UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of TEXAS UTILITIES GENERATING COMPANY, et al. (Comanche Peak Steam Electric Station Station, Units 1 and 2)	Docket Nos. 50-445-1 and 50-446-1

CASE'S ANSWER TO APPLICANTS' REPLY TO CASE'S ANSWER TO APPLICANTS' MOTION FOR SUMMARY DISPOSITION REGARDING LOCAL DISPLACEMENTS AND STRESSES

in the form of

AFFIDAVIT OF CASE WITNESS JACK DOYLE

Q: Mr. Doyle, have you reviewed Applicants' Reply to CASE's Answer to Applicants' Motion for Summary Disposition Regarding Local Displacements and Stresses?

A: Yes.

Q: Is there new information contained in Applicants' Reply to which you believe you must respond?

A: Yes, and for this particular case I will respond more than I normally would under the restricted time frame which we face.

Q: What do you mean by that?

A: In the first place, we must start with the fact that by Applicants' procedures, the stress ratio for the pipe is 39,169/44,000 equals about .9 (see Attachment A, page 8, to the Affidavit of Applicants' Witness Finneran, attached to Applicants' original Motion).

With this as a baseline, the Applicants' procedures and counter arguments for this example present a study in pencilwhipping.

Q: Do you agree with Applicants' assertion that Cygna found no serious problems with the concept of a box frame used in lieu of a clamp and further that Cygna actually accepted this principle?

A: No, I do not, for several reasons. First, on the point of Cygna's finding no serious problem, I argue that when the sophisticated analysis done by Cygna leaves Cygna in doubt as to what problems there are, then there is serious doubt as to the box frame concept itself, and this doubt may be noted in the testimony by Cygna in the April 1984 hearings. For example:

Following a discussion at Tr. 12,666-12,669, Judge Bloch asked if the support should be looked into because of the high loads indicated by finite element analysis of about 70% of the maximum allowable (3 Sm):

At Tr. 12,669/10-25 (emphases added):

"JUDGE BLOCH: I guess Mr. Doyle is asking when you're faced with a situation like this which after substantial analysis shows fairly high loads, is it your judgment it was proper to dismiss this as a matter of engineering judgment rather than analysis.

"WITNESS BJORKMAN: I believe that is correct, that this should be looked at.

"JUDGE BLOCH: Should have been looked at by the Applicants?

"WITNESS BJORKMAN: Yes.

"JUDGE BLOCH: And does it need further analysis now also, or is the analysis now sufficient?

"WITNESS BJORKMAN: No, the analysis is not sufficient because it does not contain the effects of internal pressure or the actual effects due to the bending moment in the pipe at that specific location."

And at Tr. 12,712/15-24 (emphases added):

"JUDGE JORDAN: It's your opinion then, even if the U-bolt was left off, the frame itself would provide adequate support for the pipe.

"WITNESS WILLIAMS: That's how we evaluated it. I'm not sure that, to be conservative, they shouldn't approach the design in a more traditional manner. There's a lot better designs for that particular application and I don't think that's the approach we would take. However, we accepted it as adequate."

At Tr. 12,719/14-19 (emphasis added):

"JUDGE BLOCH: Does Cygna have adequate basis, nevertheless, to believe that this is not a problem?

"WITNESS WILLIAMS: I think as we stated before, we don't think this is a good design. There is a limit as to how much we are going to sit and defend the thought processes behind it, but we think it is adequate."

At Tr. 13,027/8-13,028/3 (emphasis added):

"BY MR. BACHMANN:
"Q: Getting back to our basic box frame and U-bolt, clip angle, clamp, support, assemblage . . . Is this type of clamp and support commonly used in the nuclear industry, to your knowledge?

"A: (Witness Williams) Is the question have we seen a lot of examples of that specific configuration?

"Q: I would like to know within your experience have you seen a lot of it; have you seen none of it; is this the only place you have seen it? Just what do you know about it?

"A: In my experience, I have not seen other examples of that particular configuration.

"JUDGE BLOCH: Dr. Bjorkman, is your experience the same or otherwise?

"WITNESS BJORKMAN: Mine is the same."

In reference to the above, the acceptance by Cygna is based on speculation, since there is no history nor is there test, calculation

or other evidence of adequacy. For that matter, all of the evidence currently offered indicates that stress levels in the pipe and box frame are extremely high (.68 per cent of 3 Sm minimum by Cygna, see Tr. 12,667/16, for box frame; and by Applicants, .9 of allowable for pipe, see Attachment A, page 8, to the Affidavit of Applicants' Witness Finneran, attached to Applicants' original Motion).

Q: Do you have reason to disagree with Applicants on point 2 of their Reply at pages 5 through 9 (referencing Finneran Affidavit at pages 2 through 6)?

A: I certainly do. It is this area more than any other which proves conclusively that when justification for completed structures is required, the fundamental procedures suffer.

For example, Applicants insist on failing to state the full facts as apply to particular phenomenon. In the case of a full surface air film acting as an insulator for the box beam and Applicants' neglecting the use of this element as being conservative would mislead a "somewhat knowledgeable" engineer. The reason is that, while Applicants accept credit for conservatism because they failed to use this insulator, they failed to note that the same air film surrounds the stainless steel pipe and therefore the temperature as calculated for the surface of the pipe is non-conservative.

Therefore, the fact is that not including the use of an air film on the carbon steel box frame is more than offset by the failure to include the air film for the stainless steel pipe. At best these are offsetting, but at worst, it is non-conservative.

Applicants state that I mistakenly believed that the air film referenced was located at the interface of the pipe and box frame. This is not true. Mentally I merely cancelled the air film from both the box frame and the pipe and concentrated on the air film that exists at the interface of the pipe and the box frame which with or without the self-cancelling effects of the air film for the total structure would render Applicants' procedure non-conservative. This "contact resistance" is a well-known phenomenon which causes "engineers" to avoid calculations which ride the razor's edge (stress ratio of .9, for example). To show the Board how common this knowledge is, I offer three sources (see Attachments A, B, and C hereto).

The final statement in this sub-section by Applicants is also incorrect, as will be noted in Attachments A, B, and C. There is a "contact resistance" (air film, etc.) without a gap.

In sub-section (b) of Applicants' item 2, they offer a recent finite differential calculation which they state shows how conservative Applicants' approach to the thermal problem was.

In my previous Answer, I was addressing errors within Applicants' procedure as presented, without anticipating other offerings. I will. therefore dispose of this deception by Applicants and move on.

One fact that deserves attention relative to the tests by ITT Grinnell is that as you move away from the heat source, the temperature drops drastically. In Item 13J of CASE Exhibit 669B (accepted at Tr. 3630), point 5 (which is, by the way, fully insulated), the temperature is 542 degrees F. This is .6 of the source temperature. In the model attached to the Finneran Affidavit the minimum metal temperature at 22

inches from the source is also about .6 of the source temperature. This is not reasonable (especially when this is an uninsulated heat path). (See also CASE Exhibit 669B, items 13H and 13I.)

First, the finite program lacks a factor which is critical to accuracy. I say factor because, with the information given and the condition of the information which is given, I can only address one point which I will cover below.

As was pointed out by Cygna's Dr. Bjorkman during the April 1984 hearings, the accuracy of output depends on input. See Tr. 12,964 et. seq., especially at Tr. 12,964/12-14, where Dr. Bjorkman states ". . . the obvious conclusion is that the model is too crude to predict the actual behavior which is going on here . . . " The problem with Dr. Bjorkman's model (which he could not pinpoint) is the precise problem with the current model offered by Applicants with one exception, we know what at least one of the omissions is.

This finite differential model does not include the integration of time in the analysis and this is a critical factor, particularly when one considers the contact area between the pipe and the tube steel involves only a few thousanths of a square inch per contact point (see page 3 of Attachment A to Applicants' Reply).

It appears that at this point, we must commence with a class on what is occuring with energy conduction.

First conduction occurs by two separate phenomenon. The first mechanism of energy transfer is molecular interaction. This occurs when a molecule at a higher energy level (temperature) imparts some of its energy to adjacent molecules which are at lower temperature levels.

The second mechanism or energy transfer involves the presence of free electrons and it is the numbers of free electrons which is the principal factor involved in conductivity.

As shown above, it is the transfer of energy from one surface area (heated) to a colder (relative) surface area which determines the heat transport profile at a given instant. If the area of contact is small and the volume of the heated element is large, then the heating time will be much longer for a given temperature gradient than would be true if all parameters were the same except the contact area is large. In short, it is the contact area and volume which determines the time for energy transport.

In addition, with such a small heat input area, it is probable that the losses in the box frame at a particular heat level due to radiation and convection could equal the input due to conductance and the temperatures assumed by the standard steady state formulas would be incorrect. In short, all elements of energy transfer must be considered simultaneously, both the contributors and the losses.

This is best noted in a couple of analogies: First, the blacksmith finds no problem with heating an 18" long bar of steel to near its melting point in a forge and then working this steel with a hammer on an anvil while holding the still relatively cool end in his bare hand. As any blacksmith can attest, the longer you hold the bar in your bare hand, the hotter it will get. In other words, heat takes time to travel.

A second analogy can be found in a standard cast steel spider. This utensil for frying is one piece with an integral steel handle. To

test the validity of transport over time, just heat the spider over a medium heat until the center is hot enough to make water skip, about 3 minutes. Pick up the pan by hand and remove it from the heat. Then try and pick up the pan by the handle 10 minutes after it has been removed from the heat source.

The purpose of the above is to point out by example that heat travels slowly and is dependen ... the area exposed to the heat source, the energy path, and the volume to be heated.

In the case of the pipe and the box frame, there are major differences affecting the energy transport. The entire inside diameter of the pipe is affected by the 350 degree heat source which will be conducted through the mass which results from its 1.2 wall thickness. On the other hand, there are 4 lines with an area of a few thousanths of a square inch which will be the thermal transport windows for the large mass which makes up the box frame. It is obvious that the pipe will achieve 326 degrees F. average temperature long before the box frame reaches its maximum average temperature.

From the above, it is clear that, assuming that Applicants' output is correct (which I don't concede), the fact that at some point in time the pipe temperature averages 326 degrees F. and the box frame averages 222 degrees F. at another point in time is without relevance.

The fact is that the time when the differential temperature between the pipe and the box frame is at a maximum in its effects on the pipe and the box frame is still unknown, but one thing is know, the pipe will see stresses in excess of .9 of maximum allowable as calculated by Applicants and the stress levels for the box frame will

be considerably higher than assumed.

A major problem with the above is that the RHR system particularly varies in temperature over the life of the plant, as do the steam lines; therefore, any overstress condition is not a one-time event but is cyclic. This misapplication of heat transport by Applicants is not only wrong, it is dangerous and will result in a deterioration of the protection due the public.

Having disposed of the finite model as a means of backing up their erroneous conclusions drawn from the equations in Applicants' Attachment A, I will proceed to prove that what I said is in fact the truth of the matter.

In their calculations in Attachment A, Applicants, using standard steady state equations (which does not imply that I concur with their mathematical gymnastics) [illegible]d certain values for certain points (<u>see</u> page 1 of Attachment A) f[illegible]e inner surface of the pipe, they derived a temperature of 350 degrees F., for the outer surface of the pipe they calculated a temperature of 302 degrees F. (with an average temperature for the pipe of 326 degrees F.). For the box frame (same source) they assumed the interface temperature was 302 degrees F. and the outer frame temperature was 104 degrees F. (with an average frame temperature of 203 degrees F.).

Attached to this Affidavit is Attachment D which includes two sketches: Sketch 1 is of the RHR pipe with a thickness of 1.0 inch and indefinite diameter disc welded all around. Sketch 2 depicts the RHR pipe with a box frame and represents the conditions as they exist in the real world.

Correlating the information from Applicants' Exhibit A (given above) with my Attachment D (attached), the problem of gradients, not considered by Applicants, will become obvious.

The temperature for PT A for either Sketch 1 or 2 of my Attachment D would be 350 degrees F., the average temperature (no PT given) in either Sketch 1 or 2 would be 326 degrees, the temperature for PT B in either Sketch 1 or 2 would be 302 degrees F., the average temperature for PT C in either Sketch 1 or 2 would be 203 degrees F., the temperature for PT D in either Sketch 1 or 2 would be 104 degrees F.

Now with everything of consequence transferred to the sketches in my Attachment D, we can proceed. As can be seen, we agree that the method of determining the temperatures by Applicants' procedures would have the same values for Plane A-A in Sketch 1 or Plane B-B in Sketch 2. The divergence from reality occurs when we depart from Plane A-A or B-B.

Referring to Sketch 1, if we take any radial plane similar to Plane A-A, the values for corresponding PT's (similar to those at A-A) would be the same at PT's A, B, C, and D on Plane A-A.

Referring now to Sketch 2, it is obvious that any radial plane within a quadrant, C-C for example, would not be represented by the values as calculated by Applicants as shown in the section view of Applicants' Attachment A, page 1.

Any conductive increase in temperture at the frame corners can only result from thermal transport due to the temperatures at PT's B, C, and D, and will be something less than 302 degrees and 203 degrees. (The 104 degrees would obviously be constant); this is because the only

source of energy for the box frame is at Point B (4 places).

The temperature range at PT E plus 2-1/2 inches (at the centerline of the veritcal member) would be (using Applicants' first equation from page 1 of Attachment 1):

104 + (302-104/13) 2.5 = 142 degrees F.

. . . and the average temperature for this area is approximately:

(142 + 104)/2 = 123 degrees F. (again using Applicants' methods).

Therefore, the use of 203 degrees F. as the average temperature on which to base the calculations for thermal expansion of the box frame is incorrect and non-conservative.

Carrying Applicants' procedures forward as shown above, and not truncating as Applicants did, shows the average temperature for all cross sections of the box frame combined is not 203 degrees F. as shown by Applicants, but is somewhere between 123 degrees F. and 203 degrees F., about 163 degrees F., and this error is fatal to Applicants' equations from this point on. My argument in my initial Answer to Applicants' Motion did not extend to future analysis, accurate or not, by finite methods (of dubious input technique since we only have a field of numbers and unreadable sketches without interpretation) but only to the calc which we were supplied and for that we find an error of about 20 per cent (203-163/163 equals 20 per cent) in determining the critical force used to determine all stresses.

In reference to (c) and (d) of Applicants' Reply, I was not aware that the Board Memorandum relieved Applicants of the requirement to consider such stresses. If I am wrong, I stand corrected.

To Summarize: While Applicants' equations on page 1 of Attachment

A may be applicable to Sketch 1 of my Attachment D, they are in no way applicable to Sketch 2.

In reference to sub-paragraph (e), regarding the design properties of structures of A500 Steel, this material is not covered by ASME Section III, but rather Code Case N-71, and the physical and mechanical properties are obtained from AISC. It was clear to CASE that for expansion properties, the obvious source would be AISC.

We were not aware that Applicants would look to ASME because it had a lower value. Therefore, I stand corrected, at least as far as the lower value is concerned. As far as the value I quoted, that is the proper value and method of determining that value for designing commercial structures to AISC.

Q: Do you have any further comments on the Reply by Applicants?

A: No, I do not.

I have read the foregoing affidavit, which was prepared under my personal direction, and it is true and correct to the best of my knowledge and belief.

Jack J. Doyle

Date: Oct. 4, 1984

STATE OF Massachusetts

COUNTY OF Worcester

On this, the 3rd day of October, 1984, personally appeared Jack J. Doyle, known to me to be the person whose name is subscribed to the foregoing instrument, and acknowledged to me that he/she executed the same for the purposes therein expressed.

Subscribed and sworn before me on the 3rd day of October, 1984.

Norma A. Porter

Notary Public in and for the State of Massachusetts

My Commission Expires: MY COMMISSION EXPIRES JANUARY 3 [illegible]

ATTACHMENT A

PROCESS HEAT TRANSFER

BY

DONALD Q. KERN

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The Patterson Foundry & Machine Company, and
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Polytechnic Institute of Brooklyn

FIRST EDITION
SECOND IMPRESSION

NEW YORK TORONTO LONDON
McGRAW-HILL BOOK COMPANY, INC.
1950

rature differences exist between
guard ring. Observations are
peratures on both faces of each
f the measured electrical heat
specimen and the temperature
n are known, k can be computed

r difficulty in determining the
the heat flows through a thick
iquid or gas, it causes free con-
nd the conductivity is decep-
h. To reduce convection it is
to use very thin films and small
ure differences with attendant
measurement. A method appli-
viscous fluids consists of a bare
ire passing through a horizontal
l with test liquid. The tube is
in a constant-temperature bath.
tance of the wire is calibrated
s temperature. For a given rate
nput and for the temperature of
btained from resistance measure-
e conductivity can be calculated
ethod, however, is that of Bridg-
thin fluid annulus between two
t-temperature bath as shown in
ylinder by a resistance wire flows
where it is removed by the bath.
servoir, assures that the annulus
s. The film is $\frac{1}{64}$ in. thick, and
small.
re on k. The thermal conductivi-
iquids which in turn are greater
smit heat through a solid than a
Some solids, such as metals, have
led *conductors*. Others have low
f heat. These are *insulators*. In
pe described above the thermal
n-bent of the temperature at any
ted values of k are subsequently

(1930); *Trans. ASME*, **58**, 719 (1936).

the averages for the entire specimen, and the error introduced by this assumption can be estimated by an examination of Tables 2 to 5 in the Appendix. The conductivities of solids may either increase or decrease with temperature and in some instances may even reverse their rate of change from a decrease to an increase. For the most practical problems there is no need to introduce a correction for the variation of the thermal conductivity with temperature. However, the variation can usually be expressed by the simple linear equation

$$k = k_0 + \gamma t$$

where k_0 is the conductivity at 0°F and γ is a constant denoting the change in the conductivity per degree change in temperature. The conductivities of most liquids decrease with increasing temperature, although water is a notable exception. For all the common gases and vapors there is an increase with increasing temperature. Sutherland[1] deduced an equation from the kinetic theory which is applicable to the variation of the conductivity of gases with temperature

$$k = k_{32} \frac{492 + C_k}{T + C_k} \left(\frac{T}{492} \right)^{3/2}$$

where C_k = Sutherland constant

T = absolute temperature of the gas, °R

k_{32} = conductivity of the gas at 32°F

The influence of pressure on the conductivities of solids and liquids appears to be negligible, and the reported data on gases are too inexact owing to the effects of free convection and radiation to permit generalization. From the kinetic theory of gases it can be concluded that the influence of pressure should be small except where a very low vacuum is encountered.

Contact Resistance. One of the factors which causes error in the determination of the thermal conductivity is the nature of the bond formed between the heat source and the fluid or solid specimen which contacts it and transmits heat. If a solid receives heat by contacting a solid, it is almost impossible to exclude the presence of air or other fluid from the contact. Even when a liquid contacts a metal, the presence of minute pits or surface roughness may permanently trap infinitesimal bubbles of air, and it will be seen presently that these may cause considerable error.

Derivation of a General Conduction Equation. In Eqs. (2.1) to (2.4) a picture of heat conduction was obtained from an unqualified observation of the relation between heat flow, potential, and resistance. It is now feasible to develop an equation which will have the broadest applicability

[1] Sutherland, W., *Phil. Mag.*, **36**, 507 (1893).

leading mathematicians and physicists. It is possible to present only some of the simplest and most representative cases here and to suggest the overall nature of the study. The reader is referred to the excellent books on the subject listed below.[1] They treat the subject in greater detail and provide the solutions for a number of specific problems as well as many with more complex geometry.

In the treatment of unsteady-state conduction the simplest types of problems are those in which the surface of the solid suddenly attains a new temperature which is maintained constant. This can happen only when the film coefficient from the surface to some isothermal heat-transfer medium is infinite, and although there are not many practical applications of this type, it is an important steppingstone to the solution of numerous problems. Ordinarily, heating or cooling involves a finite film coefficient or else a contact resistance develops between the medium and the surface so that the surface never attains the temperature of the medium. Moreover, the temperature of the surface changes continuously as the solid is heated even though the temperature of the medium remains constant. It is also possible that the temperature of the medium itself varies, but this class of problem will be treated separately in the next section. The cases treated in this section include those with finite film coefficients or contact resistances as well as those with infinite coefficients. The following are considered:

Sudden change of the surface temperature (infinite coefficient)

Wall of infinite thickness heated on one side
Wall of finite thickness heated on one side
Wall of finite thickness heated on both sides (slab)

Square bar, cube, cylinder of infinite length, cylinder with length equal to its diameter, sphere

[1] Boelter, L. M. K., V. H. Cherry, H. A. Johnson, and R. C. Martinelli, "... Transfer Notes," University of California Press, Berkeley, 1946. Carslaw, H. ... J. C. Jaeger, "Conduction of Heat in Solids," Oxford University Press, New ... 1947. Grober, H., "Einfuhrung in die Lehre von der Warmeubertragung," ... Julius Springer, Berlin, 1926. Ingersoll, L. R., O. J. Zobel, and A. C. Ingersoll, "... Conduction with Engineering and Geological Applications," McGraw-Hill ... Company Inc., New York, 1948. McAdams, W. H., "Heat Transmission," ... McGraw-Hill Book Company, Inc., New York, 1942. Schack, A., "Der indu... Warmeubergang," Verlag Atahleisen, Dusseldorf, 1929; English translation ... Goldschmidt and E. P. Partridge, "Industrial Heat Transfer," John Wiley & ... Inc., New York, 1933. Sherwood, T. K., and C. E. Reed, "Applied Mathem... Chemical Engineering," McGraw-Hill Book Company, Inc., New York, 19... a review of more recent methods see Dusinberre, G. M., "Numerical Analysis ... Flow," McGraw-Hill Book Company, Inc., New York, 1949, and Jakob, M., "... Transfer," Vol. 1, John Wiley & Sons, Inc., New York, 1949.

Changes due to media having con

Wall of finite thickness
Cylinder of infinite length, s
Newman's method for comm
Graphical determination of t

Wall of Infinite Thickn thickness and at a unif roundings with constant t contact resistance betwee that the face temperature nary quenching in which t general equation for cond wall of infinite thickness it Eq. (2.12). The group k the properties of the cond duction may be represent

Fourier has indicated tha a body of uniform tempe be represented by the ex is the time, and x the dis ing point it is possible t the variation of the tem solid suddenly subjecte however, that the equat boundary conditions im of this type is given by

in which C_1, C_2, and C which describes the case ditions is given by Scha

$$t = C_1 -$$

where $\frac{2}{\sqrt{\pi}} \int_0^z e^{-z^2}\, dz$ is Gauss's error integral tions for an infinite wa $\theta = 0$, $t = t_0$ and, whe

ATTACHMENT B

APPLIED HEAT TRANSMISSION

BY

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First Edition

McGRAW-HILL BOOK COMPANY, Inc.
NEW YORK AND LONDON
1941

heat transfer by conduction through such composite bodies can be calculated as follows:

If the conduction of heat is steady, the rate of heat transfer through two *flat bodies in series*, as shown in Fig. 6, can be calculated by the equation

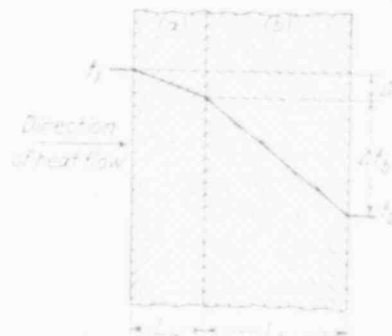

Fig. 6.—Temperature gradient through two flat bodies in series.

$$q = \frac{A(t_1 - t_2)}{(L_a/k_a) + (L_b/k_b)} \quad (6)$$

where q = the rate of heat transfer by conduction, B.t.u. per hr.
k_a and k_b = the thermal conductivities of materials a and b, evaluated at the average temperature of each, B.t.u./(ft.)(hr.)(°F.).
A = the cross-sectional area of the bodies, taken normal to the direction of heat flow, sq. ft.
t_1 and t_2 = the temperatures at the outside faces of the composite body, °F.
L_a and L_b = the thicknesses of materials a and b, ft.

This equation may also be written

$$q = \frac{(t_1 - t_2)}{R_a + R_b} \quad (6a)$$

where R_a and R_b are equal to L_a/k_aA and L_b/k_bA, respectively, and are called the *resistances* of the two materials. These two equations can be extended to include any number of flat bodies in series by adding additional L/k terms to the denominator of Eq. (6) or resistances R to the denominator of Eq. (6a).

If the conduction of heat is steady, the rate of heat transfer through *two cylindrical bodies in series*, as shown in Fig. 7, can be calculated by the equation

$$q = \frac{2\pi l(t_1 - t_2)}{2.3\left[\dfrac{\log_{10}(r_a''/r_a')}{k_a} + \dfrac{\log_{10}(r_b''/r_b')}{k_b}\right]} \qquad (7)$$

where q = the rate of heat transfer by conduction from the inner to the outer surface, B.t.u. per hr.

k_a and k_b = the thermal conductivities of materials a and b, evaluated at the average temperature of each, B.t.u./(ft.)(hr.)(°F.).

π = 3.14.

l = the length of the cylinders, ft.

t_1 and t_2 = the temperatures at the inside and outside faces of the composite body, °F.

r_a' and r_a'' = the radii (or the diameters) of the inside and outside faces of material a, ft. or in.

r_b' and r_b'' = the radii (or the diameters) of the inside and outside faces of material b, ft. or in.

This equation can be extended to include any number of concentric cylindrical bodies in series by adding additional $(1/k)\log_{10}(r''/r')$ terms to the denominator.

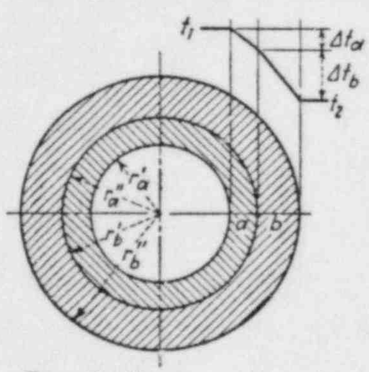

FIG. 7.—Temperature gradient through two cylindrical bodies in series.

In applying Eqs. (6) or (7), the thermal conductivity of each of the materials should be evaluated at the average temperature of the material, and consequently the temperatures between the various layers must be determined. These temperatures may also be required for design purposes if some of the materials are suitable for only a limited range of temperature. They can be determined as follows: (1) A reasonable value for each temperature is first assumed. (2) Based on these assumed values, the thermal conductivity of each of the materials is determined. (3) The rate of heat transfer q through the composite body is calculated by Eq. (6) or (7). (4) Using this value of q, the temperatures at each of the interfaces is calculated by Eq. (3) or (4). These calculated temperatures will usually be sufficiently accurate for practical purposes, although the procedure may be

(7)

$\frac{g_{10} (r_b''/r_b')}{k_b}\Big]$

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repeated if greater accuracy is desired. The method of calculation is illustrated in the following problems:

Illustrative Problem 5.—A furnace wall consists of 9 in. of firebrick covered with 4 in. of insulating blocks made of diatomaceous silica, asbestos fiber, and a bonding material. Calculate the rate of heat transfer by conduction through each square foot of the wall if the temperature at the inside face is 2000°F. and the temperature at the outside face is 200°F.

Solution.—As a first approximation, assume that the temperature at the interface between the two materials is 1600°F. Based on this assumption, the average temperatures of the firebrick and of the insulation are 1800 and 900°F., respectively, and the thermal conductivities of the two materials at these temperatures are 0.71 and 0.061 B.t.u./(ft.)(hr.)(°F.). By Eq. (6), the rate of heat transfer through the composite wall is

$$q = \frac{1 \times (2000 - 200)}{\dfrac{9}{12 \times 0.71} + \dfrac{4}{12 \times 0.061}}$$
$$= 276 \text{ B.t.u. per hr.}$$

Since this is also the rate of heat transfer through each individual material, a more accurate value of the temperature t' at the interface can be calculated by Eq. (3). Thus, for the insulation,

$$276 = \frac{0.061 \times 1 \times (t' - 200)}{4/12},$$

whence

$$t' = 1710°\text{F.}$$

The same result would be obtained by applying Eq. (3) to the firebrick. This temperature does not agree very closely with the temperature originally assumed, but an appreciably different value of q would not be obtained by repeating the calculations, since the thermal conductivities of the two materials vary only slightly with the temperature. Thus, a value of 280 B.t.u. per hr. is obtained if the calculations are repeated.

Illustrative Problem 6.—A 2-in. pipe is to be covered with two layers of insulation each 1 in. thick. An insulating material made of diatomaceous silica, asbestos, and a bonding material is to be used for the inner layer; and 85% Magnesia, which is suitable only for temperatures up to 600°F., is to be used for the outer layer. Will this covering be satisfactory if the temperature at the inside face will be 1000°F. and the temperature at the outside face will be 120°F.?

Solution.—As a first approximation, assume that the temperature at the interface will be 600°F. Based on this assumption, the average temperatures of the inner and outer layers will be 800 and 360°F., and their thermal conductivities at these temperatures will be 0.059 and 0.044 B.t.u./(ft.)(hr.)(°F.), respectively. The actual outside diameter of a 2-in. pipe is 2.375 in. Hence, by Eq. (7), the rate of heat transfer per foot of length will be

$$q = \frac{2 \times 3.14 \times 1 \times (1000 - 120)}{2.3\left[\frac{\log_{10}(4.375/2.375)}{0.059} + \frac{\log_{10}(6.375/4.375)}{0.044}\right]}$$
$$= 292 \text{ B.t.u. per hr.}$$

Since this is also the rate of heat transfer through the individual layers, the temperature t' at the interface can be calculated by Eq. (4). Thus, using the data for the outer layer,

$$292 = \frac{0.044 \times 2 \times 3.14 \times 1 \times (t' - 120)}{2.3 \log_{10}(6.375/4.375)},$$

whence

$$t' = 520°\text{F}.$$

Although a more accurate value could be obtained by repeating the calculations, the foregoing value is sufficiently accurate to indicate that the 85% Magnesia will not be overheated and that the covering will therefore be satisfactory.

Equations (6) and (7) involve the assumption that no drop in temperature takes place at the boundary between the two materials. In practice, however, the contact between the layers is usually not perfect because of the roughness of the surfaces, and consequently a drop in temperature does take place As a result, the actual rate of heat transfer by conduction is likely to be somewhat less than the calculated rate.

Equation (6) can be obtained as follows: Referring to Fig. 6, the rate of conduction through material a is, by Eq. (3),

$$q = \frac{k_a A(\Delta t_a)}{L_a},$$

or

$$\Delta t_a = \frac{qL_a}{Ak_a}.$$

Similarly,

$$\Delta t_b = \frac{qL_b}{Ak_b}.$$

Since steady flow is assumed, the rate of heat transfer q is the same through both materials. Hence, adding the last two equations,

$$t_1 - t_2 = \frac{q}{A}\left(\frac{L_a}{k_a} + \frac{L_b}{k_b}\right),$$

which is Eq. (6).

Equation (7) is obtained from Eq. (4) in a similar manner. An equation for calculating the rate of heat transfer by conduction

through two spherical bo
Eq. (5), but this case is of

10. Unsteady Conductio
temperature at each surfac
uniform over the entire s
the temperatures within th
the temperatures within th

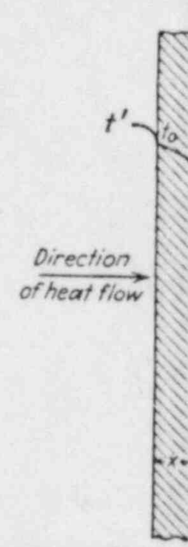


FIG. 8.—Temperature gradient for

closely approximated by th
Schmidt:[1]

1. The body is divided
thicknesses x, as shown in F
n; the larger the value the

2. The temperatures t_0,
these n imaginary laminae
equal intervals of time θ, t
equation

θ

[1] SCHMIDT, E., "A. Föppls Fe

ATTACHMENT C

Heat Transmission

BY

WILLIAM H. McADAMS
Professor of Chemical Engineering at the Massachusetts Institute of Technology

Sponsored by the Committee on Heat Transmission, National Research Council

SECOND EDITION
REVISED AND ENLARGED
ELEVENTH IMPRESSION

McGRAW-HILL BOOK COMPANY, INC.
NEW YORK AND LONDON
1942

c. Calculate the surface coefficient of heat loss h, expressed as Btu/(hr)(sq ft of outside lagging surface)(deg F difference from surface to room).

Solution.—The following diameters are needed: i.d. of pipe, 2.07 in.; o.d. of pipe, 2.37 in.; mean diameter of pipe, 2.22 in.; o.d. of first covering, 4.87 in.; logarithmic mean diameter, 3.48 in.; o.d. of second covering, 9.87 in.; mean diameter 7.07 in. The heat loss per foot is calculated from Eq. 26*d*, page 23, using k of 23.5 for wrought iron, page 380, and a wall thickness of 0.154 in.

$$q = \frac{900 - 122}{\dfrac{0.154/12}{(23.5)(2.22\pi/12)} + \dfrac{1.25/12}{(0.058)(3.48\pi/12)} + \dfrac{2.5/12}{0.042(7.07\pi/12)}}$$

$$= \frac{778}{0.00094 + 1.97 + 2.68} = \frac{778}{4.65} = 167 \text{ Btu/(hr)(ft)}$$

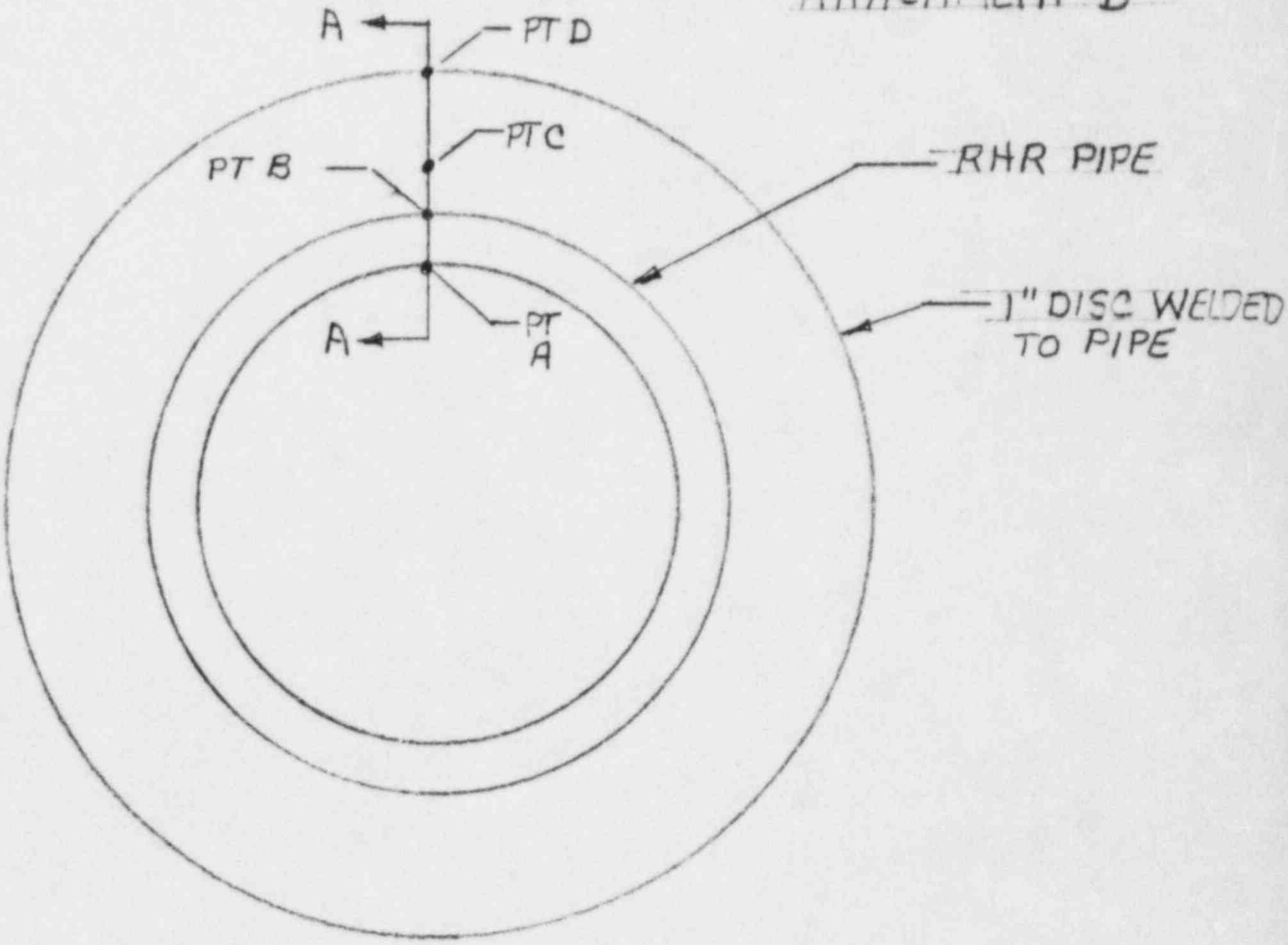
b. Since temperature drop is proportional to resistance, $900 - t_i = 778(1.97/4.65) = 330$; whence t_i equals 570°F.

$$c.\ h = \frac{q}{A_o(\Delta t)} = \frac{167}{\dfrac{9.87\pi(1)(122 - 86)}{12}} = 1.8 \text{ Btu/(hr)(sq ft)(deg F)}$$

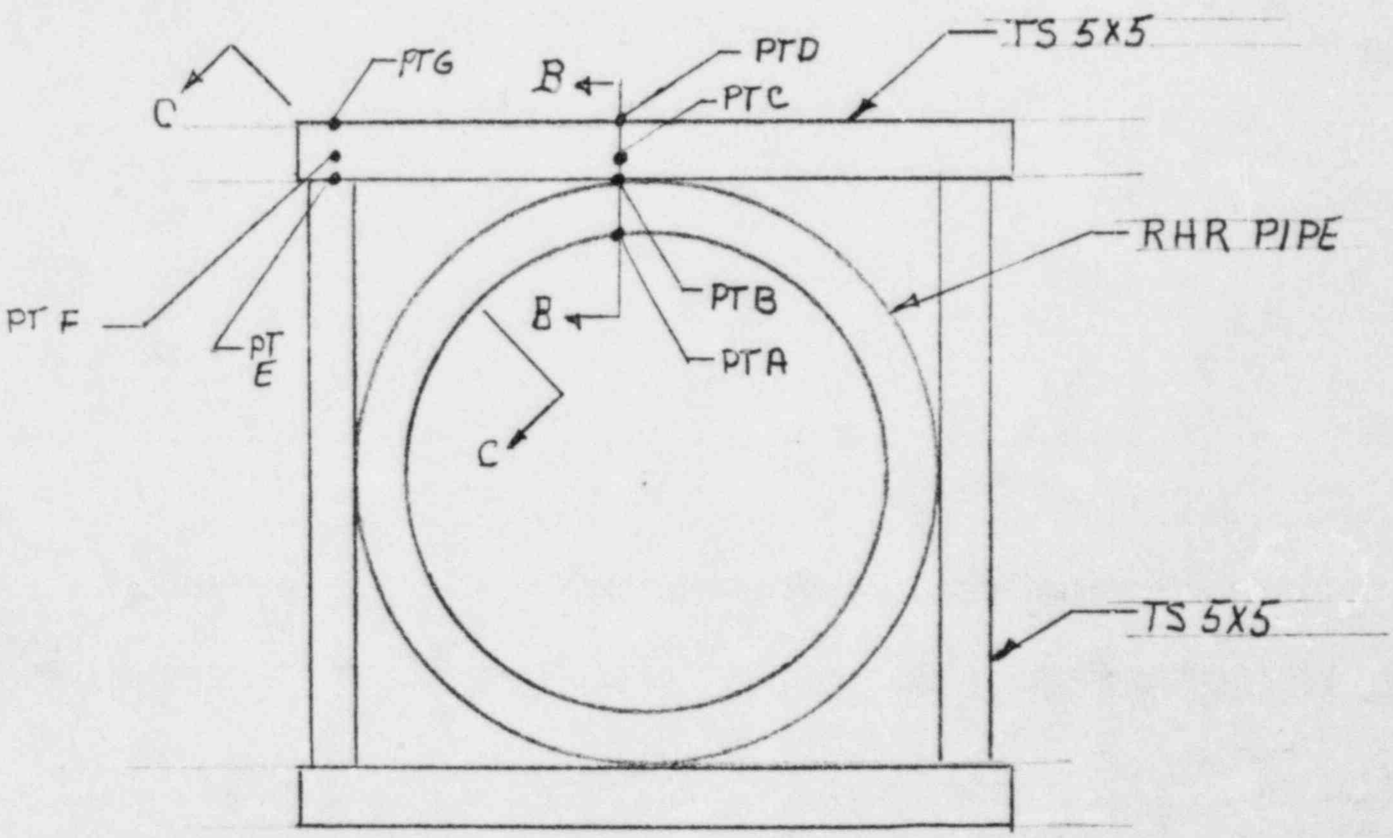
Contact Resistance.—In the preceding example, in which two solids were in contact, no allowance was made for a temperature drop at the boundary, which presupposes perfect contact. However, this requires the absence of gases or vacant spaces caused by those blowholes, bubbles, rough surfaces, etc., which are very likely to be present where two solids are brought together. Even traces of poorly conducting material between metals, such as oxide films on the surface, will cause abrupt drops in the temperature.[46,711] It is usually impossible to estimate accurately the thickness of such films, but their effect may be serious.

Instead of attempting to determine separately the conductivities of brick and mortar, it is often customary to measure the average conductivity of a brick-and-mortar wall. Van Dusen and Finck[731] report experimentally determined over-all thermal resistances of a number of walls and also individual resistances of the various components. In general, fairly satisfactory agreement was found between the predicted values and observed results. Over-all resistances for large walls in service may be determined by the use of the *heat meter*,[509] which measures the temperature drop through the known resistance of the meter, simultaneously measuring the temperature gradient through the wall itself. In this way the thermal conductivity of the whole wall, or of any layer, may be measured, even though the use of the meter reduces the heat flow compared with that from the bare wall. Precautions should be taken to secure data under steady conditions.

ATTACHMENT D



SKETCH 1



SKETCH 2

10/9/84

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	
TEXAS UTILITIES GENERATING COMPANY, et al.	Docket Nos. 50-445-OL and 50-446-OL
(Comanche Peak Steam Electric Station Station, Units 1 and 2)	

CASE'S ANSWER TO APPLICANTS' REPLY TO CASE'S ANSWER TO APPLICANTS' MOTION FOR SUMMARY DISPOSITION REGARDING LOCAL DISPLACEMENTS AND STRESSES

CASE (Citizens Association for Sound Energy), Intervenor herein, hereby files this, its Answer to Applicants' Reply to CASE's Answer to Applicants' Motion for Summary Disposition Regarding Local Displacements and Stresses.

We discussed in some detail the reasons we believe the Board should allow this and similar Answers to Applicants' replies to CASE's Answers to Applicants' Motions for Summary Disposition in our 10/1/84 and 10/2/84 Answers /1/, so we will not repeat those same arguments here but incorporate them herein by reference. We note that Applicants have filed a 10/4/84 Motion to Strike those two pleadings and any future such Answers by CASE, and we urge that the Board deny Applicants' Motion.

CASE believes that the Board must (especially because of the very unusual nature of the method adopted for handling the design/design QA/QC issues in this proceeding) base any decision in this matter primarily on its ultimate responsibility to assure a complete record on which to base a

/1/ See CASE's 10/1/84 Answer to Applicants' Reply to CASE's Answer to Applicants' Motion for Summary Disposition Regarding Consideration of Friction Forces; and CASE's 10/2/84 Answer to Applicants' Reply to CASE's Answer to Applicants' Motion Regarding Alleged Errors Made in Determining Damping Factors for OBE and SSE Loading Conditions.

DS03

reasoned, informed decision. This cannot be accomplished if the Board allows Applicants to use their replies to provide new information and analyses which CASE has not had the opportunity to address previously. CASE urges that the Board assure that all the cards are on the table on these important matters. This unusual procedure also requires that the Board take into consideration the requirements of 10 CFR 2.743(a) and 2.754(a), since we are, in effect, engaged in hearings by mail on the design/design QA/QC issues.

CASE will attempt not to abuse our filing of these Answers; for example, we are not responding to Applicants' many comments with which we merely disagree, but we are, rather, attempting to restrict our responses to addressing new information, analyses, argument, etc., included in Applicants' Replies. The Board must have CASE's response to such new information in order to have a complete record and in the interest of fairness and due process.

For the preceding reasons, the Board should accept our instant pleading and future such pleadings as being necessary to the Board's arriving at a valid decision in these proceedings.

Our Answer in this instance is contained in the attached Affidavit of CASE Witness Jack Doyle.

Respectfully submitted,

Juanita Ellis

(Mrs.) Juanita Ellis, President
CASE (Citizens Association for Sound Energy)
1426 S. Polk
Dallas, Texas 75224
214/946-9446

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	}{	
	{	
TEXAS UTILITIES ELECTRIC	}{	Docket Nos. 50-445-1
COMPANY, et al.	}{	and 50-446-1
(Comanche Peak Steam Electric	}{	
Station, Units 1 and 2)	}{	

CERTIFICATE OF SERVICE

By my signature below, I hereby certify that true and correct copies of CASE's [redacted] Answer to Applicants' Reply to CASE's Answer to Applicants' Motion for Summary Disposition Regarding Local Displacements and Stresses have been sent to the names listed below this 9th day of October, 1984, by: Express Mail where indicated by * and First Class Mail elsewhere.

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