Infrared Inspection Data and Addressing Discrepancies in A Fired Heater Program

By Ty Keeth

Infrared inspection of fired heaters has quickly become the standard for fired heater inspection. Infrared can observe and document the thermal profile of a heater unlike any other method and display it in a way that most can understand when presented properly. With the knowledge of more than just a simple tube temperature, IR can locate many other thermal anomalies that can affect how your heater performs such as heat concentrations, imbalance, hot gas impingement, and the major contributing factor to tube damage, internal fouling.

With the growth of IR applications within petro-chemical systems has come an abundance of information not previously available to process engineers and reliability personnel. Often the data is misused or misrepresented due to lack of understanding of the meaning of the data stream or how to apply the data for optimum heater performance.

Inclusion of IR data has benefits for both reliability and process operations. In a reliability sense, a properly trained technician will provide the best available temperatures for each area of the heater for protection of the tube material. In the event that a determination cannot be made due to indications of internal fouling coupled with OD fouling, the technician will err on the side of caution and may request spot cleaning of the tube section in question or OD cleaning of all available tube surfaces. The primary responsibility of the IR technician is for reliability. Operational data is secondary.

Additional information provided may be useful to process or T/A planning. Early identification of internal fouling deposits can aid in process changes or condition changes to reduce rate of growth or remove the catalyst that encourages fouling growth or aid in planning of maintenance activities. This advantage must be used at the earliest possible time to increase it's effectiveness. Often, these indications are ignored because no tube temperatures are found above operating limits. Unit maintenance periods won't address the fouling observed and a second unplanned outage will be required at a later date.

Process may also take advantage of discounting failing thermal indicators. Often as a TI fails, it will read high. While this has no effect on reliability, it may cause operations to limit the heater duty unnecessarily. With comparison of the remaining thermal indicators, IR temperature data, and IR thermal profile data, the TIs may be safely deleted from the system. Depending on remaining available TI's and the likely hood of internal fouling growth, increased inspection intervals may be suggested to maintain safety.

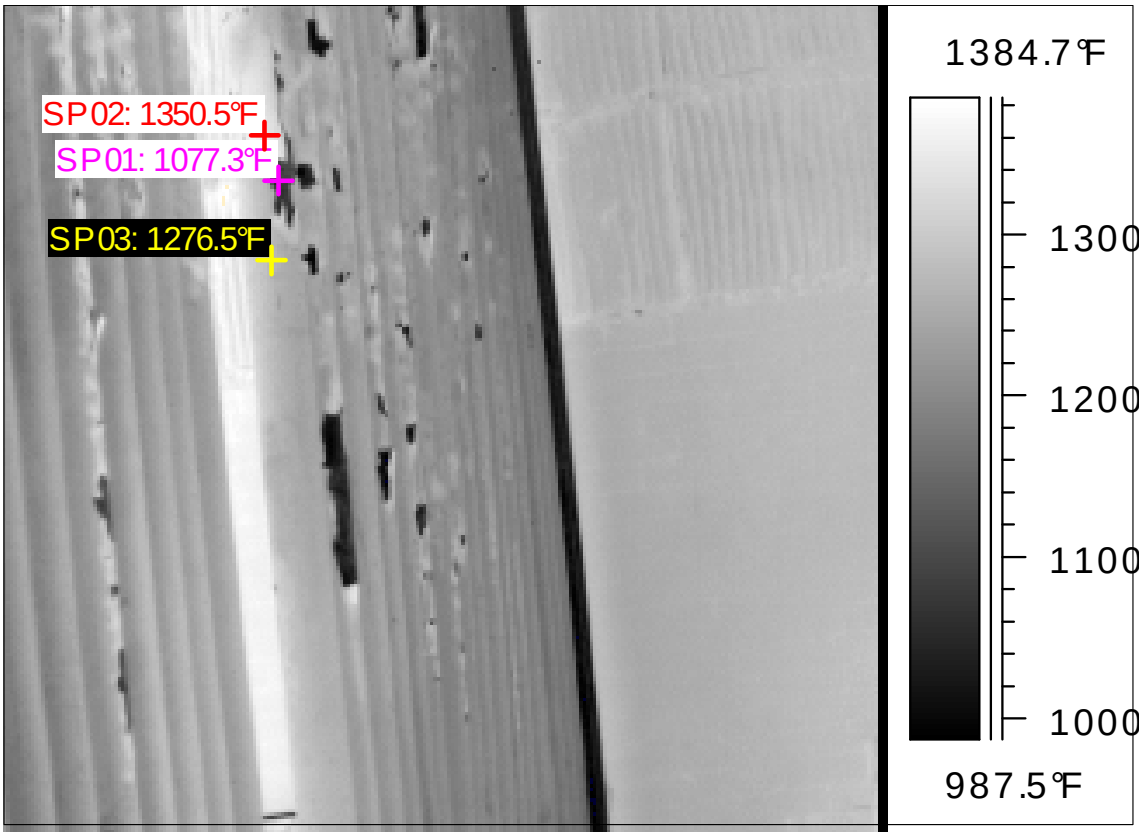
One of the biggest problems in the IR industry is lack of experience. The typical IR technician will have less than 5 years experience and much of that experience is not in fired equipment. This presents a unique challenge as fired heater inspection is not the same as any other IR application. Correct interpretation of the image allows a technician to choose temperature locations based on heater conditions rather than direction of plant personnel to a specific "spot" on a tube. Tube surface, reflected energy, flame location, flame pattern, distance, and angle must all be considered in choosing the right location for measurement. Comparisons in the profile of the image are then visually made to determine if the temperature locations are representative of the rest of the tubes in a nearby area. Often, due to lack of experience, the IR technician because of his training will choose the highest temperature in any given location. The provided temperatures at these locations are often due to outside diameter conditions such as scale, oxidation, or fuel gas contaminants. Experienced technicians will disregard these higher temperatures to determine what locations provide the best available tube temperature data. With a high number of inexperienced technicians, many operations engineers automatically assume high temperatures reported are due to scale and discount anomalies without learning whether or not the technician has already accounted for OD tube conditions. Often the technicians interpretation of the image and thermal patterns included therein are as important, if not more important, than the temperature data provided.

Thermal indicators are often used to validate IR data or vice versa. This is an accepted practice that has limitations not readily recognized inside the industry. As with the rest of the heater, tube surface is a major factor in determining where an IR reading may be taken. If there is not a clean tube surface at a TI then no direct comparison can be made. This does not mean that a general comparison is not possible. If your average nominal tube temperature is reported by TI location as 850 F. and the general IR data ranges at or near 850 F. then direct comparison is not necessary to validate either data stream. At no time should IR data be manipulated to conform to TI data. Forcing the data to meet can cause erroneous data to be included in to the system. In the case of a failing or poorly installed thermal couple it is often found they read higher than actual tube metals. Adjusting IR data to match a TI is not an acceptable practice. ***Once inspection is completed and a trend is noted that suggests the data may be skewed high or low by multiple TI locations, then and only then should a correction be applied***. Of course forcing the IR data to match the thermal couples provides for a very nice and straight line graph, but the data is then irrelevant as it is essentially falsified data. General comparison is more than adequate for most heaters as they are operating well within maximum tube limits.

Factors that affect IR vs. TI data comparison.

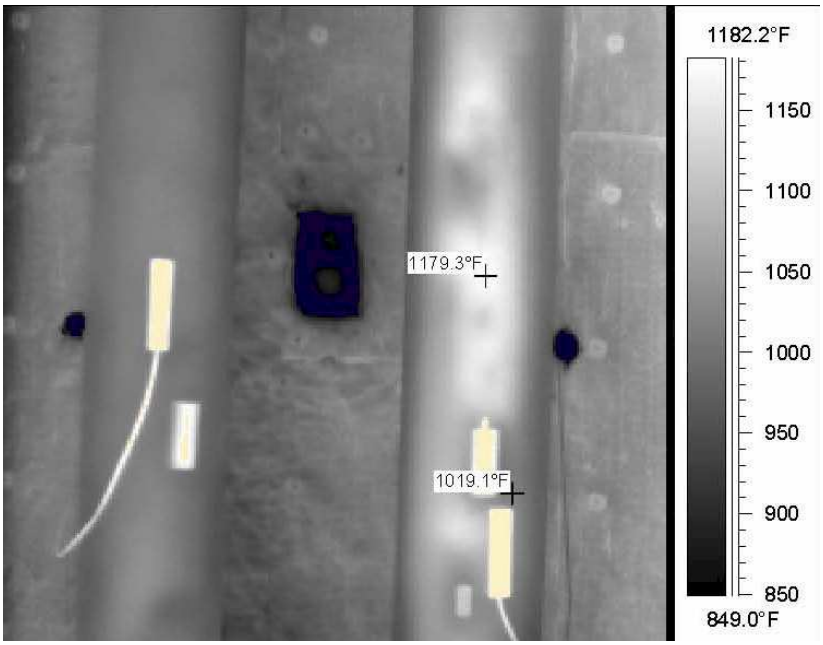
In the event of a discrepancy between the two separate data streams of thermal indicators and infrared, the first question we must ask is why? Immediate disregard of the higher reported temperatures is possibly detrimental to the equipment. More dangerous is the forcing of the data into your currently available TI data by making this data match TI readings.

1. As stated earlier, tube surface condition is often a major factor in erroneous IR data. Scale and oxidation can vary the difference between actual tube skin and reported tube skins temperature by as little as 20 F. to as much as several hundred degrees. This is why visual interpretation and correct location choosing is of the highest importance. Best practice reporting and inspection should be performed in grey scale to improve the ability to resolve OD scale from ID fouling. Use of color images for heater internals is discouraged. OD cleaning at maintenance periods is essential to return the best data possible during the next run.

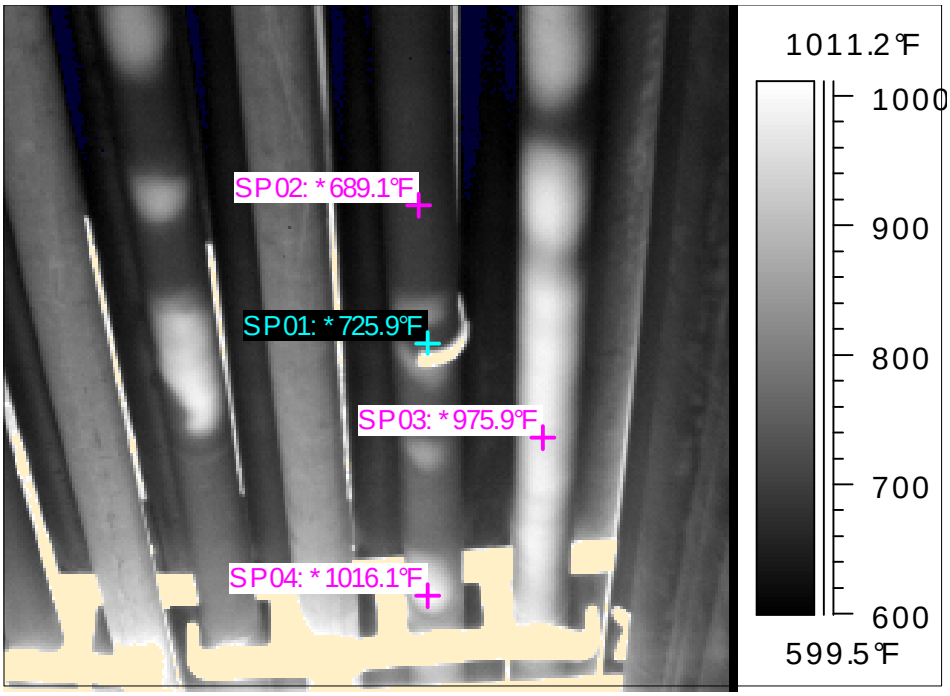


In this reformer heater, severe OD scale limits tube inspection to just a few spots. Variances seen are the result of the cleanest tube, bonded scale, and disbanded scale.

2. Internal fouling is the most significant reason for TI vs. IR data discrepancy. If you have a heater with 100 tubes at 40 ft. in length and 10 thermal indicators, you are essentially measuring less than 1 ft. of tube surface in 4000 ft. or about .025%. IR data, depending on heater configuration and port locations, can measure or observe up to 100% of the radiant section tubes. In the event you have localized fouling issues it is 99 times out of 100 not anywhere near a TI. Even if it is within a few inches of the TI location, the TI may not see any temperature increase. The delta T from the reference or coldest tube skin temperature in each area indicates how severe internal fouling may be.



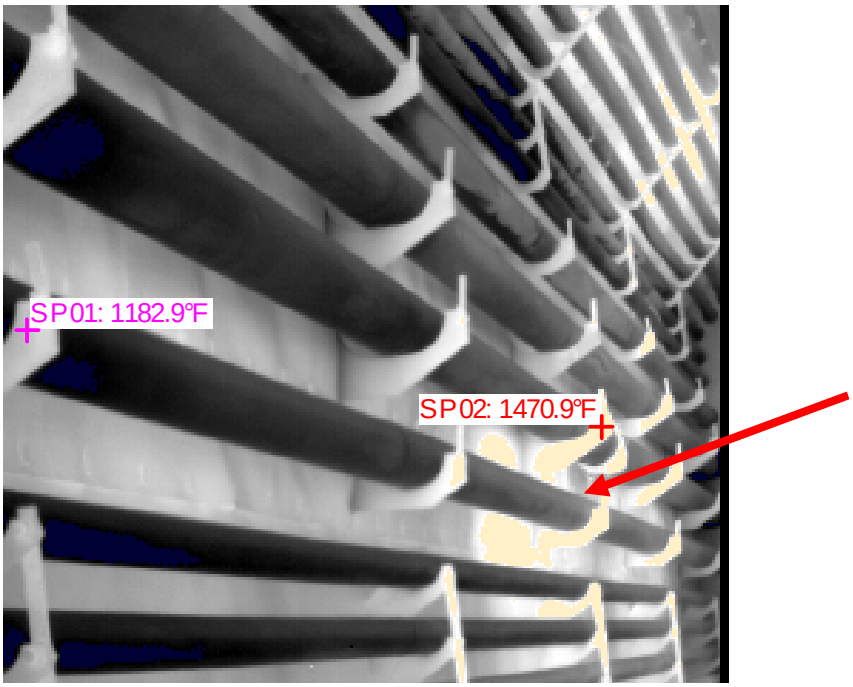
The above image is an example of localized fouling and TI readings. DCS board showed this TI reading was the highest in the heater at 1018 F. Blind comparison showed IR at 1019 F. and the adjacent tube area at 1179 F. A 160 F. delta T is observed in just about 8 inches of tube length.



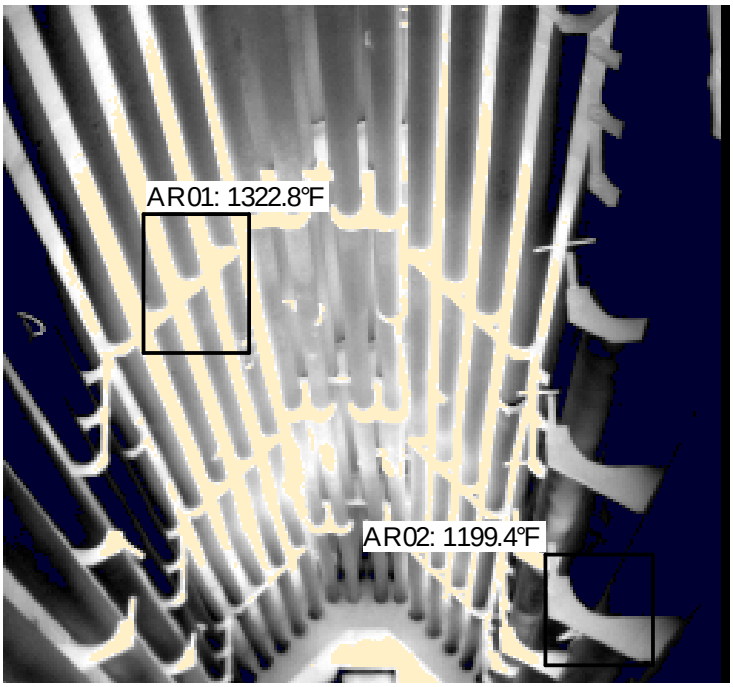
The above image shows localized fouling concentrations near a properly operating thermal couple. Tubes were OD blasted prior to start-up and in operation approx 1 week.

3. Fuel gas contamination can skew infrared data to the high side. Indirect comparison of the data will show a trend that all IR reading are potentially high and the data may be adjusted. To prevent this anomaly the plant must provide consistent fuel gas to all heaters at all times. Since this is very unlikely, if at all possible, technicians must respond on a case by case basis.

4. Poor burner operation may also be cause for discrepancy. Fouled tips, O2 levels, draft conditions, or burners in/out of service can be an additional reason for discrepancy. Often if a TI is reading high in an area, operations will remove a local burner form service. This should only be done until further analysis can be made with IR. It may be masking internal fouling indications or creating improved conditions for localized fouling growth.



Arrow shows local heat concentration due to poor burner operation. Note: No thermal couple is present in the area.



High Delta T. in the center roof area is an indication of either burners impinging on roof tubes or poor draft conditions resulting in heat pooling.

5. The final common cause for discrepancy is an improperly installed or malfunctioning thermal couple. It is often seen that TI shielding, cables, and clips are not properly installed, or that changing of brand or type is not addressed in the DCS system. Having a manufacturer's representative throughout installation to validate the procedure and observe its implementation is highly recommended.

Utilization of IR data into your heater PM/PdM program and process.

IR data and thermal couple data are two different information streams.

Thermal couples are primarily designed for operation to set process control of the equipment for desired output. TI data can obviously be used as an indicator of a detrimental condition such as internal fouling or other factors that contribute to high temperature damage or failure. Short term adjustments can be made to reduce the effect of potential high temperature, but information should be verified ASAP and an effort to return the heater to normal operation should be made as soon as the information can be verified. For example, in the event of a high temperature alarm on one thermal indicator, operations will often remove a nearby burner from service to reduce the TI temperature. This can create two issues. The first major and immediate concern is that an area of localized fouling is present that cannot be seen by this or other TI's and that operations is unaware of ongoing damage to the furnace. The second issue is a long term issue where imbalanced heater operation can attribute to increased fouling rates and create the problem operations is trying to counter.

Infrared data is primarily a visual data stream. Reporting of temperatures is used as a tool to illustrate the thermal profile of the equipment with an emphasis on tube metal protection from excessive temperatures. In equipment with localized internal fouling often IR data is not supportive of the trend information provided from TI trending. Reasons may be due to an area of localized fouling not near a TI or heat concentrations due to poor draft conditions or burner impingements. Only a generalized comparison should be made to indicate the health of the equipment and operation of thermal indicators as a whole. For example, IR data may show nominal tube skin temperatures at a range of 850 F. to 1250 F. while TI data shows only an 850 F. to 950 F. range. This indicates that nominal tube skin temperatures of approximately 850 to 950 are acceptable verifying both the TI and IR data streams are correct. The higher temperatures are then visually noted with pattern to determine if it is due to localized fouling or heater operations. Direct comparison of a TI reading out at say 1400 F. can be made to verify no adverse conditions that can affect tube life are present. IR data should not be used to "bias" TI data information due to the typical failure mechanism of thermal couples in which separation of the shielding or unseating of the TI causes the reading to be indicative of firing rather than tube skin temperatures. In this case the data stream is considered corrupt and unreliable and should be removed from the DCS.

Common errors made in IR inspection process and data utilization.

Understanding the true advantages and limitations of infrared data becomes essential to the decision making process for protection of the equipment and optimization of process.

Advantages IR over TI.

1. IR can measure many times more surface area than TI's. IR is limited only by view and available clean surface. Most inspections cover anywhere from 60 to 95 % of tube surfaces while most TI applications cover less than .05%.

2. Experienced IR technicians will recognize patterns and offer explanations. TI's just provide a single point data.

Advantages TI over IR.

1. When working properly, TI data is unaffected by fuel gas or box conditions.

2. Extremely repeatable as TI does not move.

Often the natural desire to plot or chart IR data into a format utilized by common systems is detrimental the correct application of the data stream. As stated above, TI data is constant in location and condition and trending comparisons are easily interpreted. IR data being visual makes repeatable exact location measurements extremely difficult as well as variables in fuel gas and firing rates causing some error in the reading. Any comparison or trending done with IR data should be done independently and as a whole. Point comparison is not valid as the user would be trying to take independent single point data and string them into a graph or chart typically used for repeatable controlled data streams. The primary information in the form of temperature as a result of IR inspection is the maximum tube skin (is it in limit?) and the delta T from nominal (how bad is the internal fouling indication?). Averages can be used to predict growth on a limited basis such as a known hotspot location, averaging all data together is easily skewed due to the process in which the technician chooses the locations for temperature measurement. These locations are chosen based on the highest temperatures, to illustrate thermal patterns, to illustrate internal fouling indications, and are limited by tube surface conditions, angle, distance, view, and firing. Often these conditions will change in short periods of time.

One of the more recent trends is the calculation of OD scale temperature. There is no reliable way to calculate the temperature rise of OD scale in relation to tube skin temperature. Often we see instances where someone has "calculated" the temperature rise of scale using one of several methods. None of these methods account for variables in the system such as bonded or disbonded, thickness, oxide vs. soot or salts. This is considered extremely dangerous and should not be performed. The best approach is OD cleaning and maintenance.