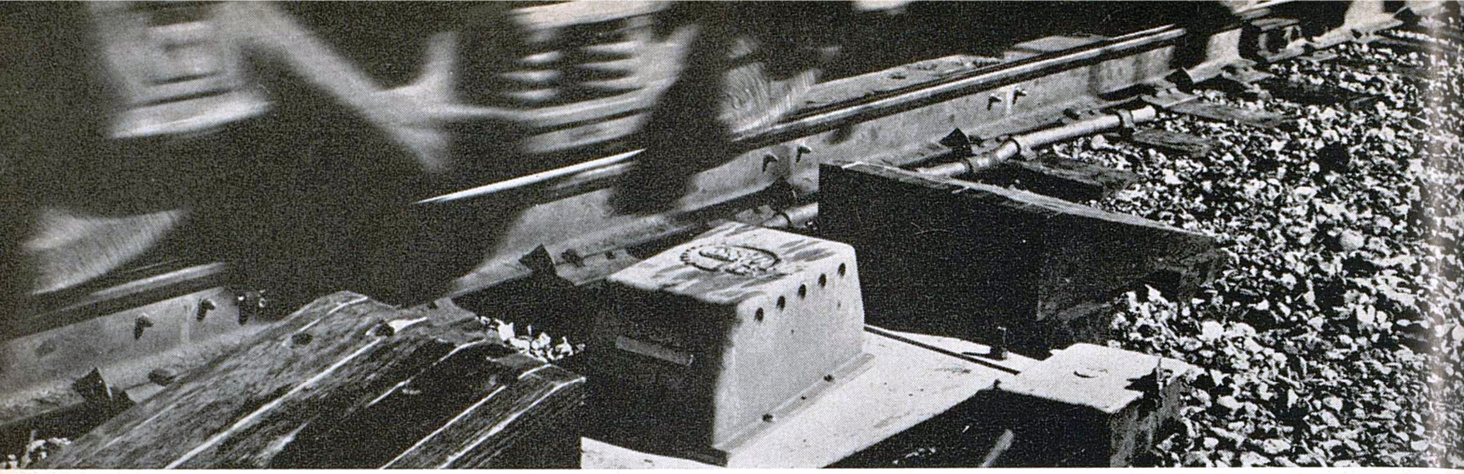

HOTBOX DETECTORS: Transient state shown

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It has become increasingly apparent that much confusion exists concerning the ability of infrared hotbox detectors to determine the actual temperature of a journal box. Personnel responsible for the operation and maintenance of detector installations are sometimes under the erroneous impression that the temperature of a journal box surface may be related, in specific terms, to the trace amplitudes registered on the graphic recorder. This article will attempt to point out why a temperature measurement cannot be made. Indeed, and more importantly, why such a temperature measurement is not necessary or practical.

In the recent past, four to five years ago, when hotboxes occurred almost five times more frequently than they do today, the manifestations of an overheated bearing were readily indicated by sight (smoke or flame), sound (screeching), or smell (an unmistakeable odor). Personnel stationed at frequent intervals along the right-of-way were able to recognize these signs often enough to prevent serious derailments.

With the advent of more efficient lubrication systems, better journal bearing designs, and better box seals, coupled with fewer stations along the railway, these once dependable signs are, more often than not, missing.

One did not ask in the old days what the temperature of a hotbox was —nor did he care. It was sufficient for the observer to know that the familiar signs were not the conditions of a normal bearing. Whether or not the car was set out depended on how severe the damage caused by the overheating. Perhaps the addition of "grease sticks" or a like remedy was enough to bring a car into the terminal with some care being exercised.

How may we best define a hot box? From what has just been described, one may suggest that any box which smokes, flames, screeches, or smells, is a hot box. There can be no argument with this definition if the aforementioned signs exist. On the other hand, if an overheated journal is accompanied by none of these signs, how is it to be classified? Such a journal is potentially much more dangerous than those which exhibit the usual signs. The roller bearing, despite its fine performance, still fails occasionally. In transit, the failure is virtually impossible to detect by ordinary means. The hotbox may be defined as follows:

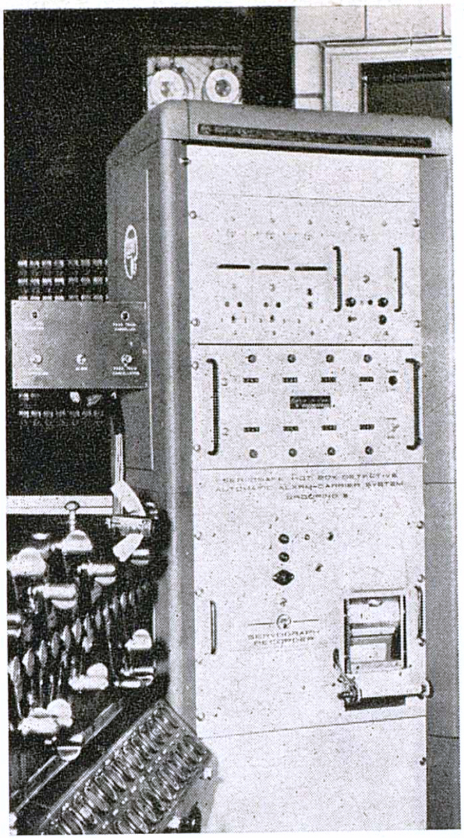
"Any bearing which departs markedly from the operating characteristics of other bearings in its class on a given train is a hotbox and remedial measures must be taken."

The definition is in conformity with the conventional methods of detection and also includes the new dimension afforded by the infrared hotbox detector.

What is the origin of a hotbox? Many of the causes for hotboxes are well-known and they are as diverse as the classes of journals. We may, however, enter all the causes under one general heading—the breakdown of lubrication. How fast does a journal rise in temperature before destruction of bearing surfaces occurs? The rate of temperatures varies; dependent upon the nature of the defect, loading, speed of the train, etc.

One seldom is able to pinpoint where a hotbox had its origin or how long it will run in an overheated condition before burn-off conditions prevail. To preclude accidents due to hotboxes, every overheated journal must be regarded as one which would derail the train if it is not detected and its disposition determined.

Because an overheated bearing can take one of many paths to the critical stages of destruction, time becomes the most important parameter in the detection process. The journal, being obscured from view in its enclosure, can only give evidence of its condition indirectly. Time is required, however, before the indirect reflections of internal conditions are in evidence. The rate of temperature rise at the journal-bearing interface may be very rapid and, if so, it becomes extremely important that some evidence of the situation appear external to the assembly in the shortest possible time. Otherwise, progression to destructive stages may prevail without warning.



Alarm controls pick out hotboxes.

For thermal flux to heat the external box surfaces, the thermal impedence of the assembly (brass, wedge, and box) must be overcome. The expression for the thermal circuit of the journal assembly may be given by $T = \phi \times R$ where T is the temperature difference between the heat producing surface and the external surfaces of the housing, ϕ is the thermal flux and R the resistance or impedance offered to the flow of heat.

For all practical purposes the statement serves to point out that the temperature difference between the bearing surface temperature and the outside box temperature can be very high depending upon the value of R, the thermal impedance. The value of R depends largely on the conductivity and mass of the material carrying the heat flux. If the mass is large and the conductivity poor, a large temperature difference exists, and a long time is required for the external surface to reach a given temperature. It is obvious, at this point, that the temperature of the outside box surface is a function of time if a journal is in the process of overheating.

A normal bearing will achieve an equilibrium or steady-state temperature after several hours running time. Stating it another way: a heat balance has been attained and the running temperature will have stabilized. The heat being generated will be exactly balanced by the heat loss of the system, consequently the temperature can rise no further unless a defect causes more heat to be generated. In such an event, the temperature will begin to rise to that level which is necessary to strike a new heat balance. If the defect is so severe as to cause the generation of so much heat that the temperature equilibrium point lies above the destructive temperature of the bearing, burn-off conditions will obtain and, unless detected in time, a derailment accident is certain.

Herein lies the difference between a normal journal and the hotbox. The normal bearing is a steady-state condition and the hotbox is in what is known as a transient condition.

While it is true that normal journal operating temperatures at equilibrium will vary from journal to journal, investigations have shown that the mean temperature for a large number of normal bearings (solid type) is 130°F above ambient temperature. The individual journal temperatures will be in a band from 110°F. to 150°F. above ambient. These slight variances from the mean temperature are caused by a wide variety of conditions such as, loading, bearing size, bearing contact surfaces, clearances, etc.

On a hot summer day, then, one would expect to find normal bearings to be operating in the vicinity of 220° F. for a 90° atmospheric temperature (90° + 130° = 220°). Let us consider this same journal operating in a winter ambient of 0°F. Now we would expect to find a normal operating temperature near 130°F. (0 + 130°F). However if under the winter environment we were to encounter a journal operating at 220°F., the journal in question poses a definite threat, for when the atmospheric temperature begins to rise the operating temperature of the journal must rise correspondingly. It is apparent that if the defective journal were to continue running at 220°F. through the winter to summer where a 90° day may be encountered. the operating temperature would rise to 310°F. (220° + 90°) which is dangerously close to the 350°F. destructive temperature of babbitt metal bearing linings.

The very large peak in set-out statistics for the hot weather months of July, August, September are due chiefly to the above phenomenon. Many hotboxes escape detection during the winter months simply because they have stabilized at abnormal operating temperatures and only give the conventional signs of a hotbox in the hot weather months when the atmospheric temperatures demand higher operating temperatures.

Certainly, those conditions giving rise to journal defects do not disappear in winter. Hotboxes occur in approximately equal numbers throughout each month of the year. Only the time of discovery belies this statement. Experience with infrared hotbox detector installations has demonstrated the validity of the analysis.

Up to this point, the discussion has concerned the internal journal temperatures. What about the external surface temperatures of the journal box? The results of the previously mentioned investigation indicated that the normal box mean temperature on the vertical surfaces is about 30°F. above ambient. This indicates that about 100°F exists between the bearing and outer surfaces of the journal assembly under steady-state conditions. Most of this temperature drop exists at the interfaces between the brass and wedge, and the wedge and the top of the box.

About 15 minutes must elapse between the time that a change takes place at the journal-bearing interface and the time that the box surfaces begin to respond to the change. Before a significant detectable change takes place at the box surface, at least a half-hour must elapse.

Much of what has already been said applies to the roller bearing journal as well. The chief difference between the solid and roller bearing, as regards temperature, is that the roller bearing has a lower thermal impedance between its outer race and the outer housing. The temperature difference between the heat producing surfaces and the external housing for roller bearings is much less than the 100°F quoted for the solid bearing case. As a consequence roller bearing indications show up on hotbox detector graphs as high amplitude traces (or pips) of a magnitude approximating that of solid bearing hotboxes. However, because of their symmetrical pattern, the roller bearings are recognizable as such.

An understanding of the nature of the hotbox is necessary to recognize that even if an exact temperature measurement of the surface of a journal box were achieved by commercially available hotbox detector systems, the data would be no more useful than that which is obtained. No hotbox detector system, now available, is able to determine the surface temperature of a passing journal box. There are too many variables which influence the response of the hotbox detector system.

We have stated that a normal journal box is in a steady-state condition after reaching equilibrium. We have also stated that the hotbox is in a transient condition. It is only necessary then, for a hotbox detector system to point out which journal boxes are in steady-state and which are in transient condition. The very fortunate set of circumstances which allows normal journals to operate in close proximity to the mean operating temperatures of 130°F establishes a reference against which wide departures from the mean may be indicated on a relative basis.

One may have indicated a 13 mm or full scale (25 mm) deflection for two given journals on a train. Both are hotboxes and require examination. To say, however, that the condition of the 25 mm box is worse than the 13 mm box may be erroneous. It is true that the surface temperature of one box is hotter than the other, but we know nothing of the history of either of the hotboxes. It is entirely possible for the brass temperature of the lower indication to be much higher than the brass temperature of the higher indication.

The explanation for this phenomenon is quite simple. The higher indication may have been a hotbox which has been developing slowly and running for hours at elevated temperatures. That box with the lower indication may have had a severe defect causing the journal temperature to rise rapidly but not having sufficient time elapse to heat up external surfaces before passing over the detector, hence the lower amplitude indication. Would an exact temperature measurement on the box in this case have been significant? Hardly. It remains that it is sufficient to indicate that the box is in a transient condition. The indication demands that the box be carefully inspected once its location has been determined by the hotbox detector.

It has often been asked, "Why can't I relate some amplitude, say a 15 mm impulse, to a specific temperature?" The answer to this question is that a 15 mm deflection will not always be a specific temperature. The radiated energy from the target (journal box) is not directly proportional to the temperature in degrees Fahrenheit, but rather to the fourth power of the Absolute Temperature. Furthermore the magnitude of the impulses is dependent upon the differences which exist in the energy levels radiated from the bottom of the car (ambient) and the energy radiated from the journal box. For example, assume a hotbox surface temperature of 100°F above ambient on a 90°F day, we find that about 3½ times more energy is radiated from the hotbox relative to ambient than is radiated from the normal box.

A similar analysis for the same boxes under a 0°F ambient with the same box temperature rise above ambient, reveals a ratio of 4:1. The conclusion is that unless the ratio were constant, the output of the heat cell could not be expected to give like readings for the two cases. It is obvious that the ratios are significantly large enough to produce wide departures from the normal box indications, however. This condition suffices to pinpoint the abnormality on the train.

The emissivity of the surface of a heated body is another variable. The emissivity, expressed as a decimal or percentage, is a measure of the ability of a surface to radiate heat energy. A body having an emissivity of 1.0 or 100% is defined as a black body. Defined in general terms, a black body is capable of absorbing all the radiant energy illuminating the body and is capable of radiating energy in a like amount. Emissivity is a measure of radiating efficiency much like the "gain" of a radio antenna is used to describe its radiating properties.

Most bodies are not black bodies, and are consequently described as grey bodies. That is, their emissivities lie somewhere between 0 and 1.0.

Two bodies heated to the same temperature but having difference emissivities will radiate infrared energy in proportion to their emissivities. In other words, if the bodies had emissivity factors of 0.8 and 0.4 respectively, the first would radiate twice as much energy as the second, though both bodies are at the same temperature.

Relating this property to journal boxes, it is fortunate that most boxes exhibit like characteristics. Occasionally a box may be newly painted or be covered with cement dust. These conditions would change the surface properties of the journal and influence the magnitude of the hotbox detector deflection for that particular box.

What has been described theretofore, in some detail, are but a few of the uncontrolled variables which make a temperature measurement by infrared pyrometry, a difficult problem. We have shown, however, that the temperature measurement, beside being impractical is not necessary. Suffice to say that by allowing all the uncontrolled factors to influence the system as they will, we at least know that the response of the system to normal journals and to hotboxes is approximately influenced to the same extent in each case. It is a qualitative rather than a quantitative analysis that the hotbox detector system performs.

Numerous other influencing factors, not mentioned in detail include: Response of graphic recorders vs high speed of trains. Attenuating characteristics of fog, rain, and snow. Variable sensitivity of heat cells under temperature extremes. The band-pass characteristics of infra-red lens materials. RSC