THERMAL CONDUCTIVITY OF A SPECIMEN OF STAINLESS STEEL TYPE 502

by

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Report to the
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California
for
U. S. Department of the Army
Ordnance Corps, Redstone Arsenal
Huntsville, Alabama
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IMPORTANT NOTICE

Approved for public release by the Director of the National Institute of Standards and Technology (NIST) on October 9, 2015.
Thermal Conductivity of a Specimen of Stainless Steel Type 502

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1. INTRODUCTION

A sample of stainless steel (type 502) was submitted by the Ordnance Corps, Redstone Arsenal, Huntsville, Alabama, for measurement of its thermal conductivity in the temperature range 100°C to about 700°C (P.O. No. 17257-56). The sample was shipped by the Jet Propulsion Laboratory, Pasadena 3, California (P.O. No. 44-495-653-18).

2. SAMPLE

The sample was a bar of metal machined to form a specimen 0.737 in. in diameter and 14 5/8 in. long. It was stated to be a sample of AISI Type 502 stainless steel. No analysis of the metal composition was furnished, or made here.

3. TEST APPARATUS AND METHOD

The thermal conductivity of the sample was determined by means of a steady-state flow of heat longitudinally in a bar specimen, with measurements of the temperature existing at the ends of six consecutive approximately 3.5 cm spars along the central length of the bar. Each determination
in addition the 1987 study itself concluded by arguing a
potential relationship between workplace performance and
employee stress. Moreover, it concluded that the relationship may
exist in more than one direction. In other words, there were
suggestive results indicating that workplace stress may also
affect performance. In 1989, a study by Cassell and associates
highlighted the importance of work stress on performance.

EMPIRICAL RESEARCH

While a meta-analysis, the meta-analysis suggested that
the relationship between workplace stress and performance
is more complex than initially thought. The study
explored various mediating and moderating variables
that may influence the relationship. The results
suggested that individual and environmental factors
play a significant role in shaping the relationship.

CONCLUSION

In conclusion, the meta-analysis and empirical
research highlight the complexity of the relationship
between workplace stress and performance. Further
research is needed to fully understand the factors
influencing this relationship.
required a pair of tests at moderately different temperature conditions, and yielded values of thermal conductivity at six different mean temperatures.

The test apparatus is shown schematically in Figure 1.

The specimen was supported at the bottom upon a thin stainless steel pin, and held concentrically within a stainless steel guard tube of 1-cm wall thickness, which in turn was held concentrically within a cylindrical outer container. The specimen was drilled at each end with a 1.35-cm hole 5.5 cm deep. An electrical heater was inserted and secured in the hole at the bottom (hot) end, and a liquid-tight stopper at the top provided a connection for circulating a coolant (water at about 40° C) through the top drill-hole.

Temperatures along the specimen were indicated by seven thermocouples located symmetrically about the longitudinal center of the specimen, spaced approximately 3.47 in apart, with one additional thermocouple near the bottom end of the specimen. Thermocouples were similarly located on the guard tube in seven positions, five of which corresponded very closely to longitudinal positions of thermocouples on the specimen.

The guard tube was equipped near its lower end with an external circumferential electric heater as shown. The guard tube was cooled at the top by means of a copper-tube coil
APPARATUS FOR MEASURING THE THERMAL CONDUCTIVITY OF METALS

NOTES
1. Dimensions in Centimeters.
2. x Indicates thermocouple positions.
soldered circumferentially at a position corresponding in effect to that of the specimen coolant well. Coolant was pumped through the specimen well and guard coil in series connection, as shown.

The electric heater for the specimen consisted of a porcelain cylinder 1.27 cm in diameter and 5.2 cm long threaded longitudinally with 30-gage nichrome heater wire. Its resistance was approximately 55 ohms. Current was brought to the heater through relatively large heater leads, to which separate potential leads were connected at the point where they entered the porcelain core. The heater was energized by an adjustable constant-voltage a-c source. Heater current and voltage drop measurements were made using standard resistors and the high precision manual potentiometer used for thermocouple observations. The guard was heated with constant voltage a-c power.

The thermocouples were made from calibrated chromel and alumel 36-gage wires, electrically welded to form a spherical junction about 1.0 mm in diameter. Junctions in the specimen were inserted into radially-drilled holes 1.1 mm in diameter and 1.7 mm deep in the side of the bar, and tightly secured by punch-pricking the metal around the hole. The thermocouple wires were individually insulated electrically with fiberglass sleeving, and were wrapped around the bar (one in each
direction) and tied at the back to assure them in the transverse plane of the junction. The wires were brought out through the powder insulation near the guard tube. The thermocouples in the guard tube were similarly attached to its exterior surface. The longitudinal positions of the thermocouple junctions were taken as those of the centers of the drilled holes, measured to the nearest 0.01 cm with a laboratory cathetometer.

After installation of the specimen, the space between it and the guard tube was filled with diatomaceous earth powder insulation, which also was used to insulate the space surrounding the guard tube.

In principle, if there were no heat exchange between the specimen and its surroundings, the conductivity could be determined from the measured power input to the specimen and the average temperature gradient for each of the six spans along the specimen, all of uniform known cross-sectional area. In practice, a perfect balance of temperatures between the bar and guard all along their lengths is not possible because of differences in their temperature coefficients of conductivity, and the effect of the outward heat losses of the guard. In addition to heat exchanges between the bar and guard from this cause, a not insignificant longitudinal flow of heat occurs in the powder insulation surrounding the specimen
In this context, we focus on the importance of understanding how different communication channels can influence the perception of trust. Trust, in this case, is a complex variable that affects how individuals interpret and respond to information. The study of communication channels is crucial, as they serve as the medium through which trust is transmitted. Understanding the role of these channels is essential in developing effective communication strategies. This is particularly relevant in today's digital age, where information is shared rapidly and widely. The effectiveness of these channels can significantly impact the spread of information and the formation of trust. Overall, the study of communication channels provides valuable insights into the dynamics of trust formation and the strategies that can be employed to enhance trust in various contexts.
the contribution of the specimen to this heat flow may
depend somewhat on the bar-to-guard temperature unbalance.

In order to evaluate the heat flow in the bar at the
center points of each of the six spans, a partly empirical
procedure was used. Two steady-state test-runs were made
with slightly different bar and guard temperatures and power
inputs. In the two tests, the heat flow and the observed
temperature drop from end to end of a given span differed, as
did also the approximate integral with respect to length of
the observed temperature differences between bar and guard,
summed from the hot end of the bar to the span center point.
It is thus possible to write for each span two equations
(one for each test-run) of the form:

\[
\frac{\Delta t}{\Delta x} \cdot f(x) = q
\]

where \( A \) is the cross-sectional area of the specimen.
\( k \) is the thermal conductivity of the specimen at the
mean of the two span mean temperatures.
\( \Delta x \) is the length of the span.
\( \Delta t \) is the adjusted temperature drop from end to end of
the span, corresponding to the mean of the span mean
temperatures in the two test runs. This is obtained
for each test-run from the observed temperature dif-
ference by an adjustment based on the variation of
temperature drop along the specimen with mean temperature, and on one-half of the difference between the observed mean temperatures of the span in the two test runs.

\( f \) is an average heat exchange coefficient which lump the thermal conductance of the heat flow path from bar to guard, and the contribution of the specimen to the longitudinal heat flow in the insulation, up to the span center point.

\( \delta \) is the approximate integral with respect to length of the observed differences of bar and guard temperature, from the hot end of the bar to the span center point.

\( q \) is the measured power input to the specimen heater.

By simultaneous solution of the two equations, the value of \( k \) for each span, corresponding to the mean span mean temperature, is obtained. All of the computation of results is effected by use of an IBM-704 digital computer, suitably programmed to compute the value of \( k \) for each of the six spans from input data consisting of the average observed temperature values at the several bar and guard positions, and the power input to the bar, for each of the two steady-state test-runs constituting a pair at nearly the same temperatures. Much time is saved by machine computation, and accidental errors in the considerable calculations are avoided.
4. RESULTS

The results of the thermal conductivity measurements are shown in Figure 2. The points plotted on the figure represent the individual values obtained in six runs on the specimen, each run yielding six values. The trend of the data appears to be best represented by two straight lines intersecting at a mean temperature of about 295°C. Values of conductivity indicated by the lines at particular values of mean temperature are tabulated below.

<table>
<thead>
<tr>
<th>°C</th>
<th>150</th>
<th>200</th>
<th>250</th>
<th>300</th>
<th>400</th>
<th>500</th>
<th>600</th>
</tr>
</thead>
<tbody>
<tr>
<td>watt/cm²</td>
<td>0.339</td>
<td>0.342</td>
<td>0.346</td>
<td>0.342</td>
<td>0.332</td>
<td>0.322</td>
<td>0.312</td>
</tr>
</tbody>
</table>

5. DISCUSSION OF RESULTS

The individual values of thermal conductivity plotted in Figure 2 show moderate scattering from the straight lines drawn to represent the trend of the data. The extreme departure (at 375°C) is about 1.5 percent; most departures are less than one percent.

The scattering is believed to chiefly to small inaccuracies in the temperatures at positions on the specimen, as indicated by its thermocouples. Such inaccuracies could arise from departure of a thermocouple from the temperature-emf calibration of the thermocouple wires, or from imprecision in ascertaining the exact longitudinal position of
the thermocouple junction, or possibly from heat conduction in
the thermocouple wires near the junction. Although the wires
encircled the specimen as nearly as possible in the trans-
verse plane of the junction, the temperature gradients in the
specimen were from 23 to 25 deg. /cm, and a slight displace-
ment of the wires from that plane would cause a temperature
gradient in them near the junction. However, an error in the
indicated temperature at a point intermediate between two
spans of the specimen would reduce the observed temperature
drop for one span by as much as it would increase that for the
other. Thus, the values of thermal conductivity for the two
spans would be approximately equally, but oppositely, affected,
and the position of a smooth curve drawn amongst a number of
such individual points would be affected little.