INFRARED SCANNER PARAMETRIC TEST USING HEATED-SIMULANT TANK WASTE

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ABSTRACT

An infrared (IR) scanner device has been developed that provides a means of determining the variation in surface temperature throughout the waste surface area in ferrocyanide tanks, or other heat generating high level waste tanks. Factors external to the IR scanner which contribute to errors in determining surface temperature variations include: target distance and humidity/moisture attenuation, surface emissivity of the waste material, and the configuration of the surface (curvature and/or inclination), otherwise known as a thermal radiation "view factor." Experimental examination of these external factors has been treated in a laboratory mockup and IR scans are presented in color displays.

BACKGROUND AND SCOPE

This report describes an experimental mockup that duplicated the geometric factors and approximated the tank gas space conditions in the heat generating waste tanks. The waste surface temperature magnitudes in these tanks are estimated to range from 70 to 120°F. The experiments described in this report addressed a lower range of anticipated waste surface temperature below 100°F by employing test tables of heated simulant. The experiments were conservative in that the IR instrument was evaluated in a lower temperature range that is more challenging to the IR detector sensitivity. The IR scanner temperature indications were compared with simulant waste temperatures measured by emplaced thermocouples.

EXPERIMENTAL FACILITY AND DESCRIPTION OF SIMULANT TABLES

A laboratory set up utilized the pit area in an experimental building. The IR scanner system consisted of a mounting tube vertically positioned through the roof of the pit area that supported the IR scanner housing and a pan/tilt mechanism. The scanner display terminal and computer software was located outside the pit and simulated the remote configuration that would be employed at a waste tank location. A section view of the pit configuration is shown in Fig. 1 with a tank outlined to indicate the geometric constraints for a typical IR imager location relative to the tank waste surface and a "worst-case" position relative to the tank roof. Various positions for testing heated-simulant tables are indicated, which represent various viewing geometries ranging from overhead to a "worst-case" distance of 10 meters and 80° viewing angle. Extremes in surface topography are indicated as convex/concave surface shapes which were provided by the simulant installation, as will be described later.

Geometric effects are seen in Fig. 2 after the simulant was poured and shaped into a surface wave which is convex (hill) at the near portion of the table view and which is concave (valley) at the far portion of the table view. Also shown are four strip heaters installed beneath the simulant which provide a heat source through a four-inch maximum simulant thickness at the convex shape and a two-inch minimum thickness at the concave surface geometry. Because the separation distance between heaters is greater than the thickness of low-conductance simulant above the heaters, it was anticipated that heater operation would result in temperature gradients at the surface that would clearly indicate subsurface "hot-spot" heat generation. In addition, the variation in simulant thickness above the heaters at the convex/concave surface topography would be expected to clearly define different surface temperature gradients reflecting the topography.

The waste simulant consisted of a Urea fertilizer that was mixed with a small amount of water and poured into the table forms. After partial hardening the surface was shaped. The selection of Urea simulant was based on its low material thermal conductivity that is representative of tank waste crust, and the textured surface that forms upon drying. Surface emissivity measurements of similar material samples exhibited a range of values from 0.94 to 0.96.

Since the pit area could be partially isolated from the building environment, a parametric effect of air humidity on IR attenuation was studied experimentally. The pit area was isolated and covered with temporary plastic sheeting and containers of water were boiled overnight to elevate the moisture content over the viewing distance from target tables to the IR scanner. Humidity measurements were performed during each test period using a wet/dry bulb instrument.

INFRARED SCANNER THERMAL PROFILES AND SIMULANT TABLE DATA EVALUATION

The data were displayed through a color monitor fed by the IR scanner. Each video color display view of the heated simulant table(s) exhibits vivid isotherm contours which

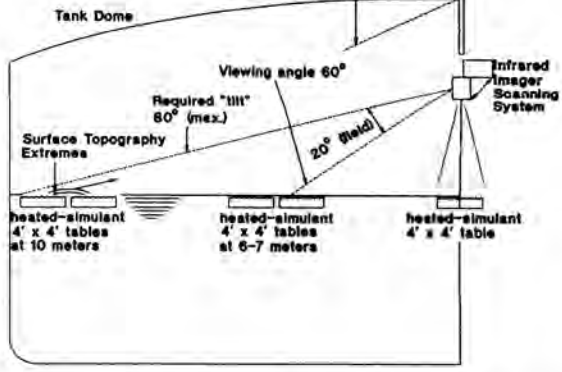

Fig. 1. Infrared scanner viewing geometry in laboratory mockup.

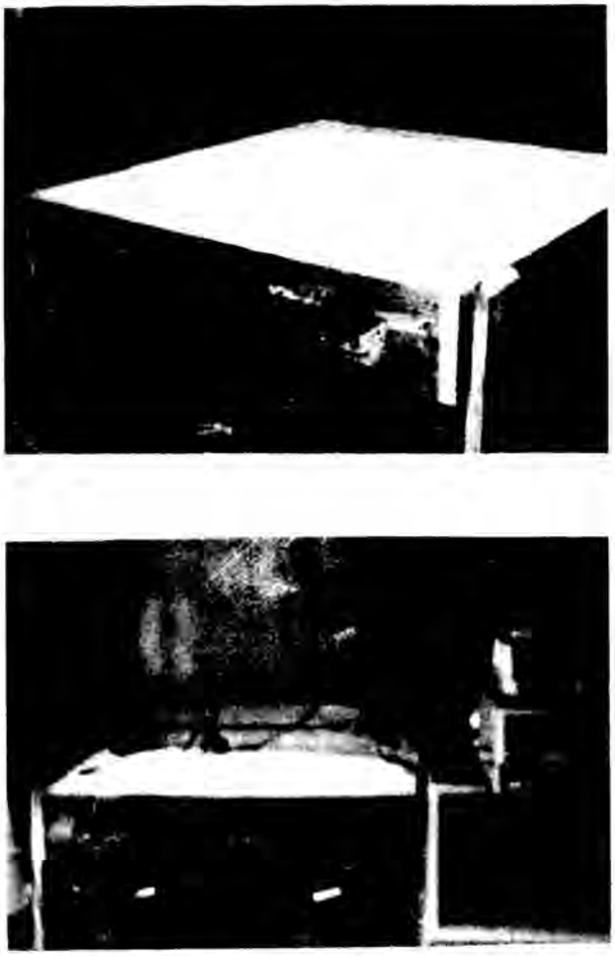

Fig. 2. Completed simulant table showing convex/concave surface and heater installation.

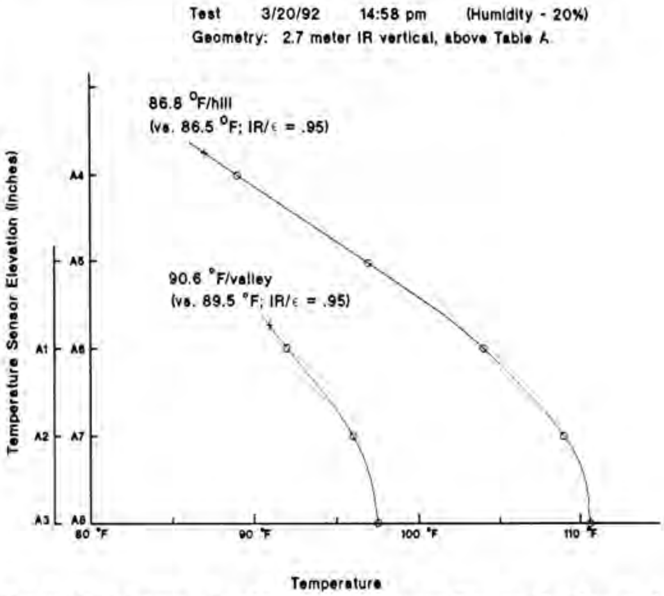

Fig. 4. 2.7 Meters - Surface Temperature Determination and Comparison.

indicate the position of each of four heating elements mounted beneath the simulant, and in addition, the depth of simulant above each heater representing the convex/concave shape extending across the width of each table. Variation in the temperature pattern across each heater location is due to different settings in the power to each heater. Since the time response to re-adjustment of a heater was on the order of hours, it was not practical to change settings once equilibrium was achieved.

Overhead Scan 2.7 Meters Normal To Surface

The IR scanner displays that are shown in Fig. 3 describe an overhead view of a heated table. The data in Fig. 3 shows temperature profiles in, bar-graph format that represent profiles across the heated table in the vicinity of the subsurface thermocouples. (Due to the color in Fig. 3 it was not reproducible, you may contact the author for copies.)These locations at convex/concave surface shapes are indicated on the plot and allow the determination of local surface temperatures at the positions where the surface temperatures are measured by thermocouples.

Figure 4 shows an example of the use of subsurface thermocouple temperature readings to determine the local surface temperature at that position. Each of the uppermost temperature values is determined by extrapolation of the data to the surface. Thus, a surface temperature is determined without the need to disturb the surface with a measuring device. A comparison of IR scanner temperature values with the surface temperature is shown at the convex, "hill," and the concave, "valley," locations. Excellent agreement is seen in this case.

Intermediate Distance Scan - 6 Meters

Figure 5 summarizes IR profile temperature data and the location of local surface temperature values at instrumented locations. (Due to the color in Fig. 5 it was not reproducible, you may contact the author for copies.) The determination of surface temperatures at instrumented locations and the comparison with IR temperature values extracted from the previous figure indicated fair agreement.

Maximum Distance Scan - 10 Meters

Figure 6 shows IR scanner temperature data and the resulting local surface temperature values at instrumented locations. (Due to the color in Fig. 6 it was not reproducible, you may contact the author for copies.) The effect of attenuation due to moisture addition to the air transmission path was evaluated with the exposure to relative humidity of up to 70%. The determination of surface temperatures and a comparison with IR temperature values yielded excellent agreement at both convex/concave geometries.

Surface Temperature Instrument Calibration

A calibration was performed of thermocouples employed in the temperature measurement of subsurface locations within the simulant bed. Accuracy of the surface temperature measurements is important in the assessment of IR scanner temperature. Calibration data show that the maximum error was ±0.1°F. This good agreement is due to the manual selection of thermocouples in a "matched-set" provided for each simulant.

CONCLUSIONS

The overall conclusion is that the IR scanner is capable of discerning temperature variations on a waste surface and is qualified as a measurement and survey tool. The evaluation of the IR scanner thermal sensitivity test data resulted in the following observations that support this conclusion:

- Temperature differences as low as 0.5°F could routinely be resolved.
- Overhead scans at 2.7 meters above a heated simulant table resulted in low readings ranging from 0.3°F to 1.1°F below the thermocouple measured/actual surface temperature for convex and concave view factors, respectively.
- Scans at an intermediate distance of 6 meters to a heated-simulant table resulted in low readings ranging from 3.7°F to 1.8°F below the thermocouple-measured surface temperatures for convex and concave view factors, respectively.
- Scans at an 80° viewing *angle or* "worst-case" geometry and maximum distance of 10 meters with 60-70 % relative humidity resulted in readings ranging from 0.1°F to 0.3°F below the measured surface temperatures for convex and concave view factors, respectively.
- The trend of observed discrepancies between IR scanner measured surface temperatures and the thermocouple-measured values indicates excellent agreement at the nearest and greatest distances-contrasted with moderate agreement at an intermediate distance. In all cases, IR readings fall below the thermocouple values due to geometric attenuation. The effect of an air/moisture medium with relative humidity of 20% at nearest and intermediate distances could not be distinguished from the effect of 70% relative humidity at the maximum distance.