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Experiments on discretely heated, vented/unvented enclosures for various radiation surface characteristics of the thermal load, enclosure temperature sensor, and enclosure walls

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Abstract

A comprehensive experimental investigation has been performed to determine the heat transfer processes occurring within an oven-like enclosure. The main focus of the work was to identify the thermal response of a load to a number of operational parameters including the radiation surface finish of the load itself and the surface finishes of the oven temperature sensor and the oven walls. In addition, the effect of the presence or absence of venting of the oven was investigated. The thermal response of the load was slowed significantly as its reflectivity was systematically increased. When the oven temperature sensor was operated either with a blackened surface or with a highly reflecting surface, the thermal response of the load was hardly affected. In the case in which the oven walls were highly reflecting and the thermal load was highly absorbing, a higher heating rate was observed. When the oven vents were sealed, the heating rate was minimally affected.

1. Introduction

The objective of this investigation is to provide basic but highly practical information about the heat transfer processes which take place within enclosed spaces having discrete heat sources deployed within the space. The prototypical applications of such a physical situation are ovens, furnaces, kilns, and the like. When viewed broadly, such applications encompass all three of the fundamental heat transfer processes – convection, radiation, conduction – with their full three-dimensional influences. Coupled directly with these heat transfer processes is a complex three-dimensional air flow that may be driven, either wholly or in part, by temperature gradients within the enclosed space. To obtain a fully definitive understanding of these highly interrelated processes requires a synergistic approach involving both experiment and analysis. The work described here represents a report on a significant portion of the experimental work. In view of the large number of independent parameters that govern the heat transfer and fluid flow processes in the enclosed space, it is expected that the experimental program will have to be continued beyond what is reported here. The envisioned analysis will involve three-dimensional, unsteady, superimposed natural and forced convection coupled with the three heat transfer mechanisms that were mentioned in the foregoing.

In the present experimental investigation, special attention is given to the radiation-related surface condition of a thermal load that is to be heated owing to its presence in the enclosed space. The impact of various surface finishes of the load on its heating rate and on the temperature field within the oven will be studied with respect to systematic variations of certain significant operating variables. The three to be considered here are: (a) the radiation-related surface finish of the temperature sensor situated within the enclosure which drives the enclosure thermal control system, (b) the absence or presence of a chimney-like throughflow of air, and (c) the surface finish of the bounding walls of the enclosed

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Nomenclature

T temperature (°C)
t time (s)

Greek symbols
ε emissivity

space. Therefore, the present experiments encompass a total of four independent parameters.

In order to obtain definitive information, a broad parametric range was accorded to each of the four investigated variables. Specifically, the emissivity ε of the surface finish of the thermal load ranged from less than 0.1 to approximately 0.9. A similar range in the emissivities of both the enclosure temperature sensor and the enclosure walls was investigated. With regard to the throughflow airstream, the strength of the stream was varied from no flow to the highest possible consistent with the geometry of the system.

The presentation of results will be strongly focused on the heating rate of the thermal load as it is affected by the various parameters and their ranges. Information will also be presented for the response of the air temperature to these variables.

A survey of the literature demonstrated the need for a definitive investigation that encompasses a deeper consideration of the participating physical phenomena. In particular, the literature review included two specific foci. The first focus dealt with work specifically related to ovens and other heating enclosures whereas the second part of the review was focused on more fundamental studies that were generally simplified versions of the oven problem but which did not deal directly with ovens and with related applications.

With regard to the literature dealing with ovens [1,2], there seems to have been an avoidance of the geometrical complexities, the unsteadiness, the multimode interactions, and the mixed convection engendered by a chimney-like throughflow and a buoyancy-driven recirculation within the enclosure. The most advanced computational model appearing in the literature is a two-step approach used to solve for the velocity and temperature fields in a forced-convection oven. The initial step lumps all of the air at a single temperature and all of the enclosure walls at a different single temperature. The solution to this lumped system is then employed to provide boundary conditions for a more detailed computational model. The flaw in this approach is that the grossness of the first step persists and deeply affects the subsequent numerical results. A more rational approach would have been to revisit the lumped-parameter model iteratively and improve it by using the results obtained from the second stage of the analysis. Such a refinement was never performed. All of the other literature known to the authors used models that were less sophisticated than the one described.

In addition to the oven literature that has been cited in the preceding paragraph, the more general non-oven-oriented literature encompasses the following topics:

- natural convection in vented cavities [3,4];
- internally baffled cavities [5,6];
- radiation in enclosures [7,8];
- isolated heat sources and sinks in enclosures [9];
- three-dimensional fluid flow problems in enclosed spaces [10,11];
- turbulence modeling with buoyancy in enclosures [12,13].

The cited references for each of the foregoing topics are representative literature and are not intended to be inclusive. Although these topics provide useful background information for the present work, the cited references were much more circumventive in their coverage of physical phenomena than what is to be investigated here.

2. The experiments

In order to maintain close touch with the cited application, a commonly encountered, commercially available, electric oven was selected as the test object for the present research. That oven is part of a stove identifiable as Kenmore model # 22 94492. The internal dimensions of the test oven are 48 cm × 61 cm × 48 cm (19 in. × 24 in. × 19 in.). This oven is heated by a Calrod heating element whose shape is illustrated in Fig. 1. The oven temperature sensor is situated centrally at the top rear of the oven cavity. In its as-arrived state, the sensor was housed in a polished metallic cylindrical sheath. The oven sidewalls are equipped with horizontal tracks to accommodate seven positions for the three racks that are part of the provided equipment. All of the oven walls were finished in black speckled porcelain.

The oven cavity contains a pair of vents that enable a chimney-like throughflow of air. The inlet vent is situated adjacent to the hinge at the lower edge of the oven door. The approximate open area of the inlet vent is a rectangle having dimensions of 15 cm$\times \sim \frac{1}{2}$ cm (6 in.$\times \sim \frac{3}{16}$ in.). An exit vent formed from a circular tube with a diameter of 3.2 cm (1 1/4 in.) is situated centrally in the right-rear burner of the stove top.

In preparation for the experimental work, the external sidewalls of the oven were removed along with the accompanying insulation. After surface preparation, thermocouples were painstakingly soldered to the

Fig. 1. Photograph showing Calrod heating element.

backsides of the internal sidewalls. These thermocouples were vertically deployed at 5 cm (2 in.) intervals along a line situated midway between the forward and backward edges of each of the sidewalls. The thermocouple leads were led out along the expected isothermal pathways with a view to minimizing the "fin effect". It was demonstrated by calculation that the temperature drop across the 0.16-cm- (1/16-in.-) thick oven walls was totally negligible, so that the backside measurements provided temperature data that could be regarded as frontside information. When the thermocouple installation had been completed, the original insulation was replaced and then augmented by the addition of insulation in the form of a $2\frac{1}{2}$-cm- (1-in.-) thick sheet of polystyrene.

The reason for the placement of the thermocouples on the backsides of the internal sidewalls rather than on the oven-facing surfaces of the sidewalls was to enhance the accuracy of the temperature determination. Had the thermocouples been affixed to the oven-facing surfaces, the effect of radiation might well have caused errant temperature readings. It is well known that a sensor such as a thermocouple measures its own temperature and that temperature is a result of the energy balance on the sensor. In the presence of radiation, convection, and conduction, there is a high likelihood of a deviation between the temperature of the sensor and that of the surface to which it is affixed.

In addition to the thermocouples that are situated on the oven walls, thermocouples were strategically dispersed in the air throughout the cavity. These thermocouples were intended to identify the extent of both the horizontal and vertical temperature variations. In view of the cyclic nature of the heating of the oven provided by its temperature control system, the time variation of the air temperature was also determined by the aforementioned thermocouples. Of great importance was the precise determination of the temperature of the thermal load. Generally, three independent thermocouples were used to determine the load's temperature. For all of the operating conditions to be reported here, the three thermal-load thermocouples provided virtually identical temperature readings.

The thermocouples were made from 30-gauge (0.025 cm, 0.010 in.), Teflon-coated, chromel and constantan wire (type E). The choice of type E wire was motivated by the fact that it produces the highest EMF per degree among all other thermocouple pairs. In addition, the thermal conductivity of type E wire is the lowest among all pairs. The low conductivity was deemed to be highly desirable in further minimizing errors caused by the fin effect.

All the thermocouples were made from a single roll of wire. The roll had been calibrated against a 0.05 °C (0.1 °F) mercury-filled thermometer traceable to NIST. The calibration encompassed both the thermocouple wire itself and the instrument that was intended to be used in the experimental work. The calibration was performed utilizing a constant-temperature water bath and a specially made copper equilibration block which, when immersed in the water bath, provided an isothermal environment for both the standard thermometer and the thermocouples to be calibrated.

The data acquisition was accomplished with an automated system consisting of a Hewlett-Packard model #34970A data logger in conjunction with a personal computer. The data logger was capable of reading 60 channels. In the experiments reported here, a total of 20 thermocouples was used, and these were capable of being read in a third of a second. The scan frequency is capable of being set over a virtually unlimited range. At the end of each data run, the data were exported to an Excel file and processed as needed.

It is well known that thermocouples used for the determination of air temperature are susceptible to errors when they are situated in a radiation field. This possible source of measurement error was explored by the use of radiation shields. These shields were fashioned from aluminum foil. Two classes of shields were employed. In one class, the thermocouple was completely surrounded by the shield, while in the other class, the shield was partly open to air. In the latter class, the opening faced away from the surfaces of highest temperature (for example, the Calrod heating element). In general, it was found that thermocouples positioned at elevations from the oven's midheight upward were virtually unaffected by the presence of the radiation stream emitted by the Calrod heater. At lower elevations, especially within a few inches of the heater, the shielded thermocouples indicated a several-degree-lower temperature than the unshielded thermocouples. These findings were employed in the subsequent experiments.

Preliminary experiments were performed to assist in the rational selection of a thermal load. In these experiments, as well as in all subsequent experiments described in this paper, the oven temperature was set at 177 °C (350 °F). In consideration of the fact that the experimental site was an oven, the first candidate for the heat load was a food product – low-fat ground turkey. A graph of the temperature history of ground turkey (T versus t) which was used as a thermal load is presented in Fig. 2. With regard to the turkey, its temperature is

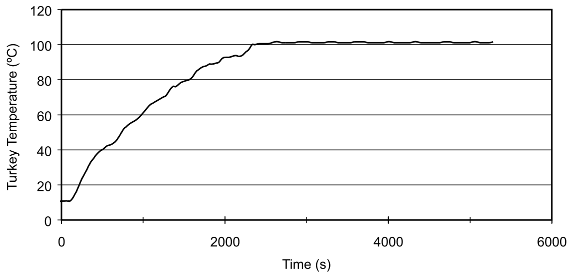

Fig. 2. Timewise variation of the temperature of ground turkey used as a thermal load.

seen to have attained a constant value of approximately 100 °C (212 °F) for times exceeding 2300 s. The constancy is due to the boiling of water which had effused from the turkey and had settled on the bottom of the baking pan. During this time period, the temperature of the thermal load was no longer responsive to the heating rate provided by the oven. Because of this, it was concluded that the lack of a calorimetric response of the ground turkey at larger times made it unsuitable as a thermal load.

In pursuit of another candidate thermal load, one that did not exude liquid water, a thick bread pudding was employed. The timewise temperature variation of the pudding was plotted in a format similar to that used in Fig. 2. Temperatures at two locations in the pudding were displayed. It was observed that after an initial period during which the two curves were more or less coincident, there was a tendency toward divergence. This behavior was the result of the contraction of the pudding during the baking process such that it receded from the wall of the pan in certain locations. This occurrence was judged to be a major obstacle to the attainment of reproducible data in that it constitutes a departure from a calorimetric behavior.

After suitable deliberation, it was decided to use an aluminum block as the thermal load. Not only does it possess a constant mass and virtually constant dimensions, 5 cm high by 15.9 cm deep by 18.7 cm wide (2 in. × 6.25 in. × 7.375 in.), throughout the entire heating period, its surface can be conditioned so as to readily provide various radiation properties. These properties included the two limiting ones: (a) a highly polished surface (low emissivity) and (b) a blackened surface (high emissivity). In addition, a third finish, measured to have an emissivity of approximately 0.15, was obtained by leaving the block surface in its as-arrived state. The very high thermal conductivity of the aluminum assured a spatially uniform temperature at all times during the heating period. The expected spatial uniformity of the aluminum was verified in all of the experimental runs.

In each experiment, the heating period was initiated with the thermal load, the air in the oven, and the oven walls at room temperature. As previously mentioned, the temperature control of the oven was set at 177 °C (350 °F) for all of the experiments. The heating period was terminated two hours after the initiation of the experiment.

3. Results and discussion

As was set forth in Section 1, the primary focus of the present experiments is to explore the effect of the surface finish of the thermal load on the heating rate of the load. Further, as was also indicated earlier, the interactions of the load's surface finish with other parameters such as the radiation-related surface condition of the oven temperature sensor and of the bounding walls of the oven were investigated, as was the effect of open versus closed oven vents.

3.1. Standard operating conditions

The first set of results pertains to the standard operating conditions defined by the as-arrived state of the oven temperature sensor and of the bounding walls and with the oven vents open. The first issue to be dealt with in the presentation is the effect of various colors of the surface of the thermal load. These various colors were achieved by the use of paints including black, white, green, and yellow. The timewise variation of the temperature of the thermal load is plotted in Fig. 3 with the four aforementioned colors as parameters. Inspection of the figure reveals that there is only a slight observable difference in the thermal behavior of the load with respect to color. This result, which may appear to be surprising, is consistent with well-established basic radiation property data for painted surfaces (emissivity $\varepsilon \sim 0.85$–0.95) [14]. The property data indicate that for infrared radiation, there is no consistent effect of color on the emissivity and the absorptivity of the participating surfaces provided that the paint layer is sufficiently thick (0.0025 cm, 0.001 in. [14]). The practical importance of this finding is that the color of a container situated in an oven is irrelevant to the rate of its heating. For example, this finding applies to plastic containers of various colors that are currently commonly in use.

The temperature of the thermal load increases rather rapidly during the early portion of the heating period, with a diminishing rate of increase as time proceeds. At the termination of the experiments, the thermal load had reached a temperature of approximately 171 °C (340 °F). It is clear that had the experiment continued beyond the two-hour time period, the load temperature would have continued to increase, albeit slowly, and ultimately would achieve a steady value.

Attention is next turned to surface finishes of the thermal load that are considerably less absorbing than the near-black surface finishes discussed in connection with Fig. 3. One of the low-emissivity surfaces was obtained by tightly wrapping the thermal load with smooth aluminum foil. From the literature, the emissivity of aluminum foil is in the range of 0.05 [15]. Still another low-emissivity surface was provided by the as-arrived state of the aluminum which constituted the thermal load. The measured emissivity of the as-arrived aluminum was approximately 0.15.

The effect of surface finish for three types of finishes is set forth in Fig. 4, which is a plot of the temperature of the thermal load as a function of time. The three finishes correspond to the blackened surface, the aluminum-foil surface, and the as-arrived aluminum surface. From the figure, it is clear that the heating rate of the load is considerably affected by surface finish – the higher the emissivity of the surface, the higher the heating rate. Over the range of investigated surface emissivities (0.05–0.9), the corresponding temperature variation at the end of the two-hour experiment spanned the range between 127 °C (261 °F) and 173 °C (344 °F).

This is a result of great practical interest in that the foregoing large temperature difference actually corresponds to a common setting of 177 °C (350 °F) of the oven temperature control. In practical terms, the use of shiny shrouds or containers may lead to the considerable undercooking of foods. For example, such situations can arise when corn or potatoes are wrapped in aluminum foil, or when foods are baked in aluminum or stainless steel containers.

In addition to the temperature history of the thermal load, it is also of interest to display the time variation of the air temperature in the oven. Figure 5 has been prepared for this purpose. The figure shows thermocouple measurements of the air temperature at two different positions in the oven. Position #1 is situated about 13 cm (5 in.) above the thermal load and is about 8 cm (3 in.) to the left of the leftmost edge of the load. Similarly, position #2 is at the same elevation but is situated about

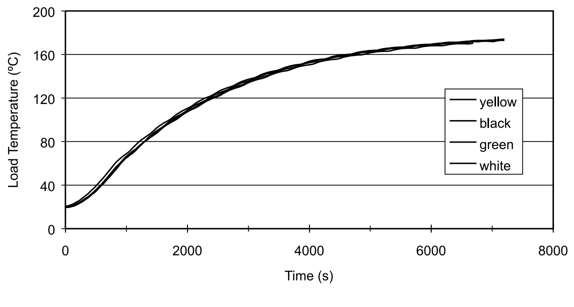

Fig. 3. Effect of color of the surface of the thermal load on its heating rate.

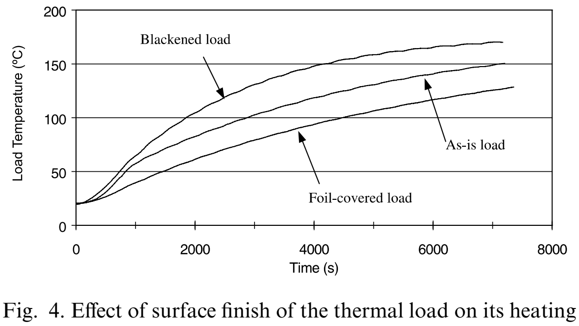

Fig. 4. Effect of surface finish of the thermal load on its heating rate.

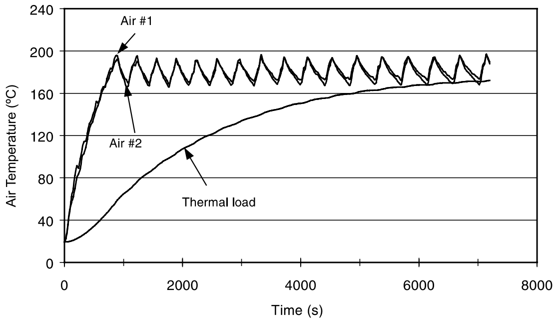

Fig. 5. Timewise variation of the air temperature in the space above the black-painted thermal load.

8 cm (3 in.) to the right of the rightmost edge of the thermal load. Within the scale of the figure, the temperatures at stations 1 and 2 are virtually identical. For reference purposes, the temperature rise of the thermal load is also displayed.

The figure shows that the air temperature experiences a regular periodic variation which is established after an initial transient whose duration for the present operating conditions is around 800 s. The periodic variation is, of course, caused by the control circuit for the Calrod heating element. Although, at first glance, the variation appears to be regular, there is, in fact, an increase in the period of successive cycles. For instance, during the early stages of the heating, the period of a cycle is approximately 330 s, whereas near the end of the heating, the period has increased to approximately 440 s. On the other hand, the amplitude of the fluctuating air temperature is quite constant with the passing of time. The mean value of the air temperature is approximately 179 °C (355 °F) – about two and a half degrees Celsius above the oven set point. The fluctuating component of the temperature amplitude is ±17 °C (30 °F) about the mean.

The excellent congruity of the individual air-temperature measurements displayed in Fig. 5 is not necessarily encountered for all cases. To demonstrate this assertion, Fig. 6 is presented. This figure exhibits a pair of air temperature measurements for the case in which the thermal load is covered with the highly reflecting wrap of aluminum foil. Inspection of the figure indicates that the amplitude of the temperature variation at position # 1 is somewhat larger than that at position #2. In particular, for position # 1, the variation of the temperature is ±15 °C (27 °F) about its mean, whereas for position #2, the variation is ±9.4 °C (17 °F) about its mean. With regard to the period of each cycle, Fig. 6 reinforces the finding that was noted for the results of Fig. 5; that is, the period increases as the heating time increases.

3.2. Radiation surface properties of oven temperature sensor

The foregoing results corresponded to oven operating conditions that may be regarded as standard. Now attention is turned to what may be regarded as non-standard operating conditions. The first of these non-standard operating conditions to be investigated is the effect of varying the surface finish of the oven temperature sensor. In a certain sense, it may be a misnomer to consider a non-shiny temperature sensor to be non-standard. This is because, under common conditions of oven use, a dark film may be deposited on the sensor and may remain there unless the oven is fastidiously cleaned.

Experiments were performed for two limiting conditions for the radiation properties of the sensor surface. The first of these is the as-arrived state that, in the present instance, appeared shiny. The second is a near-black condition achieved by the application of a paint. For each of these two conditions, data will be presented for the heating of the thermal load for both the blackened surface and the foil-covered surface. In addition, air temperature data will also be discussed.

The first set of results to be presented is for the foil-covered thermal load. These results are exhibited in Fig. 7. The figure contains two curves, respectively corresponding to the as-arrived (shiny) temperature sensor and to the blackened temperature sensor. From

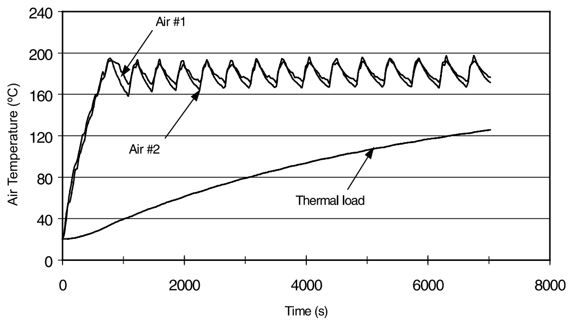

Fig. 6. Timewise variation of the air temperature in the space above the aluminum-foil-covered thermal load.

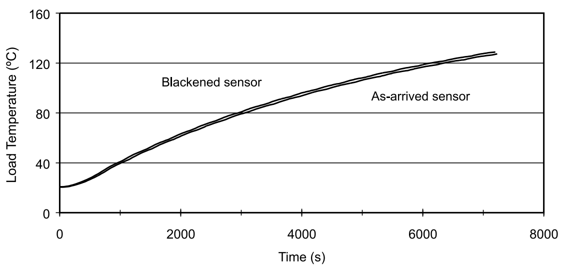

Fig. 7. Effect of radiation surface properties of the oven temperature sensor on the heating rate of a foil-covered thermal load.

the figure, it is easily seen that the radiation surface properties of the temperature sensor have virtually no effect on the heating rate of the foil-covered thermal load. This result, which might appear astonishing at first, can be readily explained by making use of the theory of radiant interchange in enclosed spaces. That theory demonstrates that the temperature of an adiabatic surface is fully independent of the radiation properties of the surface. This finding is strictly valid in the absence of convection. The fact that this finding occurs in the present situation suggests that, at least in the upper region of the oven, convection is of negligible importance compared with radiation.

A companion situation to that presented and discussed in connection with Fig. 7 is the case in which the thermal load has a blackened surface and is heated in an oven whose temperature sensor is either in the as-arrived state or the blackened state. The results for that case are exhibited in Fig. 8. This figure reaffirms the insensitivity of the heating rate of the thermal load to the surface finish of the temperature sensor. When taken together, Figs. 7 and 8 present irrefutable proof that the radiation surface condition of the oven's temperature sensor is irrelevant to the rate at which any thermal load is heated.

The cyclic air-temperature variations for the cases exhibited in Figs. 7 and 8 were carefully studied. It was observed that the periods of the oscillations increased as the experiment progressed in much the same way as was pointed out in connection with Figs. 5 and 6.

3.3. Oven vents open versus oven vents closed

The next issue to be investigated is the effect of the closure of the oven vents. In standard operation, the vents are typically open. The pattern of the presentation of results will follow that of the foregoing section in which the aluminum-foil-covered load was exhibited first followed by the blackened load.

Figure 9 displays the heating of the foil-covered load both with the vents open and the vents closed. An overall inspection of the figure reveals that the heating

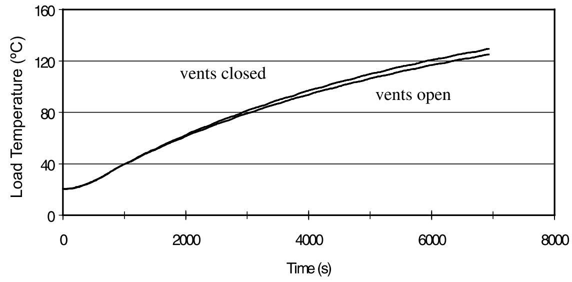

Fig. 9. Vents open versus vents closed for a foil-covered thermal load.

rate of the load is virtually unaffected by the presence or absence of venting. There is slight evidence of a higher heating rate when the vents are closed. This finding is entirely reasonable because with the vents open, there is a steady escape of heated air.

A similar graph showing the comparison of venting versus no venting for the blackened load is exhibited in Fig. 10. This figure, although for a very different surface finish of the load, is virtually identical to Fig. 9. Clearly, the vents are an irrelevant issue with regard to load heating.

It would then appear that the only practical usefulness of the venting is as a means for allowing cooking vapors to escape from the otherwise enclosed space.

3.4. Radiation surface properties of oven walls

The final non-standard operating condition to be examined is the radiation surface finish of the walls that bound the oven cavity. Most standard ovens have a porcelain finish with a dark, mottled color. However, very recently, elite ovens, with stainless steel interior walls have been incorporated in commercially available residential stoves (for example, General Electric model "Advantium 120"). The availability of such ovens has motivated an examination of the effect of the radiation surface properties of the walls of the oven on the rate of heating of the thermal load. The relatively high reflec-

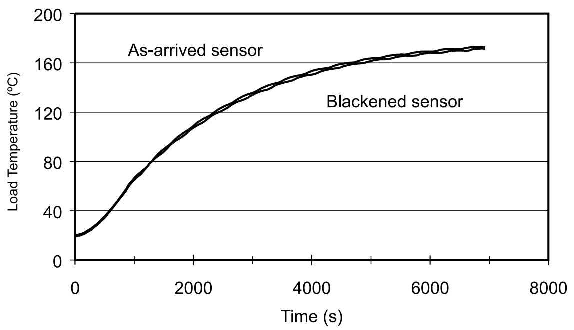

Fig. 8. Effect of radiation surface properties of the oven temperature sensor on the heating rate of a blackened thermal load.

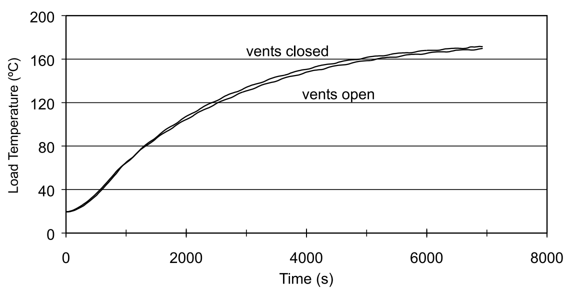

Fig. 10. Vents open versus vents closed for a blackened thermal load.

tivity of stainless steel walls was modeled in the present experiments by lining the oven cavity with aluminum foil. The foil was fitted tightly against the actual structural walls of the cavity.

Results will now be presented comparing the heating rate of the thermal load in the presence of highly reflecting oven walls and of the oven walls in the as-arrived state (mottled porcelain). The first comparison, made in Fig. 11, is for a thermal load with a highly reflecting surface finish (foil-covered). It is seen from the figure that the specifics of the radiation properties of the oven walls have only a moderate effect on the heating rate of the load. For instance, for a heating period of two hours, the temperature of the load in the presence of the as-arrived oven walls is about 8.3 °C (15 °F) higher than the temperature of the load in the presence of the highly reflecting oven walls.

A second comparison of the effect of the two types of wall surfaces is made in Fig. 12. In this figure, the results for the heating of the load correspond to the case of the load surface being blackened. Figure 12 shows a marked difference in the heating rates of the load for the two types of wall radiation-surface properties. The heating rate for the case of the foil-covered walls is substantially greater than that for the as-arrived walls. At relatively early times during the heating period, temperature differences in excess of 28 °C (50 °F) are in evidence. As time proceeds towards the end of the two-hour heating period, the difference approaches 16 °C (28 °F). It is especially interesting that the temperature of the blackened load in the presence of foil-covered walls actually exceeds the set-point temperature of the oven by approximately 11 °C (20 °F).

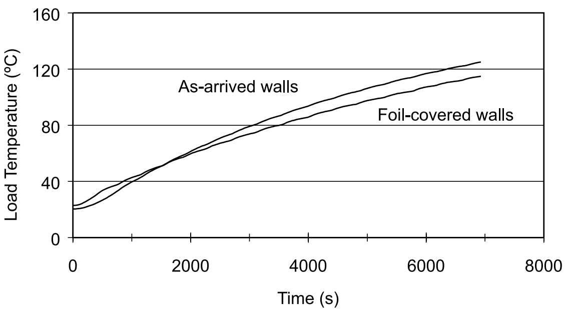

Fig. 11. Foil-covered walls versus as-arrived walls for a foil-covered thermal load.

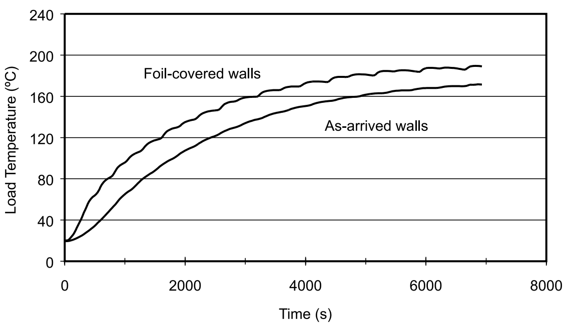

Fig. 12. Foil-covered walls versus as-arrived walls for a blackened thermal load.

These results indicate that there may be some thermal advantage in the use of ovens having highly reflecting walls when the thermal load has a surface finish which is a good absorber of radiant energy.

4. Concluding remarks

A comprehensive experimental investigation has been carried out to examine the effects of various radiation-related parameters on the heating of a thermal load situated in an electrically heated oven. The investigation was subdivided into a number of focal issues. The first focus was to study the effect of the radiation surface properties of the thermal load in the presence of standard operating conditions. These standard conditions encompassed an oven temperature sensor in its as-arrived state (a shiny external surface), oven vents which facilitate the throughflow of air, and oven walls having the usual mottled, dark surface finish.

For the standard operating conditions, it was found that the heating rate of the thermal load was independent of the painted color of the load surface. However, there was a marked difference in the heating rate when the surface was variously painted, highly reflecting, and moderately reflecting (as-arrived state for an aluminum block). These various surface finishes gave rise to load temperature differences on the order of 39 °C (70 °F) at the end of a two-hour heating period when the oven set-point temperature was 177 °C (350 °F).

Further experiments were performed using non-standard operating conditions. The first of these involved the application of a near-black coating to the external surface of the oven temperature sensor. Surprisingly, there was very little effect on the heating rate of the thermal load regardless of whether the external surface of the sensor was highly reflecting or nonreflecting. The second nonstandard operating condition investigated was to close the vents and thereby eliminate the throughflow of air. Here again, the heating of the thermal load was insensitive to the closing of the vents. The final nonstandard condition was to cover the oven walls with a highly reflecting surface in contrast to the as-arrived, near-black wall condition. It was found that when the walls were reflecting and the thermal load had a highly absorbing surface, the heating rate of the block was higher. When the block surface was highly reflecting, the reflecting cavity walls had a lesser effect and actually reduced the heating rate of the load.

The air-temperature field within the oven cavity was also investigated. In general, the periodic temperature variations induced by the oven control circuit decreased in frequency as time passed throughout the heating period.

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