Omaha Public Power District

444 South 16th Street Mall
Omaha NE 68102-2247

January 25, 2002
LIC-02-0007

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

References:
1. Docket No. 50-285
2. Letter from OPPD (R. L. Phelps) to NRC (Document Control Desk), dated October 15, 2001, "Fort Calhoun Station (FCS) Control Element Drive Mechanism (CEDM) Housing Reliability Management" (LIC-01-0095)
3. Letter from NRC (A. B. Wang) to OPPD (S. K. Gambhir), dated November 16, 2001, "Fort Calhoun Station, Unit No. 1 - Control Element Drive Mechanism Housing Cracking" (NRC-01-104)

SUBJECT: Fort Calhoun Station (FCS) Discussion of Control Element Drive Mechanism (CEDM) Housing Reliability

In response to Reference 3, Omaha Public Power District (OPPD) is providing additional information on the factors affecting material reliability management of the CEDM housings as presented to the NRC in Reference 2. The primary factors considered are welding and cold working tensile residual stresses and temperature, two components of the triad that define the transgranular stress corrosion cracking (TGSCC) phenomena. OPPD has prepared an interpretation of the possible stress magnitudes and distribution and temperature variation that is inherently used in defining the Fort Calhoun Station (FCS) inspection criteria and frequency. This interpretation concludes that: 1) the highest risk component is the j-groove weld on the CEDM seal housing assemblies, and 2) the primary driving force is the environmental condition for TGSCC.

OPPD continues to pursue all available information related to the material reliability of the CEDM housing assemblies. The scope of the inspections planned during the FCS spring 2002 refueling outage has been expanded by: 1) increasing the number of CEDM seal housing assemblies to be inspected from six to eight, and 2) adding volumetric examination of six CEDM upper housing assemblies. Increasing the number of inspected seal housing assemblies allows OPPD to complete the baseline inspection of CEDM seal housings assemblies by 2006. A semi-remote ultrasonic technique will be applied to the In-Service Inspection (ISI) program's examination of the CEDM upper housing assemblies to minimize personnel radiation exposure and to improve the examination process reliability.

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These inspections and this perspective on TGSCC contributing factors do not constitute new commitments. OPPD encourages continuing dialog with the NRC on this important inspection planning issue.

Please contact me if you have any questions.

Sincerely,

R. T. Ridenoure
Division Manager
Nuclear Operations / Site Coordinator

RTR/RLJ/rlj

Attachment

c: E. W. Merschoff, NRC Regional Administrator, Region IV
A. B. Wang, NRC Project Manager
W. C. Walker, NRC Senior Resident Inspector
Winston & Strawn

Fort Calhoun Station
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i. Executive Summary:

In response to the NRC request for additional information to Omaha Public Power District (OPPD) letter LIC-01-0095[1], OPPD has addressed residual welding stresses and the effects of cold working and temperature on the material reliability of the control element drive mechanism (CEDM) housing. This request has been bundled as an interpretation of the magnitude of the welding and cold working tensile residual stress and the range of temperature conditions that would be significant in predicting transgranular stress corrosion cracking (TGSCC) occurrences. In addition, OPPD has presented the macro assessment of welding and cold working residual stress as having limitations in determining possible occurrences of TGSCC.

The most favorable condition for TGSCC is confirmed to be located in the CEDM seal housing assemblies' j-groove weld due to stagnancy, temperatures, and transverse weld shrinkage. The CEDM upper housing assemblies' weld overlay area and double v-groove (butt welds) are shown to be of lesser significance as candidates for TGSCC occurrence, based on the same quantitative interpretations. The cold working applied in fabricating these housings is not significant enough from weld to weld to provide a measurable difference as a predictive tool. Finally, OPPD has shown that the crack rate variation with temperature is also an insignificant variable compared to operating experience.

The conclusion is the CEDM seal housing operating conditions of temperature, stagnancy, and residual tensile stresses generated by j-groove welds is the optimal area for inspection for TGSCC. However, OPPD continues to investigate and refine its model based on a micro-structural stress concept in combination with a stagnant environment. Understanding this TGSCC mechanism will assist OPPD in assuring safe operation of the Fort Calhoun Station (FCS).

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[1] Letter from OPPD (R. L. Phelps) to NRC (Document Control Desk), dated October 15, 2001, "Fort Calhoun Station (FCS) Control Element Drive Mechanism (CEDM) Housing Reliability Management" (LIC-01-0095)

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1.0 Introduction:

This discussion is in response to an NRC request for additional information regarding the material reliability of the FCS CEDM housings. This discussion presents the corrective actions taken and methodology used in managing the industry's concerns on transgranular stress corrosion cracking (TGSCC) in CEDM housing assemblies. The NRC has requested additional information on OPPD's perspective of the importance on residual stress and temperature as a primary driving force for determining inspection criteria and frequency. The discussion that follows will elaborate on the basis of OPPD's methodology for managing the material reliability of the CEDM housing assemblies and the depth of actions taken for maintaining a reasonable assurance of safe operation of FCS.

2.0 Review of the NRC's Questions:

The NRC's questions suggest that OPPD's efforts are based on a "limited area" of inspections for TGSCC. The areas that have been inspected are based on concerns as presented in OPPD letter LIC-01-0095 for all weld areas in the CEDM housing assembly with an emphasis on the J-weld and overlay weld geometries based on operating experiences and OPPD's inspections. The NRC staff questions suggest the primary driving force for TGSCC to be from the tensile stress generated possibly from welding, pre-cold working (weld joint prep), or post-cold working (finish blending) conditions. In conjunction with a notion of the housing operating temperatures decreasing significantly with increasing elevation, this variation could change the incubation/cracking rate significantly. The scope and frequency of CEDM housing inspections have been evaluated based on a "broader view" that considered the CEDM assemblies as a system. The methodology used at FCS has considered the same factors as questioned by the NRC and more in determining frequencies, inspection types, risks, and contingencies that defined the actions taken in order to manage the material reliability of the FCS CEDM housing assemblies.

3.0 Overview of OPPD Letter LIC-01-0095:

OPPD letter LIC-01-0095 discussed OPPD's corrective actions and self identification of the concerns as a result of industry experience with TGSCC. These actions were formulated into a comprehensive assessment of the potential cause and risk, and a review of previous inspections, fabrication records, inspection plans, and possible contingencies that are documented in the OPPD's program plan.

This program plan is the basis and guidance for selection, inspection, evaluation, remediation, or repair of the CEDM seal housing assemblies at FCS. This plan proposes an inspection criteria and frequency, which is based on the environmental conditions (stagnancy, tensile stress, and temperature) in relationship with the two phases of stress corrosion cracking period which is defined by the incubation and cracking duration. In

addition, the evaluation of non-destructive examination techniques was reviewed for their possible limitation in detecting tight cracks and surface geometry challenges in the areas of concern. The eddy current technique that was selected is based on a pilot study performed on the spare CEDM seal housings provided by FCS and Palisades on May 7, 1999. The enhanced eddy current technique, based on the pilot inspection, was then applied during the 1999 and 2001 refueling outages (RFO) with promising results. These results suggested the potential for predicting the incubation period, which is being investigated as a possible barometer for determining changes in the material properties and subsequently the threshold limits.

It should be noted the selection criteria for the 1999 RFO inspection were based on higher potential residual stress and temperature conditions. However, the results from this inspection were in contrast with the prediction model that suggested 2 of 6 housings would have positive indications. This information suggested the prediction model was inaccurate as a selection criteria and frequency definition for future inspections. OPPD's re-assessment of the possible environmental conditions resulted in the 2001 RFO selection criteria being focused on stagnancy, residual stress, and temperature.

In summary, OPPD's initial efforts were focused on the industry's perception in the form of a macro residual stress condition, which has been deemed as a poor prediction model for TGSCC condition. The current path being taken by OPPD emphasizes micro-stresses, or sometimes referred to as textural stresses[2], that better explain the known failure mechanism that defines TGSCC. This mechanism is believed to be more in line with the phenomena known as mechanical cleavage that is predominantly an environmental effect that lowers the material stress threshold[3]. Therefore, this approach has currently shown to be more reliable as a selection and frequency definition for FCS's CEDM housing assembly inspection criteria. The sections that follow will provide the foundation for this logic.

2

"Mechanical Metallurgy," by George E. Dieter, Jr., published by McGraw-Hill Book Company, copyright©1961

3

"Fundamentals of Electrochemical Corrosion," by E.E. Stransbury & R.A. Buchanan, published by ASM International®, copyright©2000

4.0 Response to NRC Questions:

The following sections will present OPPD's understanding of the possible residual stress conditions introduced by the fabrication process such as welding, machining, weld joint preparation, and finishing work and the operating temperature variation in the FCS's CEDM housing assemblies.

4.1 Residual Stress:

This section will focus on residual stress that can drive the alignment of slip planes, reduce dislocation energy, change grain texture, cluster voids, etc., that could increase the potential for stress corrosion cracking. These changes can occur during high tensile stresses that are introduced with the fabrication process through forming, machining, welding, abrupt geometry changes, etc., that approach or exceed the yield strength of the material into the plastic deformation range.

4.1.1 Weld Residual Stress:

The weld process inherently introduces residual stress in the weld area that could be considered to be an energy source for crack propagation in weakened grain structures. The resulting residual stress distribution varies widely with weld volume, joint geometry, and process. There were three weld geometry types used to construct the CEDM housing assemblies: the j-groove weld, overlay weld, and double v-groove weld.

The j-groove weld type is used for the CEDM seal housing's connection between the autoclave flange and drive housing (see Figure No. 1) as well as the reactor head nozzle penetration that is attached to the vessel head. This weld geometry type can generate tensile stress on the inside diameter surface in the longitudinal and circumferential directions as the result of weld transverse shrinkage. This residual stress can be approximated[4] from an estimated deformation for the longitudinal, circumferential, and radial stress magnitude in the cylinder[5] (see Figure No. 2) wall. This estimate reflects the fabrication records that document deformation up to a maximum of 75 mils exceeds the material yield strength. Therefore, in order to estimate the residual stress magnitude, a yield strain calculated at 2 mils will be applied to assess the longitudinal and circumferential

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4

"Aluminum Welding Practice," by L. Capel, published by British Welding Journal, Vol 8 (No. 5), 961, pg. 245-248

5

"Formulas For Stress and Strain," by Raymond J. Roark, published by McGraw-Hill Book Company, fourth edition copyright©1965

stress distribution. This results in circumferential tapered stress distributions through the wall thickness that denote a maximum tensile stress condition on the inside diameter near the weld root toe (see Figure No. 3). The corresponding longitudinal stress distribution also has a maximum tensile stress at the weld root toe throughout the heat affected zone (HAZ), but is only about one-third of the circumferential stress (see Figures No. 2 & 3). This magnitude and stress distribution is similar to the test report on heater sleeve nozzle mockups that exhibit maximum circumferential stress[6] at 520 MPa (75.4 ksi) and longitudinal stress at 320 MPa (46.4 ksi) that also exceeds the material yield strength. However, it should be noted the reactor vessel penetration nozzles and head were heat treated. Therefore, the reactor head penetration welds should anticipate a considerable reduction in residual stress in contrast to the CEDM seal housing's j-groove weld geometry.

In general the CEDM seal housing's j-groove weld has the potential to generate higher circumferential stress than longitudinal stress, specifically, near the tool access tube that is less rigid compared to the support provided by the autoclave flange. This residual stress condition plus the unbalanced stress condition on the inside diameter surface suggest a potential energy source to initiate crack propagation in a corrosive environment.

The overlay weld type is in the form of cladding or built-up material and is applied on the inside diameter face of the CEDM upper housing (see Figure No. 4), which provides a support for the tube and gear assembly housing's internals. This weld type can also generate tensile stresses on the inside diameter face in the longitudinal and circumferential directions due to transverse and longitudinal weld shrinkage, respectively. The radial and longitudinal deformation can be estimated based on studies on fillet welds[7] that provide a reasonable approximation of the longitudinal and circumferential stress distribution that could represent a general definition of magnitude. The resulting circumferential stress based on longitudinal shrinkage provides a nominal residual tensile stress condition on the inside diameter that is diminishing to the outside diameter face (see Figure No. 5). The longitudinal stress distribution can also be approximated based on the hot weldment concept, where the thermal contraction on cooler edges causes a mismatch between the

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6

"Measurement of Residual Stresses in Alloy 600 Pressurizer Penetration Nozzles," J.F. Hall, J.P. Molkenthin (ABB-CE), P.S. Prevéy (Lambda Research) & R.S. Pathania (EPRI), Conference on Contribution of Materials Investigation to the Resolution of Problems Encountered in Pressurizer Reactor Vessels, dated Sept.12-16, 1994

7

"Control of Distortion and Shrinkage Welding," by W. Spraragen and W.G. Ettinger, published by American Welding Society, Welding Journal , Vol 29 (No. 6 and 7) Research Supplement, 1950, pg 292s-294s and 323s-325s

edges and center[8]. The expected result is a peak longitudinal tensile stress at the center of the overlay weld, but transition into compressive stress within the weld and HAZ (see Figure No. 6). Therefore, when considering this distribution in conjunction with circumferential stress distribution, these magnitudes are reasonable in comparison to the destructive examination on the spare CEDM upper housing assemblies, which reported a 9.5 ksi to 10.9 ksi residual stress[9] condition.

The overlay weld is capable of generating longitudinal and circumferential tensile stress. However, the early through-wall longitudinal crack experience in 1990 on the spare CEDM upper housing (S/N 23866-9 & 13) in the overlay weld area was from a relatively low circumferential stress field estimated to be at one-third of the yield strength.

The double v-groove weld is also referred to as a butt weld and is based on a standardized weld end preparation detail[10], specific to a plain bevel end detail without a contour taper (see Figure No. 4). This type of weld geometry generates longitudinal tensile stress and circumferential compressive stress on the inside diameter surface, in contrast to the j-groove and overlay weld configurations. The circumferential residual stress can be estimated by evaluating longitudinal weld shrinkage deformation[11]. This assessment of residual stress magnitude for the butt weld joint is more complex since the initial weld root pass puts a tensile stress on the inside diameter, and each subsequent weld pass acts as compression jacket on the previous weldment. Therefore, each weld pass adds compressive stress to the previous weldment in the form of jacketing. This fabrication sequence stress summation results in a circumferential compression on the inside diameter with a transition to tensile stress on the outside diameter (see Figure No. 7). This circumferential distribution is confirmed by destructive examination on butt weld

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8 "Corrosion and Corrosion Control and Introduction to Corrosion Science and Engineering," by H.H. Uhlig, published by John Wiley and Sons, copyright©1963

9 "Metallurgical Evaluation of Cracking in Fort Calhoun Spare CEDM Upper Pressure Housings Serial Nos. 9 and 13," Report No. TR-M.C.-169, prepared by Combustion Engineering, Inc. Materials & Chemical Technology, dated January 1991

10 "Buttwelding Ends," ASA B16.25-1964, published by The American Society of Mechanical Engineers

11 "Transactions of the Institute of Engineers and Shipbuilders in Scotland," Vol 87 pages 238-255, by C.W.R. King, dated 1944

mockups for a 10-inch diameter, schedule 40 pipe[12] (see Figure No. 8) that is deemed to be relevant to the CEDM upper housing assembly. Therefore, the longitudinal stress presented in the Electric Power Research Institute (EPRI) report[12] appears to be a reasonable assessment of the magnitude anticipated in the FCS CEDM upper housing assembly (see Figure No. 9). In addition, the in-service condition was included in both the circumferential and longitudinal EPRI plots to determine the potential impact of the modified eccentric reducer stress concentration factor that could increase the stress by a factor of two due to the dimensional changes in pipe diameter[13]. In addition, the classical longitudinal distribution was applied to consider the difference in the fabrication jig setup that suggests a non-uniform distribution as presented in the EPRI report[12].

The double v-groove weld generated compression circumferential residual stress that is considered an enhancement in resisting in-service loading and stress corrosion cracking conditions. The longitudinal stress typically has a peak tensile stress at the weld root centerline that quickly transitions into compression stresses before extending past the weld joint and/or the HAZ. In addition, the magnitude of this tensile stress is only about two-thirds of the pipe material yield strength in contrast to typical higher weld yield strength, generally twice the strength of the base material.

In conclusion, the j-groove weld generates the highest circumferential and longitudinal residual stress that could support inside diameter surface cracking in a corrosion environment. The overlay weld, though demonstrating a nominal residual stress condition, has shown to be subject to the TGSCC condition from FCS's 1990 event of the spare CEDM housing assemblies. Finally, the double v-groove weld is the least susceptible to weld-induced residual stress based on this magnitude comparison of the different types of weld joints used in the CEDM assembly.

4.1.2 Pre-Cold Working (Weld Joint Prep):

The process of preparing a pipe or fitting end for a weld joint, as well as the prep work done after each weld pass, falls into the residual stress category of cold working. The CEDM housing assemblies' weld joint preparations were all machined except for the overlay weld. However, during the process of welding these initial residual stresses

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12

"Studies on AISI Type-304 Stainless Steel Piping Weldments for Use in BWR Application," EPRI NP-944 Project 449-2 Final Report, prepared by Electric Power Research Institute, dated December 1978

13

"Finite Element Analysis of Eccentric Reducers and Comparisons with Concentric Reducers," by R.R. Avent, M.H. Sadd, and E.C. Rodabaugh, Bulletin 285, published by Welding Research Council, dated July 1983, ISSN 0043-2326

introduced by machining or grinding should have been reformed by the fusion process. The weld joint preparation step generally is a generic process used throughout the CEDM housing assembly and therefore has no measurable significance in determining potential risk.

4.1.3 Post-Cold Working (Blending):

The finished machining or blending also falls into the residual stress category of cold working. The areas of machining are the seal housing assembly's drive housing, upper housing assembly's upper and lower flange, and modified eccentric reducer, which were all cut to a minimum of 125 micro finish[14&15]. In addition, the formed weld joints and fabrication blemishes were blended by a grinder to reduce stress risers from abrupt surface changes. The residual stresses are also generic through the assembly and again have no measurable significance in determining a magnitude difference in assessing potential risk.

4.2 Temperature:

4.2.1 Temperature Distribution:

The CEDM housing assembly temperature distribution has been previously evaluated for the possibility of loss-of-offsite power in relation to assessing the CEDM seal assemblies' o-ring failure mechanism[16]. However, this report was inconclusive in determining a specific temperature distribution and, in general, presented a linear variation from the reactor vessel head to the CEDM seal housing assembly's autoclave flange. Therefore, with the reactor head temperature at about 590° F and assuming the CEDM seal housing assembly's autoclave flange is around 250° F provides a relative temperature distribution (see Figure No. 10). The significant change between the CEDM seal housing assembly's autoclave flange to the leak-off chamber is due to a cooling water jacket that was provided to maintain a controlled temperature for the protection of the o-rings that are employed as part of the mechanical seal assembly.

4.2.2 Crack Rate Versus Temperature Distribution:

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14 "Seal Housing Assembly Detail," Drawing CND-E-2935, File 21591, Rev. 7

15 "Upper Housing Assembly," Drawing CND-E-2927, File 1324, Rev. 5

16 "CRDM Seal Leak Testing-October 1989," Prepared for Omaha Public Power District and Consumers Power Corporation, prepared by Combustion Engineering's Operations Services and Mechanical Engineering & Technology

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There are several studies on the effects of temperature on the relationship with stress corrosion cracking that generally depict an inverted bathtub curve of temperature versus crack growth rate[17] (see Figure No. 11). In an attempt to determine the temperature variation, a base temperature is selected from the operational experience from the control rod drive mechanism (CRDM) seal housing assemblies' through-wall cracking event at Palisades Nuclear Plant in 1999. This information suggests a temperature of 250° F at the j-groove weld location as discussed in section 4.2.1 and was applied in the previous section to determine a linear temperature variation throughout the assembly. In addition, FCS's similar experience in the spare CEDM upper housing assembly through-wall crack at the overlay weld location in 1990 suggests a variation from the linear interpolation previously presented. This difference is based on similar crack rates from operating experience at different locations and temperatures but suggests a delta of +50° F at the overlay weld locations from linear interpolation. However, this condition of temperature variation was proposed by the station blackout study for higher heat loads in the CEDM stack due to the internal assemblies acting as a heat escalator.

5.0 Summary:

The previous sections describe in detail OPPD's perceptions on the possible effects of residual stress generated by welding and surface cold working during the fabrication process of the CEDM housing assembly and operating temperature distribution during normal operation as suggested by the NRC. In addition, it should be noted that these factors were considered and implemented at FCS in response to the operating experience of Palisades in 1999 and are part of the current methodology and were the basis of the 1999 and 2001 RFO inspections. However, OPPD has not been satisfied with the inconsistences of industry inspection results, the operating experience, and industry data as compared to the failure mechanisms in the industry. The CEDM seal housing assembly j-groove weld is shown to have the highest longitudinal and circumferential tensile residual stress at the weld root. The Palisades experience from 1986 through 1999 has reported that circumferential and longitudinal cracks in the area of the CRDM seal drive housing are more prevalent approximately one inch above the autoclave face. This information proposes the in-service stress, nicks, and scratches are more predominant than the fabrication tensile stresses generated from welding residual stresses. The FCS experience in 1990 with a through-wall crack at the overlay weld area had relatively low circumferential tensile residual stress and no reported cold working conditions to promote a longitudinal crack in this area. The current Palisades event of through-wall cracks at the double v-groove weld has circumferential compressive residual stress and surface blending that should reduce stress in this transition area. In addition, the circumferential cracks found

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17 "BWR Water Chemistry Guidelines - 2000 Revision," Final Report No. TR-103515-R2, published by Electric Power Research Institute, February 2000

in the counterbore area of the modified eccentric reducer has no significant weld residual stress or cold working stress that could have promoted stress corrosion cracking in these areas. These conditions and their discrepancies suggest the focus on macro residual stresses from welding and cold working normal fabrication processes have significant limitations in determining an inspection and frequency criteria. However, OPPD recognizes these limitations and has implemented a more complete model by considering the stagnant condition of these assemblies in an effort to assess the material micro-stresses condition. This approach is more in line with current studies that propose the material properties are in the process of change from the installed condition. This electrochemical model[18] proposes a chemical reaction of the metal surface with the environment that introduces contaminants in exchange of good metal ions such as carbon, iron, and molybdenum in the vicinity of crack morphology.

OPPD has aggressively pursued the industry concerns for TGSCC in the CEDM housing assemblies. This task has focused on all of the available information that also included operationally difficult inspections to assess component material reliability. This effort was based on the industry's current analysis and inspection techniques to achieve a corporate goal of excellence in materiel condition of the plant. Finally, the operating experience and failure mechanism experience at FCS and Palisades and information provided in this discussion indicate the highest level of component risk is with the CEDM seal housing assembly, based on the temperature, residual stresses, and the environment.

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18 "S. Bruemmer Model," presented by Larry Nelson at the Nuclear Regulatory Commission's Workshop on Environmentally Assisted Cracking, Chaired by Mike McNeil, Thursday, April 20, 2000

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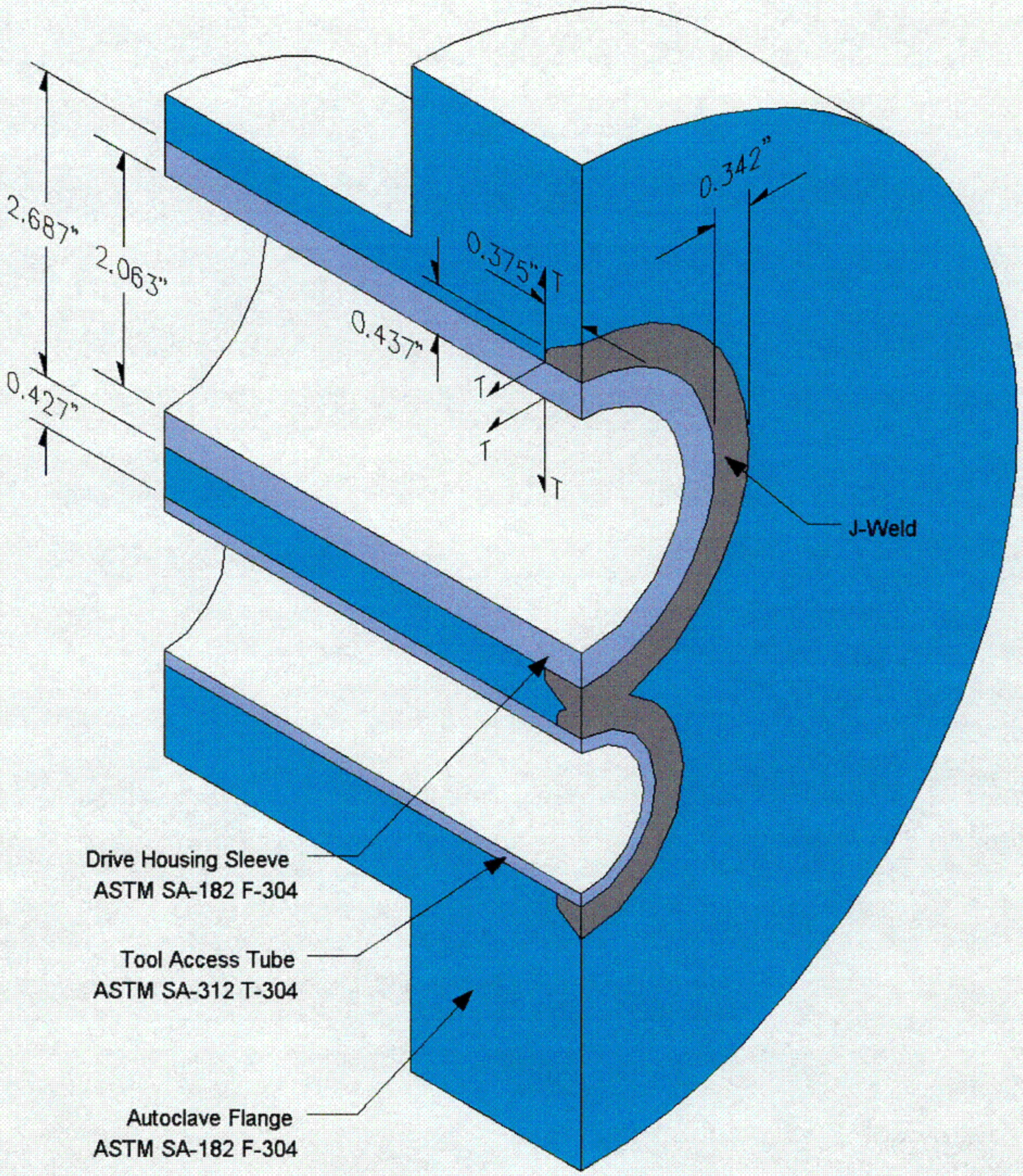

Note: T - Tension

Control Element Drive Mechanism Seal Housing Assembly J-Weld Geometry		DWG NO
DRAWN	KIRBY D. WOODS	Figure No. 1
ISSUED	November 29, 2001	SCALE None

C01

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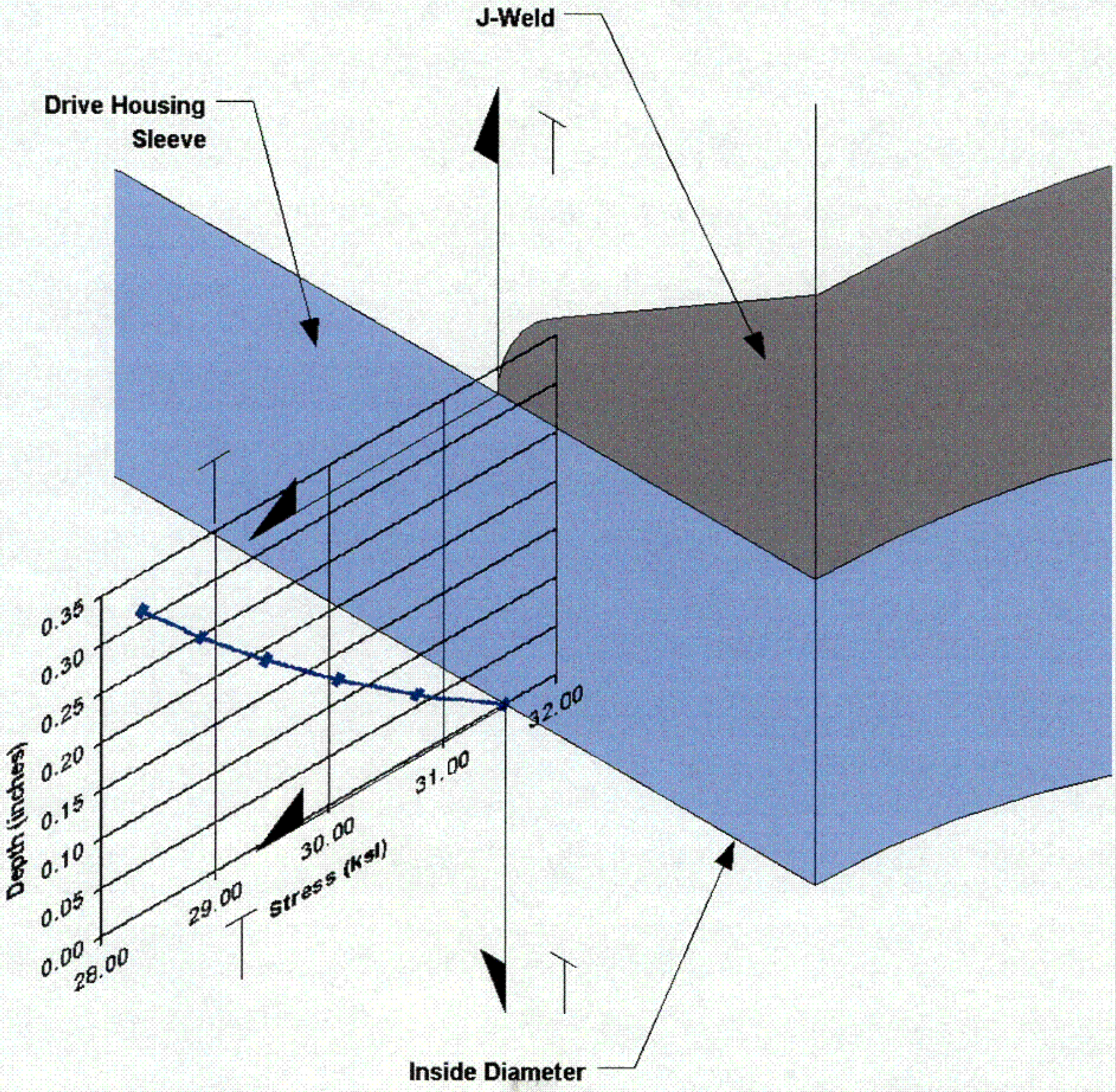
J-Weld Through-Wall Circumferential Residual Stress



Note: T - Tension

Control Element Drive Mechanism Seal Housing Assembly J-Weld Circumferential Stress	DWG NO
DRAWN KIRBY D. WOODS	Figure No. 2
ISSUED November 29, 2001	SCALE None

C02

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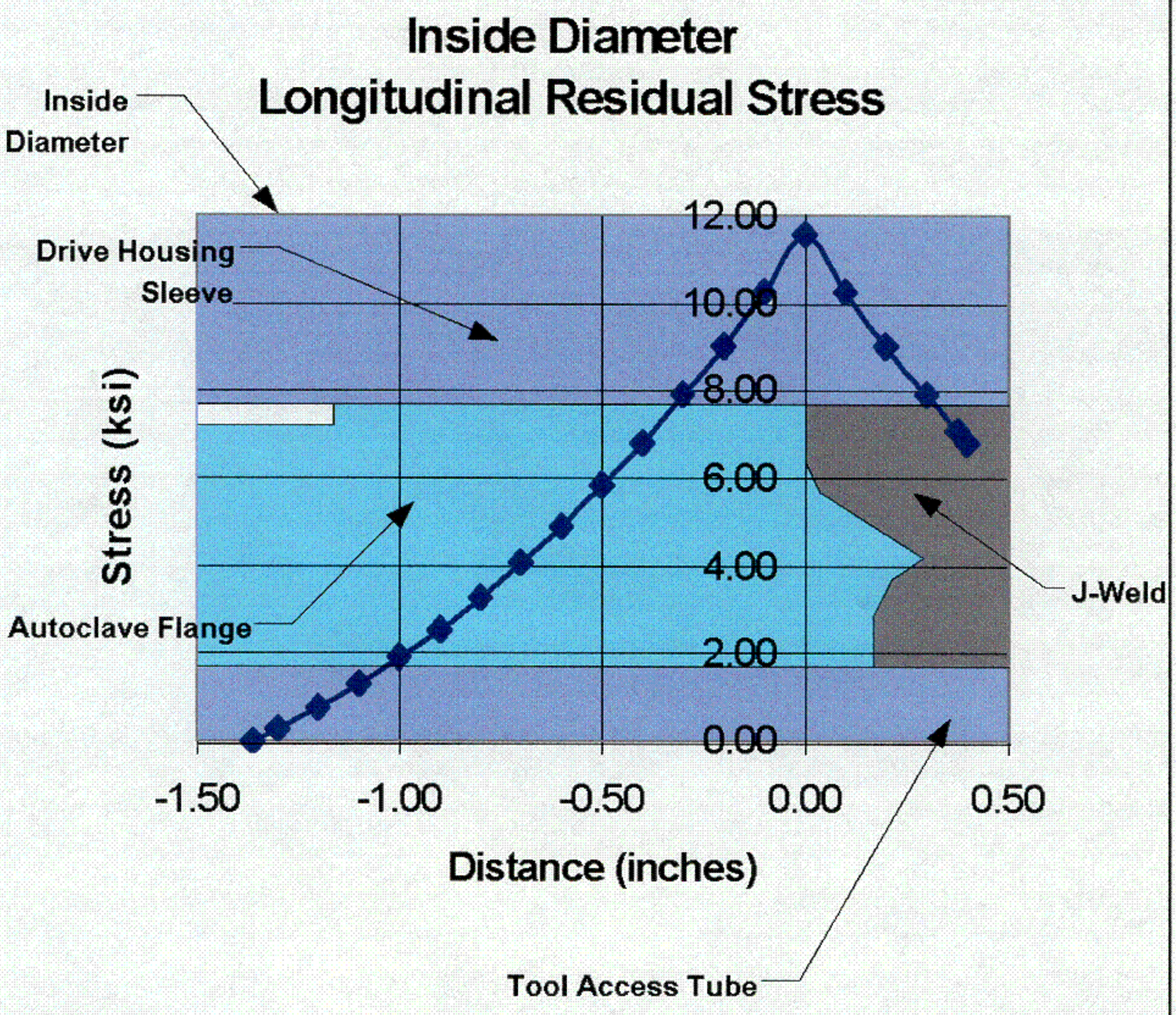

Control Element Drive Mechanism Seal Housing Assembly J-Weld Longitudinal Stress		DWG NO
DRAWN	KIRBY D. WOODS	Figure No. 3
ISSUED	November 29, 2001	SCALE None

C03

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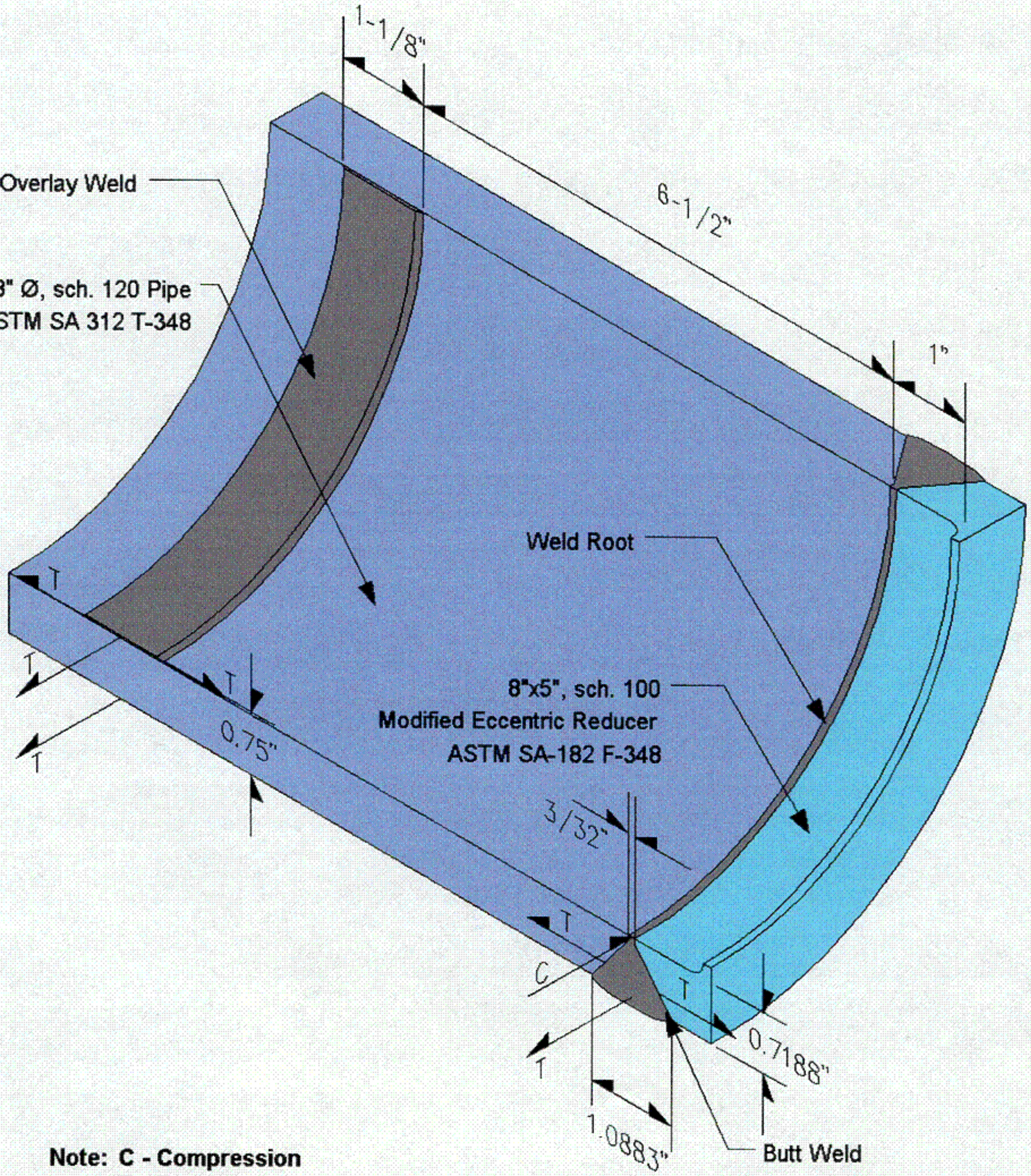

Note: C - Compression
T - Tension

Control Element Drive Mechanism Upper Housing Assembly Overlay & Butt Weld Geometry		DWG NO
DRAWN	KIRBY D. WOODS	Figure No. 4
ISSUED	November 29, 2001	SCALE None

C04

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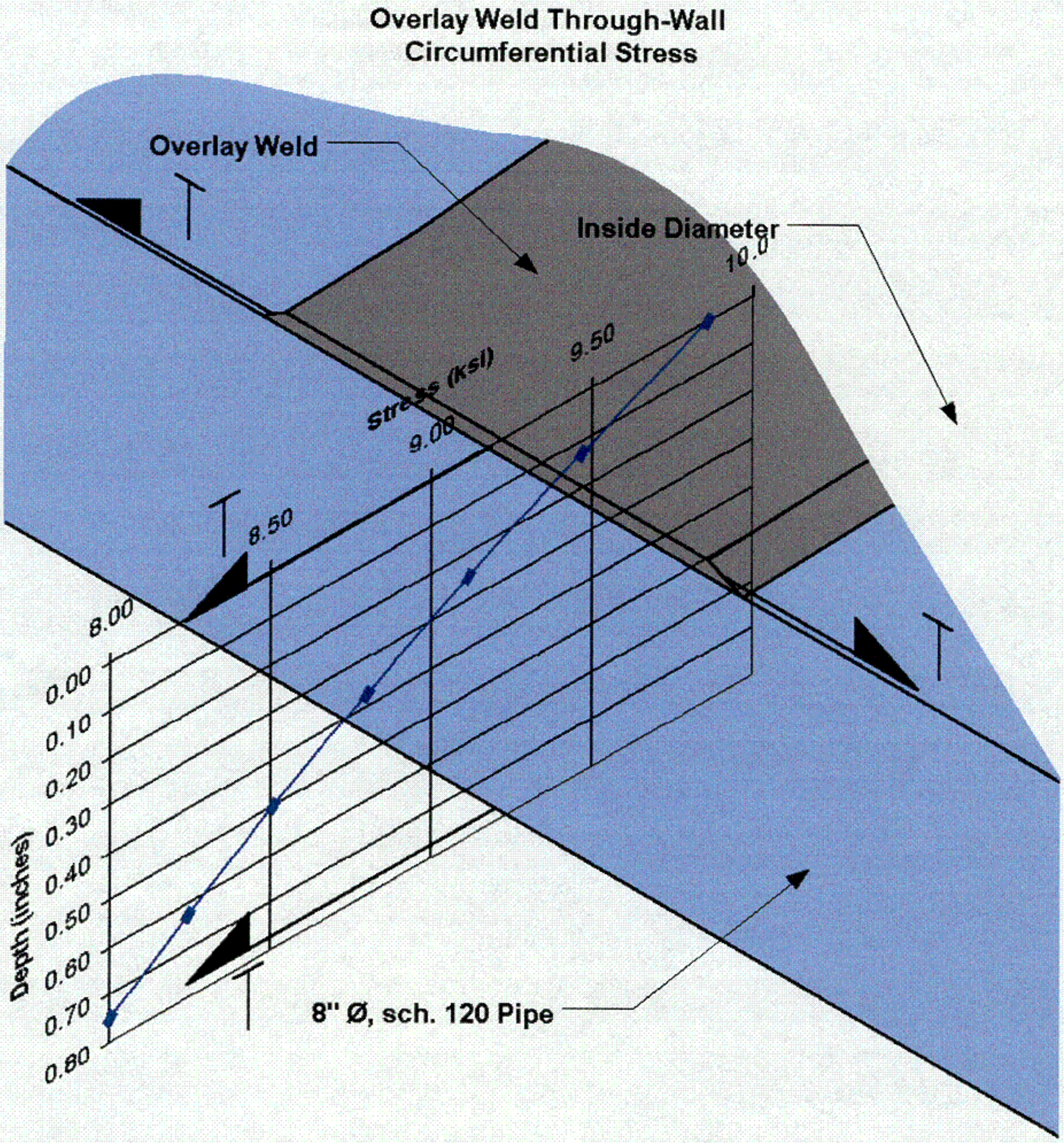

Note: T - Tension

Control Element Drive Mechanism Upper Housing Assembly Overlay Weld Circumferential Stress		DWG NO	
DRAWN	KIRBY D. WOODS	Figure No. 5	
ISSUED	November 29, 2001	SCALE	None

C05

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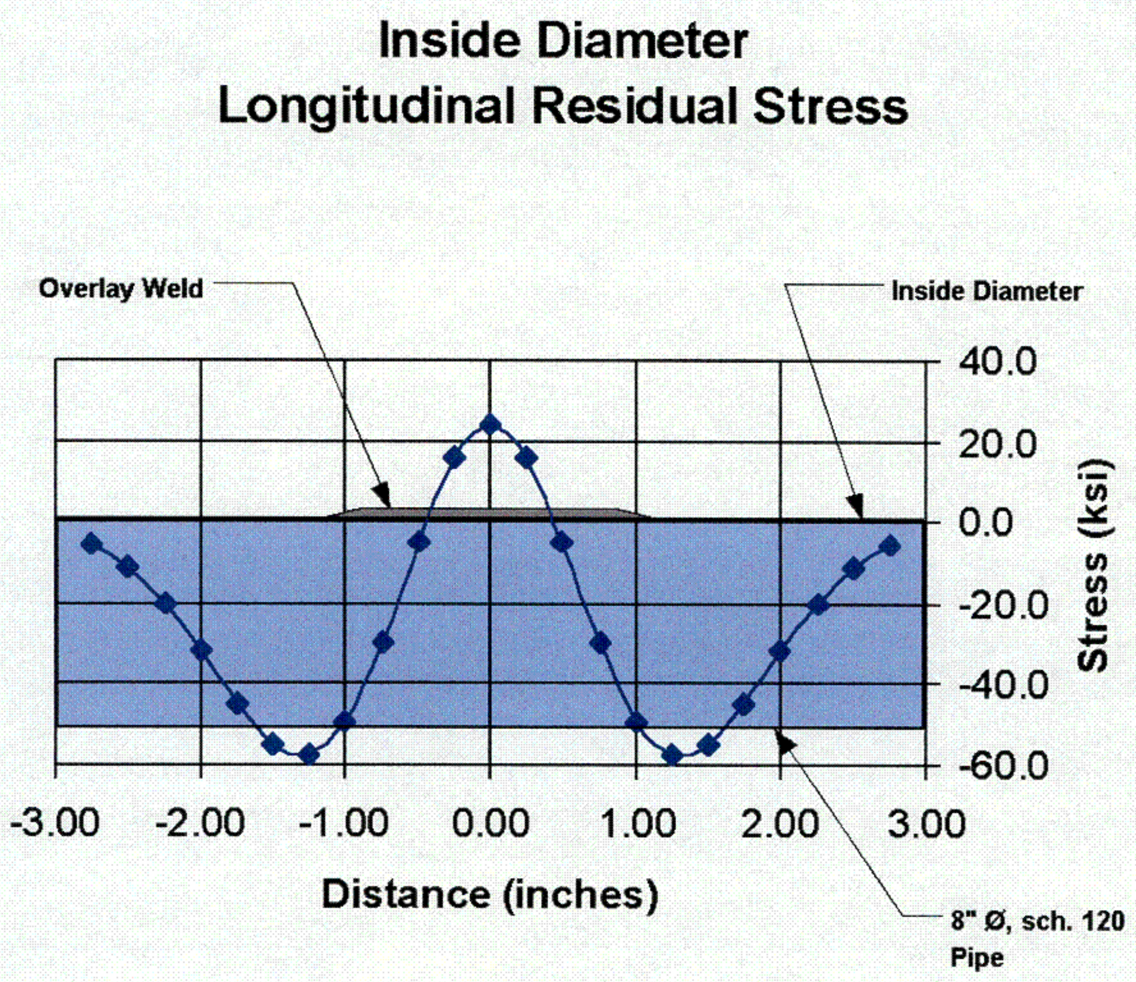
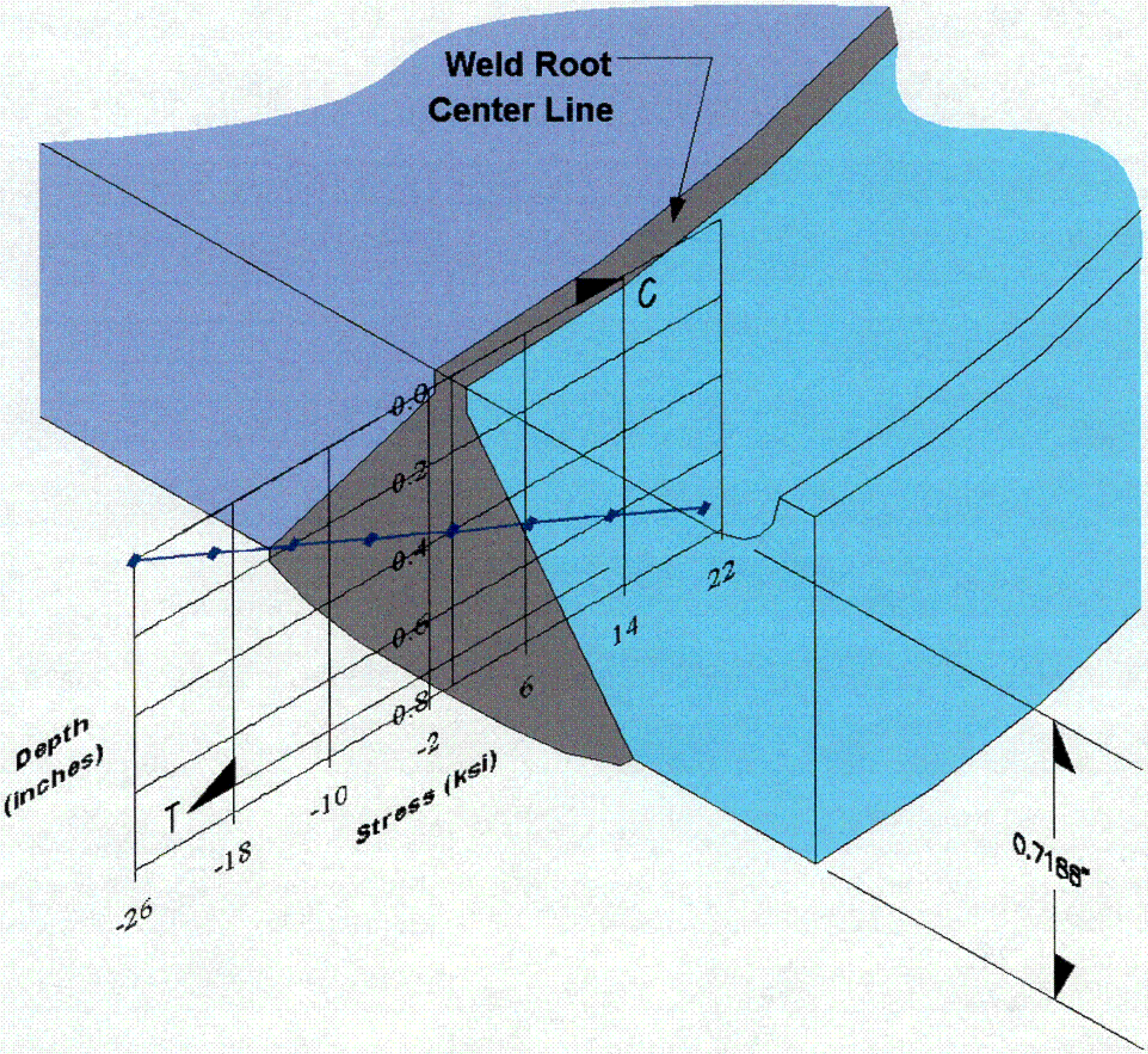


Control Element Drive Mechanism Upper Housing Assembly Overlay Weld Longitudinal Stress		DWG NO	
DRAWN	KIRBY D. WOODS	Figure No. 6	
ISSUED	November 29, 2001	SCALE	None

C06

Butt Weld Through-Wall Circumferential Stress



Note: C - Compression
T - Tension

Control Element Drive Mechanism Upper Housing Assembly Butt Weld Through-Wall Stress		DWG NO
DRAWN	KIRBY D. WOODS	Figure No. 7
ISSUED	November 29, 2001	SCALE 1 : 1

C07

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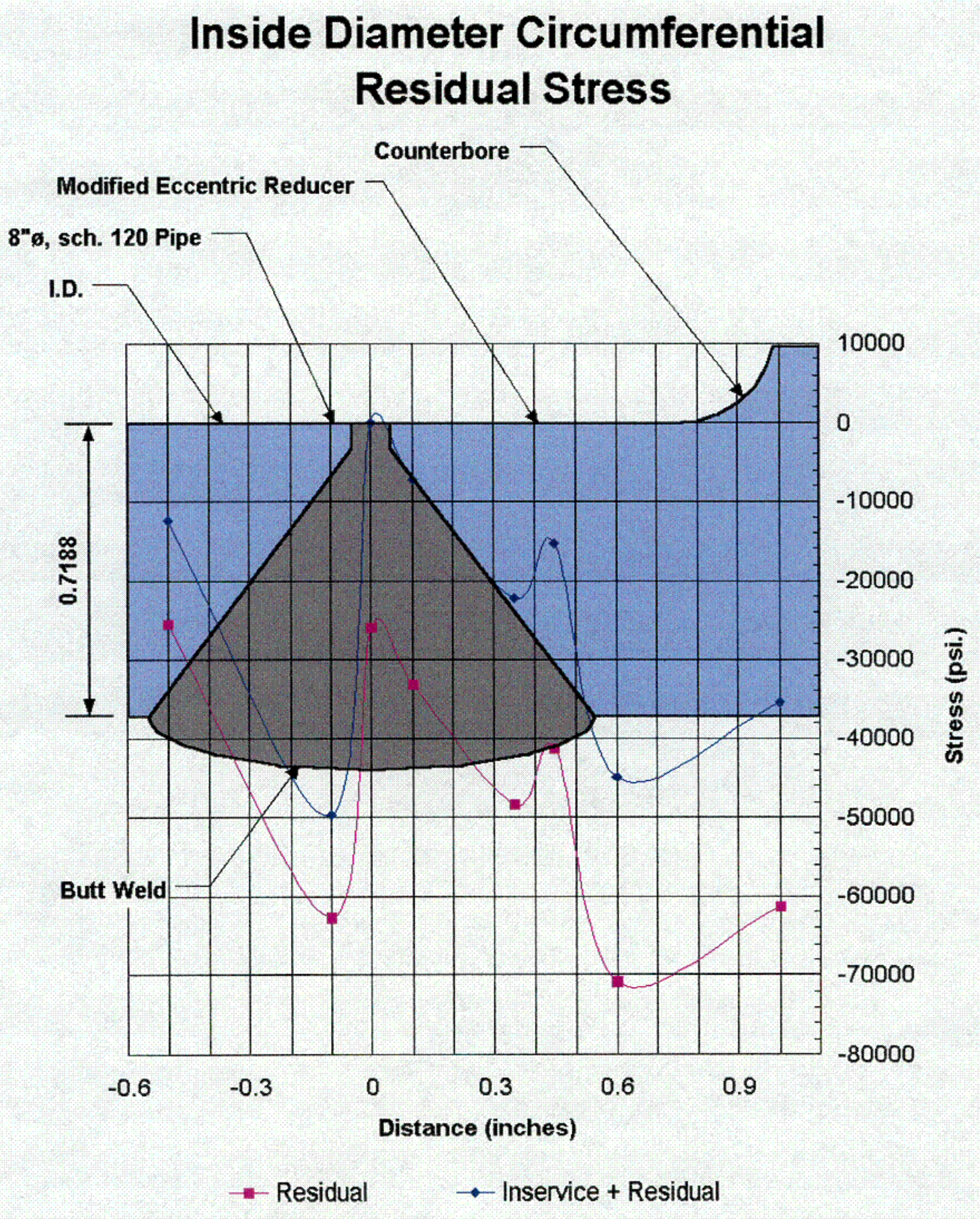

Control Element Drive Mechanism Upper Housing Assembly Circumferential Butt Weld Stress		DWG NO
DRAWN	KIRBY D. WOODS	Figure No. 8
ISSUED	November 29, 2001	SCALE None

C08

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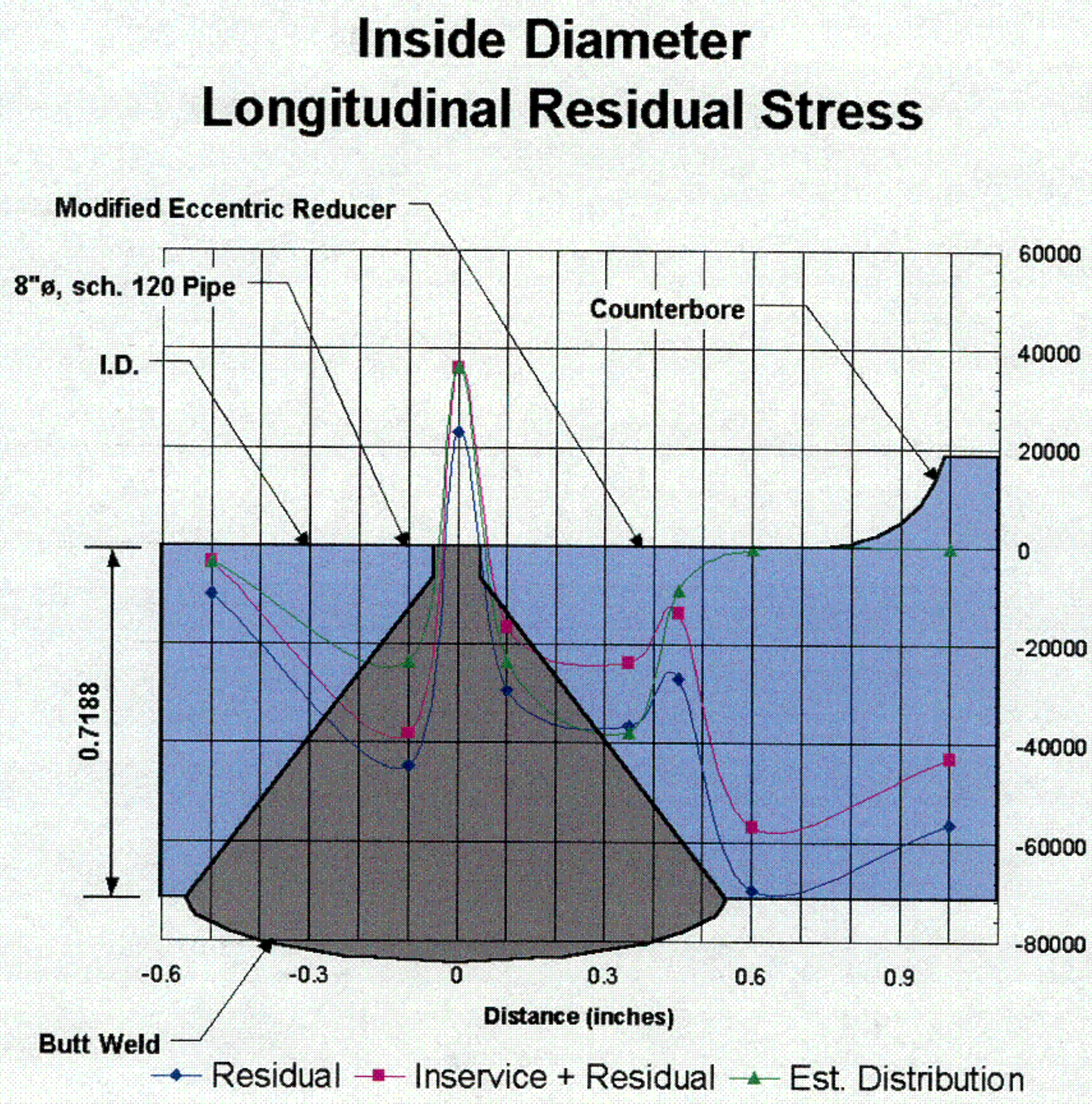

Control Element Drive Mechanism Upper Housing Assembly Longitudinal Butt Weld Stress		DWG NO
DRAWN	KIRBY D. WOODS	Figure No. 9
ISSUED	November 29, 2001	SCALE None

C09

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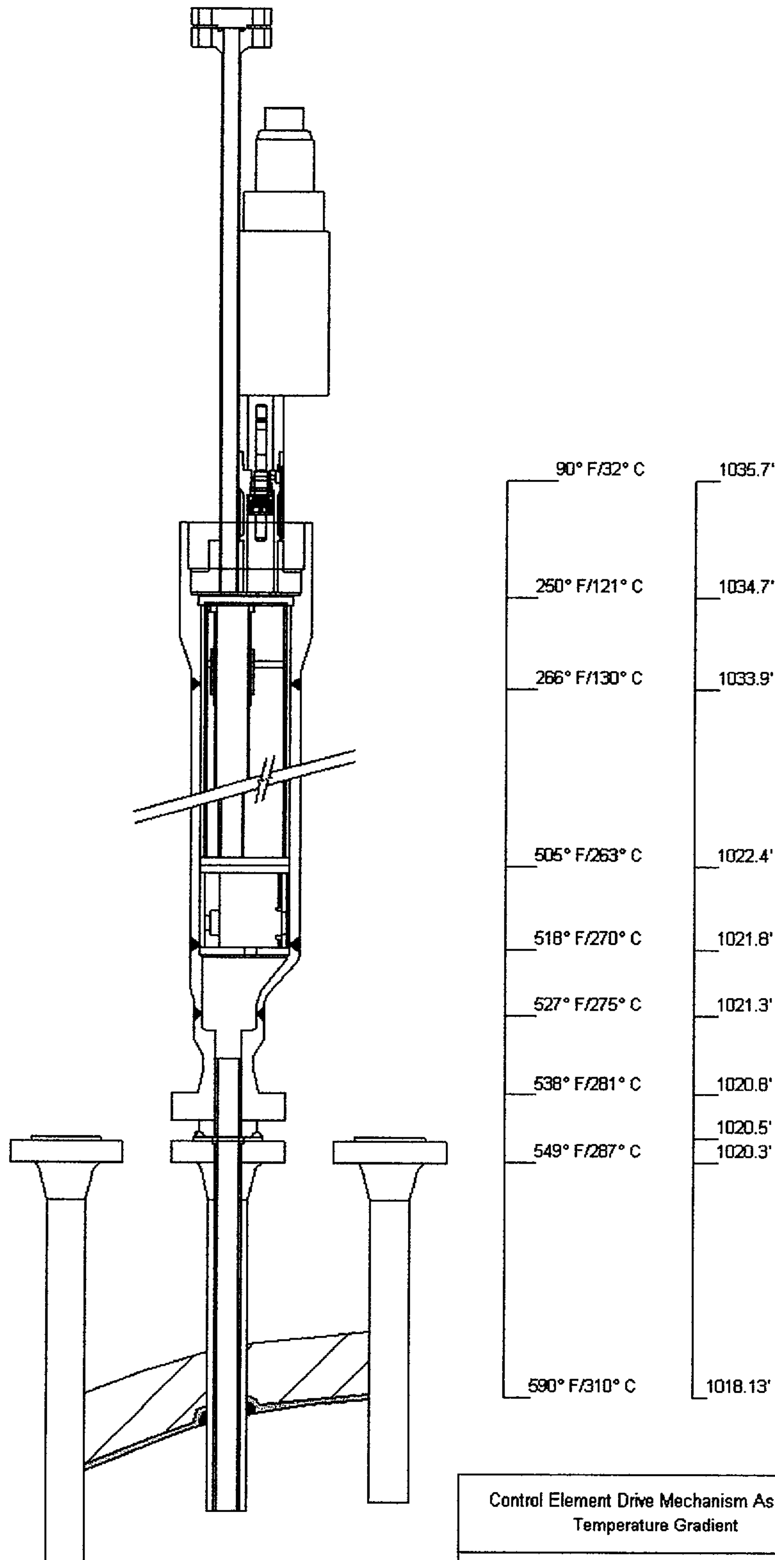

Control Element Drive Mechanism Assembly Temperature Gradient	DWG NO
DRAWN KIRBY D. WOODS	Figure No. 10
ISSUED November 29, 2001	SCALE None

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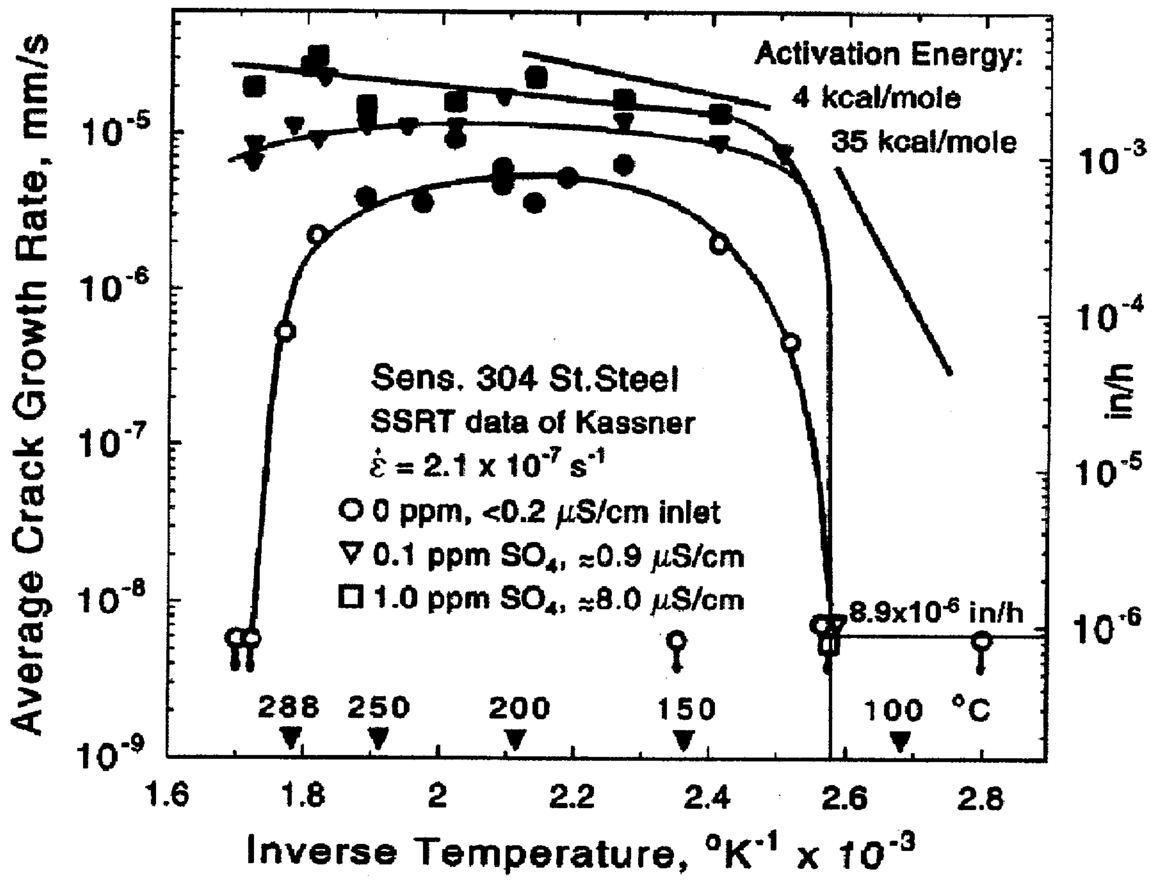

Control Element Drive Mechanism Assembly Sensitized 304 Stainless Steel Bathtub Curve		DWG NO
DRAWN	KIRBY D. WOODS	Figure No. 11
ISSUED	November 29, 2001	SCALE None