January 31, 2003

Mr. Jay Glover
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Re: Results of Skin Temperature Tests on TC Ceramic

Dear Jay,

For years, industry has operated using burn protection specifications that fail to account for the thermal inertia and heat transfer properties of the substrates. A common acceptable maximum surface temperature has been 140°F (60°C), which was interpreted from ASTM Test C1055. The challenge is that ASTM C1055 deals primarily with maximum acceptable skin temperatures and by adopting the maximum skin temperature as the maximum surface temperature, the thermal inertia and heat transfer properties of the substrate are neglected.

Real-world experiences with the insulating acrylic product, TC Ceramic, have shown that its burn safety properties far exceed those employed by industry. For example, at the well accepted maximum surface temperature of 140°F, the surface of TC Ceramic has shown to be merely warm to the touch, certainly not even close to the first degree burn that most metallic substrates would impart. This phenomenon is due to the low thermal inertia and heat transfer properties of TC Ceramic, which in turn make it safer and less likely to burn a person, even at much higher temperatures.

The following are the results of the skin temperature tests performed on TC Ceramic. The tests were carried out in order to develop scientifically supported data on the performance of TC Ceramic as a burn-safety coating on the exterior of hot pipes and tanks. The tests were completed in cooperation with Mr. Howard Mitschke of Shell Oil Company.

Two different studies were carried out to determine the "safe" surface properties using both the "safe" quantification as outlined in ASTM Test Standards C1055 and C1057, as well as "safe" as defined by physical touch-testing for a period of five seconds.

Test I. ASTM C1057 " Standard Practice for Determination of Skin Contact Temperature from Heated Surfaces Using a Mathematical Model"

Method "A" of this standard provides a mathematical model to approximate the transient heat flow and to predict the skin temperature that will result from contact with a steel surface that is coated with TC Ceramic. Test C1057 is a complement to ASTM Test Standard C1055 in that it accounts for the variability of skin contact temperature as it relates to the thermophysical properties of the substrate that the skin is contacting. Attached is a copy of the spreadsheet used in this evaluation.

ASTM Test Standard C1055 defines the "safe" or "acceptable" heated surface temperature (in industrial applications). This considers the effect on the skin that takes place within a five (5) second contact exposure interval. The result of such a contact time/temperature event is to be the first-degree burn injury for the average subject. Figure 1 in test C1055 shows that this "safe" contact skin temperature, for an exposure time of five seconds, is approximately 60°C (140°F) which is the upper limit, beyond which there is tissue damage that goes beyond the first degree burn, (i.e. the onset of second degree burning). For the purposes of evaluating TC Ceramic in the mathematical model in ASTM C1057, the "safe" contact skin temperature is not to exceed 60°C.

Table 1 below shows the thickness of TC Ceramic that is required to bring various steel surface temperatures down to such a defined "safe" level. For the purpose of this evaluation, the physical properties used for the heated surface were those of steel. (See Table 1 of ASTM C0157).

Table 1. ASTM C1057 Mathematical Model Results for TC Ceramic

Heated Surface Temperature (°C)	TC Ceramic Thickness (mils)	Skin Contact Temperature after 5 seconds (°C)
124	15	60.
150	22	60
212	40	60
266	80	60

Using the mathematical model, one can clearly see that the low thermal inertia and low conductivity properties of TC Ceramic can bring hot surfaces down to "safe" operating levels. This is achieved at relatively low film thickness. It is generally recognized that metal substrate temperatures above 70°C are considered unsafe for skin contact. However, 40 mils of TC Ceramic applied to the surface will provide a surface that is "safe" for contact exposure, even when the heated steel is as high as 210°C. (This has been validated using the ASTM C 1057 Model).

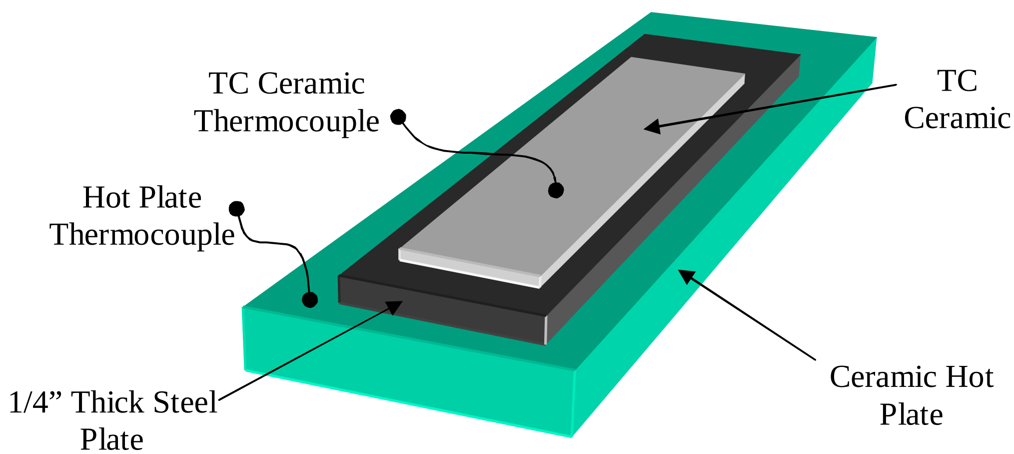
Test II. Physical Contact Exposure Test on TC Ceramic

The second thermal study involved physical contact with the coated surface to identify a more conservative "safe" (for physical contact) surface temperature of TC Ceramic. For the purpose of this test, the maximum "safe" temperature was defined as the temperature where the average person could physically place a finger on the surface of the TC Ceramic for an exposure interval of five seconds, without having to pull it away to prevent injury. It is estimated that this temperature corresponds to the 44°C internal skin tissue temperature as referenced in ASTM C1055, the temperature at which the average person does not become injured (burned). By way of comparison, the 60°C skin temperature that is mentioned in the ASTM C 1057 model can result in a first degree burn if the contact duration is five seconds.

Once the "safe" TC Ceramic surface temperature objective was determined, a series of tests were performed to identify the thickness of TC Ceramic required to achieve this.

For this test several ¼" steel samples were coated with varying thicknesses of TC Ceramic. The thickness of the TC Ceramic samples was measured in several locations

Graphic 1. Physical Contact Test Apparatus



using a dry film thickness gage and then marked on the surface of the TC Ceramic. The samples were then placed on a ceramic hot plate and the surface temperatures of the ceramic hot plate and the TC Ceramic were measured using a Type K Beaded-wire Thermocouple. The thermocouples were placed on the surface of both substrates, with the beaded-wire in intimate contact with the substrate (see Graphic 1).
When the ceramic hot plate temperature reading was constant and the steel plate had enough time to equilibrate, the second thermocouple was brought into contact with the surface of the TC Ceramic, and the temperature reading was recorded. (During this testing it was observed that an uncoated area on the surface of the steel plate exhibited a temperature that was approximately fifteen degrees cooler than that of the ceramic hot

plate). The temperature of the hot plate was progressively increased and the procedure repeated.

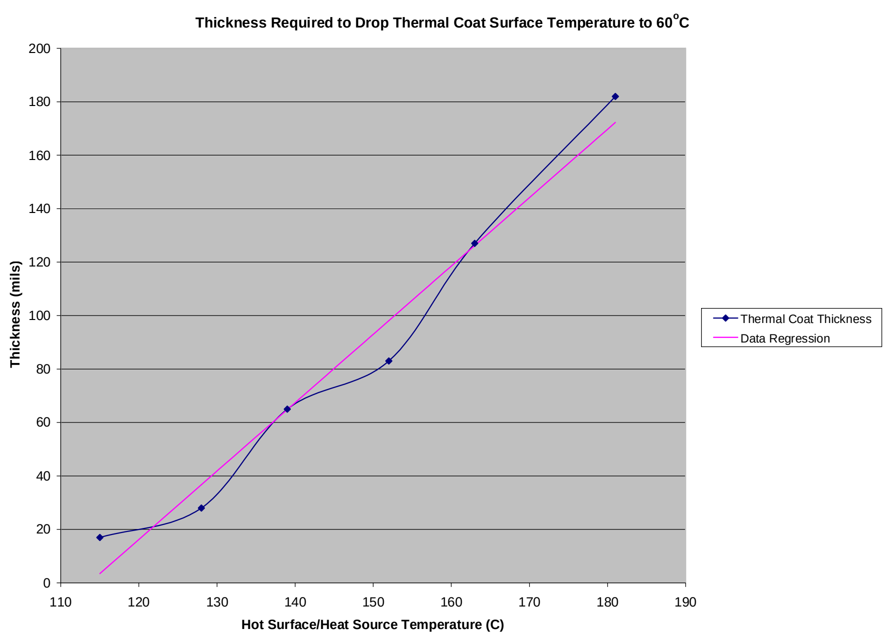
This test showed that at a TC Ceramic surface temperature of 115°C (240°F) the test subject could hold a finger on the TC Ceramic for a minimum of five seconds without having to pull away. In an effort to be conservative, a temperature of 105°C (220°F) was used as the "safe" temperature on the varying thickness test.

The data presented in Table 2 summarizes the results of the testing in a format that will correlate the relationship between the thickness of the TC Ceramic and the achievement of the 105°C surface temperature objective.

Table 2. Results of Touch Tests with TC Ceramic

Hot Plate Temperature (°C)	TC Ceramic Temperature (°C)	TC Ceramic Thickness (mils)
115	105	17
128	105	28
139	105	65
152	105	83
163	105	127
181	105	182

Figure 1 below shows the relationship between the heat source temperature and the thickness of TC Ceramic required to bring its surface down to the "safe" level (105°C). The figure also includes a regression of the data, showing its approximation as a straight



line (regression calculation is $y = 2.557x - 290.56$; $R^2 = 0.9700$).

As can be seen from the results of these two studies, one can conclude that the low thermal inertia of TC Ceramic allows for relatively low thicknesses to provide “safe” operating conditions for hot surfaces, even when the “safe” level is as conservation as no burn injury.

CONCLUSION

Two separate tests were completed to identify the “safe” surface temperatures of TC Ceramic when it is used as a mechanism to protect personnel who come into contact with heated tanks and pipes. Both the mathematical model listed in ASTM C1057, as well as a more conservative touch-testing method demonstrate that the “safe” surface temperature that is contributed by the TC Ceramic constitutes an effective mechanism to provide such operational safety to hot metal surfaces. The “safe” surface temperature that is established in the ASTM method is 140°F (60°C), which is the resulting skin tissue temperature that is the result of contact, but such a skin tissue temperature can result in first degree burn in a contact time interval of five seconds. As an alternative, the touch-testing method has shown that the TC Ceramic, because of its low thermal inertia and low heat transfer coefficient, will resist the transport of heat energy, therefore when it is touched by human skin, it feels cooler and significantly reduces the risk of injury to personnel. The testing provides the basis for determining the film thickness of TC Ceramic, which is required to provide the corresponding protection.

I hope this information is helpful. We are pleased that it validates our real-world findings that TC Ceramic is an excellent burn-safety product. Please do not hesitate to contact me should you have any questions or comments.

Sincerely,
Jeff Buratto
Jeff Buratto

Attachments: ASTM C1055-99
ASTM C0157-92
ASTM C1057 Mathematical Model Calculations Spreadsheet