on the aspirator by closing the ball valve ❶ and turning on the air supply to force air through the probe's sampling line and thermocouple passage. Verify that air is blowing from the tip of radiation shield. (See Figure 4 for valve designations) This procedure should never be performed with the probe inserted into the Furnace. Performing this procedure with the thermocouple "hot" will accelerate thermocouple deterioration and cause premature thermocouple failure.
9. If aspirating air flow is not adequate, falsely low gas temperatures will be indicated. To ensure sufficient aspirating air flow is obtained, connect a U-tube manometer to the HVT probe's ¼" SS gas sampling nipple and turn on the air supply and begin aspiration. With all valves open and aspiring air on, the U-tube should indicate a suction of 14" w.c.

Figure 4 -- HVT Probe



10. Typically, temperature measurement is documented traversing “into” the furnace, and gas samples are collected as the probe is retracted. Insert the probe into the furnace at the 2' mark, turn on the air and begin aspirating gas across the thermocouple. Do this by ensuring air is turned on at the source and valves ❶, ❷ and ❸ are open. Observe the temperature by connecting the thermocouple to a digital thermometer. When the temperature stabilizes, record and move to the next point until the temperature is recorded for all traverse points. Temperatures are sometimes "noisy" and can fluctuate as much as 50°F, this is indicative of secondary combustion and poor mixing in the burner belt zone. If this occurs, record temperatures on 10-second intervals for several cycles and average temperature for that traverse point.
11. Throughout the entire time the HVT probe is inserted into the furnace, test personnel should keep a bare (un-gloved) hand on the probe to monitor surface temperature. If the probe becomes too hot to touch, remove it from the furnace. Probe overheating is most likely caused by insufficient cooling water flow. Check to ensure water supply is adequate and water supply & drain hoses are not "kinked".
12. Verify water is flowing at all times by placing the drain hose in a location that it is visible to test personnel conducting the traverse. Test personnel should ensure that hoses do not become "kinked" during the traverse, especially when moving the probe between traverse points.
13. Upon completion of the temperature traverse, turn off air supply, close valves ❶ , ❷ and ❸ . If these valves are not closed, atmospheric Oxygen will enter through the aspirator, diluting the gas sample and resulting in falsely high indicated Oxygen levels.
14. Prior to beginning an Oxygen traverse, the gas analyzer should be calibrated. Standard gas of 2.5% Oxygen, 300 PPM Carbon Monoxide and balance Nitrogen should be utilized. If a reducing atmosphere is anticipated or observed during the traverse, additional calibration checks with 0% Oxygen, 1000 PPM Carbon Monoxide gas are recommended. A post-test calibration is also required. Analyzer drift between the pre-test and post-test calibration will be documented on the traverse data sheet.
15. Connect the Oxygen Analyzer to the probe's ¼" stainless steel nipple using tubing.
16. Leave the probe fully inserted into the furnace, while the analyzer is pumping a sample, for approximately (2-3) minutes or until Oxygen indication stabilizes. If an ECOM analyzer is used, it is critical that flow into the analyzer be monitored and maintained at (4) to (6) SCFH or (2) to (3) LPM. Record Oxygen, Carbon Monoxide and any other desired gas constituent. Then withdraw 2’ to the next traverse point and repeat the process. If the Oxygen reading tends to vary more than 0.5%, it is suggested that the readings be recorded on (30) second intervals and averaged.
17. Use of an ICT gas conditioning system in conjunction with the HVT probe and analyzer is preferred. The gas conditioner improves filtration of gas particle constituents, decreases individual sample point collection time and precisely meters flow into the gas analyzer. A schematic of the gas conditioning system is shown below:



18. Prior to use, water should be added to the bubbler on the gas conditioner and the fill/drain plug sealed with Teflon. The bubbler should be filled with 2” to 3” of water, or approximately 250 to 300 ml. The bubbler should be placed in the chiller and ice placed around it. Once temperature measurement has been completed and the valves closed, connect the sample line (from probe) to the bubbler inlet. Establish power to the gas conditioner, and connect the conditioner discharge (outlet of flow meter) to the gas analyzer. Adjust the flow meter needle valve as necessary to provide the recommended flow. **Note: The gas conditioner should never be connected to the HVT probe while the aspirating air valves are open.** The suction created by the aspiration effect could pull the water from the bubbler and possibly damage the conditioner and analyzer diaphragm pumps.

19. If at any time throughout the test the probe appears to be plugged, it should be removed from the furnace and back blown. This is accomplished by repeating step No. 8 above. Once finished, reinsert the probe and resume testing. Make sure the Oxygen analyzer shows a steady reading before moving to the next point.

20. At the end of each day of use, the HVT probe should be flushed with water (thermocouple/gas lane) to remove any deposits of corrosive gases which may have condensed in the center tube. In addition, the chiller and bubbler should be emptied and flushed out after use.

Problem	***Recommended Action***
Low Flow: The ECOM AC built-in pump pulls less than 2 LPM (4SCFH).	Check external hoses for holes or "pinching". Check pressure drop across the ECOM heater/water trap. Drop should be approximately .5 LPM (1 SCFH). Remove hoses from the scrubber canister and gently blow through it to ensure that there is no restriction to flow. Pump Cleaning: If these procedures are not effective in increasing flow, it will be necessary to access the ECOM AC pump. Remove the screws securing the top panel (screws located around top periphery). Pump is located near the center of the unit. Prior to removing the hoses, label them, and look for signs of restriction. Remove the hoses and check the flow through the pump only. The flow should be at least 3 LPM (6 SCFM). If it is less than this, the pump needs to be cleaned. Once hoses have been disconnected, use a No. 1 Phillips screwdriver to remove the (4) screws securing the pump diaphragm. Remove all pieces above the pump piston assembly, being careful to retain the proper position and orientation of each piece. Each individual piece should be cleaned using soap and water. Be sure to clear both "flapper" valves (rubber, hour glass-shaped valves secured by metal rings) thoroughly. Reassemble the diaphragm pieces and place them on the pump base. Rotate the assembly side to side to ensure that the pump piston "seats" properly. Replace the (4) screws. Re-test the flow. If flow is still low, the pump is either still dirty or there is an internal leak in the pump. Disassemble, clean, reassemble and test again. Once the pump is capable of generating adequate flow, reattach all hoses and replace the analyzer top. The unit should be ready for use.
Flow (by gas conditioner flow meter indications) is unsually steady, 0_2 reading extremely consistent and somewhat "high", and the tygon "pops" when removed from the probe: Any one of the above conditions could signal a plugged HVT probe.	Remove the probe from the furnace and allow it to cool for 2-3 minutes. Try to blow air through the probe by closing valve No. 1 and opening valves 2 and 3. If this is unsuccessful, carefully remove the radiation shield. Before removing, check to ensure that the thermocouple has not bonded to the shield. Obstruction of the probe usually occurs in the small opening at the tip of the probe. Use a pick or screwdriver to remove any buildup and clean using air pressure. Replace the radiation shield.
High O_2 readings: Could be indicative of actual conditions or could be the result of a leak or insufficient flow into the analyzer.	First verify that the probe is not plugged. If it is, follow the steps as outlined on page 8 to correct. If the probe is clear, check to see if the analyzer is pulling sufficient flow. If not, look for leaks and/or restrictions and clear the pump as described on page 8. A quick method to check for leaks across the ICT gas conditioner is to hook the sample line from the probe directly to the gas analyzer and compare the O_2 readings with and without the gas conditioner for several points. If there is a noticeable, consistent difference, check all compression fittings. If the leak persists, a compression/vacuum tester will be required to pinpoint the leak.
Bubbler overflows into water trap: This condition is indicative of a possible leak or excessive condensation layout in the probe/sample lines.	To check for a probe leak, initiate cooling water flow and place the probe on an inclined surface in order to view any water exiting the tip. Some occasional escape of water is to be expected; however, a constant flow would indicate a leak. More in-depth leak checking requires pressurization of the probe. In places with extremely cool water supplies, increased condensation and more rapid filling of the bubbler is to be expected. In such cases, dump/change the bubbler water more frequently.