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EFFECTS OF THE DEVIATION CHARACTERISTICS
OF NUCLEAR WASTE EMPLACEMENT BOREHOLES
ON BOREHOLE LINER STRESSES

David A. Glowka
Geotechnical Design Division 6314
Sandia National Laboratories

ABSTRACT

This report investigates the effects of borehole deviation on the useability of lined boreholes for the disposal of high-level nuclear waste at the proposed Yucca Mountain Repository in Nevada. Items that lead to constraints on borehole deviation include excessive stresses that could cause liner failure and possible binding of a waste container inside the liner during waste emplacement and retrieval operations. Liner stress models are developed for two general borehole configurations, one for boreholes drilled with a steerable bit and one for boreholes drilled with a non-steerable bit. Procedures are developed for calculating liner stresses that arise both during insertion of the liner into a borehole and during the thermal expansion process that follows waste emplacement. The effects of borehole curvature on the ability of the waste container to pass freely inside the liner without binding are also examined. Based on the results, specifications on borehole deviation allowances are developed for specific vertical and horizontal borehole configurations of current interest.

MASTER

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QA CONTROLS

This work was performed under WBS 124221 under the direction of Design Information Memo (DIM) 75-5. Equations programmed on the computer were checked by performing hand calculations for selected cases and comparing the results with the computer calculations. The report was reviewed by two peers and one editorial reviewer. The QA level assigned to this work is Level 3.

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1.0 INTRODUCTION

The use of lined boreholes drilled into the walls or floors of underground drifts is being investigated by the Yucca Mountain Project for disposal of high-level nuclear waste in the proposed tuff repository at Yucca Mountain, Nevada. Both horizontal and vertical boreholes are currently under consideration, as shown in Figure 1. In both orientations, the waste is placed in sealed, cylindrical containers 15.6 ft long and 28 inches in diameter before being emplaced in the boreholes.

In the horizontal orientation, several emplacement options are being investigated. These options differ in the number of waste containers emplaced in each borehole (1-15) and in the standoff distance between the drift wall and the closest container (10-100 ft). Horizontal boreholes range in length from 32 to 350 feet. In all horizontal options currently being considered, each waste container is emplaced in the borehole on a skid. The skid consists of a metallic half-cylinder with bottom runners designed for sliding inside the lined borehole during waste emplacement.

A single vertical borehole configuration is currently under investigation. In this case, each waste container is emplaced directly into the borehole with a fixed standoff distance of ten feet from the top of the container to the drift floor. The vertical emplacement borehole length is nominally 26 feet.

To meet regulatory requirements, the repository must be designed to preserve the option to retrieve the emplaced waste for up to 84 years after waste is first emplaced in the repository (SNL, 1987e). To maintain the capability of retrieving the waste during this period, a steel liner is used in the design of each borehole configuration (SNL, 1987a). The liner ensures access to the emplaced waste by preventing rockfall on and in front of the waste containers. The liner consists of sections of steel tubing welded together at the borehole to form a continuous cylinder that is inserted into the borehole prior to waste emplacement. The liner insertion operation is performed either simultaneously with borehole drilling or as a separate operation following drilling (Robbins, 1985; Friant and Dowden, 1987). The reference configuration for the vertical case includes only a partial liner, but a full liner was considered here as a worst-case analysis.

Previous analytical work has been completed to determine the ability of the liner to withstand anticipated rockfall in the borehole and to survive the corrosion that is expected during the 84-year retrievability period (SNL, 1987b). That analysis predicts that liner stresses due to rockfall will not exceed 2.5 kpsi, which is well below the anticipated liner material yield strength of 30 kpsi. The analysis also predicts that sufficient sacrificial material should be available in the 0.5-inch-thick liner for the liner to survive the rockfall even after undergoing the corrosion expected over the retrievability period.

The previous analysis does not address stresses that arise in the liner during insertion of the liner into the borehole or during the thermal expansion that will occur due to heat transfer from the emplaced waste. Accordingly, the statics and stress analyses documented in this report were

HORIZONTAL CONFIGURATION

VERTICAL CONFIGURATION

CONTAINERS PER BOREHOLE	LENGTH (FT)	STANDOFF (FT)	END CLEARANCE (FT)
1	32	10	5
1	42	20	5
2	68	20	5
3	75	20	5
15	270	20	0
15	350	100	0

Figure 1 - Emplacement borehole configurations currently under consideration.

performed. These analyses explore the effects of borehole deviation characteristics on liner stresses. The effects of borehole deviation characteristics on the potential for waste containers to bind against the liner wall are also investigated.

The analysis in Chapter 2 focuses on liner stresses that arise during insertion of the liner into the borehole. These stresses are produced by the compressive force required to insert the liner against friction as well as bending stresses that are introduced as the liner is forced around deviations in the borehole. A model that predicts liner insertion stresses in both vertical and horizontal boreholes is developed using elastic theory and statics.

In Chapter 3, a model is developed for predicting stresses that arise in the liner after waste emplacement. These stresses are produced by bending and frictional drag against the borehole wall as the liner expands in response to the elevated temperatures caused by the emplaced waste.

In Chapter 4, a model is developed for determining the maximum allowable borehole curvature as limited by the clearance between the waste container and the inside wall of the liner.

Finally, the models are used in Chapter 5 to develop guidance on borehole deviation allowances for specific borehole configurations and conditions expected in the tuff repository. Possible liner failure modes are identified and examined relative to their potential for occurring in the repository. Specifications on allowable borehole deviation for current borehole designs are developed, based on the need to prevent liner failure and avoid interference between the waste container and the liner during waste emplacement and retrieval operations.

2.0 LINER INSERTION STRESSES

It is currently proposed that the vertical and short (≤ 75 ft) horizontal emplacement boreholes be drilled using rotary methods that employ a derrick erected in the emplacement drift (Robbins, 1984). A sketch of such a drilling system for vertical boreholes is shown in Figure 2. In-hole stabilizers would be used, if necessary, to minimize deviation of the drill bit.

After a borehole is drilled, the drilling system is removed and equipment is assembled to weld the sections of liner together and insert the liner into the borehole. This equipment would consist of welding units, transport wagons, a jacking frame, and a mine truck equipped with a boom (Kenny, 1987). A sketch of the equipment for horizontal boreholes is shown in Figure 3.

It has been recognized for several years that long horizontal boreholes probably cannot be efficiently drilled within allowable deviations unless a drilling system with an actively steered drill bit is employed. Design work has been completed on such a system, referred to as the Development Prototype Boring Machine (DPBM) (Robbins, 1985; Friant and Dowden, 1987). A sketch of the system is shown in Figure 4. The system employs an in-hole drill motor steered with hydraulically actuated reaction shoes. Drilling thrust is provided by a derrick erected in the emplacement drift. The thrust is transmitted to the drill motor and drill bit through the borehole liner, which is inserted as the borehole is drilled. The eccentrically mounted drill bit can be centered in the liner to allow it and the in-hole motor to be withdrawn through the liner at the completion of drilling.

The diameter of the borehole and liner as well as the deviation characteristics of the borehole dictate the shape of the liner trajectory as it is forced into the borehole. It is, therefore, necessary to assume some borehole geometry in order to calculate liner stresses. Two general cases are considered for borehole geometry:

- o In the first case, it is assumed that the drill bit that creates the borehole is steerable, as with the DPBM. With this type of drilling system, errors that occur in the bit trajectory can be corrected, so the borehole is assumed to deviate cyclicly from a straight line.
- o In the second case, the bit is assumed to be non-steerable, as with the rotary systems proposed for short boreholes. In this case, the borehole is assumed to deviate monotonically from a straight line because there is no active steering capability to counteract the effects of gravity and rock stratigraphy.

Liner stress analyses for these borehole deviation characteristics are presented in the following two subsections.

2.1 Boreholes Drilled with a Steerable Bit

Shown in Figure 5 is the assumed liner and borehole configuration for a borehole drilled with a steerable bit. It is assumed that beyond some

Figure 2 - Rotary drilling system proposed for drilling vertical emplacement boreholes.

Figure 3 - Equipment system for inserting liner into horizontal emplacement boreholes.

Figure 4 - Development Prototype Boring Machine (DPBM) proposed for drilling long (>75 ft) horizontal boreholes.

Figure 5 - Assumed borehole configuration for boreholes drilled with a steerable bit. (Gravity vector shown for horizontal boreholes; vector points in +x-direction in vertical boreholes.)

location x_0 , the borehole deviates cyclicly from a straight line. The amplitude of the deviation is δ_b and the wavelength is L . To facilitate the analysis, the centerline of the borehole in the cyclic region is assumed to follow circular arcs with a constant radius of curvature ρ_b . It is also assumed that some entrance region exists in which the borehole changes from a linear trajectory to the cyclic deviation. Finally, it is assumed for simplicity that borehole deviations occur in a single plane, with deviations of zero in other directions. The assumed borehole geometry is admittedly an idealization of an actual borehole; however, the assumed geometry is simple enough to be amenable to analysis and is general enough to be useful in drawing general conclusions about the effects of borehole deviation characteristics on liner stresses.

The borehole liner has an inner diameter of d_i and an outer diameter of d_o , which is less than the diameter of the borehole, d_b . The stiffness of the liner tends to make the liner deviate less than the borehole deviates. Gravity also influences the deviation of the liner; thus it is necessary to differentiate between horizontal and vertical borehole configurations in the analysis. We first assume a horizontal borehole, as implied by the gravity vector in Figure 5.

2.1.1 Horizontal Boreholes

For each borehole section of wavelength L , gravity in a horizontal borehole forces the liner to contact the bottom of the borehole at points x_0 , x_1 , x_3 , and so forth. The borehole deviation, the diametral clearance between the liner and the borehole, and the liner cross-sectional dimensions and elastic properties determine whether the liner:

- o contacts the bottom of the borehole at points such as x_2, y_4 ;
- o spans a region about x_2 without contacting the borehole; or
- o contacts the top of the borehole at points such as x_2, y_2 .

This liner behavior is illustrated by examining a case where diametral clearance, deviation wavelength, and liner weight per unit length are fixed while borehole deviation amplitude is varied.

Small Borehole Deviations

With small borehole deviations, gravity will force the liner to maintain contact with the bottom of the borehole along its entire length. Under these conditions, the minimum radius of curvature of the liner, ρ_L , occurs at positions such as x_1 and x_3 and is simply related to the radius of curvature of the borehole, ρ_b . Since the liner maintains contact with the bottom of the borehole, the liner and borehole are concentric (in the x-y plane) at x_1 and x_3 ; thus

$$\rho_L = \rho_b - \frac{d_b}{2} + \frac{d_o}{2} \quad (1)$$

In the middle of each bend in the borehole (e.g., at x_0, y_0), the borehole radius of curvature is related to the borehole deviation amplitude and wavelength by the equation:

$$\rho_b^2 = (\rho_b - \delta_b)^2 + \left(\frac{L}{4}\right)^2, \quad (2)$$

or

$$\sigma_B = \frac{L^2}{32\delta_b} + \frac{\delta_b}{2}. \quad (3)$$

The maximum bending stress in the liner occurs at the point of minimum radius of curvature. The maximum bending stress thus occurs on the outside surface of the liner in the middle of each bend (Timoshenko and Gere, 1972):

$$\sigma_B = \pm \frac{Ed_o}{2\rho_L}, \quad (4)$$

where the positive sign is used for compressive stresses along the inner radius of each bend and the negative sign is used for tensile stresses along the outer radius of each bend. Combining Eqs. 1, 3, and 4,

$$\sigma_B = \pm \frac{E d_o}{\frac{L^2}{16\delta_b} + \delta_b - d_b + d_o}. \quad (5)$$

With small borehole deviations, the liner does not contact the top of the borehole. Consequently, frictional drag of the liner against the borehole occurs only along the bottom of the borehole and is caused solely by gravity. The maximum drag occurs just as the liner is fully inserted into the borehole; thus

$$F_f = \mu w L_b, \quad (6)$$

where μ is the friction coefficient between the liner and the borehole wall, w is the weight per unit length of the liner, and L_b is the length of the borehole.

In addition to friction, the force that must be imparted to the liner to insert it into a borehole in simultaneous drilling cases includes the drilling force transmitted through the liner to the drill bit, F_b . The total thrust force required to insert the liner is thus

$$F_t = F_f + F_b. \quad (7)$$

In cases where liner insertion is performed separately from drilling, F_b is zero.

The longitudinal compressive stress imposed by the liner thrust force is

$$\sigma_t = \frac{4 F_t}{\pi(d_o^2 - d_i^2)}. \quad (8)$$

This stress occurs near the borehole entrance, while the compressive bending stress determined with Eq. 5 occurs at each bend in the liner. A conservative estimate of the combined maximum compressive stress in the liner can be obtained by assuming that the compressive stress due to the liner thrust force is the same at the first bend as it is near the borehole

entrance. This is a reasonable assumption because the friction force opposing liner insertion does not decrease significantly between the borehole entrance and the first bend.

Using this assumption, superposition can be employed to arrive at an expression for the combined maximum compressive liner insertion stress:

$$\sigma_{\max} = \sigma_B + \sigma_t \quad , \quad (9)$$

using the positive value of σ_B calculated with Eq. 5. Of course, superposition is valid only as long as the combined stress is below the elastic limit for the liner material, which is the assumed case.

Combined liner insertion stresses along the outer radius of each bend in the liner are lower than those along the inner radius of each bend. This is because the bending stresses are tensile (negative) along the outer radius of each bend and tend to balance part or all of the compressive thrust stresses.

Moderate Borehole Deviations

As the borehole deviation amplitude is increased, the liner begins to lose contact with the bottom of the borehole at points such as x_2 , causing it to span a region about x_2 without contacting the borehole. Under these conditions, the minimum radius of curvature of the liner still occurs where the liner deflects to follow the curvature of the borehole wall, at positions such as x_1 and x_3 . Furthermore, since the liner does not contact the top of the borehole in this case, friction between the liner and the borehole is the same as in the small-deviation case. As a result, Eqs. 1-9 are valid in determining the maximum liner stress for this case as well.

Large Borehole Deviations

As the borehole deviation is further increased, two independent trends develop in the deflection characteristics of the liner:

- o Interference between the liner and the borehole occurs when the liner develops contact with the top of the borehole at points such as x_2, y_2 . As borehole deviation is further increased, the contact forces at these points increase in magnitude.
- o The liner loses increasingly more contact with the bottom of the borehole between x_1 and x_3 . Eventually as the deviation amplitude increases, the radius of curvature of the bottom of the borehole becomes less than the stiffness of the liner will allow it to follow. In other words, the distributed contact about x_1 and x_3 tends to go to point contact (neglecting the relatively small degree of force distribution caused by deflection of the liner cross-section and rock surface). Under these conditions, the bending stress is not simply related to the borehole radius of curvature as in the small-deviation case.

With large borehole deviations, the bending stress may be determined by considering the liner to be a simply supported beam with the equivalent beam loading shown in Figure 6. Note that point, rather than distributed, contact is assumed at x_1, x_2 , and x_3 . In this equivalent loading, P is the

Figure 6 - Equivalent beam loading of liner in cyclic region of boreholes drilled with a steerable bit.

contact force between the liner and the top of the borehole at x_2, y_2 , and R is one-half the reaction force at each contact point along the bottom of the borehole.

Superposition is used to account for the effects of gravity and to ensure that the equivalent beam follows the trajectory imposed by the borehole. Cases 1-4 of Figure 6 illustrate the simply supported beams that are superimposed to construct the equivalent beam that represents the liner. The midpoint deflection and endpoint slopes for the four cases are given by the equations listed in Figure 6.

The principle of superposition states that the total deflection of the liner, δ , is the sum of the deflections for each of the four cases, assuming that the resulting liner stresses are below the elastic limit for the material. Taking into account the proper direction of these deflections,

$$\delta = \delta_1 + \delta_2 - \delta_3 - \delta_4 \quad (10)$$

Similarly, the slope of the liner at the left (L) and right (R) sides of the equivalent beam is the sum of the respective slopes for cases 1-4. A boundary condition on the liner trajectory is that the slope of the liner at these points is zero, due to symmetry. Thus

$$\theta_L = \theta_{1L} + \theta_{2L} - \theta_{3L} - \theta_{4L} = 0 \quad (11)$$

and

$$\theta_R = \theta_{1R} + \theta_{2R} - \theta_{3R} - \theta_{4R} = 0 \quad (12)$$

Inserting the appropriate equations from Figure 6 into Eq. 11 and solving for M_o gives the result

$$M_o = \frac{PL}{8} + \frac{wL^2}{12} \quad (13)$$

Inserting Eq. 13 and the appropriate equations from Figure 6 into Eq. 10 gives the deflection of the liner in terms of the midpoint contact force P , the deviation wavelength L , the weight per unit length of the liner w , and the stiffness characteristics of the liner EI :

$$\delta = \frac{L^3}{384 EI} (2P + wL) \quad (14)$$

For this case, where the the liner contacts the top of the borehole at x_2 , the relationship between the borehole deviation amplitude and the liner deflection is given by the equations:

$$\delta = (y_1 + \frac{d_o}{2}) - (y_2 - \frac{d_o}{2}) \quad (15)$$

where

$$\begin{aligned} y_1 + \frac{d_b}{2} - \delta_b &= y_2 - \frac{d_b}{2} + \delta_b \\ y_1 - y_2 &= 2\delta_b - d_b \end{aligned} \quad (16)$$

or, combining Eqs. 15 and 16,

$$\delta = 2 \delta_b - d_b + d_o \quad (17)$$

Equating Eqs. 17 and Eq. 14, we arrive at an expression for determining the midpoint contact force P as a function of the borehole deviation characteristics:

$$P = \frac{384 EI}{L^3} \left(\delta_b - \frac{d_b - d_o}{2} \right) - \frac{wL}{2} \quad (18)$$

This equation is valid for all values of δ_b that produce a non-negative value of P . By setting P to zero and solving for δ_b , we obtain an equation for the borehole deviation below which contact with the top of the borehole at x_2 vanishes:

$$(\delta_b)_t = \frac{w L^4}{768 EI} + \frac{d_b - d_o}{2} \quad (19)$$

Thus $P = 0$ for $\delta_b < (\delta_b)_t$.

The maximum compressive bending stress in the equivalent beam occurs at x_1 and x_3 :

$$\sigma_B = \frac{M_o d_o}{2I} \quad (20)$$

where M_o is given by Eq. 13. Since liner curvature is limited by borehole curvature, the maximum compressive bending stress at x_1 and x_3 has an upper limit defined by Eq. 5. (Eq. 5 was developed based on continuous liner contact along the bottom of the borehole.). As a result, the value of σ_B predicted by Eq. 20 is valid only if it is less than the value predicted by Eq. 5. If Eq. 5 predicts a lower value than Eq. 20, then the value predicted by Eq. 5 is the valid prediction. Thus the maximum compressive bending stress in the liner under all conditions is the minimum of the values computed according to Eqs. 5 and 20.

The frictional drag force for cases where interference exists between the liner and the borehole may be found by making the assumption that in the entrance region of the borehole, the liner has the same equivalent loading as a section of length L in the cyclicly deviating region. This is a conservative assumption because the borehole curvature in the entrance region was initially assumed to be larger than the curvature in the cyclic region. As a result, the same assumed liner loading in the entrance region leads to slightly higher predicted friction forces than the larger borehole curvature in that region implies.

Under this assumption, the entire borehole length L_b can be considered to consist of n sections of length L , where

$$n = L_b/L \quad (21)$$

Summing all the contact forces along the liner and multiplying by the friction coefficient, we obtain

$$F_f = n \mu (P + 2R) \quad (22)$$

From Fig. 6, it is seen that

$$R = \frac{P}{2} + \frac{wL}{2} ; \quad (23)$$

thus

$$F_f = \frac{\mu L_b}{L} (2P + wL) \quad (24)$$

The maximum liner stress can then be calculated for this case by inserting Eqs. 20, 24, 7, and 8 into Eq. 9.

In summary, the procedure for calculating the maximum stress in a liner that is being forced into a horizontal borehole drilled with a steerable bit is as follows:

- 1) Specify E , d_o , d_i , γ , F_b , L_b , δ_b , and L , where γ is the weight per unit volume of the liner material and all other terms have been previously defined.
- 2) Calculate $w = \frac{\pi}{4} (d_o^2 - d_i^2) \gamma$
- 3) Calculate $I = \frac{\pi}{64} (d_o^4 - d_i^4)$.
- 4) Calculate P using Eq. 18; if $P < 0$, set $P = 0$.
- 5) Calculate M_o using Eq. 13.
- 6) Calculate σ_B using Eq. 20; set $(\sigma_B)_1 = \sigma_B$.
- 7) Calculate σ_B using the positive value predicted by Eq. 5; set $(\sigma_B)_2 = \sigma_B$.
- 8) Set σ_B to $(\sigma_B)_1$ or $(\sigma_B)_2$, whichever is less.
- 9) Calculate F_f using Eq. 24; note that this equation is valid for $P = 0$ or $P > 0$.
- 10) Calculate σ_t using Eqs. 7 and 8.
- 11) Calculate σ_{max} using Eq. 9.

This algorithm is incorporated into computer programs named DEVIAT1 and STRESS1, which are listed in Appendix A. DEVIAT1 uses this procedure to calculate by iteration the maximum allowable deviation of boreholes drilled with a steerable bit. STRESS1 uses the procedure to calculate the maximum liner stress as a function of the input conditions. These and other programs are used in the parametric studies of Section 5.

2.1.2 Vertical Boreholes

The procedure for calculating the maximum stress in a liner forced into a vertical borehole drilled with a steerable bit is identical to that for a horizontal borehole with one exception. With vertical boreholes, gravitational forces act in a longitudinal direction and thus do not contribute significantly to bending stresses caused by borehole deviation. Because of the limited 26-ft length of the vertical borehole under consideration, longitudinal stresses due to the weight of the liner are also

negligible. As a result, gravitational forces play no significant role in determining liner stresses in vertical boreholes. The only modification to the above procedure required for vertical boreholes is thus to specify that $w = 0$ in step 2.

2.2 Boreholes Drilled with a Non-Steerable Bit

Shown in Figure 7 is the assumed liner and borehole configuration for a borehole drilled with a non-steerable bit. It is assumed that the centerline of the borehole follows a trajectory with a monotonically increasing deviation from a straight line. For simplicity, the trajectory is assumed to be circular, with a constant radius of curvature ρ_b . The deviation of the liner is assumed to occur in a single plane, with zero deviation in other directions. The total deviation at the end of the borehole is δ_b .

As in the case of the steerable bit, the assumed geometry here is an idealization of an actual borehole. In non-homogenous rock formations, deviation of a non-steerable bit may not be monotonic in one direction but rather may be more cyclic in nature or even random. The assumed borehole geometry, however, is amenable to analysis and is again general enough to investigate the effects of borehole deviation characteristics on liner stresses.

The borehole liner has an inner diameter of d_i and an outer diameter of d_o , which is less than the diameter of the borehole, d_b . The stiffness of the liner tends to make the liner deviate less than the borehole deviates. Gravity also influences the deviation of the liner; thus it is again necessary to differentiate between horizontal and vertical borehole configurations in the analysis. We first assume a horizontal borehole, as implied by the direction of the gravity vector in Figure 7.

2.2.1 Horizontal Boreholes

Gravity in a horizontal borehole forces the liner to contact the bottom of the borehole at x_1, y_1 . The borehole deviation, the diametral clearance between the liner and the borehole, and the liner cross-sectional dimensions and elastic properties determine whether the liner:

- o contacts the bottom of the borehole at x_4, y_4 and x_3, y_3 ;
- o balances at x_1, y_1 without touching the borehole wall at x_0, x_2, x_3 , or x_4 ; or
- o contacts the top of the borehole at x_0, y_0 and x_2, y_2 .

This liner behavior is illustrated by examining the case where diametral clearance, borehole length, and liner weight per unit length are fixed and total borehole deviation is varied.

Figure 7 - Assumed borehole configuration for boreholes drilled with a non-steerable bit. (Gravity vector shown for horizontal boreholes; vector points in +x-direction in vertical boreholes.)

Small Borehole Deviations

With small borehole deviations, gravity will force the liner to maintain contact with the bottom of the borehole along its entire length. Under these conditions, the radius of curvature of the liner is constant along its entire length and is simply related to the radius of curvature of the borehole:

$$\rho_L = \rho_b - \frac{d_b}{2} + \frac{d_o}{2} \quad (25)$$

The borehole radius of curvature is related to the length of the borehole and the total borehole deviation by the following equation:

$$\delta_b = \rho_b (1 - \cos \theta_b) \quad (26)$$

where

$$\theta_b = \frac{L_b}{\rho_b} \quad (27)$$

The maximum bending stress in the liner occurs on its outside surface along its entire length and is given by the equation:

$$\sigma_B = \pm \frac{E d_o}{2 \rho_L} \quad (28)$$

where the positive sign is used for compressive stresses along the inner radius of the bend and the negative sign is used for tensile stresses along the outer radius of the bend. Combining Eqs. 25 and 28,

$$\sigma_B = \pm \frac{E d_o}{2 \rho_b - d_b + d_o} \quad (29)$$

where ρ_b is found for a given value of δ_b by solving the transcendental relation represented by Eqs. 26 and 27.

With small borehole deviations, the liner does not contact the top of the borehole. Consequently, frictional drag of the liner against the borehole wall occurs only along the bottom of the borehole and is caused solely by gravity. The maximum drag occurs just as the liner is fully inserted into the borehole; thus:

$$F_f = \mu w L_b \quad (30)$$

The total thrust force required to insert the liner into the borehole is

$$F_t = F_f + F_b \quad (31)$$

where F_b is zero in cases where drilling is not performed simultaneously with liner insertion operations.

The compressive stress caused by the liner thrust force is

$$\sigma_t = \frac{4 F_t}{\pi (d_o^2 - d_i^2)} \quad (32)$$

This stress occurs near the borehole entrance, while the compressive bending stress determined with Eq. 29 occurs along the entire length of the liner. The combined maximum compressive stress in the liner can be obtained with superposition:

$$\sigma_{\max} = \sigma_B + \sigma_t \quad , \quad (33)$$

using the positive value of σ_B calculated with Eq. 29.

Combined liner insertion stresses along the outer radius of the bend in the liner are lower than those along the inner radius because of the tensile (negative) bending stresses that develop along the outer radius.

Moderate Borehole Deviations

As the total borehole deviation is increased, the liner begins to lose contact with the borehole at x_4 and x_3 . The stiffness of the liner causes the ends of the liner to be suspended so that they no longer contact the bottom of the borehole. Under these conditions, the minimum radius of curvature of the liner occurs where the liner deflects to follow the curvature of the borehole wall at x_1 . Furthermore, since the liner does not contact the top of the borehole in this case, friction between the liner and the borehole is the same as in the small-deviation case. As a result, Eqs. 25-33 are also valid for this case in determining the maximum liner stress.

Large Borehole Deviations

As the total borehole deviation is further increased, two independent trends develop in the deflection characteristics of the liner:

- o Interference between the liner and the borehole occurs when the liner develops contact with the top of the borehole at x_0, y_0 and x_2, y_2 . As borehole deviation is further increased, the contact forces at these points increase in magnitude.
- o The liner loses increasingly more contact with the bottom of the borehole on either side of x_1 . Eventually as the total borehole deviation is further increased, the radius of curvature of the bottom of the borehole becomes less than the stiffness of the liner will allow it to follow. In other words, the distributed contact about x_1 tends to go to point contact (neglecting the relatively small amount of force distribution caused by deflection of the liner cross-section and the rock surface). Under these conditions, the bending stress in the liner is not simply related to the borehole radius of curvature as in the small-deviation case.

With large borehole deviations, the bending stress in the liner may be approximated by considering the liner to consist of two cantilevered beams with the equivalent beam loading shown in Figure 8. The liner orientation in this figure has been changed slightly to illustrate the near symmetry of the liner geometry and loading configuration. Since the gravity vector is not perfectly parallel with the y-axis, the equivalent liner loading due to gravity includes a small component in the x-direction. For the relatively small borehole deviations of interest, however, this component is very small and is therefore neglected.

In the equivalent loading shown in Figure 8, P is the contact force between the liner and the top of the borehole at x_0, y_0 and x_2, y_2 . R is one-half the contact force at x_1, y_1 . Superposition is used to account for the effects of gravity and to ensure that the equivalent beam follows the trajectory imposed by the borehole. The principle of superposition states that the total deflection of the liner, δ , is the sum of the deflections for the two beam cases shown in the figure:

$$\delta = \delta_1 + \delta_2 \quad (34)$$

Inserting the appropriate equations from Figure 8 into Eq. 34 gives the deflection of the equivalent beam in terms of the endpoint contact force P, the length of the borehole, the weight per unit length of the liner w, and the stiffness characteristics of the liner EI:

$$\delta = \frac{wL^4}{8EI} + \frac{PL^3}{3EI} \quad (35)$$

In this equation,

$$L \approx L_b/2 \quad (36)$$

for the relatively small borehole deviations under consideration. Similarly, the slope of the free end of the equivalent beam is the sum of the respective slopes for cases 1 and 2.

$$\theta = \theta_1 + \theta_2 \quad (37)$$

Inserting the appropriate equations from Figure 8 into Eq. 37 gives the result:

$$\theta = \frac{wL^3}{6EI} + \frac{PL^2}{2EI} \quad (38)$$

For this case, where the liner contacts the top of the borehole at x_0 and x_2 , the relationship between the total borehole deviation and the liner deflection results from the following development. Geometry considerations produce the relation:

$$\delta = (y_1 + \frac{d_0}{2}) - (y_2 - \frac{d_0}{2} \cos \frac{\theta_b}{2}) \quad (39)$$

But

$$y_1 = p_b - \frac{d_b}{2} \quad (40)$$

EQUIVALENT
BEAM
LOADING

①

$$\delta_1 = \frac{w L^4}{8 EI}$$

(Timoshenko and
Gere, 1972)

$$\theta_1 = \frac{w L^3}{6 EI}$$

②

$$\delta_2 = \frac{P L^3}{3 EI}$$

$$\theta_2 = \frac{P L^2}{2 EI}$$

Figure 8 - Equivalent beam loading of liner in boreholes drilled with a non-steerable bit.

and

$$y_2 = \rho_b \cos \frac{\theta_b}{2} + \frac{d_b}{2} \cos \frac{\theta_b}{2} \quad (41)$$

Inserting Eqs. 40 and 41 into 39,

$$\delta = \rho_b (1 - \cos \frac{\theta_b}{2}) - \frac{d_b - d_o}{2} (1 + \cos \frac{\theta_b}{2}) \quad (42)$$

Combining Eqs. 35 and 42, we arrive at an expression for determining the endpoint contact force P as a function of the borehole deviation characteristics:

$$P = \frac{3EI}{L^3} [\rho_b (1 - \cos \frac{\theta_b}{2}) - \frac{d_b - d_o}{2} (1 + \cos \frac{\theta_b}{2})] - \frac{3wL}{8} \quad (43)$$

This equation is valid for all values of θ_b (or δ_b) that produce a non-zero value of P .

The maximum bending moment in the equivalent beam occurs at x_1 :

$$M(x_1) = PL + \frac{wL^2}{2} \quad (44)$$

Thus the maximum compressive bending stress in the liner also occurs at x_1 :

$$\sigma_B = \frac{d_o L}{2 I} (P + \frac{wL}{2}) \quad (45)$$

Since liner curvature is limited by borehole curvature, the maximum compressive bending stress at x_1 has an upper limit defined by Eq. 29. As a result, the value of σ_B predicted by Eq. 45 is valid only if it is less than the value predicted by Eq. 29. If Eq. 29 predicts a lower value than Eq. 45, then the value predicted by Eq. 29 is the valid prediction. Thus the maximum compressive bending stress in the liner under all conditions is the minimum of the values computed according to Eqs. 29 and 45.

The frictional drag force for cases where interference exists between the liner and the borehole may be found by noting that the liner is constructed of two equivalent cantilevered beams. Summing the contact forces along the liner and multiplying by the friction coefficient, we obtain

$$F_f = 2 \mu (P + R) \quad (46)$$

From Fig. 8, it is seen that

$$R = P + wL \quad (47)$$

Inserting Eq. 47 into Eq. 46 and again recognizing that $L \approx L_b/2$,

$$F_f = \mu (4P + wL_b) \quad (48)$$

The maximum liner stress can then be calculated for this case by inserting Eqs. 45, 48, 31, and 32 into Eq. 33.

In summary, the procedure for calculating the maximum stress in a liner that is being forced into a horizontal borehole drilled with a non-steerable bit is as follows:

- 1) Specify E , d_b , d_o , d_i , γ , F_b , L_b , and δ_b .
- 2) Calculate ρ_b and θ_b with the transcendental expression given in Eqs. 26 and 27.
- 3) Calculate $w = \frac{\pi}{4} (d_o^2 - d_i^2) \gamma$.
- 4) Calculate $L = L_b/2$.
- 5) Calculate $I = \frac{\pi}{64} (d_o^4 - d_i^4)$.
- 6) Calculate P using Eq. 43; if $P < 0$, set $P = 0$.
- 7) Calculate σ_B using Eq. 45; set $(\sigma_B)_1 = \sigma_B$.
- 8) Calculate σ_B using the positive value predicted by Eq. 29; set $(\sigma_B)_2 = \sigma_B$.
- 9) Set σ_B to $(\sigma_B)_1$ or $(\sigma_B)_2$, whichever is less.
- 10) Calculate F_f using Eq. 48.
- 11) Calculate σ_t using Eqs. 31 and 32.
- 12) Calculate σ_{max} using Eq. 33.

This algorithm is incorporated into computer programs DEVIAT2 and STRESS2, listed in Appendix A. DEVIAT2 calculates the maximum allowable deviation of boreholes drilled with a non-steerable bit. STRESS2 calculates the maximum liner stress as a function of the input conditions.

2.2.2 Vertical Boreholes

The procedure for calculating the maximum stress in a liner that is being forced into a vertical borehole drilled with a non-steerable bit is identical to that for a horizontal borehole with one exception. With vertical boreholes, gravitational forces act in a longitudinal direction and thus do not significantly contribute to bending stresses caused by borehole deviation. Because of the limited 26-ft length of the vertical borehole under consideration, stresses due to the weight of the hanging liner are also negligible. As a result, gravitational forces play no significant role in determining liner stresses in vertical borehole. The only modification to the above procedure required for vertical boreholes is thus to specify that $w = 0$ in step 3.

3.0 POST-EMPLACEMENT LINER STRESSES

When the liner insertion force is removed from the end of the liner at the completion of insertion operations, compressive forces throughout the liner relax to residual levels. Schematics of the residual liner loading configurations for the steerable- and non-steerable-bit cases are shown in Figure 9. As the compressive liner stresses relax, the stored elastic energy causes the liner to expand slightly in the longitudinal direction. If it is assumed that the ends of the liner do not bind against the borehole wall, then longitudinal forces at the ends of the liner relax to zero. Because of symmetry, the liner must expand from the middle of the liner outward, in both directions. Since friction opposes the outward expansion, friction forces at all contact points along the length of the liner are oriented toward the middle of the liner. As a result, residual forces are largest in the middle of the liner. The compressive longitudinal force there relaxes to the sum of the friction forces along one-half of the liner length. The residual compressive stresses due to friction in the middle of the liner are thus one-half of the levels predicted using Eqs. 24 and 48 for steerable and non-steerable bits, respectively.

The bending stresses imposed on the liner by borehole deviations remain undiminished after liner insertion. The magnitude of these stresses is the minimum of the values predicted by Eqs. 5 and 20 for the steerable-bit case and by Eqs. 29 and 45 for the non-steerable-bit case. The relative sizes of the bending stresses and stresses due to friction dictate the relative size of residual liner stresses after liner insertion and before waste emplacement.

Emplacement of nuclear waste into a lined borehole causes further change in the liner loading configuration:

- o the effective weight per unit length of the liner, w , increases significantly in horizontal boreholes due to the weight of the containerized waste; and
- o the liner begins to undergo thermal expansion due to the thermal output of the waste.

The magnitudes of these changes in loading configuration are discussed below.

In the sections of a horizontal borehole loaded with waste containers, the effective weight per unit length of the liner is

$$w = \frac{\pi}{4} (d_o^2 - d_i^2) \gamma + \frac{W_c}{L_c} \quad , \quad (49)$$

where γ is the weight per unit volume of the liner material, W_c is the effective weight of a loaded waste container, and L_c is the effective length of the container.

For example, if a steel liner ($\gamma = 489 \text{ lb/ft}^3$) with a 36-inch outside diameter and a 35-inch inside diameter is assumed, the weight per unit

Figure 9 - Residual liner loading configuration after liner insertion into boreholes drilled with steerable and non-steerable bits.

length of the unloaded liner is initially 189 lb/ft. The effective weight of the waste container in a horizontal borehole includes the weight of the container itself (13,211 lb) and the weight of the skid (1,774 lb), for a total weight of 14,985 lb (see Appendix C). The effective length of the waste container is the skid length, 16.7 ft. According to Eq. 49, the weight per unit length of the fully loaded liner is 1086 lb/ft. Loading the liner with waste therefore has a significant effect on the mechanical loading configuration of the liner.

The liner will be inserted into the borehole at an initial temperature of 68°F (see Appendix C). The temperature of the borehole wall in the vertical borehole is predicted to increase to a maximum of 441°F in about 13 years after emplacement, with slightly smaller increases predicted for the horizontal boreholes (SNL, 1987c). It is necessary to design the liner to withstand the thermal expansion caused by the 373°F increase in temperature that could occur during the retrievability period.

Thermal expansion of the liner in the radial direction is given by the equation (Timoshenko and Gere, 1972),

$$\Delta r = \alpha_L \frac{d}{2} \Delta T, \quad (50)$$

where d is the initial diameter of the liner, α_L is the thermal expansion coefficient of the liner material, and ΔT is the change in temperature that causes the thermal expansion. Assuming a steel liner ($\alpha_L = 6.5 \times 10^{-6}/^\circ\text{F}$) (Timoshenko and Gere, 1972) with an average diameter of 35.5 inches, the result is

$$\Delta r = 0.04 \text{ inch},$$

for $\Delta T = 373^\circ\text{F}$. The radial thermal expansion of the liner is not significant because of the large diametral clearance (≈ 1 inch) that will be employed between the liner and the borehole. Even in cases where bending already occurs due to interference, the relatively small radial expansion would not increase bending forces significantly.

The liner also undergoes thermal expansion in the longitudinal direction. Again assuming a steel liner, the thermal expansion coefficient of the liner material is higher than that of the tuff at Yucca Mountain ($\approx 4.9 \times 10^{-6}/^\circ\text{F}$) (SNL, 1987d). As a result of this difference in thermal expansion coefficients, the liner would be subjected to compressive thermal stresses if it were bonded to the borehole wall as has been suggested. The magnitude of these stresses would be approximately

$$\sigma_{th} = E (\alpha_L - \alpha_R) \Delta T, \quad (51)$$

where α_L and α_R are the thermal expansion coefficients of the liner and rock, respectively. Using $E = 30 \times 10^6$ psi and $\Delta T = 373^\circ\text{F}$, the result is

$$\sigma_{th} = 17,900 \text{ psi}.$$

This stress would be superimposed on any residual bending stresses that exist in the liner. When compared with the yield strength of low carbon steel (≈ 30 ksi), this stress is significant.

If, on the other hand, the liner were free to undergo unrestricted longitudinal thermal expansion, the increase in the length of the liner relative to that of the surrounding rock would be

$$\Delta L = (\alpha_L - \alpha_R) L_b \Delta T \quad , \quad (52)$$

where L_b is the initial length. This thermal expansion would range from 0.2 inches for a 26-foot borehole to 2.5 inches for a 350-foot borehole.

The above considerations indicate that provisions in the borehole design should be made to allow the liner to slide within the borehole in order to limit the magnitude of thermal stresses that develop. In cases where there is no interference between the liner and the borehole, the only forces that oppose thermal expansion of the liner are those that arise from friction caused by the weight of the liner against the borehole wall. In cases where interference between the liner and borehole wall does occur because of borehole deviation, additional friction forces develop at the liner/borehole wall contact points; these forces increase the compressive thermal stresses that develop in the liner. The following subsections develop equations for estimating these stresses for the case where the liner is not bonded to the borehole wall. The analysis is again divided into steerable and non-steerable bits, horizontal and vertical boreholes.

3.1 Boreholes Drilled with a Steerable Bit

The borehole design and thermal loading configuration differ between the vertical and horizontal borehole orientations. The analysis is therefore divided into two separate subsections below.

3.1.1 Horizontal Boreholes

In a horizontal borehole, it is possible to design the liner such that it is free to expand along its entire length, including at both ends. This is accomplished by providing an end clearance between the end of the liner and the end of the borehole, as shown in Figure 1, and by designing a slip joint for the liner in the borehole entry region. As in the case of residual forces after liner insertion, symmetry dictates that the maximum compressive force due to thermal expansion occurs at the middle of the liner. The loading configuration during thermal expansion is then the same as the residual loading configuration shown in Figure 9.

The friction force that develops in the middle of the liner is the force that opposes the sliding of one-half of the liner inside the borehole. The magnitude of this friction force is one-half of the value predicted by Eq. 24, or

$$F_f = \frac{\mu L_b}{2L} (2P + wL) \quad , \quad (53)$$

where P is calculated using Eq. 18 (which is valid for the small, moderate and large deviation cases). The thermal stress that develops in the liner due to this friction force is compressive and is given by the equation,

$$\sigma_{th} = \frac{4 F_f}{\pi(d_o^2 - d_i^2)} \quad . \quad (54)$$

The combined maximum compressive post-emplacement liner stress is found by superimposing the thermal stress on the bending stress:

$$\sigma_{\max} = \sigma_B + \sigma_{th} \quad (55)$$

where σ_B is the minimum of values predicted by Eqs. 5 and 20.

In summary, the procedure for calculating the maximum post-emplacement stress in a liner in a horizontal borehole drilled with a steerable bit is as follows:

- 1) Specify E , d_b , d_o , d_i , γ , W_c , L_c , L_b , δ_b , and L .
- 2) Calculate $w = \frac{\pi}{4} (d_o^2 - d_i^2) \gamma + W_c/L_c$.
- 3) Calculate $I = \frac{\pi}{64} (d_o^4 - d_i^4)$.
- 4) Calculate P using Eq. 18; if $P < 0$, set $P = 0$.
- 5) Calculate M_o using Eq. 13.
- 6) Calculate σ_B using Eq. 20; set $(\sigma_B)_1 = \sigma_B$.
- 7) Calculate σ_B using Eq. 5; set $(\sigma_B)_2 = \sigma_B$.
- 8) Set σ_B to $(\sigma_B)_1$ or $(\sigma_B)_2$, whichever is less.
- 9) Calculate F_f using Eq. 53.
- 10) Calculate σ_{th} using Eq. 54.
- 13) Calculate $\sigma_{\max}$ using Eq. 55.

This algorithm is incorporated into computer programs DEVIAT1 and STRESS1. The programs allow the user to specify either liner insertion or post-emplacement conditions on which to base the calculations for boreholes drilled with a steerable bit.

3.1.2 Vertical Boreholes

In vertical boreholes, it is assumed that the bottom end of the liner rests on the bottom of the borehole, and therefore the liner is not able to expand longitudinally at the bottom end. The liner thus expands from the bottom upward, meaning that friction forces at all contact points are directed downward. The maximum friction force during thermal expansion therefore occurs at the bottom of the liner and is given by Eq. 24. The procedure for calculating the maximum post-emplacement stress in a liner in a vertical borehole drilled with a steerable bit is then:

- 1) Specify E , d_b , d_o , d_i , W_c , L_c , L_b , δ_b , and L .
- 2) Specify $w = 0$.
- 3) Calculate $I = \frac{\pi}{64} (d_o^4 - d_i^4)$.
- 4) Calculate P using Eq. 18; if $P < 0$, set $P = 0$.

- 5) Calculate M_o using Eq. 13.
- 6) Calculate σ_B using Eq. 20; set $(\sigma_B)_1 = \sigma_B$.
- 7) Calculate σ_B using Eq. 5; set $(\sigma_B)_2 = \sigma_B$.
- 8) Set σ_B to $(\sigma_B)_1$ or $(\sigma_B)_2$, whichever is less.
- 9) Calculate F_f using Eq. 24.
- 10) Calculate σ_{th} using 54.
- 11) Calculate σ_{max} using Eq. 55.

This algorithm is also incorporated into DEVIAT1 and STRESS1. The programs use one set of equations for horizontal boreholes and another set for vertical boreholes.

3.2 Boreholes Drilled with a Non-Steerable Bit

The development of equations for predicting post-emplacement liner stresses in boreholes drilled with a non-steerable bit is presented in the next two subsections.

3.2.1 Horizontal Boreholes

Again it is assumed that for horizontal boreholes the liner is free to expand longitudinally at both ends. The magnitude of the friction force that develops in the middle of the liner is one-half of the value predicted by Eq. 48, or

$$F_f = \frac{\mu}{2} (4P + wL_b) \quad , \quad (56)$$

where P is calculated using Eq. 43. The thermal stress that develops in the liner due to this friction force is compressive and is given by Eq. 54. The combined maximum compressive stress in the liner is then found by superimposing the thermal stress on the bending stress, as in Eq. 55.

In summary, the procedure for calculating the maximum post-emplacement stress in a liner in a horizontal borehole drilled with a non-steerable bit is as follows:

- 1) Specify E , d_o , d_i , γ , W_c , L_c , L_b , and δ_b .
- 2) Calculate ρ_b and ρ_b with the transcendental expression given in Eqs. 26 and 27.
- 3) Calculate $w = \frac{\pi}{4} (d_o^2 - d_i^2) \gamma + W_c/L_c$.
- 4) Calculate $L = L_b/2$.
- 5) Calculate $I = \frac{\pi}{64} (d_o^4 - d_i^4)$.
- 6) Calculate P using Eq. 43; if $P < 0$, set $P = 0$.

- 7) Calculate σ_B using Eq. 45; set $(\sigma_B)_1 = \sigma_B$.
- 8) Calculate σ_B using Eq. 29; set $(\sigma_B)_2 = \sigma_B$.
- 9) Set σ_B to $(\sigma_B)_1$ or $(\sigma_B)_2$, whichever is less.
- 10) Calculate F_f using Eq. 56.
- 11) Calculate σ_{th} using Eq. 54.
- 12) Calculate σ_{max} using Eq. 55.

This algorithm is incorporated into DEVIAT2 and STRESS2. The programs allows the user to specify either liner insertion stresses or post-emplacment liner stresses on which to base the calculations for boreholes drilled with a non-steerable bit.

3.2.2 Vertical Boreholes

Again with vertical boreholes, it is assumed that the bottom end of the liner rests on the bottom of the borehole, and therefore the liner is not able to expand longitudinally at the bottom end. The maximum friction force during thermal expansion in this case occurs at the bottom of the liner and is given by Eq. 48. The procedure for calculating the maximum post-emplacment stress in a liner in a vertical borehole drilled with a steerable bit is then:

- 1) Specify E , d_b , d_o , d_i , W_c , L_c , L_b , and δ_b .
- 2) Calculate σ_b and σ_b with the transcendental expression given in Eqs. 26 and 27.
- 3) Specify $w = 0$.
- 4) Calculate $L = L_b/2$.
- 5) Calculate $I = \frac{\pi}{64} (d_o^4 - d_i^4)$.
- 6) Calculate P using Eq. 43; if $P < 0$, set $P = 0$.
- 7) Calculate $(\sigma_B)_1$ using Eq. 45.
- 8) Calculate $(\sigma_B)_2$ using Eq. 29.
- 9) Set σ_B to $(\sigma_B)_1$ or $(\sigma_B)_2$, whichever is less.
- 10) Calculate F_f using Eq. 48.
- 11) Calculate σ_{th} using Eq. 54.
- 12) Calculate σ_{max} using Eq. 55.

This algorithm is also incorporated into DEVIAT2 and STRESS2. The programs use one set of equations for horizontal boreholes and another set for vertical boreholes.

4.0 WASTE CONTAINER CLEARANCE CONSTRAINTS

Aside from constraints caused by liner stresses, the allowable borehole deviation is limited by the need to ensure that waste containers do not bind against the inside wall of the liner during emplacement or retrieval operations. The deviation of boreholes drilled with both steerable and non-steerable bits is of interest. Shown in Figure 10 is a waste container emplaced in a lined, non-linear borehole. The radius of curvature of the liner as shown is such that interference with the waste container occurs. The container will not pass through a liner with a sharper deviation, i.e., a smaller radius of curvature. Geometry considerations produce an equation for the minimum allowable radius of curvature for the liner, based on container clearance constraints:

$$[(\rho_L)_{all} + \frac{d_1}{2}]^2 = [\frac{L_c}{2}]^2 + [(\rho_L)_{all} - \frac{d_1}{2} + d_c]^2 ,$$

or

$$(\rho_L)_{all} = \frac{L_c^2}{8(d_1 - d_c)} - \frac{d_c}{2} , \quad (57)$$

where d_c is the effective diameter of the waste container. Interference between the waste container and the liner can be avoided by ensuring that the liner radius of curvature is larger than $(\rho_L)_{all}$. In other words, at all points along the length of the liner, it must be ensured that

$$\rho_L > (\rho_L)_{all} . \quad (58)$$

The liner radius of curvature, ρ_L , can be calculated using Eq. 1 for cases where the liner follows the curvature of the borehole at the contact points. In cases where the liner radius of curvature at the contact points is greater than that of the borehole wall, the liner radius of curvature is given by the equation

$$\rho_L = \frac{EI}{M} , \quad (59)$$

where M is given by M_0 (Eq. 13) for boreholes drilled with a steerable bit and by $M(x_1)$ (Eq. 44) for boreholes drilled with a non-steerable bit. These equations are used in Section 5 to ensure that waste container clearance problems can be avoided.

Figure 10 - Waste container in a curved section of liner, showing interference between container and liner wall.

5.0 MAXIMUM ALLOWABLE BOREHOLE DEVIATION

In this section, the stress models developed in Sections 2-4 are used to establish guidelines on the maximum allowable borehole deviation. First, development of the procedure for establishing these guidelines is discussed. Specific values are then assigned to the variables in the models, and borehole deviation specifications are developed for specific borehole configurations of current interest.

5.1 Determination of Maximum Allowable Borehole Deviation

Several modes of irreversible liner deflection are possible for the configurations of interest:

- o plastic deformation, where liner stresses exceed the compressive or tensile yield strength of the liner material;
- o rupture, where liner stresses exceed the ultimate compressive or tensile strength of the liner material; and
- o shell buckling, where instability of the liner cross-section causes localized collapse of the liner.

The borehole configurations under investigation have relatively small diametral clearances (0.5-6.0 inches) compared with the diameter of the borehole (36.5-42.0 inches). As a result, column buckling is not considered possible for these borehole configurations.

The potential for shell buckling of the liner under these conditions can be determined by examining the predictions of equations for shell buckling of thin-wall cylinders. The first case is for uniform longitudinal compression of a long, thin-wall cylinder. The critical longitudinal compressive stress at which shell buckling occurs is given by the theoretical equation (Timoshenko and Gere, 1961)

$$(\sigma_c)_{cr} = \frac{E t}{r \sqrt{3 (1-\nu^2)}} \quad , \quad (60)$$

where t is the thickness of the liner, r is the mean radius of the liner cross-section, and ν is Poisson's ratio for the liner material. Tests with thin-walled cylinders indicate that the actual critical compressive stress can be as small as 40% of the theoretical value (Roarke, 1971). Accordingly, the above equation is modified to account for empirical observation:

$$(\sigma_c)_{cr} = 0.4 \frac{E t}{r \sqrt{3 (1-\nu^2)}} \quad . \quad (61)$$

Similarly, the critical bending moment at which buckling occurs in a thin-wall cylinder subjected to pure bending is given by the equation (Roarke, 1971)

$$M_{cr} = 0.72 \frac{E r t^2}{1-\nu^2} \quad , \quad (62)$$

where the constant 0.72 accounts for the empirical observation that the actual critical bending moment is about 72% of the theoretical value. Inserting the relation,

$$(\sigma_B)_{cr} = \frac{M_{cr} r}{I} \quad (63)$$

into Eq. 62, we determine the critical bending stress at which shell buckling of the liner occurs:

$$(\sigma_B)_{cr} = \frac{0.72 E r^2 t^2}{I (1-\nu^2)} \quad (64)$$

For a steel liner of the dimensions under consideration ($r = 17.75$ in., $t = 0.5$ in., $E = 30 \times 10^6$ psi, $I = 8786$ in⁴, $\nu = 0.29$; see Appendix C), Eqs. 61 and 64 predict

$$(\sigma_c)_{cr} = 204 \text{ kpsi}$$

and

$$(\sigma_B)_{cr} = 211 \text{ kpsi} .$$

Thus the critical buckling stress for both pure compression and pure bending of the liner is well above the ultimate strength of the liner material (≈ 70 kpsi). According to Timoshenko and Gere (1961), it is safe to assume that the critical stress for combined bending and compression is above the critical stress for pure compression. It is thus concluded that the critical buckling stress for combined bending and compression is well above the ultimate strength of the liner material. Preventing rupture of the liner material is therefore a more stringent design criterion than preventing shell buckling.

To prevent rupture of the liner, the maximum compressive and tensile stresses must be maintained below the ultimate strength of the liner material, within a specified safety factor. In other words, the maximum allowable liner stress is given by the equation,

$$(\sigma_{max})_{all} = S_u / F_s \quad (65)$$

where S_u is the ultimate strength of the liner material and F_s is the factor of safety.

A safety factor of 4 is chosen for this analysis. This particular value is chosen for several reasons:

- o The consequences of liner rupture after waste emplacement could be rather severe in that normal waste retrieval operations, if required, could be hampered.
- o A safety factor of 4 based on ultimate strength is often used in other applications where structural failure could pose a safety hazard (e.g., high-pressure fluid containment).
- o Assuming an ultimate strength of 70 kpsi, the resulting safety factor against shell buckling of the liner is approximately 12.

- o Assuming a liner material yield strength of approximately 35 kpsi, the resulting safety factor against plastic deformation of the liner is about 2.

The maximum allowable borehole deviation is defined as the deviation at which the liner stress reaches its maximum allowable value. A procedure for using the liner stress models to calculate the allowable deviation is summarized below.

- 1) Specify S_u and F_s .
- 2) Calculate the maximum allowable liner stress, $(\sigma_{\max})_{\text{all}}$, according to Eq. 65.
- 3) Calculate the maximum allowable borehole deviation based on liner insertion stresses:
 - a. Assume some small value for borehole deviation amplitude, δ_b .
 - b. Calculate the maximum liner stress, $\sigma_{\max}$, for the given set of conditions according to the appropriate procedures outlined in:
 - Subsection 2.1 for liner insertion stresses in boreholes drilled with a steerable bit;
 - Subsection 2.2 for liner insertion stresses in boreholes drilled with a non-steerable bit;
 - c. Compare $\sigma_{\max}$ with $(\sigma_{\max})_{\text{all}}$:
 - If $\sigma_{\max} = (\sigma_{\max})_{\text{all}}$ within an acceptable error, the current value of δ_b is the maximum allowable borehole deviation based on liner insertion stresses, i.e;

$$(\delta_b)_i = \delta_b \quad ;$$

proceed with step 4.
 - If $\sigma_{\max} < (\sigma_{\max})_{\text{all}}$, increase the estimate of δ_b and return to step 3b.
 - If $\sigma_{\max} > (\sigma_{\max})_{\text{all}}$, reduce the estimate of δ_b and return to step 3b.
- 4) Calculate the maximum allowable borehole deviation based on post-emplacement liner stresses:
 - a. Assume some small value for borehole deviation amplitude, δ_b .
 - b. Calculate the maximum liner stress, $\sigma_{\max}$, for the given set of conditions according to the appropriate procedures outlined in:
 - Subsection 3.1 for post-emplacement liner stresses in boreholes drilled with a steerable bit;

- Subsection 3.2 for post-emplacement liner stresses in boreholes drilled with a non-steerable bit;

c. Compare $\sigma_{\max}$ with $(\sigma_{\max})_{\text{all}}$:

- If $\sigma_{\max} = (\sigma_{\max})_{\text{all}}$ within an acceptable error, the current value of δ_b is the maximum allowable borehole deviation based on post-emplacement liner stresses, i.e;

$$(\delta_b)_p = \delta_b ;$$

proceed with step 5.

- If $\sigma_{\max} < (\sigma_{\max})_{\text{all}}$, increase the estimate of δ_b and return to step 4b.
- If $\sigma_{\max} > (\sigma_{\max})_{\text{all}}$, reduce the estimate of δ_b and return to step 4b.

5) Compare the maximum allowable borehole deviation based on liner insertion stresses with the allowable deviation based on post-emplacement stresses:

- If $(\delta_b)_i < (\delta_b)_p$, then $(\delta_b)_{\text{all}} = (\delta_b)_i$;
- If $(\delta_b)_i > (\delta_b)_p$, then $(\delta_b)_{\text{all}} = (\delta_b)_p$;

where $(\delta_b)_{\text{all}}$ is the maximum allowable borehole deviation based on all liner stresses.

Computer programs DEVIAT1 and DEVIAT2, listed in Appendix A, have been written to perform the above procedure for boreholes drilled with both steerable and non-steerable bits. In addition to performing this procedure, these programs also check for waste container clearance problems. To do this, the maximum allowable borehole deviations resulting from the above procedure are checked according to Eqs. 57 and 58 to ensure that such deviations would not result in interference between the liner and the waste container. The programs print a flag in the output file if the calculated liner radius of curvature under the maximum allowable borehole deviation is smaller than the minimum allowable radius of curvature.

5.2 Definition of Conditions for Parametric Study

The primary objective of the parametric study was to determine the maximum allowable borehole deviation for the borehole configurations and liner insertion methods listed in Table I.

TABLE I
EMPLACEMENT BOREHOLE CONFIGURATIONS AND LINER INSERTION METHODS
INVESTIGATED IN PARAMETRIC STUDY

<u>Emplacement Borehole Configuration</u>			<u>Liner Insertion Method</u>	
<u>Orientation</u>	<u>Length, ft</u>	<u>Number of Waste Containers</u>	<u>Steerable Bit Simultaneous Drilling & Lining</u>	<u>Non-Steerable Bit Separate Drilling & Lining Operations</u>
Vertical	26	1		X
Horizontal	32	1		X
Horizontal	42	1		X
Horizontal	58	2		X
Horizontal	75	3		X
Horizontal	270	15	X	
Horizontal	350	15	X	

As seen in Table I, it is assumed that the vertical and short horizontal boreholes are drilled with a non-steerable bit, followed by a separate liner insertion operation. The long (> 75 ft) horizontal boreholes are assumed to be drilled with a steerable bit, with the liner being inserted simultaneously.

The parameter values that were fixed and those that were varied in the parametric study are shown in Table II on the following page. A comparison of these values with those reported in the Reference Information Base (RIB) of the NNWSI Project (SNL, 1987e) is provided in Appendix C. Justification for these values is provided in the remainder of this subsection.

The borehole liner is assumed to consist of mild steel tubing with a 36-inch outside diameter and a 35-inch inside diameter. The material properties assumed for mild steel include an ultimate tensile and ultimate compressive strength of 70 kpsi.

TABLE II
PARAMETER VALUES USED IN
BOREHOLE DEVIATION PARAMETRIC STUDY

<u>Parameter</u>	<u>Fixed (F) or Variable (V)</u>	<u>Parameter Value(s)</u>
d_o , liner outer diameter	F	36 inches
d_i , liner inner diameter	F	35 inches
r , mean radius of liner cross-section	F	17.75 inches
t , liner thickness	F	0.5 inch
E , liner elastic modulus	F	30×10^6 psi
γ , liner weight per unit volume	F	489 lb/ft ³
ν , Poisson's ratio for liner material	F	0.29
S_u , ultimate tensile and compressive strength of liner material	F	70 kpsi
μ , liner/borehole wall friction coefficient	F	0.6
d_b , borehole diameter	V	36.5, 37, 38, 39, 40, 41, and 42 in
W_c , weight of waste container	F	14,985 lb
L_c , length of waste container	F	16.7 inches
d_c , diameter of waste container	F	28.75 inches
L_b , borehole length	V	26 ft for vertical; 32, 42, 58, 75, 270, and 350 ft for horizontal
F_s , factor of safety	F	4.0
F_b , drilling thrust	V	470,000 lb for lining while drilling; 0 for liner insertion only
L , borehole deviation wavelength	V	0 to L_b for boreholes drilled with a steerable bit

Measurements of the friction coefficient between various types of rock and various types of metals are compiled by Ortega and Glowka (1984) and Glowka and Stone (1985). The data indicate that the friction coefficient is a function of the sliding speed and the presence or absence of water, as well as rock and metal types. Most of the available data fall in the range of $\mu = 0.1-0.7$. A value reported for steel on "dry tuff" is $\mu = 0.6$. In the absence of data for the specific tuff/steel combination of interest, this is the value assumed for this analysis.

Boreholes ranging in diameter from 36.5 to 42 inches are considered. This allows an investigation of the effects of borehole diameter on allowable borehole deviations.

The effective weight of the waste container is based on the heaviest waste container specified in the RIB and includes the weight of the skid used in horizontal boreholes. The effective length and diameter of the container also include the dimensions of the skid.

The borehole lengths considered in the analysis range from 26 to 350 ft, according to the emplacement configurations listed in Table I.

The factor of safety assumed in this analysis is 4. Justification for this particular value is provided in Section 5.1.

The drilling force imparted to the bit is the sum of several components:

$$F_b = F_1 + F_2 + F_3 + F_4 + F_5 \quad , \quad (66)$$

where

- F_1 = cutterhead thrust force
- F_2 = dead-weight friction attributed to inhole equipment
- F_3 = stabilizer friction
- F_4 = rock shearing force
- F_5 = gravity component

- o Based upon an estimate provided by The Robbins Co. for a 37-inch diameter roller bit, the cutterhead thrust force is estimated to be $F_1 = 150,000$ lb (Robbins, 1987).
- o The dead-weight friction caused by inhole equipment in horizontal boreholes is estimated as follows:
 - weight of inhole drill motor and bit = 21,000 lb; plus
 - weight of muck tubes & cabling =

20,000 lb for 350-ft borehole
15,400 lb for 270-ft borehole
4,300 lb for 75-ft borehole
3,300 lb for 58-ft borehole
2,400 lb for 42-ft borehole
1,800 lb for 32-ft borehole

Sum of weight times friction coefficient (0.6) gives:

$$F_2 = \begin{array}{l} 24,600 \text{ lb for 350-ft borehole} \\ 21,800 \text{ lb for 270-ft borehole} \\ 15,200 \text{ lb for 75-ft borehole} \\ 14,600 \text{ lb for 58-ft borehole} \\ 14,000 \text{ lb for 42-ft borehole} \\ 13,700 \text{ lb for 32-ft borehole} \end{array}$$

- o Stabilizer friction is based on an estimate made by Robbins (1987) for lateral stabilizing force on a 37-inch drill bit. Multiplying the stabilizing force (240,000 lb) by the friction coefficient (0.6), the stabilizer friction force $F_3 = 144,000 \text{ lb}$.
- o It is assumed that the leading edge of the liner may be forced to shear a small rock shoulder produced by a sudden change in drill bit direction. The rock shoulder in the 37-inch diameter borehole is assumed to be 0.2 inches high and to cover one-fourth of the circumference of the borehole. The frontal area of the rock shoulder is then

$$\pi (37 \text{ in}) (0.2 \text{ in})/4 = 5.8 \text{ in}^2.$$

Assuming a rock unconfined compressive strength of 24,100 psi (171 MPa) (SNL, 1987d),

$$F_4 = (5.8 \text{ in}^2) (24,100 \text{ psi}) = 140,000 \text{ lb}.$$

This rock shearing force value is also assumed for other borehole diameters.

- o It is assumed that the horizontal boreholes could be inclined such that the liner and the inhole drilling equipment must be pushed up-gradient to force it into the borehole. The weight of the liner and inhole equipment is:
107,200 lb for 350-ft borehole
87,400 lb for 270-ft borehole
39,500 lb for 75-ft borehole
35,300 lb for 58-ft borehole
31,300 lb for 42-ft borehole
28,800 lb for 32-ft borehole

Assuming a worst slope in the borehole of 3° , the gravity component is (weight times $\sin(3^\circ)$):

$$F_5 = \begin{array}{l} 5,600 \text{ lb for 350-ft borehole} \\ 4,600 \text{ lb for 270-ft borehole} \\ 2,100 \text{ lb for 75-ft borehole} \\ 1,800 \text{ lb for 58-ft borehole} \\ 1,600 \text{ lb for 42-ft borehole} \end{array}$$

Inserting the values for F_1 through F_5 into Eq. 66 gives the result:

$$F_b = \begin{array}{l} 464,000 \text{ lb for 350-ft borehole} \\ 460,000 \text{ lb for 270-ft borehole} \\ 451,000 \text{ lb for 75-ft borehole} \\ 450,000 \text{ lb for 58-ft borehole} \\ 450,000 \text{ lb for 42-ft borehole} \\ 449,000 \text{ lb for 32-ft borehole} \end{array}$$

Because these thrust force values are within 3.3% of each other, a single value is appropriate for all borehole lengths. The value chosen for this analysis is the largest of the calculated values, rounded up to two significant digits: $F_b = 470,000 \text{ lb}$.

Finally, for boreholes drilled with a steerable bit, the deviation wavelength considered in the analysis ranges from zero to the length of the borehole. Larger wavelengths are considered not valid for the present stress models; at least one full wavelength is necessary to approximate the bending configuration assumed in the stress model development.

5.3 Parametric Study Results

Results of the parametric study are tabulated in Appendix B. The various tables present the calculated maximum allowable borehole deviation for the range of conditions assumed in the study. Selected results are discussed below, first for boreholes drilled with a non-steerable bit. Results for boreholes drilled with a steerable bit are more complex and are, therefore, presented second.

5.3.1 Boreholes Drilled with a Non-Steerable Bit

The maximum liner stress, $\sigma_{\max}$, generally increases with the borehole deviation, δ_b . Because of the changing liner loading configuration with increasing deviation, the relationship between $\sigma_{\max}$ and δ_b is somewhat complex. Figure 11 illustrates this relationship for horizontal boreholes drilled with a non-steerable bit (i.e., monotonic deviation).

The $\sigma_{\max}$ vs. δ_b curve displays three regions. In Region A (small borehole deviations), the liner rests on the bottom of the borehole with contact along its entire length. Since the liner is forced by gravity to follow the curvature of the borehole in this case, the maximum liner stress is dependent on the magnitude of the curvature, which in turn is a function of the borehole deviation. The $\sigma_{\max}$ vs. δ_b curve thus has a positive slope in Region A. The diameter of the borehole has no effect in this region since the liner does not contact the top of the borehole.

In Region B (moderate borehole deviations), contact is lost between the ends of the liner and the bottom of the borehole. Borehole deviation in this case has reached the point where the liner stiffness prevents the liner from following the borehole curvature as deviation is further increased.

MAXIMUM
LINER
STRESS
 $\sigma_{\max}$

BOREHOLE DEVIATION δ_b

REGION A —
Small
Borehole
Deviations

REGION B —
Moderate
Borehole
Deviations

REGION C —
Large
Borehole
Deviations

Figure 11 - Effects of borehole deviation on maximum liner stresses for boreholes drilled with a non-steerable bit.

Theoretically, the liner in this state is balanced about its midpoint, with both ends cantilevered as shown in Figure 11. Since the liner ends do not contact the borehole wall in this state, small increases in borehole deviation have no effect on liner loading. In other words, $\sigma_{\max}$ is independent of δ_b over some finite range of δ_b , and the curve thus has zero slope in Region B.

In Region C (large borehole deviations), the top of the borehole interferes with the ends of the liner. The liner is thereby subjected to increased bending as borehole deviation is further increased. The $\sigma_{\max}$ vs. δ_b curve thus has a positive slope in Region C. The maximum liner stress is also strongly dependent on borehole diameter in this region because of the effect of diameter on the interference with the top of the liner.

These general behavior trends are seen in the calculated results presented in Figure 12. Shown here are the maximum liner stresses based on post-emplacment loading in a 40-inch borehole for various horizontal borehole lengths. (See Table B.3 for tabulated results). Note that the curves for the 58- and 75-ft boreholes display all three regions illustrated in the previous figure. Results were not computed for stress levels low enough to show the Region A portions of the 32- and 42-ft curves.

Also shown in Figure 12 is a dashed line that represents the maximum allowable liner stress of 17,500 psi. This allowable stress is obtained by dividing the ultimate compressive strength of the liner material, S_u , by the assumed safety factor, F_s , of 4. The point of intersection of each curve with the allowable stress line defines the maximum allowable deviation based on post-emplacment stresses, $(\delta_b)_p$. Note that the curve for the 58-ft borehole intersects the allowable stress line in its Region C portion, as do the curves for the 32- and 42-ft boreholes. The maximum allowable borehole deviation for these borehole lengths should thus be a function of the borehole diameter. The 75-ft-borehole curve, however, intersects the allowable stress line in its Region A portion. As a result, the maximum allowable borehole deviation for the 75-ft borehole should be independent of borehole diameter.

These conclusions are confirmed in Figure 13, where the maximum allowable borehole deviation based on post-emplacment loading, $(\delta_b)_p$, is plotted against borehole diameter for various borehole lengths. (For tabulated results see Table B.2). The results show that with the 75-ft borehole, the liner reaches its maximum allowable stress level at a relatively low deviation of about 13 inches, regardless of the borehole diameter. The stiffness (EI/L_b) of the liner with this large L_b is too small to allow the liner to reach the Region B configuration without exceeding the allowable stress. Since the liner rests on the bottom of the borehole in this case, the borehole diameter has no effect on the borehole stresses or the allowable deviation. Results for the shorter boreholes, on the other hand, indicate that interference with the top of the liner occurs,

Figure 12 - Calculated post-emplacement liner stresses as a function of borehole deviation characteristics in boreholes drilled with a non-steerable bit.

Figure 13 - Calculated maximum allowable borehole deviation based on post-emplacement liner stresses in boreholes drilled with a non-steerable bit.

as in Region C. The allowable deviations are thus strong functions of the borehole diameter for these shorter boreholes.

For comparison, the calculated values of the maximum allowable borehole deviation based on liner insertion stresses, $(\delta_b)_1$, are plotted in Figure 14. (See Table B.1 for tabulated results.) The loading configuration for liner insertion without simultaneous drilling is sufficiently different from post-emplacement loading that the curve for the 75-ft borehole is significantly different. This emphasizes the need in any borehole to examine both liner insertion stresses and post-emplacement liner stresses to determine which conditions place more stringent restrictions on borehole deviation.

The tabulated results for boreholes drilled with a non-steerable bit indicate that 88-97% of the liner stresses that occur at the maximum allowable borehole deviation are bending-induced, with the remaining 3-12% caused by friction against the borehole wall.

5.3.2 Boreholes Drilled with a Steerable Bit

As in the case with the non-steerable bit, the liner stresses that develop in cyclicly deviating boreholes are also a complicated function of the deviation magnitude. Shown in Figure 15 is a schematic for an arbitrary borehole diameter and deviation wavelength. Three regions are again evident along the $\sigma_{\max}$ vs. δ_b curve. In Region A (small borehole deviations), the liner rests on the bottom of the borehole and follows its curvature along its entire length. Since the borehole curvature is a function of the borehole deviation amplitude, there is a strong effect of δ_b on $\sigma_{\max}$ in this range. Thus the $\sigma_{\max}$ vs. δ_b curve has a positive slope in Region A. Since the borehole curvature is also a function of the deviation wavelength, L , it is clear that L also has a strong effect on $\sigma_{\max}$ in this range. Since the borehole does not contact the top of the liner in this region, there is no effect of borehole diameter in Region A.

In Region B (moderate borehole deviations), the stiffness of the liner prevents it from following the increasing curvature of the borehole as deviation is further increased. Contact between the liner and the bottom of the borehole is lost at the low point in each deviation cycle. Since the top of the borehole is not yet contacting the liner, and since the liner no longer follows the borehole curvature, there is no effect of increasing borehole deviation amplitude on the liner stresses in this case. As a result, the slope of the $\sigma_{\max}$ vs. δ_b curve in Region B is zero.

In Region C (large borehole deviations), borehole deviation is so large that the top of the borehole begins to interfere with the top of the liner at the low point in each deviation cycle. Increased deviation places the liner under increasingly higher bending loads. As a result, the slope of the $\sigma_{\max}$ vs. δ_b curve is positive in Region C. Furthermore, both the borehole diameter and the deviation wavelength have strong effects on the bending loads and thus $\sigma_{\max}$ in this region.

Figure 14 - Calculated maximum allowable borehole deviation based on liner insertion stresses (no simultaneous drilling) in boreholes drilled with a non-steerable bit.

MAXIMUM
LINER
STRESS
 $\sigma_{\max}$

BOREHOLE DEVIATION AMPLITUDE δ_b

REGION A —
Small
Borehole
Deviations

REGION B —
Moderate
Borehole
Deviations

REGION C —
Large
Borehole
Deviations

Figure 15 - Effects of borehole deviation amplitude on maximum liner stresses for boreholes drilled with a steerable bit.

These general behavior trends are seen in the calculated results presented in Figure 16. (See Table B.4 for tabulated results). Shown here are the maximum liner stresses for a 40-inch-diameter, 350-ft-long horizontal borehole, based on post-emplacement loading. Results are shown for various deviation wavelengths, L . Note that the curves for wavelengths of 58, 75, and 90 ft display all three regions illustrated in the previous figure. Results were not computed for stress levels large enough to show the Region B and C portions of the 120- and 140-ft curves.

Also shown in Figure 16 is a dashed line that represents the maximum allowable liner stress of 17,500 psi. Note that the curves for the 58- and 75-ft wavelengths intersect the allowable stress line in their Region C portions. Curves for larger wavelengths (90, 120, and 140 ft), however, intersect the allowable stress line in their Region A portions. The allowable borehole deviation therefore undergoes a significant drop in magnitude between deviation wavelengths of 75 and 90 ft.

This effect is further illustrated in Figure 17, where the maximum allowable deviation based on post-emplacement loading, $(\delta_b)_p$, is plotted against deviation cycle wavelength. (See Table B.5 for tabulated results). Note that the curves for all borehole diameters undergo a discontinuity at a wavelength of about 80 ft. (Results were calculated for discrete values of L every 5 ft; thus an uncertainty of ± 5 ft exists in the location of the discontinuity points. It should also be noted that the discontinuity for a borehole diameter of 36.5 inches is too small to discern in this figure.) These discontinuities, as explained above, are due to a sudden change with wavelength in the liner configuration that exists when the maximum allowable stress is attained. To the left of the discontinuities, the allowable stress is attained when interference occurs between the top of the borehole and the top of the liner, as in Region C. In this region, the liner stresses and thus the allowable borehole deviation are strongly dependent on the borehole diameter. To the right of the discontinuities, the deviation cycle wavelength is so large that the liner cannot support itself and is therefore forced by gravity to rest along the bottom of the borehole, as in Region A. In this region, the borehole diameter has no effect on the liner stresses or the allowable deviation; thus all the curves collapse to a single curve to the right of the discontinuities.

The results in Table B.5 also indicate that to the left of the discontinuities, the liner stress goes from being about 2% bending-induced at small L to about 88% bending-induced at the discontinuities. To the right of the discontinuities, the liner stress is consistently 88% bending-induced, with only 12% due to friction against the borehole wall. This indicates that small deviation wavelengths lead to multiple interference points between the liner and the borehole, resulting in significant friction-induced stresses. Larger deviation wavelengths lead to fewer interference points and lower friction, resulting in larger allowable bending stresses and, therefore, larger allowable deviation amplitudes.

Similar results are predicted for the 270-ft horizontal borehole, as shown in Figure 18. The maximum allowable borehole deviation amplitudes based on post-emplacement liner stresses are, in general, higher for the 270-ft borehole than for the 350-ft borehole. This is because of the shorter, lighter liner in the shorter borehole and the reduced number of interference points for a given deviation cycle wavelength.

Figure 16 - Calculated post-emplacement liner stresses as a function of borehole deviation characteristics in a 350-ft horizontal borehole drilled with a steerable bit.

Figure 17 - Calculated maximum allowable borehole deviation based on post-emplacement liner stresses in a 350-ft horizontal borehole drilled with a steerable bit.

Figure 18 - Calculated maximum allowable borehole deviation based on post-emplacment liner stresses in a 270-ft horizontal borehole drilled with a steerable bit.

For comparison, the maximum allowable borehole deviation amplitudes based on liner insertion stresses, $(\delta_b)_i$, are shown in Figures 19 and 20 for 350-ft and 270-ft horizontal boreholes drilled with a steerable bit. The detailed results are tabulated in Table B.6. In this case, simultaneous drilling and lining is assumed. The thrust force transmitted through the liner to the steerable drill bit increases liner stresses and therefore decreases the allowable borehole deviation. As a result, the allowable deviation based on liner insertion stresses is generally lower than the allowable deviation based on post-emplacment liner stresses; i.e., liner insertion operations generally impose more severe restrictions on borehole deviation than does the thermal expansion process. This is not true for the full range of deviation wavelength, however.

During liner insertion, the liner is not mechanically loaded by the weight of the waste containers. The effect of gravity on liner deflection is therefore not as significant in this case as in the post-emplacment case. The smaller effect of gravity for the liner insertion case results in a larger wavelength range over which Region C-type loading is possible. The curves for liner insertion collapse to a single curve at a deviation wavelength of about 140 ft, as opposed to 80 ft for the post-emplacment case. As a result, the maximum allowable borehole deviation based on liner insertion stresses, $(\delta_b)_i$, is greater than the allowable deviation based on post-emplacment stresses, $(\delta_b)_p$, over a portion of the wavelength range, from about 80 to 140 ft. In other words, post-emplacment stresses impose more severe restrictions on borehole deviation than liner insertion stresses over a 60-ft range in deviation wavelength. This again illustrates the need to examine both liner insertion and post-emplacment liner stresses when determining the allowable deviation for a given borehole.

5.3.3 Short Boreholes with Cyclic Deviation

The results for long boreholes drilled with a steerable bit indicate that the allowable interference between the liner and the borehole vanishes as the deviation wavelength goes to zero (see Figures 17-20). In other words, at $L = 0$, the maximum allowable borehole deviation goes to one-half the diametral clearance ($d_b - d_o$) between the liner and the borehole. This suggests that cyclic deviation in short boreholes may not be allowable if the deviation results in significant interference between the liner and the borehole.

To investigate this concern, the steerable-bit computer program (DEVIAT1) was exercised for the short horizontal boreholes. The maximum allowable borehole deviation based on liner insertion stresses (no simultaneous drilling) was calculated, as was the maximum allowable borehole deviation based on post-emplacment stresses. The results are compiled in Tables B.5 and B.7. Selected results for the 75-ft borehole are presented in Figures 21 and 22.

As seen in both of these figures, the maximum allowable borehole deviation is indeed very close to one-half the diametral clearance between the liner and the borehole under all conditions. This confirms that with the shorter boreholes (≤ 75 ft), cyclic deviation cannot be tolerated if the deviation amplitude results in significant interference between the liner

Figure 19 - Calculated maximum allowable borehole deviation based on liner insertion stresses (with simultaneous drilling) in a 350-ft horizontal borehole drilled with a steerable bit.

Figure 20 - Calculated maximum allowable borehole deviation based on liner insertion stresses (with simultaneous drilling) in a 270-ft horizontal borehole drilled with a steerable bit.

MAXIMUM
ALLOWABLE
DEVIATION
(δ_b)_i
(in.)

Figure 21 - Calculated maximum allowable borehole deviation based on liner insertion stresses (no simultaneous drilling) in a 75-ft horizontal borehole drilled with a steerable bit.

Figure 22 - Calculated maximum allowable borehole deviation based on post-
emplacement liner stresses in a 75-ft horizontal borehole
drilled with a steerable bit.

and the borehole. Cyclic deviation that results in significant interference is allowable only in the long boreholes, and then only as large-wavelength deviations.

5.3.4 Waste Container Clearance

The tabulated results for both the steerable- and the non-steerable-bit cases indicate that waste container clearance is not a problem in borehole configurations of current interest. The calculated minimum allowable liner radius of curvature based on interference between the container and the inside of the liner is about 66 ft (see Appendix B). Under no condition assumed in the parametric study is the liner radius of curvature less than this minimum value if the borehole is drilled within the allowable borehole deviation based on liner stresses.

5.4 Discussion and Interpretation of Results

In this section, several topics are discussed that relate to the results of the parametric studies.

5.4.1 Generalized Interpretation

It has been shown that the contact forces that develop at the bends in the liner also produce friction forces that tend to resist sliding of the liner in the borehole. The larger the number of contact or interference points, the greater the total resistance against sliding becomes. As a result, the frequency of changes in borehole direction that result in interference between the liner and the borehole should be minimized.

Based on this observation, a more general interpretation of the results is offered. Actual boreholes would not follow the ideal shapes assumed for boreholes drilled with steerable and non-steerable bits but rather would deviate in a more random manner. The total borehole deviation at any point along the borehole can be considered to be the superposition of cyclic components that occur on three broad scales:

- 1) a small-wavelength scale, where the wavelength is an order of magnitude smaller than the length of the borehole (i.e., $L < L_b/10$);
- 2) a medium-wavelength scale, where the wavelength ranges from the length of the borehole down to the small-wavelength scale (i.e., $L_b/10 < L < L_b$); and
- 3) a large-wavelength scale, where the wavelength is larger than the length of the borehole (i.e., $L > L_b$).

Superposition of these different-scale deviation components to represent a general borehole configuration is similar in concept to a Fourier series.

Small-wavelength deviation components are characterized by the assumed geometry of the borehole drilled with a steerable bit where the deviation undergoes many cycles (more than 10). Such components tend to impose on the liner large compressive stresses due to friction. The calculated results

indicate that the amplitude of small-wavelength deviation components must not be much larger than one-half the diametral clearance between the liner and the borehole if the combined liner stresses are expected to be below the maximum allowable liner stress defined in this study. In other words, any small-wavelength deviation components that exist in either short or long boreholes must not have amplitudes large enough to cause significant interference between the liner and the borehole wall.

Medium-wavelength deviation components are characterized by the geometry where the deviation undergoes from one to ten cycles. Medium-wavelength deviation components that result in significant interference are allowable only in the 270-ft and 350-foot horizontal boreholes. Medium-wavelength components in the shorter boreholes are allowed amplitudes only slightly larger than one-half the diametral clearance.

Large-wavelength deviation components are characterized by the assumed geometry of the borehole drilled with a non-steerable bit. In other words, the geometry of the borehole drilled with a non-steerable bit is similar to the geometry of a borehole drilled with a steerable bit where the deviation undergoes only one-half cycle. Such borehole deviation components tend to impose on the liner large bending stresses and relatively small compressive stresses due to friction. Large-wavelength deviation components that result in significant interference between the liner and the borehole are allowable with all borehole lengths. The single bend, as opposed to multiple bends, in the liner for large-wavelength deviation components tends to moderate stresses caused by sliding friction. The allowable deviation amplitude for large-wavelength deviation components is significantly greater than one-half the diametral clearance for all borehole lengths.

5.4.2 Liner Survivability

An issue of interest is how liner survivability during liner insertion operations compares with liner survivability during thermal expansion. It has been shown that in some cases, liner insertion stresses are higher than post-emplacement stresses. Under those conditions, a liner that survives insertion into any borehole, regardless of its deviation, should also survive the thermal expansion process following waste emplacement.

In other cases, post-emplacement liner stresses have been found to be higher than liner insertion stresses. In such cases, successful liner insertion does not necessarily guarantee survival under post-emplacement thermal loading. A significant safety factor has been incorporated into the analysis, however. It is therefore likely that if a liner can be inserted into a given borehole without undergoing severe plastic deformation, then the liner will not rupture or collapse under post-emplacement loading in that borehole, regardless of the borehole deviation.

5.4.3 Effects of Binding

If one end of a liner in a horizontal borehole should happen to bind against the borehole wall during thermal expansion, stresses throughout the liner would increase. The loading configuration for this case would be similar to that assumed for post-emplacement loading in vertical boreholes.

Because of the relative sizes of bending and longitudinal friction stresses, the combined stresses caused by large-wavelength borehole deviation components would not increase significantly if one end of the liner binds against the borehole wall.

Liner stresses caused by small-wavelength deviation components, on the other hand, are largely composed of longitudinal friction stresses. Doubling these friction stresses by restraining one end of the liner would therefore have a significant effect on combined liner stresses. Because of the safety factor employed, however, the combined stresses would still remain below the yield strength of the liner material.

5.4.4 Point-Contact Assumption

The liner stress models developed in this report assume that when the radius of curvature of the liner is greater than that required to follow the curvature of the borehole, any contact between the liner and the borehole is a point contact. In reality, the contact loads (P) calculated with the models for the configurations of interest are large enough that local deflection of the liner cross-section would occur (see the tabulated data in Appendix B). The geometry of the liner within the borehole is such that very small deflections of the liner cross-section at a contact point are sufficient to spread the load over a significant length. Because of this load distribution and the relative stability of the liner cross-section, it is not expected that liner collapse due to lateral loading would occur before the maximum compressive stress due to bending and friction reaches its allowable level. More work using refined liner stress models would be necessary to fully investigate the implications of the point-contact assumption.

A model that includes the effects of load distribution at the contact points would predict slightly larger sliding friction forces and slightly smaller bending stresses than those predicted using the point-contact assumption. Thus the error caused by the point-contact assumption in calculating the total liner stress tends to be self-canceling and is further accommodated by the safety factor and other conservative features incorporated into the analysis.

5.5 Specifications for Selected Borehole Configurations

The results obtained in the parametric study can be used to determine borehole deviation specifications for a wide variety of borehole configurations. At the present point in repository design, a borehole diameter of 37 inches is attractive from the standpoint of feasibility and economy. This subsection develops borehole deviation specifications for this particular diameter and the various borehole orientations and lengths currently under consideration.

Possible uses of emplacement borehole deviation specifications include:

- o as a measure of performance against which to judge proposed drilling methods to determine if they meet drilling accuracy requirements; and

- o as a quality control measure to evaluate each borehole after it is drilled to verify its acceptability for liner installation and waste emplacement.

In developing specifications for the borehole geometries of interest, it is assumed that the deviation of any emplacement borehole can be categorized as being either primarily cyclic or monotonic in nature. Borehole deviation specifications are developed for each category in the following subsections. The criteria for determining which category is applicable for a given drilling method is also discussed.

5.5.1 Monotonically Deviating Boreholes

Purely monotonic deviation is similar to that assumed for boreholes drilled with a non-steerable bit, as shown in Figure 7. The total deviation at the end of the borehole, δ_b , is the measure of deviation magnitude in this case. A primarily monotonic borehole deviation is one where the primary deviation is monotonic but where cyclic deviation components may also exist. Such a geometry may be a more realistic one than the idealized geometry assumed for boreholes drilled with a non-steerable bit. The stiffness of the drill string in such cases may be sufficient to dampen any small-wavelength deviation components to low levels but may not be able to resist gradual lateral movement caused by gravity and rock anisotropy.

It has been shown that cyclic deviation components do not cause interference between the liner and the borehole unless the amplitude of such components is greater than one-half the diametral clearance ($d_b - d_o$) between the liner and the borehole. It is then safe to assume that a cyclic deviation component with an amplitude less than one-half the diametral clearance does not contribute significantly to liner stresses.

It follows that such small cyclic deviation components can be superimposed on the monotonic deviation component without significantly increasing liner stresses, as long as the maximum allowable (end-to-end) borehole deviation for the monotonic component is not exceeded. It is thus concluded that the maximum allowable borehole deviation is controlled by the monotonic deviation component as long as the amplitudes of the cyclic deviation components are less than one-half the diametral clearance between the liner and the borehole. The specifications that result from this reasoning are summarized in Table III on the following page.

5.5.2 Cyclicly Deviating Boreholes

Purely cyclic deviation is similar to that assumed for boreholes drilled with a steerable bit, as shown in Figure 5. The amplitude of the cyclic deviation, δ_b , is the measure of the deviation magnitude in this case. A primarily cyclic borehole deviation is one where a primary cyclic deviation component is superimposed on a relatively minor monotonic deviation component. Minor cyclic deviation components of different wavelengths than the primary component may also be present. Such a geometry may be a more realistic one than the idealized geometry assumed for boreholes drilled with a steerable bit. Instead of deviating about a straight line, the borehole under primarily cyclic deviation deviates about a monotonic curve that deviates from a straight line.

TABLE III
BOREHOLE DEVIATION SPECIFICATIONS
FOR 37-INCH DIAMETER,
MONOTONICALLY DEVIATING BOREHOLES

<u>Borehole Orientation</u>	<u>Borehole Length, ft</u>	<u>Maximum Allowable Borehole Deviation, in.†</u>	
		<u>Monotonic Component (Total deviation at end of borehole)</u>	<u>Cyclic Component (all wavelengths)</u>
Vertical	26	4.93	0.5
Horizontal	32	5.42	0.5
Horizontal	42	6.40	0.5
Horizontal	58	8.24	0.5
Horizontal	75	12.5	0.5
Horizontal	270	$\frac{82.8}{155} *$	0.5
Horizontal	350	$\frac{136}{252} *$	0.5

† Both monotonic and cyclic deviation components of the magnitudes shown are allowed simultaneously, but the total end-to-end borehole deviation should not exceed that shown for the monotonic component.

* Specifications for the long boreholes are of the format:

$$\frac{S_1}{S_2}$$

where S_1 = specification assuming simultaneous drilling and lining (value taken as the minimum of values from Tables B.2 and B.8)

S_2 = specification assuming separate lining operation (value taken as the minimum of values from Tables B.1 and B.2)

All other specifications assume separate drilling and lining operations and are taken as the minimum of values from Tables B.1 and B.2.

It is reasonable to assume that a steerable drilling system would be capable of meeting the same deviation specifications for the monotonic deviation component as for the primary cyclic deviation components. The results tabulated in Table D.2 indicate that liner stresses are negligible if the amplitude in monotonic deviation is only of the same order as the allowable amplitude for cyclic deviation components in the same size borehole.

It is again recognized that significant liner stresses do not develop as a result of cyclic deviation unless the amplitudes of the cyclic components exceed one-half the diametral clearance between the liner and the borehole. It follows then that small secondary cyclic deviation components and a small monotonic deviation component may be superimposed on the primary cyclic deviation component without significantly increasing liner stresses, as long as the maximum allowable borehole deviation for the primary component is not exceeded at any point along the borehole. It is concluded that the maximum allowable borehole deviation is controlled by the primary cyclic deviation component as long as:

- o the amplitude of the monotonic component is no larger than that of the primary cyclic component; and
- o the secondary cyclic components do not have amplitudes larger than one-half the diametral clearance or result in total borehole deviation at any point that exceeds the allowable deviation of the primary cyclic component.

The specifications that result for this case are shown in Table IV on the following page.

5.5.3 Interpretation of Borehole Deviation Specifications

The specifications listed in Tables III and IV can be viewed as two separate options for borehole geometry. If it is not possible to tightly control overall borehole deviation of a monotonic nature, as with a non-steerable bit, then cyclic deviation amplitudes must be maintained at relatively low levels (one-half the diametral clearance between the liner and the borehole). The use of near-bit stabilization and oversize drill string to increase drill string stiffness may be all that is necessary to adequately control cyclic deviation components.

If it is possible to maintain tighter control on overall monotonic deviation, as with a steerable bit, then a larger cyclic deviation amplitude is allowable. For short boreholes, this increase in allowable cyclic deviation amplitude is negligible; the allowable cyclic deviation amplitude is only slightly larger than one-half the diametral clearance. For the long (>75 ft) horizontal boreholes, however, significant increases in allowable deviation amplitude are possible with larger deviation wavelengths. The fewer the number of significant bends in the liner, the fewer the number of interference points between the liner and the borehole and the greater the allowable amplitude of the cyclic and monotonic deviation components.

The specifications developed here do not appear to be too severe for the drilling methods proposed. If future work finds that the required

TABLE IV
BOREHOLE DEVIATION SPECIFICATIONS
FOR 37-INCH DIAMETER,
CYCLICLY DEVIATING BOREHOLES

Borehole Orientation	Length, ft	Maximum Allowable Borehole Deviation, in.†										
		----- Deviation Cycle Wavelength (ft) -----										
		5	16	26	32	42	58	75	135	175	270	350
Vertical	26	0.50	0.51	0.55								
Horizontal	32	0.50	0.51	0.55	0.58							
Horizontal	42	0.50	0.51	0.55	0.58	0.65						
Horizontal	58	0.50	0.51	0.54	0.57	0.64	0.78					
Horizontal	75	0.50	0.51	0.54	0.57	0.63	0.77	0.93				
Horizontal	270 *	<u>0.50</u> 0.50	<u>0.50</u> 0.51	<u>0.51</u> 0.52	<u>0.52</u> 0.53	<u>0.54</u> 0.58	<u>0.60</u> 0.71	<u>0.70</u> 0.88	<u>1.26</u> 2.37	<u>2.16</u> 4.06	<u>5.18</u> 9.67	
Horizontal	350 *	<u>0.50</u> 0.50	<u>0.50</u> 0.50	<u>0.51</u> 0.51	<u>0.52</u> 0.53	<u>0.54</u> 0.57	<u>0.59</u> 0.69	<u>0.67</u> 0.87	<u>1.23</u> 2.30	<u>2.12</u> 3.94	<u>5.08</u> 9.39	<u>8.53</u> 15.8

† Maximum allowable borehole deviation = primary cyclic deviation component amplitude.
A monotonic deviation component of the same magnitude is allowed simultaneously.
Secondary cyclic deviation components of any wavelength are also allowed simultaneously if their combined amplitudes do not exceed 0.5 inch or cause the total deviation at any point to exceed the specification for the primary cyclic component.

* Specifications for the long boreholes are of the format:

$$\frac{S_1}{S_2}$$

where S_1 = specification assuming simultaneous drilling and lining (value taken as the minimum of values from Tables B.5 and B.8)
 S_2 = specification assuming separate lining operation (value taken as the minimum of values from Tables B.5 and B.7)

All other specifications assume separate drilling and lining operations and are taken as the minimum values from Tables B.5 and B.7.

specifications cannot be met with a particular drilling method or borehole length, a viable option in most cases would be to increase the borehole diameter. This would increase the maximum allowable deviation for the monotonic deviation component as well as for small-wavelength cyclic deviation components. Procedures similar to those used in compiling Tables III and IV would have to be followed to develop specifications for larger diameter boreholes, using the tabulated data in Appendix B.

6.0 CONCLUSIONS

The following conclusions can be drawn from the results presented in this report:

- 1) The mechanical loading configuration for emplacement borehole liner insertion operations is significantly different from the loading that results after waste emplacement. The weight and thermal output of the waste containers significantly modify the distribution and magnitude of liner stresses.
- 2) The cross-section of the steel liner under consideration is relatively stable in that the predicted stress required to cause shell buckling is well above the ultimate strength of the liner material.
- 3) Liner stresses can be directly related to borehole deviation, allowing specifications to be developed for allowable borehole deviation. Preliminary specifications for borehole deviation have been established for 37-inch boreholes ranging from 26 to 350 ft in length.
- 4) The primary constraint on borehole deviation is that the number of points of interference between the liner and the borehole wall must be limited. In other words, the number of significant changes in borehole direction must be maintained as small as possible. Significant changes here are defined as those that cause interference (friction) between the liner and the borehole wall. In short boreholes, significant changes in direction should not occur more than once or twice over the borehole length. In the longer (> 75 ft) boreholes under consideration, changes in borehole direction that cause interference should not occur more than three or four times over the borehole length.
- 5) Constraints on borehole deviation can, in general, be relaxed by drilling a larger diameter borehole to provide a larger diametral clearance between the liner and the borehole. For the 36-inch diameter borehole liner considered in the parametric study, the allowable borehole deviation for a 38-inch borehole is up to twice that for a 37-inch borehole, depending upon the deviation characteristics.
- 6) With all borehole configurations, the liner must be able to slide in the borehole in response to thermal expansion stresses if adequate safety against plastic deformation and possible failure of the liner is to be ensured. The design of horizontal boreholes should include provisions for liner expansion at both ends.
- 7) A case-by-case examination of results is necessary for most borehole configurations to determine whether liner insertion stresses or post-emplacement stresses impose more stringent constraints on maximum allowable borehole deviation.

- 8) A liner that survives insertion into the borehole without severe plastic deformation should, in most cases, also survive the thermal expansion process following waste emplacement. Again, however, a case-by-case examination of results is necessary to determine whether liner insertion operations or post-emplacement stresses are more severe.
- 9) Under the conditions (liner diameter, waste container diameter, waste container length, etc.) assumed in this study, no problems with interference between the waste containers and the inside wall of the liner should be encountered if borehole deviation specifications based on liner stresses are satisfied.

7.0 NOMENCLATURE

d	= mean diameter of liner cross-section (in)
d_b	= borehole diameter (in)
d_c	= effective diameter of waste container (in)
d_i	= liner inside diameter (in)
d_o	= liner outside diameter (in)
E	= modulus of elasticity of liner material (lb/in ²)
F_b	= drilling thrust force transmitted to bit through liner in simultaneous drilling and lining operations (lb)
F_f	= total friction force resisting sliding between liner and borehole wall (lb)
F_s	= safety factor
F_t	= thrust force required to insert liner into borehole (lb)
I	= moment of inertia for liner cross-section (in ⁴)
L	= borehole deviation wavelength for boreholes drilled with a steerable bit (in)
L	= one-half borehole length for boreholes drilled with a non-steerable bit (in)
L_b	= borehole length; also assumed liner length (in)
L_c	= effective length of waste container (in)
M_{cr}	= critical liner bending moment at which shell buckling occurs (in-lb)
M_o	= maximum liner bending moment in boreholes drilled with a steerable bit (ft-lb)
$M(x1)$	= maximum liner bending moment in boreholes drilled with a non-steerable bit (ft-lb)
n	= number of borehole deviation cycles = L_b/L for boreholes drilled with a steerable bit
P	= contact force between liner and top of borehole (lb)

r	= mean radius of liner cross-section (in)
Δr	= change in liner radius due to thermal expansion (in)
R	= one-half of reaction force between liner and bottom of borehole (lb)
S_u	= ultimate strength of liner material (lb/in ²)
t	= thickness of liner cross-section (in)
ΔT	= change in liner temperature after waste emplacement (°F)
w	= liner weight per unit length (lb/in)
W_c	= effective weight of loaded waste container (lb)
α_L	= thermal expansion coefficient of liner material (°F ⁻¹)
α_R	= thermal expansion coefficient of tuff (rock) (°F ⁻¹)
γ	= weight per unit volume of liner material (lb/in ³)
δ	= midpoint deflection of liner in boreholes drilled with a steerable bit (in)
δ	= endpoint deflection of liner in boreholes drilled with a non-steerable bit (in)
δ_b	= borehole deviation amplitude (in)
$(\delta_b)_{all}$	= maximum allowable borehole deviation amplitude based on all liner stresses (in)
$(\delta_b)_i$	= maximum allowable borehole deviation amplitude based on liner insertion stresses (in)
$(\delta_b)_p$	= maximum allowable borehole deviation amplitude based on post-emplacement liner stresses (in)
$(\delta_b)_t$	= borehole deviation amplitude at which interference develops between the liner and the borehole walls (in)
θ_b	= endpoint slope of liner in boreholes drilled with a non-steerable bit (rad)
θ_L	= left endpoint slope of equivalent beam in boreholes drilled with a steerable bit (rad)

θ_R	= right endpoint slope of equivalent beam in boreholes drilled with a steerable bit (rad)
$(\sigma_B)_{cr}$	= critical bending stress at which shell buckling occurs (lb/in ²)
$(\sigma_c)_{cr}$	= critical compressive stress at which shell buckling occurs (lb/in ²)
μ	= friction coefficient between liner and borehole wall
ν	= Poisson's ratio for liner material
ρ_b	= borehole radius of curvature (in)
ρ_{bo}	= borehole radius of curvature in entrance region of boreholes drilled with a steerable bit (in)
ρ_L	= minimum liner radius of curvature (minimum over length) (in)
$(\rho_L)_{all}$	= minimum allowable liner radius of curvature (based on container clearance) (in)
σ_B	= maximum bending stress in liner (lb/in ²)
σ_{max}	= combined maximum compressive stress in liner ("liner insertion stress" or "post-emplacment liner stress") (lb/in ²)
$(\sigma_{max})_{all}$	= maximum allowable liner stress (lb/in ²)
σ_t	= maximum longitudinal compressive stress in liner due to thrust force required to insert liner into borehole (lb/in ²)
σ_{th}	= maximum longitudinal compressive thermal stress in liner due to friction against borehole wall (lb/in ²)

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 - c. Appendix A, Expected Temperatures for Borehole Walls and Drifts After Spent Fuel Emplacement
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APPENDIX A
FORTRAN PROGRAM LISTINGS

This appendix contains listings of the Fortran programs used in the parametric study. The nomenclature used in these programs is listed below.

DB	= borehole diameter, d_b (inches)
DBF	= borehole diameter, d_b (ft)
DBT	= tabulated borehole diameters, d_b (inches)
DELB	= borehole deviation amplitude, δ_b (inches)
DELBF	= borehole deviation amplitude, δ_b (ft)
DI	= liner inside diameter, d_i (inches)
DIF	= liner inside diameter, d_i (ft)
DO	= liner outside diameter, d_o (inches)
DOF	= liner outside diameter, d_o (ft)
E	= elastic modulus, E (lb/ft ²)
FB	= drilling thrust force transmitted to bit, F_b (lb)
FF	= friction force between liner and borehole wall, F_f (lb)
FS	= factor of safety, F_s
GAM	= liner weight per unit volume, γ (lb/ft ³)
L	= deviation wavelength, L (ft)
LB	= borehole length, L_b (ft)
LBT	= tabulated borehole lengths, L_b (ft)
LC	= effective length of waste container, L_c (ft)
LT	= tabulated deviation wavelength, L (ft)
MI	= liner moment of inertia, I (ft ⁴)
MO	= liner bending moment, M_o (ft-lb)
MX1	= liner bending moment, $M(x_1)$ (ft-lb)
MU	= rock/liner friction coefficient, μ
P	= mid-point or end-point contact force between liner and borehole wall, P (lb)

RB	= borehole radius of curvature, ρ_b (ft)
RL	= liner radius of curvature, ρ_L (ft)
RLMIN	= minimum allowable liner radius of curvature based on waste container clearance, $(\rho_L)_{all}$ (ft)
SI	= liner stress due to thrust force required to insert liner into borehole, σ_t (lb/in ²)
SIG	= combined compressive liner stress, σ_{max} (lb/in ²)
SIGCRTB	= critical compressive stress for shell buckling, $(\sigma_c)_{cr}$ (lb/in ²)
SIGCRTC	= critical bending stress for shell buckling, $(\sigma_B)_{cr}$ (lb/in ²)
SIGTH	= combined compressive liner stress based on post-emplacement loading, σ_{max} (lb/in ²)
SAFSIG	= maximum allowable liner stress, $(\sigma_{max})_{all}$ (lb/in ²)
SB	= bending stress, σ_B (lb/in ²)
SBBC	= bending stress assuming continuous contact between the liner and the borehole wall, σ_B (lb/in ²)
SU	= ultimate compressive liner strength, S_u (lb/in ²)
W	= liner weight per unit length, w (lb/ft)
WC	= effective weight of waste container, W_c (lb)
WTH	= liner weight per unit length, fully loaded with waste, w (lb/ft)

Nomenclature for the output data in Appendix B is listed at the beginning of Appendix B.

A.1 Listing of PROGRAM DEVIAT1

This section of Appendix A lists a Fortran program (DEVIAT1.FOR) for computing the maximum allowable borehole deviation based on either liner insertion stresses or post-emplacement liner stresses in either horizontal or vertical boreholes drilled with a steerable bit. This program was used to generate the output listed in Tables B.5, B.6, and B.7 in Appendix B.

```

PROGRAM DEVIAT1
IMPLICIT REAL*8(A-H,L,M,O-Z)
REAL*8 DELBDB(7),DBT(7),LBT(7),LT(35),I
CHARACTER*1 CONT,REST
OPEN(UNIT=2,NAME='TTABULAT.DAT',STATUS='NEW')
OPEN(UNIT=3,NAME='TABULAT.DAT',STATUS='NEW')
OPEN(UNIT=4,NAME='DELBVL.DAT',STATUS='NEW')
WRITE(3,6666)
6666 FORMAT(' RUN WITH DEVIAT1.FOR')
CONT='V'
DBT(1)=36.5
DBT(2)=37.
DBT(3)=38.
DBT(4)=39.
DBT(5)=40.
DBT(6)=41.
DBT(7)=42.
LBT(1)=26.
LBT(2)=32.
LBT(3)=42.
LBT(4)=58.
LBT(5)=75.
LBT(6)=270.
LBT(7)=350.
LT(1)=5.
LT(2)=10.
LT(3)=16.
LT(4)=21.
LT(5)=26.
LT(6)=32.
LT(7)=42.
LT(8)=58.
LT(9)=75.
LT(10)=80.
LT(11)=85.
LT(12)=90.
LT(13)=95.
LT(14)=100.
LT(15)=110.
LT(16)=120.
LT(17)=135.
LT(18)=140.
LT(19)=150.
LT(20)=160.
LT(21)=170.
LT(22)=175.
LT(23)=200.
LT(24)=240.
LT(25)=270.
LT(26)=300.
LT(27)=350.
WRITE(5,6669)
6669 FORMAT(' LINER INSERTION (1) OR POST-EMPLACEMENT (2) LOADING?')
READ(5,*)ITYPE
IF(ITYPE.EQ.1)WRITE(3,6670)
6670 FORMAT(' LINER INSERTION LOADING SPECIFIED')
IF(ITYPE.EQ.2)WRITE(3,6671)
6671 FORMAT(' POST-EMPLACEMENT LOADING SPECIFIED')
PI=3.14159
E=30.0E+06*144.
MU=0.6
DO=36.
DOF=DO/12.
DI=35.
DIF=DI/12.
MI=PI/64.*(DOF**4-DIF**4)
GAM=489.0
WC=14985.
LC=16.7
W=PI/4.*(DOF**2-DIF**2)*GAM
WTH=W+WC/LC
IF(ITYPE.EQ.2)W=WTH
WH=W
WTHH=WTH
WV=0.
WTHV=0.
DC=28.75
DCF=DC/12.
RLMIN=LC**2/8./(DIF*DCF)*DCF/2.
WRITE(5,6667)RLMIN
WRITE(3,6667)RLMIN
6667 FORMAT(' MINIMUM ALLOWABLE LINER RADIUS OF CURVATURE=',
1 F10.2,' FT (BASED ON CONTAINER CLEARANCE)')
RNUF=1.-0.29**2

```

```

SIOCRTB=0.72*E/144.*((DIF+DOF)/4.)*2*(0.5/12)**2/RNUF/M1
SIOCRTC=0.4*E/144.*(0.5/12.)/((DIF+DOF)/4.)/(3**0.5)/RNUF**0.5
WRITE(5,666B)SIOCRTB,SIOCRTC
WRITE(3,666B)SIOCRTB,SIOCRTC
666B FORMAT(' CRITICAL BUCKLING STRESS BASED ON BENDING='
1 ,E12.4,' PSI')
1 ' CRITICAL BUCKLING STRESS BASED ON COMPRESSION='
3 ,E12.4,' PSI')
FS=4.0
WRITE(3,3)FS
WRITE(4,3)FS
3 FORMAT(' FS=',F7.2)
SU=70000.
SAFSIG=SU/FS
FB=0.
IF(ITYPE.EQ.1)THEN
WRITE(5,4)
4 FORMAT(' ENTER FB IN LB')
READ(5,*)FB
ENDIF
WRITE(3,6)FB
WRITE(4,6)FB
6 FORMAT(' FB=',F10.2,' LBF')
WRITE(2,2777)
2777 FORMAT(' LB (FT) L (FT) DB = 36.5 37 38'
1 ' 39 40 41 42')
DO 800 I1=1,7
LB=LBT(I1)
I(I1.EQ.1)THEN
W=WV
WTH=WTHV
WRITE(3,21)LB
WRITE(4,21)LB
21 FORMAT(/' LB=',F7.3,' FEET (VERTICAL)')
ENDIF
IF(I1.NE.1)THEN
W=WH
WTH=WTHH
WRITE(3,22)LB
WRITE(4,22)LB
22 FORMAT(/' LB=',F7.3,' FEET (HORIZONTAL)')
ENDIF
DO 790 J=1,7
DB=DBT(J)
WRITE(3,32)DB
WRITE(4,32)DB
32 FORMAT(/' DB=',F7.3,' INCHES')
DBF=DB/12.
WRITE(3,61)
61 FORMAT(/1X,' L (FT) DELBM
1 (IN) ',
2 ' P (LB) SB (PSI) SI (PSI) SIG (PSI) '
3 ' CONTACT SIGTH (PSI) REST ' )
IF(I1.EQ.1)K1=5
IF(I1.EQ.2)K1=6
IF(I1.EQ.3)K1=7
IF(I1.EQ.4)K1=8
IF(I1.EQ.5)K1=9
IF(I1.EQ.6)K1=25
IF(I1.EQ.7)K1=27
DO 780 K=1,K1
L=LT(K)
DELB0=0.25+0.0000001
IFLAG=0
NI=10000
DIT=0.01
100 DO 400 I2=1,NI
DELB=DELB0+I2*DIT
DELB=DELB/12.
P=384.*E*M1/L**3*(DELB*(DBF+DOF)/2.)*W*L/2
MO=P*L/8.+W*L**2/12.
RL=E*M1/MO
RB=L**2/32./DELB+DELB/2.
IF(P.GT.0.)THEN
CONT='T'
SB=DOF*L/M1*(P/16.+W*L/24.)/144.
SBBC=E*DOF/(L**2/16./DELB+DELB*DBF+DOF)/144.
IF(SB.GT.SBBC)THEN
SB=SBBC
CONT='D'
RL=RB*DBF/2.+DOF/2.
ENDIF
FF=MU*LB/L*(2.*P+W*L)
IF(ITYPE.EQ.2.AND.I1.NE.1)FF=FF/2.

```



```

SI=4./PI/(DOF**2-DIF**2)*(FF+FB)/144.
SIG=SB+SI
GO TO 300
ENDIF
P=0.
CONT='H'
MO=W*L**2/12.
IF(W.EQ. 0.)THEN
  RL=1.0E+6
  GO TO 105
ENDIF
RL=E*MI/MO
105 SB=DOF/MI*W*L**2/24./144.
SBBCE=E*DOF/(L**2/16./DELBF+DELBF-DBF+DOF)/144.
IF(SB.GT. SBBCE)THEN
  SB=SBBCE
  CONT='B'
  RL=RB-DBF/2.+DOF/2.
ENDIF
FF=MU*W*LB
IF(ITYPE.EQ. 2.AND. I1.NE. 1)FF=FF/2.
SI=4./PI/(DOF**2-DIF**2)*(FF+FB)/144.
SIG=SB+SI
300 IF(IFLAG.EQ.4)GO TO 500
IF(SIG.GT. SAFSIG)GO TO 410
400 CONTINUE
410 DELB0=DELB-DIT
IFLAG=IFLAG+1
NI=10
IF(IFLAG.EQ.1)DIT=0.001
IF(IFLAG.EQ.2)DIT=0.0001
IF(IFLAG.EQ.3)DIT=0.00001
IF(IFLAG.EQ.4)THEN
  DIT=0.
  NI=1
ENDIF
GO TO 100
500 'RL.LT. RLMIN)THEN
  IF(CONT.NE. 'D')CONT='C'
  IF(CONT.EQ. 'D')CONT='Z'
ENDIF
IF(SIG.GT. SAFSIG)CONT='W'
DELBDB(J)=DELB
PTH=3B4.*E*MI/L**3*(DELBF-(DBF-DOF)/2.)*WTH*L/2
MOTH=PTH*L/8.+WTH*L**2/12.
IF(PTH.GT. 0.)THEN
  SBTH=DOF*L/MI*(PTH/16.+WTH*L/24.)/144.
  SBBCTH=E*DOF/(L**2/16./DELBF+DELBF-DBF+DOF)/144.
  IF(SBTH.GT. SBBCTH)THEN
    SBTH=SBBCTH
  ENDIF
  FFTH=MU*LB/L*(2.*PTH+WTH*L)
  FFTH=FFTH/2.
  IF(I1.EQ. 1)FFTH=FFTH*2.
  SITH=4./PI/(DOF**2-DIF**2)*FFTH/144.
  SIGTH=SBTH+SITH
  GO TO 520
ENDIF
PTH=0.
SBTH=DOF/MI*WTH*L**2/24./144.
SBBCTH=E*DOF/(L**2/16./DELBF+DELBF-DBF+DOF)/144.
IF(SBTH.GT. SBBCTH)THEN
  SBTH=SBBCTH
ENDIF
FFTH=MU*WTH*LB
FFTH=FFTH/2.
IF(I1.EQ. 1)FFTH=FFTH*2.
SITH=4./PI/(DOF**2-DIF**2)*FFTH/144.
SIGTH=SBTH+SITH
520 CONTINUE
REST='I'
IF(SIGTH.GE.SIG)REST='T'
WRITE(3,530)L,DELB,P,SB,SI,SIG,CONT,SIGTH,REST
530 FORMAT(1X,F12.1,1X,F12.5,1X,E12.1,
1 1X,F12.2,1X,F12.2,1X,F12.2,5X,A,4X,F12.2,4X,A1)
CONT='V'
IF(K.EQ.1)THEN
  LDUM=0.
  DELBDUM=(DB-DO)/2.
  WRITE(4,600)LDUM,DELBUM
ENDIF
WRITE(4,600)L,DELB
600 FORMAT(F10.1,' ',F10.5)
700 CONTINUE

```



```
790  CONTINUE
      WRITE(2,785)LB,L,DELBDB(1),DELBDB(2),DELBDB(3),DELBDB(4),
1    DELBDB(5),DELBDB(6),DELBDB(7)
785  FORMAT(4X,F4.0,8X,F4.0,8X,7(2X,F6.3))
800  CONTINUE
1000 CONTINUE
      END
```

A.2 Listing of PROGRAM STRESS1

This section of Appendix A lists a Fortran program (STRESS1.FOR) for computing the maximum liner stress as a function of deviation cycle amplitude and wavelength for liner insertion or post-emplacement liner loading in either horizontal or vertical boreholes drilled with a steerable bit. This program was used to generate the output listed in Table B.4 in Appendix B.

```

PROGRAM STRESS1
IMPLICIT REAL*8(A-H,L,M,O-Z)
REAL*8 DELBDB(7),DBT(7),LBT(6),LT(25),I
CHARACTER*1 CONT
OPEN(UNIT=2,NAME='TTABULAT.DAT',STATUS='NEW')
OPEN(UNIT=3,NAME='TABULAT.DAT',STATUS='NEW')
OPEN(UNIT=4,NAME='DELBVL.DAT',STATUS='NEW')
WRITE(3,6666)
6666 FORMAT(' RUN WITH STRESS1.FOR')
CONT='V'
DBT(1)=36.5
DBT(2)=37.
DBT(3)=38.
DBT(4)=39.
DBT(5)=40.
DBT(6)=41.
DBT(7)=42.
LBT(1)=350.
LT(1)=42.
LT(2)=58.
LT(3)=75.
LT(4)=80.
LT(5)=85.
LT(6)=90.
LT(7)=120.
LT(8)=140.
WRITE(5,6669)
6669 FORMAT(' LINER INSERTION (1) OR THERMAL EXPANSION (2) ?')
READ(5,*)ITYPE
IF(ITYPE .EQ. 1)WRITE(3,6670)
6670 FORMAT(' LINER INSERTION SPECIFIED')
IF(ITYPE .EQ. 2)WRITE(3,6671)
6671 FORMAT(' LINER THERMAL EXPANSION SPECIFIED')
PI=3.14159
E=30.0E+06*144.
MU=0.6
DO=36.
DOF=DO/12.
DI=35.
DIF=DI/12.
MI=PI/64.*(DOF**4-DIF**4)
GAM=489.0
WC=14985.
LC=16.7
W=PI/4.*(DOF**2-DIF**2)*GAM
IF(ITYPE .EQ. 2)W=W+WC/LC
DC=28.75
DCF=DC/12.
RLMIN=LC**2/8./(DIF-DCF)-DCF/2.
WRITE(5,6667)RLMIN
WRITE(3,6667)RLMIN
6667 FORMAT(' MINIMUM ALLOWABLE LINER RADIUS OF CURVATURE='
1 F10.2,' FT (BASED ON CONTAINER CLEARANCE)')
RNUF=1.-0.29**2
SIGCRTB=0.72*E/144.*((DIF+DOF)/4. )**2*(0.5/12)**2/RNUF/MI
SIGCRTC=0.6*E/144.*(0.5/12.)/((DIF+DOF)/4.)/(3**0.5)/RNUF**0.5
WRITE(5,6668)SIGCRTB,SIGCRTC
WRITE(3,6668)SIGCRTB,SIGCRTC
6668 FORMAT(' CRITICAL BUCKLING STRESS BASED ON BENDING='
1 ,E12.4,' PSI')
1 ,E12.4,' CRITICAL BUCKLING STRESS BASED ON COMPRESSION='
3 ,E12.4,' PSI')
FB=0.
IF(ITYPE .EQ. 1)THEN
WRITE(5,4)
4 FORMAT(' ENTER FB IN LB')
READ(5,*)FB
ENDIF
WRITE(3,6)FB
WRITE(4,6)FB
6 FORMAT(' FB=',F10.2,' LBF')
DO 800 I1=1,1
LB=LBT(I1)
WRITE(3,22)LB
WRITE(4,22)LB
22 FORMAT(' LB=',F7.3,' FEET (HORIZONTAL)')
DO 790 J=5,5
DB=DBT(J)
WRITE(3,32)DB
WRITE(4,32)DB
32 FORMAT(' DB=',F7.3,' INCHES')
DBF=DB/12.
WRITE(3,60)
60 FORMAT(' L (FT) DELBM

```

```

1 (IN) ',
2      P (LB)      SB (PS1)      SI (PS1)      SIG (PS1) '
3      CONTACT')
DO 780 K=1,8
L=LT(K)
NI=40
DIT=0.1
100 DO 400 I2=1,NI
DELBI=I2*DIT
DELBF=DELBI/12.
P=384.*E*M1/L**3*(DELBF*(DBF+DOF)/2.)*W*L/2
MO=P*L/8.+W*L**2/12.
RL=E*M1/MO
RB=L**2/32./DELBF+DELBF/2.
IF(P.GT. 0.)THEN
CONT='I'
SB=DOF*L/M1*(P/16.+W*L/24.)/144.
SBBC=E*DOF/(L**2/16./DELBF+DELBF*DBF+DOF)/144.
IF(SB.GT. SBBC)THEN
SB=SBBC
CONT='D'
RL=RB-DBF/2.+DOF/2.
ENDIF
FF=MU*LB/L*(2.*P+W*L)
IF(ITYPE.EQ. 2)FF=FF/2.
SI=4./PI/(DOF**2-DIF**2)*(FF+FB)/144.
SIG=SB+SI
GO TO 300
ENDIF
P=0.
CONT='H'
MO=W*L**2/12.
RL=E*M1/MO
SB=DOF/M1*W*L**2/24./144.
SBBC=E*DOF/(L**2/16./DELBF+DELBF*DBF+DOF)/144.
IF(SB.GT. SBBC)THEN
SB=SBBC
CONT='B'
RL=RB-DBF/2.+DOF/2.
ENDIF
FF=MU*W*LB
IF(ITYPE.EQ. 2)FF=FF/2.
SI=4./PI/(DOF**2-DIF**2)*(FF+FB)/144.
SIG=SB+SI
300 CONTINUE
305 IF(RL.LT. RLMIN)THEN
IF(CONT.NE. 'D')CONT='C'
IF(CONT.EQ. 'D')CONT='Z'
ENDIF
WRITE(3,310)L,DELBI,P,SB,SI,SIG,CONT
310 FORMAT(1X,F12.1,1X,F12.5,1X,E12.4,
1 1X,F12.2,1X,F12.2,1X,F12.2,5X,A1)
CONT='V'
WRITE(4,320)DELBI,SIG
320 FORMAT(F10.5,' ',E12.4)
400 CONTINUE
780 CONTINUE
790 CONTINUE
800 CONTINUE
1000 CONTINUE
END

```

A.3 Listing of PROGRAM DEVIAT2

This section of Appendix A lists a Fortran program (DEVIAT2.FOR) for computing the maximum allowable borehole deviation based on either liner insertion stresses or post-emplacement liner stresses in either horizontal or vertical boreholes drilled with a non-steerable bit. This program was used to generate the output listed in Tables B.1, B.2, and B.8 in Appendix B.

```

PROGRAM DEVIAT2
IMPLICIT REAL*8(A-H,L,M,O-Z)
REAL*8 DBT(7),LBT(7),I
CHARACTER*1 CONT,REST
OPEN(UNIT=3,NAME='TABULAT.DAT',STATUS='NEW')
OPEN(UNIT=4,NAME='DELBVL.DAT',STATUS='NEW')
CONT='V'
WRITE(3,6666)
6666 FORMAT(' RUN WITH DEVIAT2.FOR')
DBT(1)=36.5
DBT(2)=37.
DBT(3)=38.
DBT(4)=39.
DBT(5)=40.
DBT(6)=41.
DBT(7)=42.
LBT(1)=26.
LBT(2)=32.
LBT(3)=42.
LBT(4)=58.
LBT(5)=75.
LBT(6)=270.
LBT(7)=350.
WRITE(5,6669)
6669 FORMAT(' LINER INSERTION (1) OR POST-EMPLACEMENT (2) LOADING?')
READ(5,*)ITYPE
IF(ITYPE .EQ. 1)WRITE(3,6670)
6670 FORMAT(' LINER INSERTION LOADING SPECIFIED')
IF(ITYPE .EQ. 2)WRITE(3,6671)
6671 FORMAT(' POST-EMPLACEMENT LOADING SPECIFIED')
PI=3.14159
E=30.0E+06*144.
MU=0.6
DO=36.
DOF=DO/12.
DI=35.
DIF=DI/12.
MI=PI/64.*(DOF**4-DIF**4)
GAM=489.0
WC=14985.
LC=16.7
W=PI/4.*(DOF**2-DIF**2)*GAM
WTH=W+WC/LC
IF(ITYPE .EQ. 2)W=WTH
WH=W
WTHH=WTH
WV=0.
WTHV=0.
DC=28.75
DCF=DC/12.
RLMIN=LC**2/8./((DIF-DCF)-DCF/2.
WRITE(5,6667)RLMIN
WRITE(3,6667)RLMIN
6667 FORMAT(' MINIMUM ALLOWABLE LINER RADIUS OF CURVATURE='
1 F10.2,' FT (BASED ON CONTAINER CLEARANCE)')
RNUF=1.-0.29**2
SIGCRTB=0.72*E/144.*((DIF+DOF)/4.)*2*(0.5/12)**2/RNUF/MI
SIGCRTC=0.4*E/144.*((0.5/12.)/((DIF+DOF)/4.)/(3**0.5)/RNUF**0.5
WRITE(5,6668)SIGCRTB,SIGCRTC
WRITE(3,6668)SIGCRTB,SIGCRTC
6668 FORMAT(' CRITICAL BUCKLING STRESS BASED ON BENDING='
1 ,E12.4,' PSI')
1 , CRITICAL BUCKLING STRESS BASED ON COMPRESSION='
3 ,E12.4,' PSI')
FS=4.0
WRITE(3,3)FS
WRITE(4,3)FS
3 FORMAT(' FS=',F7.2)
SU=70000.
SAFSIG=SU/FS
FB=0.
IF(ITYPE .EQ. 1)THEN
WRITE(5,4)
4 FORMAT(' ENTER FB IN LB')
READ(5,*)FB
ENDIF
WRITE(3,6)FB
WRITE(4,6)FB
6 FORMAT(' FB=',F10.2,' LBF')
DO 800 I1=1,7
LB=LBT(I1)
L=LB/2.
IF(I1 .EQ. 1)THEN
W=WV

```

```

      WTH=WTHV
      WRITE(3,7)LB
      WRITE(4,7)LB
7     FORMAT(/' LB=',F7.3,' FEET (VERTICAL)')
      ENDIF
      IF(11.NE.1)THEN
        W=WH
        WTH=WTHH
        WRITE(3,8)LB
        WRITE(4,8)LB
8     FORMAT(/' LB=',F7.3,' FEET')
      ENDIF
      WRITE(3,13)
13    FORMAT(/1X,'DB (IN)      RB (FT)
1      DELBM (IN) ',
2      ' P (LB)      SB (PSI)      SI (PSI)      SIG (PSI) '
3      ' CONTACT      SIGTH (PSI) REST')
      DO 790 J=1,7
      DB=DBT(J)
      DBF=DB/12.
      IFLAG=0
      NI=1000
      DIT=500.
      RBO=0.
118   DO 400 IG=NI,1,-1
      RB=RBO+IG*DIT
      THBR=(LB/RB)
      CTH2=COS(THBR/2.)
      CTH=COS(THBR)
      DELB=RB*(1-CTH)*12.
      P=3.*E*MI/L**3*(RB*(1-CTH2)-(DBF-DOF)/2.*(1+CTH2))-3.*W*L/8.
      MX1=P*L+W*L**2/2.
      RL=E*MI/MX1
      IF(P.GT.0.)THEN
        CONT='T'
        SB=DOF*L/2./MI*(P+W*L/2.)/144.
        SBBC=E*DOF/(2.*RB-DBF+DOF)/144.
        IF(SB.GT.SBBC)THEN
          SB=SBBC
          CONT='D'
          RL=RB-DBF/2.+DOF/2.
        ENDIF
        FF=2.*MU*(2.*P+W*L)
        IF(ITYPE.EQ.2.AND.11.NE.1)FF=FF/2.
        SI=4./PI/(DOF**2-DIF**2)*(FF+FB)/144.
        SIG=SB+SI
        GO TO 300
      ENDIF
      P=0.
      CONT='H'
      MX1=W*L**2/2.
      IF(W.EQ.0)THEN
        RL=1.0E+06
        GO TO 290
      ENDIF
      RL=E*MI/MX1
290   SB=DOF*L/2./MI*(W*L/2.)/144.
      SBBC=E*DOF/(2.*RB-DBF+DOF)/144.
      IF(SB.GT.SBBC)THEN
        SB=SBBC
        CONT='B'
        RL=RB-DBF/2.+DOF/2.
      ENDIF
      FF=MU*W*LB
      IF(ITYPE.EQ.2.AND.11.NE.1)FF=FF/2.
      SI=4./PI/(DOF**2-DIF**2)*(FF+FB)/144.
      SIG=SB+SI
300   CONTINUE
      IF(SIG.GT.SAFSIG)GO TO 500
400   CONTINUE
      IF(IFLAG.EQ.4)GO TO 700
      RB=RB-DIT
500   RBO=RB
      IFLAG=IFLAG+1
      NI=100
      IF(IFLAG.EQ.1)DIT=5.
      IF(IFLAG.EQ.2)DIT=0.05
      IF(IFLAG.EQ.3)DIT=0.0005
      IF(IFLAG.EQ.4)THEN
        DIT=0.0005
        NI=1
      ENDIF
      GO TO 118
700   THEND=W*L**3/6./E/MI+P*L**2/2./E/MI

```

```

THMAX=THBR/2.
IF(THEND .GT. THMAX)THEN
  IF(CONT .EQ. 'T')CONT='A'
  IF(CONT .EQ. 'D')CONT='A'
ENDIF
IF(RL .LT. RLMIN)CONT='C'
IF(SIG. GT. SAFSIG)CONT='W'
PTH=3.*E*MI/L**3*(RB*(1-CTH2)·(DBF·DOF)/2.*(1+CTH2))-3.*WTH*L/8.
MX1TH=PTH*L+WTH*L**2/2.
IF(PTH .GT. 0.)THEN
  SBTH=DOF*L/2./MI*(PTH+WTH*L/2.)/144.
  SBBCTH=E*DOF/(2.*RB·DBF+DOF)/144.
  IF(SBTH .GT. SBBCTH)THEN
    SBTH=SBBCTH
  ENDIF
  FFTH=2.*MU*(2.*PTH+WTH*L)
  FFTH=FFTH/2.
  IF(I1 .EQ. 1)FFTH=FFTH*2.
  SITH=4./PI/(DOF**2·DIF**2)*FFTH/144.
  SIGTH=SBTH+SITH
  GO TO 708
ENDIF
PTH=0.
SBTH=DOF*L/2./MI*(WTH*L/2.)/144.
SBBCTH=E*DOF/(2.*RB·DBF+DOF)/144.
IF(SBTH .GT. SBBCTH)THEN
  SBTH=SBBCTH
ENDIF
FFTH=MU*WTH*LB
FFTH=FFTH/2.
IF(I1 .EQ. 1)FFTH=FFTH*2.
SITH=4./PI/(DOF**2·DIF**2)*FFTH/144.
SIGTH=SBTH+SITH
708 CONTINUE
REST='I'
IF(SIGTH .GE. SIG)REST='T'
WRITE(3,715)DB,RB,DELB,P,SB,S1,SIG,CONT,SIGTH,REST
715 FORMAT(1X,F6.2,1X,F12.1,1X,F12.5,1X,E12.4,
1 1X,F12.2,1X,F12.2,1X,F12.2,5X,A1,4X,F12.2,4X,A1)
CONT='V'
WRITE(4,720)DB,DELB
720 FORMAT(F10.1,' ',F10.5)
780 CONTINUE
790 CONTINUE
800 CONTINUE
1000 CONTINUE
END

```


A.4 Listing of PROGRAM STRESS2

This section of Appendix A lists a Fortran program (STRESS2.FOR) for computing the maximum liner stress as a function of deviation amplitude and borehole length for liner insertion or post-emplacement liner loading in either horizontal or vertical boreholes drilled with a non-steerable bit. This program was used to generate the output listed in Table B.3 in Appendix B.

```

PROGRAM STRESS2
IMPLICIT REAL*8(A-H,L,M,O-Z)
REAL*8 DELBDB(7),DBT(7),LBT(6),LT(25),I
CHARACTER*1 CONT
OPEN(UNIT=2,NAME='ITABULAT.DAT',STATUS='NEW')
OPEN(UNIT=3,NAME='TABULAT.DAT',STATUS='NEW')
OPEN(UNIT=4,NAME='DELBVL.DAT',STATUS='NEW')
WRITE(3,6666)
6666 FORMAT(' RUN WITH STRESS2.FOR')
CONT='V'
DBT(1)=40.
LBT(1)=32.
LBT(2)=42.
LBT(3)=58.
LBT(4)=75.
WRITE(5,6669)
6669 FORMAT(' LINER INSERTION (1) OR POST-EMPLACEMENT (2) LOADING?')
READ(5,*)ITYPE
IF(ITYPE .EQ. 1)WRITE(3,6670)
6670 FORMAT(' LINER INSERTION SPECIFIED')
IF(ITYPE .EQ. 2)WRITE(3,6671)
6671 FORMAT(' POST-EMPLACEMENT LOADING SPECIFIED')
PI=3.14159
E=30.0E+06*144.
MU=0.6
DO=36.
DOF=DO/12.
DI=35.
DIF=DI/12.
MI=PI/64.*(DOF**4-DIF**4)
GAM=489.0
WC=14985.
LC=16.7
W=PI/4.*(DOF**2-DIF**2)*GAM
IF(ITYPE .EQ. 2)W=W+WC/LC
DC=28.75
DCF=DC/12.
RLMIN=LC**2/8./((DIF-DCF)-DCF/2.
WRITE(5,6667)RLMIN
WRITE(3,6667)RLMIN
6667 FORMAT(' MINIMUM ALLOWABLE LINER RADIUS OF CURVATURE=',
1 F10.2,' FT (BASED ON CONTAINER CLEARANCE)')
RNUF=1.-0.29**2
SIGCRTB=0.72*E/144.*((DIF+DOF)/4.）**2*(0.5/12)**2/RNUF/MI
SIGCRTC=0.6*E/144.*((0.5/12.)/((DIF+DOF)/4.)/(3**0.5)/RNUF**0.5
WRITE(5,6668)SIGCRTB,SIGCRTC
WRITE(3,6668)SIGCRTB,SIGCRTC
6668 FORMAT(' CRITICAL BUCKLING STRESS BASED ON BENDING=',
1 ,E12.4,' PSI')
1 , CRITICAL BUCKLING STRESS BASED ON COMPRESSION='
3 ,E12.4,' PSI')
FB=0.
IF(ITYPE .EQ. 1)THEN
WRITE(5,4)
4 FORMAT(' ENTER FB IN LB')
READ(5,*)FB
ENDIF
WRITE(3,6)FB
WRITE(4,6)FB
6 FORMAT(' FB=',F10.2,' LBF')
DO 800 I1=1,4
LB=LBT(I1)
L=LB/2
WRITE(3,22)LB
WRITE(4,22)LB
22 FORMAT(' LB=',F7.3,' FEET (HORIZONTAL)')
DO 790 J=1,1
DB=DBT(J)
WRITE(3,32)DB
WRITE(4,32)DB
32 FORMAT(' DB=',F7.3,' INCHES')
DBF=DB/12.
WRITE(3,60)
60 FORMAT(/1X,' DB (IN) DELB
1 (IN) ',
2 ' P (LB) SB (PSI) SI (PSI) SIG (PSI) '
3 ' CONTACT')
NI=150
DI1=0.01
DO 400 I2=1,NI
THB=12*DI1
CTH2=COS(THB/2.)
RB=LB/THB
DELBFB=RB*(1-COS(THB))

```

```

DELB=DELB*12.
P=3.*E*M1/L**3*(RB*(1+CTH2)*(DBF*DOF)/2.*(1+CTH2))-3.*W*L/8.
MX1=P*L+W*L**2/2.
RL=E*M1/MX1
IF(P.GT. 0.)THEN
  CONT='I'
  SB=DOF*L/2./M1*(P+W*L/2.)/144.
  SBBC=E*DOF/(2.*RB*DBF+DOF)/144.
  IF(SB.GT. SBBC)THEN
    SB=SBBC
    CONT='D'
    RL=RB*DBF/2.+DOF/2.
  ENDIF
  FF=2.*MU*(2.*P+W*L)
  IF(ITYPE.EQ. 2)FF=FF/2.
  SI=4./PI/(DOF**2-DIF**2)*(FF+FB)/144.
  SIG=SB+SI
  GO TO 300
ENDIF
P=0.
CONT='H'
MX1=W*L**2/2.
RL=E*M1/MX1
SB=DOF*L/2./M1*(W*L/2.)/144.
SBBC=E*DOF/(2.*RB*DBF+DOF)/144.
IF(SB.GT. SBBC)THEN
  SB=SBBC
  CONT='B'
  RL=RB*DBF/2.+DOF/2.
ENDIF
FF=MU*W*LB
IF(ITYPE.EQ. 2)FF=FF/2.
SI=4./PI/(DOF**2-DIF**2)*(FF+FB)/144.
SIG=SB+SI
300 CONTINUE
305 IF(RL.LT. RLMIN)THEN
  IF(CONT.NE. 'D')CONT='C'
  IF(CONT.EQ. 'D')CONT='Z'
ENDIF
WRITE(3,310)DB,DELB,P,SB,SI,SIG,CONT
310 FORMAT(1X,F12.1,1X,F12.5,1X,E12.4,
1 1X,F12.2,1X,F12.2,1X,F12.2,5X,A1)
CONT='V'
WRITE(4,320)DELB,SIG
320 FORMAT(F10.5,' ',',',E12.4)
400 CONTINUE
780 CONTINUE
790 CONTINUE
800 CONTINUE
1000 CONTINUE
END

```

APPENDIX B
TABULATED PROGRAM OUTPUT

This appendix contains the output listings from the Fortran programs listed in Appendix A for the parametric study conditions. Nomenclature used in the tables in this appendix is listed below.

FS	= factor of safety, F_s
FB	= drilling thrust force transmitted to bit, F_b (lb)
LB	= borehole length, L_b (ft)
DB	= borehole diameter, d_b (in)
RB	= minimum allowable borehole radius of curvature based on stress (ft)
DELBM	= maximum allowable borehole deviation based on stress, $(\delta_b)_i$ or $(\delta_b)_p$, (lb/in ²)
P	= mid-point or end-point contact force between liner and borehole wall, P , under maximum allowable borehole deviation (lb)
SB	= liner bending stress, σ_B , under maximum allowable borehole deviation (lb/in ²)
SI	= longitudinal compressive stress due to liner insertion force, σ_i , or due to thermal expansion friction force, σ_{th} , under maximum allowable borehole deviation (lb/in ²)
SIG	= combined compressive stress in liner under maximum allowable borehole deviation, σ_{max} (lb/in ²)
SIGTH	= combined compressive stress in liner under maximum allowable borehole deviation, σ_{max} , assuming post-placement loading (lb/in ²)
CONTACT	= type of contact between the liner and the borehole wall; = T if the ends of the liner contact the top of the borehole wall ($P > 0$) <u>and</u> point contact with the bottom of the borehole wall is calculated = D if the ends of the liner contact the top of the borehole wall ($P > 0$) <u>and</u> distributed contact with the bottom of the borehole wall is calculated = H if the ends of the liner do not contact the top of the borehole wall ($P = 0$) <u>and</u> point contact with the bottom of the borehole wall is calculated = B if the ends of the liner do not contact the top of the borehole wall ($P = 0$) <u>and</u> distributed contact with the bottom of the borehole wall is calculated = C if contact (interference) between the waste container and the inside of the borehole liner is calculated = W if combined compressive liner stress is greater than the maximum allowable liner stress of 17,500 psi.

REST = flag for determining whether liner insertion loading or post-
 emplacement loading provides a greater restriction on the maximum
 allowable borehole deviation; valid only in tables for liner
 insertion stresses;
 = I if liner insertion stresses impose greater constraints on
 borehole deviation
 = T if post-emplacement (thermal) stresses impose greater
 constraints on borehole deviation

Table B.1 Maximum Allowable Borehole Deviation Based on Liner Insertion Stresses in Boreholes Drilled with a Non-Steerable Bit

This section of Appendix B lists the output file from PROGRAM DEVIAT1 for maximum allowable borehole deviation based on liner insertion stresses during liner insertion operations with no simultaneous drilling in horizontal and vertical boreholes drilled with a non-steerable bit.

The following parameter values were used in computing these results:

L_b = 26 ft (vertical borehole)

L_b = 32, 44, 58, 75, 270, and 350 feet (horizontal boreholes)

d_b = 36.5, 37, 38, 39, 40, 41, and 42 inches

F_b = 0 (no simultaneous drilling).

Other parameter values were fixed as listed in Section 5.2.

RUN WITH DEVIAT2.FOR
 LINER INSERTION LOADING SPECIFIED
 MINIMUM ALLOWABLE LINER RADIUS OF CURVATURE= 65.74 FT (BASED ON CONTAINER CLEARANCE)
 CRITICAL BUCKLING STRESS BASED ON BENDING= 0.2114E+06 PSI
 CRITICAL BUCKLING STRESS BASED ON COMPRESSION= 0.2039E+06 PSI
 FS= 4.00
 FB= 0.00 LBF

LB= 26.000 FEET (VERTICAL)

DB (IN)	RB (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	1385.8	2.92664	0.4826E+05	15422.99	2077.00	17499.99	T	17499.99	T
37.00	823.3	4.92619	0.4826E+05	15422.97	2076.99	17499.96	T	17499.96	T
38.00	454.4	8.92329	0.4826E+05	15422.99	2077.00	17499.99	T	17499.99	T
39.00	313.8	12.91604	0.4826E+05	15422.68	2076.95	17499.63	T	17499.63	T
40.00	239.7	16.90253	0.4826E+05	15422.46	2076.92	17499.30	T	17499.39	T
41.00	194.0	20.88082	0.4826E+05	15422.94	2076.99	17499.93	T	17499.93	T
42.00	162.9	24.84886	0.4825E+05	15421.76	2076.83	17498.58	T	17498.58	T

LB= 32.000 FEET

DB (IN)	RB (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	1795.3	3.42212	0.3859E+05	15774.02	1725.97	17499.99	T	17381.53	I
37.00	1133.1	5.42176	0.3859E+05	15774.03	1725.97	17500.00	T	17381.53	I
38.00	652.1	9.41960	0.3859E+05	15773.98	1725.96	17499.95	T	17381.48	I
39.00	457.8	13.41445	0.3859E+05	15773.88	1725.95	17499.83	T	17381.38	I
40.00	352.8	17.40503	0.3859E+05	15773.80	1725.94	17499.75	T	17381.30	I
41.00	286.9	21.39003	0.3859E+05	15773.85	1725.95	17499.80	T	17381.35	I
42.00	241.8	25.36818	0.3859E+05	15773.88	1725.95	17499.83	T	17381.38	I

LB= 42.000 FEET

DB (IN)	RB (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	2355.9	4.49248	0.2930E+05	16153.35	1346.65	17499.99	T	18093.38	T
37.00	1630.2	6.49217	0.2930E+05	16153.35	1346.65	17500.00	T	18093.38	T
38.00	1008.8	10.49060	0.2930E+05	16153.33	1346.64	17499.97	T	18093.36	T
39.00	730.4	14.48712	0.2930E+05	16153.30	1346.64	17499.94	T	18093.33	T
40.00	572.4	18.48100	0.2930E+05	16153.30	1346.64	17499.94	T	18093.33	T
41.00	470.7	22.47146	0.2930E+05	16153.29	1346.64	17499.93	T	18093.32	T
42.00	399.7	26.45775	0.2930E+05	16153.19	1346.63	17499.82	T	18093.22	T

LB= 58.000 FEET

DB (IN)	RB (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	2745.6	7.35116	0.2304E+05	16390.07	1109.93	17500.00	D	17015.03	I
37.00	2296.6	8.78812	0.2040E+05	16503.69	996.31	17499.99	T	19390.83	T
38.00	1578.3	12.78687	0.2040E+05	16503.68	996.31	17499.99	T	19390.82	T
39.00	1202.3	16.78444	0.2040E+05	16503.68	996.31	17499.99	T	19390.82	T
40.00	971.0	20.78042	0.2040E+05	16503.67	996.31	17499.98	T	19390.81	T
41.00	814.4	24.77443	0.2040E+05	16503.68	996.31	17499.99	T	19390.83	T
42.00	701.3	28.76605	0.2040E+05	16503.63	996.30	17499.94	T	19390.77	T

LB= 75.000 FEET

DB (IN)	RB (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	2728.4	12.36929	0.1983E+05	16493.55	1006.45	17500.00	D	17087.29	I
37.00	2699.8	12.50005	0.1578E+05	16668.07	831.93	17500.00	D	17174.55	I
38.00	2115.9	15.94868	0.1459E+05	16719.44	780.55	17499.99	T	21077.86	T
39.00	1691.7	19.94664	0.1459E+05	16719.45	780.55	17500.00	T	21077.86	T
40.00	1409.2	23.94349	0.1459E+05	16719.45	780.55	17500.00	T	21077.86	T
41.00	1207.6	27.93900	0.1459E+05	16719.43	780.55	17499.98	T	21077.85	T
42.00	1056.5	31.93294	0.1459E+05	16719.44	780.55	17499.99	T	21077.85	T

LB=270.000 FEET

DB (IN)	RB (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	2654.9	164.60952	0.0000E+00	16949.87	550.13	17500.00	B	18528.33	T
37.00	2654.9	164.60822	0.0000E+00	16949.87	550.13	17500.00	B	18528.33	T
38.00	2655.0	164.60566	0.0000E+00	16949.87	550.13	17500.00	B	18528.33	T
39.00	2655.0	164.60309	0.0000E+00	16949.87	550.13	17500.00	B	18528.34	T
40.00	2655.1	164.60049	0.0000E+00	16949.87	550.13	17500.00	B	18528.33	T
41.00	2655.1	164.59792	0.0000E+00	16949.87	550.13	17500.00	B	18528.33	T
42.00	2655.1	164.59535	0.0000E+00	16949.87	550.13	17500.00	B	18528.34	T

LB=350.000 FEET

DB (IN)	RB (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	2680.7	273.79417	0.0000E+00	16786.87	713.13	17500.00	B	18833.03	T
37.00	2680.7	273.79208	0.0000E+00	16786.87	713.13	17500.00	B	18833.03	T
38.00	2680.7	273.78781	0.0000E+00	16786.87	713.13	17500.00	B	18833.03	T
39.00	2680.8	273.78358	0.0000E+00	16786.87	713.13	17500.00	B	18833.03	T
40.00	2680.8	273.77935	0.0000E+00	16786.87	713.13	17500.00	B	18833.03	T
41.00	2680.9	273.77508	0.0000E+00	16786.87	713.13	17500.00	B	18833.03	T
42.00	2680.9	273.77085	0.0000E+00	16786.87	713.13	17500.00	B	18833.03	T

Table B.2 Maximum Allowable Borehole Deviation Based on Post-Emplacement
Liner Stresses in Boreholes Drilled with a Non-Steerable Bit

This section of Appendix B lists the output file from PROGRAM DEVIAT1 for maximum allowable borehole deviation based on post-emplacement liner stresses in horizontal and vertical boreholes drilled with a non-steerable bit.

The following parameter values were used in computing these results:

$L_b = 26$ ft (vertical borehole)

$L_b = 32, 42, 58, 75, 270,$ and 350 feet (horizontal boreholes)

$d_b = 36.5, 37, 38, 39, 40, 41,$ and 42 inches

$F_b = 0.$

Other parameter values were fixed as listed in Section 5.2.

RUN WITH DEVIAT2.FOR
 POST-EMPLACEMENT LOADING SPECIFIED
 MINIMUM ALLOWABLE LINER RADIUS OF CURVATURE= 65.74 FT (BASED ON CONTAINER CLEARANCE)
 CRITICAL BUCKLING STRESS BASED ON BENDING= 0.2114E+06 PSI
 CRITICAL BUCKLING STRESS BASED ON COMPRESSION= 0.2039E+06 PSI
 FS= 4.00
 FB= 0.00 LBF

LB= 26.000 FEET (VERTICAL)

DB (IN)	RB (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	1385.8	2.92664	0.4826E+05	15422.99	2077.00	17499.99	T	17499.99	T
37.00	823.3	4.92619	0.4826E+05	15422.97	2076.99	17499.96	T	17499.96	T
38.00	454.4	8.92329	0.4826E+05	15422.99	2077.00	17499.99	T	17499.99	T
39.00	313.8	12.91604	0.4826E+05	15422.68	2076.95	17499.63	T	17499.63	T
40.00	239.7	16.90253	0.4826E+05	15422.46	2076.92	17499.39	T	17499.39	T
41.00	194.0	20.88082	0.4826E+05	15422.94	2076.99	17499.93	T	17499.93	T
42.00	162.9	24.84886	0.4825E+05	15421.76	2076.83	17498.58	T	17498.58	T

LB= 32.000 FEET

DB (IN)	RB (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	1790.0	3.43234	0.3349E+05	16592.25	907.75	17499.99	T	17499.99	T
37.00	1131.0	5.43198	0.3349E+05	16592.25	907.75	17500.00	T	17500.00	T
38.00	651.4	9.42982	0.3349E+05	16592.23	907.75	17499.98	T	17499.98	T
39.00	457.5	13.42466	0.3349E+05	16592.12	907.74	17499.86	T	17499.86	T
40.00	352.6	17.41523	0.3349E+05	16592.10	907.74	17499.84	T	17499.84	T
41.00	286.8	21.40023	0.3349E+05	16592.20	907.75	17499.94	T	17499.94	T
42.00	241.7	25.37833	0.3349E+05	16591.88	907.73	17499.61	T	17499.61	T

LB= 42.000 FEET

DB (IN)	RB (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	2403.7	4.40316	0.2113E+05	16799.73	700.27	17500.00	T	17500.00	T
37.00	1652.9	6.40287	0.2113E+05	16799.73	700.27	17500.00	T	17500.00	T
38.00	1017.4	10.40133	0.2113E+05	16799.73	700.27	17500.00	T	17500.00	T
39.00	734.9	14.39789	0.2113E+05	16799.70	700.27	17499.97	T	17499.97	T
40.00	575.2	18.39182	0.2113E+05	16799.71	700.27	17499.98	T	17499.98	T
41.00	472.6	22.38235	0.2113E+05	16799.63	700.26	17499.90	T	17499.90	T
42.00	401.0	26.36875	0.2113E+05	16799.70	700.27	17499.97	T	17499.97	T

LB= 58.000 FEET

DB (IN)	RB (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	2670.0	7.55924	0.1426E+05	16854.03	645.97	17500.00	D	17500.00	T
37.00	2449.6	8.23937	0.8070E+04	16987.25	512.75	17500.00	T	17500.00	T
38.00	1649.1	12.23823	0.8070E+04	16987.24	512.75	17499.99	T	17499.99	T
39.00	1242.9	16.23595	0.8070E+04	16987.24	512.75	17499.99	T	17499.99	T
40.00	997.3	20.23213	0.8070E+04	16987.22	512.75	17499.97	T	17499.97	T
41.00	832.8	24.22639	0.8070E+04	16987.24	512.75	17499.99	T	17499.99	T
42.00	714.9	28.21831	0.8070E+04	16987.24	512.75	17499.99	T	17499.99	T

LB= 75.000 FEET

DB (IN)	RB (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	2664.0	12.66829	0.7864E+04	16892.30	607.70	17500.00	D	17500.00	T
37.00	2649.8	12.73583	0.3672E+04	16982.51	517.49	17500.00	D	17500.00	T
38.00	2637.6	12.79489	0.0000E+00	17061.54	438.46	17500.00	B	17500.00	T
39.00	2637.6	12.79468	0.0000E+00	17061.54	438.46	17500.00	B	17500.00	T
40.00	2637.7	12.79448	0.0000E+00	17061.54	438.46	17500.00	B	17500.00	T
41.00	2637.7	12.79428	0.0000E+00	17061.54	438.46	17500.00	B	17500.00	T
42.00	2637.8	12.79408	0.0000E+00	17061.54	438.46	17500.00	B	17500.00	T

LB=270.000 FEET

DB (IN)	RB (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	2826.4	154.63855	0.0000E+00	15921.54	1578.46	17500.00	B	17500.00	T
37.00	2826.4	154.63741	0.0000E+00	15921.54	1578.46	17500.00	B	17500.00	T
38.00	2826.4	154.63514	0.0000E+00	15921.54	1578.46	17500.00	B	17500.00	T
39.00	2826.5	154.63284	0.0000E+00	15921.54	1578.46	17500.00	B	17500.00	T
40.00	2826.5	154.63058	0.0000E+00	15921.54	1578.46	17500.00	B	17500.00	T
41.00	2826.6	154.62831	0.0000E+00	15921.54	1578.46	17500.00	B	17500.00	T
42.00	2826.6	154.62602	0.0000E+00	15921.54	1578.46	17500.00	B	17500.00	T

LB=350.000 FEET

DB (IN)	RB (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	2911.9	252.10726	0.0000E+00	15453.85	2046.15	17500.00	B	17500.00	T
37.00	2911.9	252.10545	0.0000E+00	15453.84	2046.15	17500.00	B	17500.00	T
38.00	2912.0	252.10186	0.0000E+00	15453.85	2046.15	17500.00	B	17500.00	T
39.00	2912.0	252.09828	0.0000E+00	15453.85	2046.15	17500.00	B	17500.00	T
40.00	2912.1	252.09465	0.0000E+00	15453.84	2046.15	17500.00	B	17500.00	T
41.00	2912.1	252.09107	0.0000E+00	15453.85	2046.15	17500.00	B	17500.00	T
42.00	2912.1	252.08748	0.0000E+00	15453.85	2046.15	17500.00	B	17500.00	T

Table B.3 Post-Emplacement Liner Stresses in Horizontal Boreholes Drilled with a Non-Steerable Bit

This section of Appendix B lists the output file from PROGRAM STRESS1 for maximum liner stresses based on post-emplacement loading in 40-inch-diameter horizontal boreholes drilled with a non-steerable bit.

The following parameter values were used in computing these results:

$L_b = 32, 42, 58, 75$ feet (horizontal)

$d_b = 40$ inches

$F_b = 0.$

Other parameter values were fixed as listed in Section 5.2.

RUN WITH STRESS2.FOR
 POST-EMPLACEMENT LOADING SPECIFIED
 MINIMUM ALLOWABLE LINER RADIUS OF CURVATURE= 65.74 FT (BASED ON CONTAINER CLEARANCE)
 CRITICAL BUCKLING STRESS BASED ON BENDING= 0.2114E+06 PSI
 CRITICAL BUCKLING STRESS BASED ON COMPRESSION= 0.3059E+06 PSI
 FB= 0.00 LBF

LB= 32.000 FEET (HORIZONTAL)

DB= 40.000 INCHES

DB (IN)	DEL B (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT
40.0	1.91998	0.0000E+00	3419.48	187.08	3606.56	H
40.0	3.83987	0.0000E+00	3419.48	187.08	3606.56	H
40.0	5.75957	0.0000E+00	3419.48	187.08	3606.56	H
40.0	7.67898	0.0000E+00	3419.48	187.08	3606.56	H
40.0	9.59800	0.0000E+00	3419.48	187.08	3606.56	H
40.0	11.51654	0.0000E+00	3419.48	187.08	3606.56	H
40.0	13.43451	0.0000E+00	3419.48	187.08	3606.56	H
40.0	15.35181	0.0000E+00	3419.48	187.08	3606.56	H
40.0	17.26834	0.2938E+05	14974.31	819.23	15793.54	T
40.0	19.18401	0.8303E+05	36077.02	1973.74	38050.76	T
40.0	21.09871	0.1367E+06	57179.29	3128.23	60307.52	T
40.0	23.01237	0.1903E+06	78280.85	4282.68	82563.53	T

LB= 42.000 FEET (HORIZONTAL)

DB= 40.000 INCHES

DB (IN)	DEL B (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT
40.0	2.51998	0.0000E+00	5890.59	245.54	6136.12	H
40.0	5.03983	0.0000E+00	5890.59	245.54	6136.12	H
40.0	7.55943	0.0000E+00	5890.59	245.54	6136.12	H
40.0	10.07866	0.0000E+00	5890.59	245.54	6136.12	H
40.0	12.59738	0.0000E+00	5890.59	245.54	6136.12	H
40.0	15.11546	0.0000E+00	5890.59	245.54	6136.12	H
40.0	17.63280	0.1174E+05	11951.59	498.18	12449.77	T
40.0	20.14925	0.4288E+05	28026.93	1168.25	29195.18	T
40.0	22.66470	0.7402E+05	44101.93	1838.31	45940.24	T
40.0	25.17901	0.1052E+06	60176.40	2508.34	62684.74	T
40.0	27.69206	0.1363E+06	76250.13	3178.35	79428.48	T
40.0	30.20373	0.1674E+06	92322.93	3848.32	96171.25	T

LB= 58.000 FEET (HORIZONTAL)

DB= 40.000 INCHES

DB (IN)	DEL B (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT
40.0	3.47997	0.0000E+00	7758.84	339.08	8097.92	B
40.0	6.95977	0.0000E+00	11233.52	339.08	11572.60	H
40.0	10.43922	0.0000E+00	11233.52	339.08	11572.60	H
40.0	13.91814	0.0000E+00	11233.52	339.08	11572.60	H
40.0	17.39638	0.0000E+00	11233.52	339.08	11572.60	H
40.0	20.87374	0.1108E+05	19135.04	577.58	19712.62	T
40.0	24.35005	0.2741E+05	30774.24	928.90	31703.14	T
40.0	27.82516	0.4373E+05	42413.09	1280.21	43693.30	T
40.0	31.29886	0.6006E+05	54051.44	1631.51	55682.95	T
40.0	34.77101	0.7638E+05	65689.15	1982.79	67671.94	T
40.0	38.24142	0.9270E+05	77326.08	2334.04	79660.12	T
40.0	41.70991	0.1090E+06	88962.07	2685.27	91647.34	T

LB= 75.000 FEET (HORIZONTAL)

DB= 40.000 INCHES

DB (IN)	DEL B (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT
40.0	4.49996	0.0000E+00	6000.13	438.46	6438.59	B
40.0	8.99970	0.0000E+00	12000.53	438.46	12438.99	B
40.0	13.49899	0.0000E+00	18001.20	438.46	18439.66	B
40.0	17.99760	0.0000E+00	18783.76	438.46	19222.22	H
40.0	22.49531	0.0000E+00	18783.76	438.46	19222.22	H
40.0	26.99190	0.8586E+04	26699.09	623.23	27322.31	T
40.0	31.48714	0.1835E+05	35699.31	833.31	36532.62	T
40.0	35.98080	0.2811E+05	44699.14	1043.39	45742.53	T
40.0	40.47267	0.3787E+05	53698.47	1253.46	54951.93	T
40.0	44.96251	0.4763E+05	60013.34	1463.51	61476.85	D
40.0	49.45011	0.5739E+05	66016.14	1673.55	67689.69	D
40.0	53.93523	0.6711E+05	72019.21	1883.57	73902.77	D
40.0	58.41766	0.7691E+05	78022.54	2093.56	80116.10	D
40.0	62.89717	0.8667E+05	84026.14	2303.53	86329.67	D
40.0	67.37353	0.9642E+05	90030.01	2513.48	92543.49	D
40.0	71.84653	0.1062E+06	96034.15	2723.39	98757.53	D

Table B.4 Post-Emplacement Liner Stresses in a Horizontal Borehole Drilled with a Steerable Bit

This section of Appendix B lists the output file from PROGRAM STRESS2 for maximum liner stresses based on post-emplacement loading in a 40-inch-diameter, 350-ft-long horizontal borehole drilled with a steerable bit.

The following parameter values were used in computing these results:

$L_b = 350$ feet (horizontal)

$d_b = 40$ inches

$F_b = 0$

$L = 0$ to L_b .

Other parameter values were fixed as listed in Section 5.2.

RUN WITH STRESS1.FOR
 LINER THERMAL EXPANSION SPECIFIED
 MINIMUM ALLOWABLE LINER RADIUS OF CURVATURE= 65.74 FT (BASED ON CONTAINER CLEARANCE)
 CRITICAL BUCKLING STRESS BASED ON BENDING= 0.2114E+06 PSI
 CRITICAL BUCKLING STRESS BASED ON COMPRESSION= 0.3059E+06 PSI
 FB= 0.00 LBF

LB=350.000 FEET (HORIZONTAL)

DB= 40.000 INCHES

L (FT)	DELM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT
42.0	0.10000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	0.20000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	0.30000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	0.40000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	0.50000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	0.60000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	0.70000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	0.80000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	0.90000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	1.00000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	1.10000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	1.20000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	1.30000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	1.40000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	1.50000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	1.60000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	1.70000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	1.80000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	1.90000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	2.00000	0.0000E+00	3927.06	2046.15	5973.21	H
42.0	2.10000	0.5624E+05	11185.85	7088.98	18274.83	T
42.0	2.20000	0.1353E+06	21389.93	14177.96	35567.89	T
42.0	2.30000	0.2144E+06	31594.01	21266.94	52860.95	T
42.0	2.40000	0.2934E+06	41798.09	28355.92	70154.01	T
42.0	2.50000	0.3725E+06	52002.17	35444.90	87447.07	T
58.0	0.10000	0.0000E+00	3567.23	2046.15	5613.38	B
58.0	0.20000	0.0000E+00	7134.54	2046.15	9180.70	B
58.0	0.30000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	0.40000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	0.50000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	0.60000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	0.70000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	0.80000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	0.90000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	1.00000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	1.10000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	1.20000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	1.30000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	1.40000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	1.50000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	1.60000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	1.70000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	1.80000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	1.90000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	2.00000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	2.10000	0.0000E+00	7489.01	2046.15	9535.17	H
58.0	2.20000	0.2853E+05	12573.80	3898.51	16472.31	T
58.0	2.30000	0.5855E+05	17924.57	5847.77	23772.34	T
58.0	2.40000	0.8857E+05	23275.35	7797.02	31072.37	T
58.0	2.50000	0.1186E+06	28626.12	9746.28	38372.40	T
58.0	2.60000	0.1486E+06	33976.89	11695.54	45672.43	T
58.0	2.70000	0.1786E+06	39327.66	13644.79	52972.46	T
58.0	2.80000	0.2087E+06	44678.44	15594.05	60272.49	T
58.0	2.90000	0.2387E+06	50029.21	17543.31	67572.52	T
58.0	3.00000	0.2687E+06	55379.98	19492.56	74872.54	T
58.0	3.10000	0.2987E+06	60730.76	21441.82	82172.57	T
58.0	3.20000	0.3287E+06	66081.53	23391.07	89472.60	T
58.0	3.30000	0.3588E+06	71432.30	25340.33	96772.63	T
75.0	0.10000	0.0000E+00	2133.35	2046.15	4179.50	B
75.0	0.20000	0.0000E+00	4266.73	2046.15	6312.88	B
75.0	0.30000	0.0000E+00	6400.14	2046.15	8446.29	B
75.0	0.40000	0.0000E+00	8533.58	2046.15	10579.73	B
75.0	0.50000	0.0000E+00	10667.04	2046.15	12713.19	B
75.0	0.60000	0.0000E+00	12522.50	2046.15	14568.66	H
75.0	0.70000	0.0000E+00	12522.50	2046.15	14568.66	H
75.0	0.80000	0.0000E+00	12522.50	2046.15	14568.66	H
75.0	0.90000	0.0000E+00	12522.50	2046.15	14568.66	H
75.0	1.00000	0.0000E+00	12522.50	2046.15	14568.66	H
75.0	1.10000	0.0000E+00	12522.50	2046.15	14568.66	H
75.0	1.20000	0.0000E+00	12522.50	2046.15	14568.66	H
75.0	1.30000	0.0000E+00	12522.50	2046.15	14568.66	H
75.0	1.40000	0.0000E+00	12522.50	2046.15	14568.66	H

75.0	1.50000	0.0000E+00	12522.50	2046.15	14568.66	H
75.0	1.60000	0.0000E+00	12522.50	2046.15	14568.66	H
75.0	1.70000	0.0000E+00	12522.50	2046.15	14568.66	H
75.0	1.80000	0.0000E+00	12522.50	2046.15	14568.66	H
75.0	1.90000	0.0000E+00	12522.50	2046.15	14568.66	H
75.0	2.00000	0.0000E+00	12522.50	2046.15	14568.66	H
75.0	2.10000	0.0000E+00	12522.50	2046.15	14568.66	H
75.0	2.20000	0.0000E+00	12522.50	2046.15	14568.66	H
75.0	2.30000	0.9030E+03	12730.63	2091.50	14822.12	T
75.0	2.40000	0.1479E+05	15930.63	2788.66	18719.29	T
75.0	2.50000	0.2867E+05	19130.63	3485.83	22616.45	T
75.0	2.60000	0.4256E+05	22330.63	4182.99	26513.62	T
75.0	2.70000	0.5644E+05	25530.63	4880.16	30410.78	T
75.0	2.80000	0.7032E+05	28730.63	5577.32	34307.95	T
75.0	2.90000	0.8421E+05	31930.63	6274.49	38205.11	T
75.0	3.00000	0.9809E+05	35130.63	6971.65	42102.28	T
75.0	3.10000	0.1120E+06	38330.63	7668.82	45999.45	T
75.0	3.20000	0.1259E+06	41530.63	8365.99	49896.61	T
75.0	3.30000	0.1397E+06	44730.63	9063.15	53793.78	T
75.0	3.40000	0.1536E+06	47930.63	9760.32	57690.94	T
75.0	3.50000	0.1675E+06	51130.63	10457.48	61588.11	T
75.0	3.60000	0.1814E+06	54330.63	11154.65	65485.27	T
75.0	3.70000	0.1953E+06	57530.63	11851.81	69382.44	T
75.0	3.80000	0.2092E+06	60730.63	12548.98	73279.60	T
75.0	3.90000	0.2231E+06	63930.63	13246.14	77176.77	T
75.0	4.00000	0.2369E+06	67130.63	13943.31	81073.93	T
80.0	0.10000	0.0000E+00	1875.01	2046.15	3921.17	B
80.0	0.20000	0.0000E+00	3750.05	2046.15	5796.20	B
80.0	0.30000	0.0000E+00	5625.11	2046.15	7671.26	B
80.0	0.40000	0.0000E+00	7500.19	2046.15	9546.34	B
80.0	0.50000	0.0000E+00	9375.28	2046.15	11421.44	B
80.0	0.60000	0.0000E+00	11250.40	2046.15	13296.55	B
80.0	0.70000	0.0000E+00	13125.53	2046.15	15171.68	B
80.0	0.80000	0.0000E+00	14247.83	2046.15	16293.98	H
80.0	0.90000	0.0000E+00	14247.83	2046.15	16293.98	H
80.0	1.00000	0.0000E+00	14247.83	2046.15	16293.98	H
80.0	1.10000	0.0000E+00	14247.83	2046.15	16293.98	H
80.0	1.20000	0.0000E+00	14247.83	2046.15	16293.98	H
80.0	1.30000	0.0000E+00	14247.83	2046.15	16293.98	H
80.0	1.40000	0.0000E+00	14247.83	2046.15	16293.98	H
80.0	1.50000	0.0000E+00	14247.83	2046.15	16293.98	H
80.0	1.60000	0.0000E+00	14247.83	2046.15	16293.98	H
80.0	1.70000	0.0000E+00	14247.83	2046.15	16293.98	H
80.0	1.80000	0.0000E+00	14247.83	2046.15	16293.98	H
80.0	1.90000	0.0000E+00	14247.83	2046.15	16293.98	H
80.0	2.00000	0.0000E+00	14247.83	2046.15	16293.98	H
80.0	2.10000	0.0000E+00	14247.83	2046.15	16293.98	H
80.0	2.20000	0.0000E+00	14247.83	2046.15	16293.98	H
80.0	2.30000	0.0000E+00	14247.83	2046.15	16293.98	H
80.0	2.40000	0.2295E+04	14811.96	2154.17	16966.13	T
80.0	2.50000	0.1374E+05	17624.46	2692.72	20317.18	T
80.0	2.60000	0.2518E+05	20436.96	3231.26	23668.22	T
80.0	2.70000	0.3662E+05	23249.46	3769.81	27019.26	T
80.0	2.80000	0.4806E+05	26061.96	4308.35	30370.31	T
80.0	2.90000	0.5950E+05	28874.46	4846.89	33721.35	T
80.0	3.00000	0.7094E+05	31686.96	5385.44	37072.39	T
80.0	3.10000	0.8238E+05	34499.46	5923.98	40423.44	T
80.0	3.20000	0.9382E+05	37311.96	6462.52	43774.48	T
80.0	3.30000	0.1053E+06	40124.46	7001.07	47125.52	T
80.0	3.40000	0.1167E+06	42936.96	7539.61	50476.57	T
80.0	3.50000	0.1281E+06	45749.46	8078.16	53827.61	T
80.0	3.60000	0.1396E+06	48561.96	8616.70	57178.66	T
80.0	3.70000	0.1510E+06	51374.46	9155.24	60529.70	T
80.0	3.80000	0.1625E+06	54186.96	9693.79	63880.74	T
80.0	3.90000	0.1739E+06	56999.46	10232.33	67231.79	T
80.0	4.00000	0.1853E+06	59811.96	10770.87	70582.83	T
85.0	0.10000	0.0000E+00	1660.91	2046.15	3707.06	B
85.0	0.20000	0.0000E+00	3321.84	2046.15	5367.99	B
85.0	0.30000	0.0000E+00	4982.78	2046.15	7028.94	B
85.0	0.40000	0.0000E+00	6643.75	2046.15	8689.90	B
85.0	0.50000	0.0000E+00	8304.72	2046.15	10350.88	B
85.0	0.60000	0.0000E+00	9965.71	2046.15	12011.86	B
85.0	0.70000	0.0000E+00	11626.71	2046.15	13672.86	B
85.0	0.80000	0.0000E+00	13287.72	2046.15	15333.87	B
85.0	0.90000	0.0000E+00	14948.74	2046.15	16994.89	B
85.0	1.00000	0.0000E+00	16084.46	2046.15	18130.61	H
85.0	1.10000	0.0000E+00	16084.46	2046.15	18130.61	H
85.0	1.20000	0.0000E+00	16084.46	2046.15	18130.61	H
85.0	1.30000	0.0000E+00	16084.46	2046.15	18130.61	H
85.0	1.40000	0.0000E+00	16084.46	2046.15	18130.61	H
85.0	1.50000	0.0000E+00	16084.46	2046.15	18130.61	H
85.0	1.60000	0.0000E+00	16084.46	2046.15	18130.61	H
85.0	1.70000	0.0000E+00	16084.46	2046.15	18130.61	H
85.0	1.80000	0.0000E+00	16084.46	2046.15	18130.61	H

85.0	1.90000	0.0000E+00	16084.46	2046.15	18130.61	H
85.0	2.00000	0.0000E+00	16084.46	2046.15	18130.61	H
85.0	2.10000	0.0000E+00	16084.46	2046.15	18130.61	H
85.0	2.20000	0.0000E+00	16084.46	2046.15	18130.61	H
85.0	2.30000	0.0000E+00	16084.46	2046.15	18130.61	H
85.0	2.40000	0.0000E+00	16084.46	2046.15	18130.61	H
85.0	2.50000	0.1506E+04	16477.86	2112.88	18590.74	T
85.0	2.60000	0.1104E+05	18969.21	2535.46	21504.67	T
85.0	2.70000	0.2058E+05	21460.56	2958.03	24418.60	T
85.0	2.80000	0.3012E+05	23951.91	3380.61	27332.52	T
85.0	2.90000	0.3966E+05	26443.26	3803.19	30246.45	T
85.0	3.00000	0.4920E+05	28934.61	4225.76	33160.37	T
85.0	3.10000	0.5873E+05	31425.96	4648.34	36074.30	T
85.0	3.20000	0.6827E+05	33917.31	5070.92	38988.23	T
85.0	3.30000	0.7781E+05	36408.66	5493.49	41902.15	T
85.0	3.40000	0.8735E+05	38900.01	5916.07	44816.08	T
85.0	3.50000	0.9689E+05	41391.36	6338.65	47730.00	T
85.0	3.60000	0.1064E+06	43882.71	6761.22	50643.93	T
85.0	3.70000	0.1160E+06	46374.06	7183.80	53557.85	T
85.0	3.80000	0.1255E+06	48865.41	7606.37	56471.78	T
85.0	3.90000	0.1350E+06	51355.76	8028.95	59385.71	T
85.0	4.00000	0.1446E+06	53848.10	8451.53	62299.63	T
90.0	0.10000	0.0000E+00	1481.49	2046.15	3527.64	B
90.0	0.20000	0.0000E+00	2962.99	2046.15	5009.15	B
90.0	0.30000	0.0000E+00	4444.51	2046.15	6490.67	B
90.0	0.40000	0.0000E+00	5926.04	2046.15	7972.20	B
90.0	0.50000	0.0000E+00	7407.59	2046.15	9453.74	B
90.0	0.60000	0.0000E+00	8889.14	2046.15	10935.29	B
90.0	0.70000	0.0000E+00	10370.70	2046.15	12416.85	B
90.0	0.80000	0.0000E+00	11852.27	2046.15	13898.42	B
90.0	0.90000	0.0000E+00	13333.84	2046.15	15380.00	B
90.0	1.00000	0.0000E+00	14815.42	2046.15	16861.58	B
90.0	1.10000	0.0000E+00	16297.01	2046.15	18343.16	B
90.0	1.20000	0.0000E+00	17778.60	2046.15	19824.75	B
90.0	1.30000	0.0000E+00	18032.41	2046.15	20078.56	H
90.0	1.40000	0.0000E+00	18032.41	2046.15	20078.56	H
90.0	1.50000	0.0000E+00	18032.41	2046.15	20078.56	H
90.0	1.60000	0.0000E+00	18032.41	2046.15	20078.56	H
90.0	1.70000	0.0000E+00	18032.41	2046.15	20078.56	H
90.0	1.80000	0.0000E+00	18032.41	2046.15	20078.56	H
90.0	1.90000	0.0000E+00	18032.41	2046.15	20078.56	H
90.0	2.00000	0.0000E+00	18032.41	2046.15	20078.56	H
90.0	2.10000	0.0000E+00	18032.41	2046.15	20078.56	H
90.0	2.20000	0.0000E+00	18032.41	2046.15	20078.56	H
90.0	2.30000	0.0000E+00	18032.41	2046.15	20078.56	H
90.0	2.40000	0.0000E+00	18032.41	2046.15	20078.56	H
90.0	2.50000	0.0000E+00	18032.41	2046.15	20078.56	H
90.0	2.60000	0.0000E+00	18032.41	2046.15	20078.56	H
90.0	2.70000	0.7344E+04	20063.66	2353.47	22417.13	T
90.0	2.80000	0.1538E+05	22285.88	2609.68	24975.56	T
90.0	2.90000	0.2341E+05	24508.10	3025.89	27533.99	T
90.0	3.00000	0.3145E+05	26730.32	3362.10	30092.43	T
90.0	3.10000	0.3948E+05	28952.55	3698.31	32650.86	T
90.0	3.20000	0.4752E+05	31174.77	4034.52	35209.29	T
90.0	3.30000	0.5555E+05	33396.99	4370.73	37767.72	T
90.0	3.40000	0.6359E+05	35619.21	4706.94	40326.16	T
90.0	3.50000	0.7162E+05	37841.43	5043.15	42884.59	T
90.0	3.60000	0.7966E+05	40063.66	5379.36	45443.02	T
90.0	3.70000	0.8769E+05	42285.88	5715.57	48001.45	T
90.0	3.80000	0.9573E+05	44508.10	6051.78	50559.88	T
90.0	3.90000	0.1038E+06	46730.32	6387.99	53118.32	T
90.0	4.00000	0.1118E+06	48952.55	6724.20	55676.75	T
120.0	0.10000	0.0000E+00	833.34	2046.15	2879.49	B
120.0	0.20000	0.0000E+00	1666.68	2046.15	3712.83	B
120.0	0.30000	0.0000E+00	2500.02	2046.15	4546.18	B
120.0	0.40000	0.0000E+00	3333.37	2046.15	5379.52	B
120.0	0.50000	0.0000E+00	4166.72	2046.15	6212.88	B
120.0	0.60000	0.0000E+00	5000.08	2046.15	7046.23	B
120.0	0.70000	0.0000E+00	5833.44	2046.15	7879.59	B
120.0	0.80000	0.0000E+00	6666.80	2046.15	8712.95	B
120.0	0.90000	0.0000E+00	7500.16	2046.15	9546.32	B
120.0	1.00000	0.0000E+00	8333.53	2046.15	10379.68	B
120.0	1.10000	0.0000E+00	9166.89	2046.15	11213.05	B
120.0	1.20000	0.0000E+00	10000.26	2046.15	12046.41	B
120.0	1.30000	0.0000E+00	10833.63	2046.15	12879.78	B
120.0	1.40000	0.0000E+00	11666.99	2046.15	13713.15	B
120.0	1.50000	0.0000E+00	12500.36	2046.15	14546.52	B
120.0	1.60000	0.0000E+00	13333.73	2046.15	15379.88	B
120.0	1.70000	0.0000E+00	14167.09	2046.15	16213.25	B
120.0	1.80000	0.0000E+00	15000.46	2046.15	17046.61	B
120.0	1.90000	0.0000E+00	15833.82	2046.15	17879.97	B
120.0	2.00000	0.0000E+00	16667.18	2046.15	18713.34	B
120.0	2.10000	0.0000E+00	17500.54	2046.15	19546.69	B
120.0	2.20000	0.0000E+00	18333.89	2046.15	20380.05	B

120.0	2.30000	0.0000E+00	19167.24	2046.15	21213.40	B
120.0	2.40000	0.0000E+00	20000.59	2046.15	22046.75	B
120.0	2.50000	0.0000E+00	20833.94	2046.15	22880.09	B
120.0	2.60000	0.0000E+00	21667.28	2046.15	23713.43	B
120.0	2.70000	0.0000E+00	22500.61	2046.15	24546.76	B
120.0	2.80000	0.0000E+00	23333.94	2046.15	25380.09	B
120.0	2.90000	0.0000E+00	24167.26	2046.15	26213.42	B
120.0	3.00000	0.0000E+00	25000.58	2046.15	27046.73	B
120.0	3.10000	0.0000E+00	25833.89	2046.15	27880.04	B
120.0	3.20000	0.0000E+00	26667.19	2046.15	28713.35	B
120.0	3.30000	0.0000E+00	27500.49	2046.15	29546.64	B
120.0	3.40000	0.0000E+00	28333.78	2046.15	30379.93	B
120.0	3.50000	0.0000E+00	29167.06	2046.15	31213.21	B
120.0	3.60000	0.0000E+00	30000.33	2046.15	32046.49	B
120.0	3.70000	0.0000E+00	30833.60	2046.15	32879.75	B
120.0	3.80000	0.0000E+00	31666.85	2046.15	33713.01	B
120.0	3.90000	0.0000E+00	32057.61	2046.15	34103.76	H
120.0	4.00000	0.2595E+04	33014.40	2127.58	35141.98	T
140.0	0.10000	0.0000E+00	612.25	2046.15	2658.40	B
140.0	0.20000	0.0000E+00	1224.50	2046.15	3270.65	B
140.0	0.30000	0.0000E+00	1836.75	2046.15	3882.90	B
140.0	0.40000	0.0000E+00	2449.00	2046.15	4495.15	B
140.0	0.50000	0.0000E+00	3061.25	2046.15	5107.41	B
140.0	0.60000	0.0000E+00	3673.51	2046.15	5719.67	B
140.0	0.70000	0.0000E+00	4285.77	2046.15	6331.92	B
140.0	0.80000	0.0000E+00	4898.03	2046.15	6944.18	B
140.0	0.90000	0.0000E+00	5510.29	2046.15	7556.45	B
140.0	1.00000	0.0000E+00	6122.55	2046.15	8168.71	B
140.0	1.10000	0.0000E+00	6734.82	2046.15	8780.97	B
140.0	1.20000	0.0000E+00	7347.08	2046.15	9393.23	B
140.0	1.30000	0.0000E+00	7959.34	2046.15	10005.50	B
140.0	1.40000	0.0000E+00	8571.61	2046.15	10617.76	B
140.0	1.50000	0.0000E+00	9183.87	2046.15	11230.02	B
140.0	1.60000	0.0000E+00	9796.13	2046.15	11842.29	B
140.0	1.70000	0.0000E+00	10408.39	2046.15	12454.55	B
140.0	1.80000	0.0000E+00	11020.66	2046.15	13066.81	B
140.0	1.90000	0.0000E+00	11632.92	2046.15	13679.07	B
140.0	2.00000	0.0000E+00	12245.18	2046.15	14291.33	B
140.0	2.10000	0.0000E+00	12857.43	2046.15	14903.59	B
140.0	2.20000	0.0000E+00	13469.69	2046.15	15515.84	B
140.0	2.30000	0.0000E+00	14081.94	2046.15	16128.10	B
140.0	2.40000	0.0000E+00	14694.20	2046.15	16740.35	B
140.0	2.50000	0.0000E+00	15306.45	2046.15	17352.60	B
140.0	2.60000	0.0000E+00	15918.70	2046.15	17964.85	B
140.0	2.70000	0.0000E+00	16530.94	2046.15	18577.10	B
140.0	2.80000	0.0000E+00	17143.18	2046.15	19189.34	B
140.0	2.90000	0.0000E+00	17755.42	2046.15	19801.58	B
140.0	3.00000	0.0000E+00	18367.66	2046.15	20413.81	B
140.0	3.10000	0.0000E+00	18979.89	2046.15	21026.05	B
140.0	3.20000	0.0000E+00	19592.12	2046.15	21638.28	B
140.0	3.30000	0.0000E+00	20204.35	2046.15	22250.50	B
140.0	3.40000	0.0000E+00	20816.57	2046.15	22862.72	B
140.0	3.50000	0.0000E+00	21428.78	2046.15	23474.94	B
140.0	3.60000	0.0000E+00	22041.00	2046.15	24087.15	B
140.0	3.70000	0.0000E+00	22653.20	2046.15	24699.36	B
140.0	3.80000	0.0000E+00	23265.41	2046.15	25311.56	B
140.0	3.90000	0.0000E+00	23877.60	2046.15	25923.76	B
140.0	4.00000	0.0000E+00	24489.80	2046.15	26535.95	B

Table B.5 Maximum Allowable Borehole Deviation Based on Post-Emplacement Liner Stresses in Boreholes Drilled with a Steerable Bit

This section of Appendix B lists the output file from PROGRAM DEVIAT2 for maximum allowable borehole deviation based on post-emplacement liner stresses in horizontal and vertical boreholes drilled with a steerable bit.

The following parameter values were used in computing these results:

$L_b = 26$ ft (vertical borehole)

$L_b = 32, 42, 58, 75, 270, \text{ and } 350$ feet (horizontal boreholes)

$d_b = 36.5, 37, 38, 39, 40, 41, \text{ and } 42$ inches

$F_b = 0$

$L = 0$ to L_b .

Other parameter values were fixed as listed in Section 5.2.

RUN WITH DEVIAT1.FOR
 POST-EMPLACEMENT LOADING SPECIFIED
 MINIMUM ALLOWABLE LINER RADIUS OF CURVATURE= 65.74 FT (BASED ON CONTAINER CLEARANCE)
 CRITICAL BUCKLING STRESS BASED ON BENDING= 0.2114E+06 PSI
 CRITICAL BUCKLING STRESS BASED ON COMPRESSION= 0.2039E+06 PSI
 FS= 4.00
 FB= 0.00 LBF

LB= 26.000 FEET (VERTICAL)

DB= 36.500 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25029	0.1359E+06	2088.64	15211.36	17300.00	T	17300.00	T
10.0	0.25344	0.2015E+06	6192.16	11274.21	17466.37	T	17466.37	T
16.0	0.26454	0.2079E+06	10223.50	7271.15	17494.65	T	17494.65	T
21.0	0.28034	0.1919E+06	12383.71	5112.77	17496.48	T	17496.48	T
26.0	0.30177	0.1725E+06	13784.94	3712.80	17497.74	T	17497.74	T

DB= 37.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50029	0.1359E+06	2088.64	15211.36	17300.00	T	17300.00	T
10.0	1.00344	0.2015E+06	6192.16	11274.21	17466.37	T	17466.37	T
16.0	0.51454	0.2079E+06	10223.50	7271.15	17494.65	T	17494.65	T
21.0	0.53034	0.1919E+06	12383.71	5112.77	17496.48	T	17496.48	T
26.0	0.55177	0.1725E+06	13784.94	3712.80	17497.74	T	17497.74	T

DB= 38.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00029	0.1359E+06	2088.64	15211.36	17300.00	T	17300.00	T
10.0	1.00344	0.2015E+06	6192.16	11274.21	17466.37	T	17466.37	T
16.0	1.01454	0.2079E+06	10223.50	7271.15	17494.65	T	17494.65	T
21.0	1.03034	0.1919E+06	12383.71	5112.77	17496.48	T	17496.48	T
26.0	1.05177	0.1725E+06	13784.94	3712.80	17497.74	T	17497.74	T

DB= 39.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50029	0.1359E+06	2088.64	15211.36	17300.00	T	17300.00	T
10.0	1.50344	0.2015E+06	6192.16	11274.21	17466.37	T	17466.37	T
16.0	1.51454	0.2079E+06	10223.50	7271.15	17494.65	T	17494.65	T
21.0	1.53034	0.1919E+06	12383.71	5112.77	17496.48	T	17496.48	T
26.0	1.55177	0.1725E+06	13784.94	3712.80	17497.74	T	17497.74	T

DB= 40.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00029	0.1359E+06	2088.64	15211.36	17300.00	T	17300.00	T
10.0	2.00344	0.2015E+06	6192.16	11274.21	17466.37	T	17466.37	T
16.0	2.01454	0.2079E+06	10223.50	7271.15	17494.65	T	17494.65	T
21.0	2.03034	0.1919E+06	12383.71	5112.77	17496.48	T	17496.48	T
26.0	2.05177	0.1725E+06	13784.94	3712.80	17497.74	T	17497.74	T

DB= 41.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50029	0.1359E+06	2088.64	15211.36	17300.00	T	17300.00	T
10.0	2.50344	0.2015E+06	6192.16	11274.21	17466.37	T	17466.37	T
16.0	2.51454	0.2079E+06	10223.50	7271.15	17494.65	T	17494.65	T
21.0	2.53034	0.1919E+06	12383.71	5112.77	17496.48	T	17496.48	T
26.0	2.55177	0.1725E+06	13784.94	3712.80	17497.74	T	17497.74	T

DB= 42.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00029	0.1359E+06	2088.64	15211.36	17300.00	T	17300.00	T
10.0	3.00344	0.2015E+06	6192.16	11274.21	17466.37	T	17466.37	T
16.0	3.01454	0.2079E+06	10223.50	7271.15	17494.65	T	17494.65	T
21.0	3.03034	0.1919E+06	12383.71	5112.77	17496.48	T	17496.48	T
26.0	3.05177	0.1725E+06	13784.94	3712.80	17497.74	T	17497.74	T

LB= 32.000 FEET (HORIZONTAL)

CB= 36.500 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25044	0.2035E+06	3182.56	14201.16	17383.71	T	17383.71	T
10.0	0.25457	0.2623E+06	8281.82	9216.96	17498.77	T	17498.77	T
16.0	0.26717	0.2368E+06	12215.20	5283.91	17499.11	T	17499.11	T
21.0	0.28370	0.2017E+06	14000.58	3494.75	17495.33	T	17495.33	T
26.0	0.30516	0.1697E+06	15063.83	2434.41	17498.24	T	17498.24	T
32.0	0.33681	0.1378E+06	15829.50	1669.68	17499.18	T	17499.18	T

DB= 37.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50044	0.2035E+06	3182.56	14201.16	17383.71	T	17383.71	T
10.0	0.50457	0.2623E+06	8281.82	9216.96	17498.77	T	17498.77	T
16.0	0.51717	0.2368E+06	12215.20	5283.91	17499.11	T	17499.11	T
21.0	0.53370	0.2017E+06	14000.58	3494.75	17495.33	T	17495.33	T
26.0	0.55516	0.1697E+06	15063.83	2434.41	17498.24	T	17498.24	T
32.0	0.58681	0.1378E+06	15829.50	1669.68	17499.18	T	17499.18	T

DB= 38.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00044	0.2035E+06	3182.56	14201.16	17383.71	T	17383.71	T
10.0	1.00457	0.2623E+06	8281.82	9216.96	17498.77	T	17498.77	T
16.0	1.01717	0.2368E+06	12215.20	5283.91	17499.11	T	17499.11	T
21.0	1.03370	0.2017E+06	14000.58	3494.75	17495.33	T	17495.33	T
26.0	1.05516	0.1697E+06	15063.83	2434.41	17498.24	T	17498.24	T
32.0	1.08681	0.1378E+06	15829.50	1669.68	17499.18	T	17499.18	T

DB= 39.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50044	0.2035E+06	3182.56	14201.16	17383.71	T	17383.71	T
10.0	1.50457	0.2623E+06	8281.82	9216.96	17498.77	T	17498.77	T
16.0	1.51717	0.2368E+06	12215.20	5283.91	17499.11	T	17499.11	T
21.0	1.53370	0.2017E+06	14000.58	3494.75	17495.33	T	17495.33	T
26.0	1.55516	0.1697E+06	15063.83	2434.41	17498.24	T	17498.24	T
32.0	1.58681	0.1378E+06	15829.50	1669.68	17499.18	T	17499.18	T

DB= 40.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00044	0.2035E+06	3182.56	14201.16	17383.71	T	17383.71	T
10.0	2.00457	0.2623E+06	8281.82	9216.96	17498.77	T	17498.77	T
16.0	2.01717	0.2368E+06	12215.20	5283.91	17499.11	T	17499.11	T
21.0	2.03370	0.2017E+06	14000.58	3494.75	17495.33	T	17495.33	T
26.0	2.05516	0.1697E+06	15063.83	2434.41	17498.24	T	17498.24	T
32.0	2.08681	0.1378E+06	15829.50	1669.68	17499.18	T	17499.18	T

DB= 41.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50044	0.2035E+06	3182.56	14201.16	17383.71	T	17383.71	T
10.0	2.50457	0.2623E+06	8281.82	9216.96	17498.77	T	17498.77	T
16.0	2.51717	0.2368E+06	12215.20	5283.91	17499.11	T	17499.11	T
21.0	2.53370	0.2017E+06	14000.58	3494.75	17495.33	T	17495.33	T
26.0	2.55516	0.1697E+06	15063.83	2434.41	17498.24	T	17498.24	T
32.0	2.58681	0.1378E+06	15829.50	1669.68	17499.18	T	17499.18	T

DB= 42.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00044	0.2035E+06	3182.56	14201.16	17383.71	T	17383.71	T
10.0	3.00457	0.2623E+06	8281.82	9216.96	17498.77	T	17498.77	T
16.0	3.01717	0.2368E+06	12215.20	5283.91	17499.11	T	17499.11	T
21.0	3.03370	0.2017E+06	14000.58	3494.75	17495.33	T	17495.33	T
26.0	3.05516	0.1697E+06	15063.83	2434.41	17498.24	T	17498.24	T
32.0	3.08681	0.1378E+06	15829.50	1669.68	17499.18	T	17499.18	T

LB= 42.000 FEET (HORIZONTAL)

DB= 36.500 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25035	0.1613E+06	2534.56	14827.27	17361.82	T	17361.82	T
10.0	0.25392	0.2242E+06	7111.82	10376.67	17488.49	T	17488.49	T
16.0	0.26567	0.2154E+06	11160.51	6329.27	17489.78	T	17489.78	T
21.0	0.28170	0.1891E+06	13184.25	4314.65	17498.90	T	17498.90	T
26.0	0.30281	0.1619E+06	14438.09	3059.04	17497.13	T	17497.13	T
32.0	0.33421	0.1331E+06	15372.47	2125.82	17498.29	T	17498.29	T
42.0	0.39942	0.9531E+05	16228.71	1271.08	17499.80	T	17499.80	T

DB= 37.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50035	0.1613E+06	2534.56	14827.27	17361.82	T	17361.82	T
10.0	0.50392	0.2242E+06	7111.82	10376.67	17488.49	T	17488.49	T
16.0	0.51567	0.2154E+06	11160.51	6329.27	17489.78	T	17489.78	T
21.0	0.53170	0.1891E+06	13184.25	4314.65	17498.90	T	17498.90	T
26.0	0.55281	0.1619E+06	14438.09	3059.04	17497.13	T	17497.13	T
32.0	0.58421	0.1331E+06	15372.47	2125.82	17498.29	T	17498.29	T
42.0	0.64942	0.9531E+05	16228.71	1271.08	17499.80	T	17499.80	T

DB= 38.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00035	0.1613E+06	2534.56	14827.27	17361.82	T	17361.82	T
10.0	1.00392	0.2242E+06	7111.82	10376.67	17488.49	T	17488.49	T
16.0	1.01567	0.2154E+06	11160.51	6329.27	17489.78	T	17489.78	T
21.0	1.03170	0.1891E+06	13184.25	4314.65	17498.90	T	17498.90	T
26.0	1.05281	0.1619E+06	14438.09	3059.04	17497.13	T	17497.13	T
32.0	1.08421	0.1331E+06	15372.47	2125.82	17498.29	T	17498.29	T
42.0	1.14942	0.9531E+05	16228.71	1271.08	17499.80	T	17499.80	T

DB= 39.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50035	0.1613E+06	2534.56	14827.27	17361.82	T	17361.82	T
10.0	1.50392	0.2242E+06	7111.82	10376.67	17488.49	T	17488.49	T
16.0	1.51567	0.2154E+06	11160.51	6329.27	17489.78	T	17489.78	T
21.0	1.53170	0.1891E+06	13184.25	4314.65	17498.90	T	17498.90	T
26.0	1.55281	0.1619E+06	14438.09	3059.04	17497.13	T	17497.13	T
32.0	1.58421	0.1331E+06	15372.47	2125.82	17498.29	T	17498.29	T
42.0	1.64942	0.9531E+05	16228.71	1271.08	17499.80	T	17499.80	T

DB= 40.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00035	0.1613E+06	2534.56	14827.27	17361.82	T	17361.82	T
10.0	2.00392	0.2242E+06	7111.82	10376.67	17488.49	T	17488.49	T
16.0	2.01567	0.2154E+06	11160.51	6329.27	17489.78	T	17489.78	T
21.0	2.03170	0.1891E+06	13184.25	4314.65	17498.90	T	17498.90	T
26.0	2.05281	0.1619E+06	14438.09	3059.04	17497.13	T	17497.13	T
32.0	2.08421	0.1331E+06	15372.47	2125.82	17498.29	T	17498.29	T
42.0	2.14942	0.9531E+05	16228.71	1271.08	17499.80	T	17499.80	T

DB= 41.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50035	0.1613E+06	2534.56	14827.27	17361.82	T	17361.82	T
10.0	2.50392	0.2242E+06	7111.82	10376.67	17488.49	T	17488.49	T
16.0	2.51567	0.2154E+06	11160.51	6329.27	17489.78	T	17489.78	T
21.0	2.53170	0.1891E+06	13184.25	4314.65	17498.90	T	17498.90	T
26.0	2.55281	0.1619E+06	14438.09	3059.04	17497.13	T	17497.13	T
32.0	2.58421	0.1331E+06	15372.47	2125.82	17498.29	T	17498.29	T
42.0	2.64942	0.9531E+05	16228.71	1271.08	17499.80	T	17499.80	T

DB= 42.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00035	0.1613E+06	2534.56	14827.27	17361.82	T	17361.82	T
10.0	3.00392	0.2242E+06	7111.82	10376.67	17488.49	T	17488.49	T
16.0	3.01567	0.2154E+06	11160.51	6329.27	17489.78	T	17489.78	T
21.0	3.03170	0.1891E+06	13184.25	4314.65	17498.90	T	17498.90	T
26.0	3.05281	0.1619E+06	14438.09	3059.04	17497.13	T	17497.13	T
32.0	3.08421	0.1331E+06	15372.47	2125.82	17498.29	T	17498.29	T
42.0	3.14942	0.9531E+05	16228.71	1271.08	17499.80	T	17499.80	T

LB= 58.000 FEET (HORIZONTAL)

DB= 36.500 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25026	0.1192E+06	1886.56	15211.90	17098.46	T	17098.46	T
10.0	0.25319	0.1814E+06	5797.82	11661.21	17459.03	T	17459.03	T
16.0	0.26376	0.1881E+06	9817.54	7675.07	17492.61	T	17492.61	T
21.0	0.27894	0.1716E+06	12057.72	5439.56	17497.28	T	17497.28	T
26.0	0.29945	0.1507E+06	13543.42	3955.62	17499.04	T	17499.04	T
32.0	0.33037	0.1263E+06	14697.47	2801.79	17499.26	T	17499.26	T
42.0	0.39516	0.9194E+05	15794.02	1705.26	17499.28	T	17499.28	T
58.0	0.52543	0.5117E+05	16609.89	889.69	17499.59	T	17499.59	T

DB= 37.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50026	0.1192E+06	1886.56	15211.90	17098.46	T	17098.46	T
10.0	0.50319	0.1814E+06	5797.82	11661.21	17459.03	T	17459.03	T
16.0	0.51376	0.1881E+06	9817.54	7675.07	17492.61	T	17492.61	T
21.0	0.52894	0.1716E+06	12057.72	5439.56	17497.28	T	17497.28	T
26.0	0.54945	0.1507E+06	13543.42	3955.62	17499.04	T	17499.04	T
32.0	0.58037	0.1263E+06	14697.47	2801.79	17499.26	T	17499.26	T
42.0	0.64516	0.9194E+05	15794.02	1705.26	17499.28	T	17499.28	T
58.0	0.77543	0.5117E+05	16609.89	889.69	17499.59	T	17499.59	T

DB= 38.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00026	0.1192E+06	1886.56	15211.90	17098.46	T	17098.46	T
10.0	1.00319	0.1814E+06	5797.82	11661.21	17459.03	T	17459.03	T
16.0	1.01376	0.1881E+06	9817.54	7675.07	17492.61	T	17492.61	T
21.0	1.02894	0.1716E+06	12057.72	5439.56	17497.28	T	17497.28	T
26.0	1.04945	0.1507E+06	13543.42	3955.62	17499.04	T	17499.04	T
32.0	1.08037	0.1263E+06	14697.47	2801.79	17499.26	T	17499.26	T
42.0	1.14516	0.9194E+05	15794.02	1705.26	17499.28	T	17499.28	T
58.0	1.27543	0.5117E+05	16609.89	889.69	17499.59	T	17499.59	T

DB= 39.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50026	0.1192E+06	1886.56	15211.90	17098.46	T	17098.46	T
10.0	1.50319	0.1814E+06	5797.82	11661.21	17459.03	T	17459.03	T
16.0	1.51376	0.1881E+06	9817.54	7675.07	17492.61	T	17492.61	T
21.0	1.52894	0.1716E+06	12057.72	5439.56	17497.28	T	17497.28	T
26.0	1.54945	0.1507E+06	13543.42	3955.62	17499.04	T	17499.04	T
32.0	1.58037	0.1263E+06	14697.47	2801.79	17499.26	T	17499.26	T
42.0	1.64516	0.9194E+05	15794.02	1705.26	17499.28	T	17499.28	T
58.0	1.77543	0.5117E+05	16609.89	889.69	17499.59	T	17499.59	T

DB= 40.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00026	0.1192E+06	1886.56	15211.90	17098.46	T	17098.46	T
10.0	2.00319	0.1814E+06	5797.82	11661.21	17459.03	T	17459.03	T
16.0	2.01376	0.1881E+06	9817.54	7675.07	17492.61	T	17492.61	T
21.0	2.02894	0.1716E+06	12057.72	5439.56	17497.28	T	17497.28	T
26.0	2.04945	0.1507E+06	13543.42	3955.62	17499.04	T	17499.04	T
32.0	2.08037	0.1263E+06	14697.47	2801.79	17499.26	T	17499.26	T
42.0	2.14516	0.9194E+05	15794.02	1705.26	17499.28	T	17499.28	T
58.0	2.27543	0.5117E+05	16609.89	889.69	17499.59	T	17499.59	T

DB= 41.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50026	0.1192E+06	1886.56	15211.90	17098.46	T	17098.46	T
10.0	2.50319	0.1814E+06	5797.82	11661.21	17459.03	T	17459.03	T
16.0	2.51376	0.1881E+06	9817.54	7675.07	17492.61	T	17492.61	T
21.0	2.52894	0.1716E+06	12057.72	5439.56	17497.28	T	17497.28	T
26.0	2.54945	0.1507E+06	13543.42	3955.62	17499.04	T	17499.04	T
32.0	2.58037	0.1263E+06	14697.47	2801.79	17499.26	T	17499.26	T
42.0	2.64516	0.9194E+05	15794.02	1705.26	17499.28	T	17499.28	T
58.0	2.77543	0.5117E+05	16609.89	889.69	17499.59	T	17499.59	T

DB= 42.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00026	0.1192E+06	1886.56	15211.90	17098.46	T	17098.46	T
10.0	3.00319	0.1814E+06	5797.82	11661.21	17459.03	T	17459.03	T
16.0	3.01376	0.1881E+06	9817.54	7675.07	17492.61	T	17492.61	T
21.0	3.02894	0.1716E+06	12057.72	5439.56	17497.28	T	17497.28	T
26.0	3.04945	0.1507E+06	13543.42	3955.62	17499.04	T	17499.04	T
32.0	3.08037	0.1263E+06	14697.47	2801.79	17499.26	T	17499.26	T
42.0	3.14516	0.9194E+05	15794.02	1705.26	17499.28	T	17499.28	T
58.0	3.27543	0.5117E+05	16609.89	889.69	17499.59	T	17499.59	T

LB= 75.000 FEET (HORIZONTAL)

DB= 36.500 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25021	0.9573E+05	1526.56	15889.06	17415.62	T	17415.62	T
10.0	0.25267	0.1510E+06	4861.82	12621.18	17483.00	T	17483.00	T
16.0	0.26218	0.1655E+06	8706.60	8785.06	17491.66	T	17491.66	T
21.0	0.27649	0.1561E+06	11057.72	6438.44	17496.16	T	17496.16	T
26.0	0.29631	0.1402E+06	12707.32	4790.23	17497.55	T	17497.55	T
32.0	0.32665	0.1196E+06	14043.56	3455.31	17498.87	T	17498.87	T
42.0	0.39090	0.8858E+05	15359.32	2140.37	17499.69	T	17499.69	T
58.0	0.52091	0.4982E+05	16368.04	1131.59	17499.62	T	17499.62	T
75.0	0.78299	0.3325E+05	16703.72	796.25	17499.96	D	17499.96	T

DB= 37.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50021	0.9573E+05	1526.56	15889.06	17415.62	T	17415.62	T
10.0	0.50267	0.1510E+06	4861.82	12621.18	17483.00	T	17483.00	T
16.0	0.51218	0.1655E+06	8706.60	8785.06	17491.66	T	17491.66	T
21.0	0.52649	0.1561E+06	11057.72	6438.44	17496.16	T	17496.16	T
26.0	0.54631	0.1402E+06	12707.32	4790.23	17497.55	T	17497.55	T
32.0	0.57665	0.1196E+06	14043.56	3455.31	17498.87	T	17498.87	T

42.0	0.64090	0.8858E+05	15359.32	2140.37	17499.69	T	17499.69	T
58.0	0.77091	0.4982E+05	16368.04	1131.59	17499.62	T	17499.62	T
75.0	0.92901	0.1882E+05	16858.95	640.91	17499.86	T	17499.86	T

DB= 38.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00021	0.9573E+05	1526.56	15889.06	17415.62	T	17415.62	T
10.0	1.00267	0.1510E+06	4861.82	12621.18	17483.00	T	17483.00	T
16.0	1.01218	0.1655E+06	8706.60	8785.06	17491.66	T	17491.66	T
21.0	1.02649	0.1561E+06	11057.72	6438.44	17496.16	T	17496.16	T
26.0	1.04631	0.1402E+06	12707.32	4790.23	17497.55	T	17497.55	T
32.0	1.07665	0.1196E+06	14043.56	3455.31	17498.87	T	17498.87	T
42.0	1.14090	0.8858E+05	15359.32	2140.37	17499.69	T	17499.69	T
58.0	1.27091	0.4982E+05	16368.04	1131.59	17499.62	T	17499.62	T
75.0	1.42901	0.1882E+05	16858.95	640.91	17499.86	T	17499.86	T

DB= 39.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50021	0.9573E+05	1526.56	15889.06	17415.62	T	17415.62	T
10.0	1.50267	0.1510E+06	4861.82	12621.18	17483.00	T	17483.00	T
16.0	1.51218	0.1655E+06	8706.60	8785.06	17491.66	T	17491.66	T
21.0	1.52649	0.1561E+06	11057.72	6438.44	17496.16	T	17496.16	T
26.0	1.54631	0.1402E+06	12707.32	4790.23	17497.55	T	17497.55	T
32.0	1.57665	0.1196E+06	14043.56	3455.31	17498.87	T	17498.87	T
42.0	1.64090	0.8858E+05	15359.32	2140.37	17499.69	T	17499.69	T
58.0	1.77091	0.4982E+05	16368.04	1131.59	17499.62	T	17499.62	T
75.0	1.92901	0.1882E+05	16858.95	640.91	17499.86	T	17499.86	T

DB= 40.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00021	0.9573E+05	1526.56	15889.06	17415.62	T	17415.62	T
10.0	2.00267	0.1510E+06	4861.82	12621.18	17483.00	T	17483.00	T
16.0	2.01218	0.1655E+06	8706.60	8785.06	17491.66	T	17491.66	T
21.0	2.02649	0.1561E+06	11057.72	6438.44	17496.16	T	17496.16	T
26.0	2.04631	0.1402E+06	12707.32	4790.23	17497.55	T	17497.55	T
32.0	2.07665	0.1196E+06	14043.56	3455.31	17498.87	T	17498.87	T
42.0	2.14090	0.8858E+05	15359.32	2140.37	17499.69	T	17499.69	T
58.0	2.27091	0.4982E+05	16368.04	1131.59	17499.62	T	17499.62	T
75.0	2.42901	0.1882E+05	16858.95	640.91	17499.86	T	17499.86	T

DB= 41.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50021	0.9573E+05	1526.56	15889.06	17415.62	T	17415.62	T
10.0	2.50267	0.1510E+06	4861.82	12621.18	17483.00	T	17483.00	T
16.0	2.51218	0.1655E+06	8706.60	8785.06	17491.66	T	17491.66	T
21.0	2.52649	0.1561E+06	11057.72	6438.44	17496.16	T	17496.16	T
26.0	2.54631	0.1402E+06	12707.32	4790.23	17497.55	T	17497.55	T
32.0	2.57665	0.1196E+06	14043.56	3455.31	17498.87	T	17498.87	T
42.0	2.64090	0.8858E+05	15359.32	2140.37	17499.69	T	17499.69	T
58.0	2.77091	0.4982E+05	16368.04	1131.59	17499.62	T	17499.62	T
75.0	2.92901	0.1882E+05	16858.95	640.91	17499.86	T	17499.86	T

DB= 42.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00021	0.9573E+05	1526.56	15889.06	17415.62	T	17415.62	T
10.0	3.00267	0.1510E+06	4861.82	12621.18	17483.00	T	17483.00	T
16.0	3.01218	0.1655E+06	8706.60	8785.06	17491.66	T	17491.66	T
21.0	3.02649	0.1561E+06	11057.72	6438.44	17496.16	T	17496.16	T
26.0	3.04631	0.1402E+06	12707.32	4790.23	17497.55	T	17497.55	T
32.0	3.07665	0.1196E+06	14043.56	3455.31	17498.87	T	17498.87	T
42.0	3.14090	0.8858E+05	15359.32	2140.37	17499.69	T	17499.69	T
58.0	3.27091	0.4982E+05	16368.04	1131.59	17499.62	T	17499.62	T
75.0	3.42901	0.1882E+05	16858.95	640.91	17499.86	T	17499.86	T

LB=270.000 FEET (HORIZONTAL)

DB= 36.500 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25006	0.2544E+05	446.56	16360.42	16806.98	T	16806.98	T
10.0	0.25092	0.4846E+05	1711.82	15656.93	17368.75	T	17368.75	T
16.0	0.25526	0.6653E+05	3840.98	13658.09	17499.06	T	17499.06	T
21.0	0.26344	0.7360E+05	5731.19	11759.84	17491.04	T	17491.04	T
26.0	0.27681	0.7522E+05	7515.01	9983.47	17498.48	T	17498.48	T
32.0	0.30007	0.7212E+05	9371.30	8125.59	17496.89	T	17496.89	T
42.0	0.35539	0.6050E+05	11735.86	5763.41	17499.26	T	17499.26	T
58.0	0.47799	0.3693E+05	14071.49	3428.31	17499.80	T	17499.80	T
75.0	0.70548	0.2249E+05	15050.20	2449.63	17499.83	D	17499.83	T
80.0	0.80939	0.2053E+05	15176.00	2323.97	17499.97	D	17499.97	T

85.0	0.92179	0.1789E+05	15309.92	2189.95	17499.87	D	17499.87	T
90.0	1.04251	0.1478E+05	15444.47	2055.47	17499.95	D	17499.95	T
95.0	1.17138	0.1133E+05	15574.99	1924.96	17499.94	D	17499.94	T
100.0	1.30827	0.7654E+04	15699.06	1800.83	17499.89	D	17499.89	T
110.0	1.60544	0.0000E+00	15921.46	1578.46	17499.92	B	17499.92	T
120.0	1.91062	0.0000E+00	15921.50	1578.46	17499.96	B	17499.96	T
135.0	2.41815	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T
140.0	2.60059	0.0000E+00	15921.49	1578.46	17499.95	B	17499.95	T
150.0	2.98539	0.0000E+00	15921.50	1578.46	17499.96	B	17499.96	T
160.0	3.39673	0.0000E+00	15921.49	1578.46	17499.95	B	17499.95	T
170.0	3.83462	0.0000E+00	15921.52	1578.46	17499.98	B	17499.98	T
175.0	4.06352	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T
200.0	5.30755	0.0000E+00	15921.52	1578.46	17499.98	B	17499.98	T
240.0	7.64314	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T
270.0	9.67364	0.0000E+00	15921.53	1578.46	17500.00	B	17500.00	T

DB= 37.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50006	0.2544E+05	446.56	16360.42	16806.98	T	16806.98	T
10.0	0.50092	0.4846E+05	1711.82	15656.93	17368.75	T	17368.75	T
16.0	0.50526	0.6653E+05	3840.98	13658.09	17499.06	T	17499.06	T
21.0	0.51344	0.7360E+05	5731.19	11759.84	17491.04	T	17491.04	T
26.0	0.52681	0.7522E+05	7515.01	9983.47	17498.48	T	17498.48	T
32.0	0.55007	0.7212E+05	9371.30	8125.59	17496.89	T	17496.89	T
42.0	0.60539	0.6050E+05	11735.86	5763.41	17499.26	T	17499.26	T
58.0	0.72799	0.3693E+05	14071.49	3428.31	17499.80	T	17499.80	T
75.0	0.88443	0.1263E+05	15432.39	2067.52	17499.91	T	17499.91	T
80.0	0.93179	0.5932E+04	15706.05	1793.86	17499.92	T	17499.92	T
85.0	0.95860	0.0000E+00	15921.40	1578.46	17499.86	B	17499.86	T
90.0	1.07470	0.0000E+00	15921.47	1578.46	17499.93	B	17499.93	T
95.0	1.19743	0.0000E+00	15921.46	1578.46	17499.92	B	17499.92	T
100.0	1.32680	0.0000E+00	15921.52	1578.46	17499.99	B	17499.99	T
110.0	1.60543	0.0000E+00	15921.48	1578.46	17499.94	B	17499.94	T
120.0	1.91061	0.0000E+00	15921.54	1578.46	17500.00	B	17500.00	T
135.0	2.41813	0.0000E+00	15921.51	1578.46	17499.97	B	17499.97	T
140.0	2.60057	0.0000E+00	15921.48	1578.46	17499.94	B	17499.94	T
150.0	2.98537	0.0000E+00	15921.51	1578.46	17499.97	B	17499.97	T
160.0	3.39671	0.0000E+00	15921.52	1578.46	17499.98	B	17499.98	T
170.0	3.83459	0.0000E+00	15921.51	1578.46	17499.97	B	17499.97	T
175.0	4.06349	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T
200.0	5.30751	0.0000E+00	15921.52	1578.46	17499.98	B	17499.98	T
240.0	7.64308	0.0000E+00	15921.52	1578.46	17499.99	B	17499.99	T
270.0	9.67357	0.0000E+00	15921.54	1578.46	17500.00	B	17500.00	T

DB= 38.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00006	0.2544E+05	446.56	16360.42	16806.98	T	16806.98	T
10.0	1.00092	0.4846E+05	1711.82	15656.93	17368.75	T	17368.75	T
16.0	1.00526	0.6653E+05	3840.98	13658.09	17499.06	T	17499.06	T
21.0	1.01344	0.7360E+05	5731.19	11759.84	17491.04	T	17491.04	T
26.0	1.02681	0.7522E+05	7515.01	9983.47	17498.48	T	17498.48	T
32.0	1.05007	0.7212E+05	9371.30	8125.59	17496.89	T	17496.89	T
42.0	1.10539	0.6050E+05	11735.86	5763.41	17499.26	T	17499.26	T
58.0	1.22799	0.3693E+05	14071.49	3428.31	17499.80	T	17499.80	T
75.0	1.38443	0.1263E+05	15432.39	2067.52	17499.91	T	17499.91	T
80.0	1.43179	0.5932E+04	15706.05	1793.86	17499.92	T	17499.92	T
85.0	0.95859	0.0000E+00	15921.46	1578.46	17499.93	B	17499.93	T
90.0	1.07468	0.0000E+00	15921.40	1578.46	17499.87	B	17499.87	T
95.0	1.19741	0.0000E+00	15921.43	1578.46	17499.89	B	17499.89	T
100.0	1.32678	0.0000E+00	15921.52	1578.46	17499.98	B	17499.98	T
110.0	1.60541	0.0000E+00	15921.51	1578.46	17499.98	B	17499.98	T
120.0	1.91058	0.0000E+00	15921.52	1578.46	17499.98	B	17499.98	T
135.0	2.41809	0.0000E+00	15921.48	1578.46	17499.94	B	17499.94	T
140.0	2.60054	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T
150.0	2.98533	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T
160.0	3.39666	0.0000E+00	15921.52	1578.46	17499.98	B	17499.98	T
170.0	3.83454	0.0000E+00	15921.54	1578.46	17500.00	B	17500.00	T
175.0	4.06343	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T
200.0	5.30743	0.0000E+00	15921.51	1578.46	17499.98	B	17499.98	T
240.0	7.64297	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T
270.0	9.67342	0.0000E+00	15921.52	1578.46	17499.99	B	17499.99	T

DB= 39.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50006	0.2544E+05	446.56	16360.42	16806.98	T	16806.98	T
10.0	1.50092	0.4846E+05	1711.82	15656.93	17368.75	T	17368.75	T
16.0	1.50526	0.6653E+05	3840.98	13658.09	17499.06	T	17499.06	T
21.0	1.51344	0.7360E+05	5731.19	11759.84	17491.04	T	17491.04	T
26.0	1.52681	0.7522E+05	7515.01	9983.47	17498.48	T	17498.48	T
32.0	1.55007	0.7212E+05	9371.30	8125.59	17496.89	T	17496.89	T
42.0	1.60539	0.6050E+05	11735.86	5763.41	17499.26	T	17499.26	T
58.0	1.72799	0.3693E+05	14071.49	3428.31	17499.80	T	17499.80	T

75.0	1.88443	0.1263E+05	15432.39	2067.52	17499.91	T	17499.91	T
80.0	1.93179	0.5932E+04	15706.05	1793.86	17499.92	T	17499.92	T
85.0	0.95858	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T
90.0	1.07467	0.0000E+00	15921.49	1578.46	17499.95	B	17499.95	T
95.0	1.19740	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T
100.0	1.32676	0.0000E+00	15921.51	1578.46	17499.98	B	17499.98	T
110.0	1.60538	0.0000E+00	15921.45	1578.46	17499.91	B	17499.91	T
120.0	1.91055	0.0000E+00	15921.51	1578.46	17499.97	B	17499.97	T
135.0	2.41806	0.0000E+00	15921.52	1578.46	17499.98	B	17499.98	T
140.0	2.60050	0.0000E+00	15921.52	1578.46	17499.98	B	17499.98	T
150.0	2.98528	0.0000E+00	15921.50	1578.46	17499.96	B	17499.96	T
160.0	3.39661	0.0000E+00	15921.52	1578.46	17499.98	B	17499.98	T
170.0	3.83448	0.0000E+00	15921.52	1578.46	17499.98	B	17499.98	T
175.0	4.06337	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T
200.0	5.30735	0.0000E+00	15921.51	1578.46	17499.97	B	17499.97	T
240.0	7.64286	0.0000E+00	15921.54	1578.46	17500.00	B	17500.00	T
270.0	9.67328	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T

DB= 40.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00006	0.2544E+05	446.56	16360.42	16806.98	T	16806.98	T
10.0	2.00092	0.4846E+05	1711.82	15656.93	17368.75	T	17368.75	T
16.0	2.00526	0.6653E+05	3840.98	13658.09	17499.06	T	17499.06	T
21.0	2.01344	0.7360E+05	5731.19	11759.84	17491.04	T	17491.04	T
26.0	2.02681	0.7522E+05	7515.01	9983.47	17498.48	T	17498.48	T
32.0	2.05007	0.7212E+05	9371.30	8125.59	17496.89	T	17496.89	T
42.0	2.10539	0.6050E+05	11735.86	5763.41	17499.26	T	17499.26	T
58.0	2.22799	0.3693E+05	14071.49	3428.31	17499.80	T	17499.80	T
75.0	2.38443	0.1263E+05	15432.39	2067.52	17499.91	T	17499.91	T
80.0	2.43179	0.5932E+04	15706.05	1793.86	17499.92	T	17499.92	T
85.0	0.95856	0.0000E+00	15921.44	1578.46	17499.90	B	17499.90	T
90.0	1.07465	0.0000E+00	15921.43	1578.46	17499.89	B	17499.89	T
95.0	1.19738	0.0000E+00	15921.50	1578.46	17499.96	B	17499.96	T
100.0	1.32674	0.0000E+00	15921.51	1578.46	17499.97	B	17499.97	T
110.0	1.60536	0.0000E+00	15921.49	1578.46	17499.95	B	17499.95	T
120.0	1.91052	0.0000E+00	15921.49	1578.46	17499.95	B	17499.95	T
135.0	2.41802	0.0000E+00	15921.49	1578.46	17499.95	B	17499.95	T
140.0	2.60046	0.0000E+00	15921.51	1578.46	17499.97	B	17499.97	T
150.0	2.98524	0.0000E+00	15921.52	1578.46	17499.98	B	17499.98	T
160.0	3.39656	0.0000E+00	15921.52	1578.46	17499.98	B	17499.98	T
170.0	3.83442	0.0000E+00	15921.51	1578.46	17499.97	B	17499.97	T
175.0	4.06331	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T
200.0	5.30728	0.0000E+00	15921.53	1578.46	17500.00	B	17500.00	T
240.0	7.64274	0.0000E+00	15921.52	1578.46	17499.98	B	17499.98	T
270.0	9.67314	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T

DB= 41.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50006	0.2544E+05	446.56	16360.42	16806.98	T	16806.98	T
10.0	2.50092	0.4846E+05	1711.82	15656.93	17368.75	T	17368.75	T
16.0	2.50526	0.6653E+05	3840.98	13658.09	17499.06	T	17499.06	T
21.0	2.51344	0.7360E+05	5731.19	11759.84	17491.04	T	17491.04	T
26.0	2.52681	0.7522E+05	7515.01	9983.47	17498.48	T	17498.48	T
32.0	2.55007	0.7212E+05	9371.30	8125.59	17496.89	T	17496.89	T
42.0	2.60539	0.6050E+05	11735.86	5763.41	17499.26	T	17499.26	T
58.0	2.72799	0.3693E+05	14071.49	3428.31	17499.80	T	17499.80	T
75.0	2.88443	0.1263E+05	15432.39	2067.52	17499.91	T	17499.91	T
80.0	2.93179	0.5932E+04	15706.05	1793.86	17499.92	T	17499.92	T
85.0	0.95855	0.0000E+00	15921.50	1578.46	17499.97	B	17499.97	T
90.0	1.07464	0.0000E+00	15921.52	1578.46	17499.98	B	17499.98	T
95.0	1.19736	0.0000E+00	15921.47	1578.46	17499.93	B	17499.93	T
100.0	1.32672	0.0000E+00	15921.50	1578.46	17499.96	B	17499.96	T
110.0	1.60534	0.0000E+00	15921.52	1578.46	17499.99	B	17499.99	T
120.0	1.91049	0.0000E+00	15921.48	1578.46	17499.94	B	17499.94	T
135.0	2.41799	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T
140.0	2.60042	0.0000E+00	15921.50	1578.46	17499.96	B	17499.96	T
150.0	2.98519	0.0000E+00	15921.49	1578.46	17499.95	B	17499.95	T
160.0	3.39651	0.0000E+00	15921.52	1578.46	17499.98	B	17499.98	T
170.0	3.83437	0.0000E+00	15921.53	1578.46	17500.00	B	17500.00	T
175.0	4.06325	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T
200.0	5.30720	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T
240.0	7.64263	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T
270.0	9.67300	0.0000E+00	15921.54	1578.46	17500.00	B	17500.00	T

DB= 42.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00006	0.2544E+05	446.56	16360.42	16806.98	T	16806.98	T
10.0	3.00092	0.4846E+05	1711.82	15656.93	17368.75	T	17368.75	T
16.0	3.00526	0.6653E+05	3840.98	13658.09	17499.06	T	17499.06	T
21.0	3.01344	0.7360E+05	5731.19	11759.84	17491.04	T	17491.04	T
26.0	3.02681	0.7522E+05	7515.01	9983.47	17498.48	T	17498.48	T
32.0	3.05007	0.7212E+05	9371.30	8125.59	17496.89	T	17496.89	T
42.0	3.10539	0.6050E+05	11735.86	5763.41	17499.26	T	17499.26	T
58.0	3.22799	0.3693E+05	14071.49	3428.31	17499.80	T	17499.80	T

75.0	3.38443	0.1263E+05	15432.39	2067.52	17499.91	T	17499.91	T
80.0	3.43179	0.5932E+04	15706.05	1793.86	17499.92	T	17499.92	T
85.0	0.95853	0.0000E+00	15921.41	1578.46	17499.87	B	17499.87	T
90.0	1.07462	0.0000E+00	15921.45	1578.46	17499.92	B	17499.92	T
95.0	1.19734	0.0000E+00	15921.44	1578.46	17499.90	B	17499.90	T
100.0	1.32670	0.0000E+00	15921.50	1578.46	17499.96	B	17499.96	T
110.0	1.60531	0.0000E+00	15921.46	1578.46	17499.92	B	17499.92	T
120.0	1.91046	0.0000E+00	15921.46	1578.46	17499.92	B	17499.92	T
135.0	2.41795	0.0000E+00	15921.50	1578.46	17499.96	B	17499.96	T
140.0	2.60038	0.0000E+00	15921.49	1578.46	17499.95	B	17499.95	T
150.0	2.98515	0.0000E+00	15921.51	1578.46	17499.97	B	17499.97	T
160.0	3.39646	0.0000E+00	15921.52	1578.46	17499.98	B	17499.98	T
170.0	3.83431	0.0000E+00	15921.52	1578.46	17499.98	F	17499.98	T
175.0	4.06319	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T
200.0	5.30712	0.0000E+00	15921.52	1578.46	17499.98	B	17499.98	T
240.0	7.64252	0.0000E+00	15921.53	1578.46	17499.99	B	17499.99	T
270.0	9.67285	0.0000E+00	15921.52	1578.46	17499.99	B	17499.99	T

LB=350.000 FEET (HORIZONTAL)

DB= 36.500 INCHES

(FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25004	0.1607E+05	302.56	14149.16	14451.71	T	14451.71	T
10.0	0.25073	0.3733E+05	1369.82	16104.86	17474.68	T	17474.68	T
16.0	0.25426	0.5223E+05	3137.85	14339.03	17476.88	T	17476.88	T
21.0	0.26118	0.5930E+05	4808.74	12680.87	17489.61	T	17489.61	T
26.0	0.27286	0.6206E+05	6463.24	11034.82	17498.06	T	17498.06	T
32.0	0.29384	0.6098E+05	8276.18	9222.58	17498.76	T	17498.76	T
42.0	0.34551	0.5269E+05	10727.69	6770.69	17498.38	T	17498.38	T
58.0	0.46407	0.3275E+05	13326.66	4172.77	17499.43	T	17499.43	T
75.0	0.67984	0.1893E+05	14503.22	2996.70	17499.92	D	17499.92	T
80.0	0.78086	0.1727E+05	14641.07	2858.91	17499.98	D	17499.98	T
85.0	0.89065	0.1492E+05	14792.73	2707.24	17499.96	D	17499.96	T
90.0	1.00900	0.1209E+05	14948.04	2551.84	17499.88	D	17499.88	T
95.0	1.13574	0.8896E+04	15101.12	2398.79	17499.91	D	17499.91	T
100.0	1.27071	0.5454E+04	15248.36	2251.56	17499.91	D	17499.91	T
110.0	1.55828	0.0000E+00	15453.78	2046.15	17499.94	B	17499.94	T
120.0	1.85449	0.0000E+00	15453.78	2046.15	17499.94	B	17499.94	T
135.0	2.34711	0.0000E+00	15453.81	2046.15	17499.97	B	17499.97	T
140.0	2.52420	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
150.0	2.89769	0.0000E+00	15453.82	2046.15	17499.97	B	17499.97	T
160.0	3.29695	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
170.0	3.72197	0.0000E+00	15453.83	2046.15	17499.99	B	17499.99	T
175.0	3.94414	0.0000E+00	15453.83	2046.15	17499.98	B	17499.98	T
200.0	5.15162	0.0000E+00	15453.83	2046.15	17499.99	B	17499.99	T
240.0	7.41858	0.0000E+00	15453.85	2046.15	17500.00	B	17500.00	T
270.0	9.38940	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
300.0	11.59222	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
350.0	15.77925	0.0000E+00	15453.85	2046.15	17500.00	B	17500.00	T

DB= 37.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50004	0.1607E+05	302.56	14149.16	14451.71	T	14451.71	T
10.0	0.50073	0.3733E+05	1369.82	16104.86	17474.68	T	17474.68	T
16.0	0.50426	0.5223E+05	3137.85	14339.03	17476.88	T	17476.88	T
21.0	0.51118	0.5930E+05	4808.74	12680.87	17489.61	T	17489.61	T
26.0	0.52286	0.6206E+05	6463.24	11034.82	17498.06	T	17498.06	T
32.0	0.54384	0.6098E+05	8276.18	9222.58	17498.76	T	17498.76	T
42.0	0.59551	0.5269E+05	10727.69	6770.69	17498.38	T	17498.38	T
58.0	0.71407	0.3275E+05	13326.66	4172.77	17499.43	T	17499.43	T
75.0	0.86871	0.1044E+05	14929.35	2570.52	17499.87	T	17499.87	T
80.0	0.91593	0.4117E+04	15259.99	2239.97	17499.96	T	17499.96	T
85.0	0.93044	0.0000E+00	15453.69	2046.15	17499.85	B	17499.85	T
90.0	1.04313	0.0000E+00	15453.77	2046.15	17499.92	B	17499.92	T
95.0	1.16226	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
100.0	1.28782	0.0000E+00	15453.78	2046.15	17499.93	B	17499.93	T
110.0	1.55827	0.0000E+00	15453.79	2046.15	17499.95	B	17499.95	T
120.0	1.85448	0.0000E+00	15453.81	2046.15	17499.97	B	17499.97	T
135.0	2.34709	0.0000E+00	15453.79	2046.15	17499.95	B	17499.95	T
140.0	2.52418	0.0000E+00	15453.83	2046.15	17499.98	B	17499.98	T
150.0	2.89767	0.0000E+00	15453.82	2046.15	17499.97	B	17499.97	T
160.0	3.29692	0.0000E+00	15453.80	2046.15	17499.96	B	17499.96	T
170.0	3.72194	0.0000E+00	15453.82	2046.15	17499.97	B	17499.97	T
175.0	3.94411	0.0000E+00	15453.92	2046.15	17499.98	B	17499.98	T
200.0	5.15158	0.0000E+00	15453.82	2046.15	17499.98	B	17499.98	T
240.0	7.41852	0.0000E+00	15453.83	2046.15	17499.98	B	17499.98	T
270.0	9.38933	0.0000E+00	15453.83	2046.15	17499.99	B	17499.99	T
300.0	11.59214	0.0000E+00	15453.84	2046.15	17500.00	B	17500.00	T
350.0	15.77913	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T

DB= 38.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00004	0.1607E+05	302.56	14149.16	14451.71	T	14451.71	T
10.0	1.00073	0.3733E+05	1369.82	16104.86	17474.68	T	17474.68	T
16.0	1.00426	0.5223E+05	3137.85	14339.03	17476.88	T	17476.88	T
21.0	1.01118	0.5930E+05	4808.74	12680.87	17489.61	T	17489.61	T
26.0	1.02286	0.6206E+05	6463.24	11034.82	17498.06	T	17498.06	T
32.0	1.04384	0.6098E+05	8276.18	9222.58	17498.76	T	17498.76	T
42.0	1.09551	0.5269E+05	10727.69	6770.69	17498.38	T	17498.38	T
58.0	1.21407	0.3275E+05	13326.66	4172.77	17499.43	T	17499.43	T
75.0	1.36871	0.1044E+05	14929.35	2570.52	17499.87	T	17499.87	T
80.0	1.41593	0.4117E+04	15259.99	2239.97	17499.96	T	17499.96	T
85.0	0.93043	0.0000E+00	15453.75	2046.15	17499.90	B	17499.90	T
90.0	1.04312	0.0000E+00	15453.84	2046.15	17500.00	B	17500.00	T
95.0	1.16224	0.0000E+00	15453.79	2046.15	17499.95	B	17499.95	T
100.0	1.28780	0.0000E+00	15453.76	2046.15	17499.91	B	17499.91	T
110.0	1.55825	0.0000E+00	15453.82	2046.15	17499.97	B	17499.97	T
120.0	1.85445	0.0000E+00	15453.78	2046.15	17499.94	B	17499.94	T
135.0	2.34706	0.0000E+00	15453.82	2046.15	17499.97	B	17499.97	T
140.0	2.52414	0.0000E+00	15453.80	2046.15	17499.96	B	17499.96	T
150.0	2.89763	0.0000E+00	15453.83	2046.15	17499.98	B	17499.98	T
160.0	3.29688	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
170.0	3.72189	0.0000E+00	15453.83	2046.15	17499.99	B	17499.99	T
175.0	3.94405	0.0000E+00	15453.81	2046.15	17499.96	B	17499.96	T
200.0	5.15151	0.0000E+00	15453.83	2046.15	17499.99	B	17499.99	T
240.0	7.41842	0.0000E+00	15453.84	2046.15	17500.00	B	17500.00	T
270.0	9.38920	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
300.0	11.59197	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
350.0	15.77891	0.0000E+00	15453.84	2046.15	17500.00	B	17500.00	T

DB= 39.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50004	0.1607E+05	302.56	14149.16	14451.71	T	14451.71	T
10.0	1.50073	0.3733E+05	1369.82	16104.86	17474.68	T	17474.68	T
16.0	1.50426	0.5223E+05	3137.85	14339.03	17476.88	T	17476.88	T
21.0	1.51118	0.5930E+05	4808.74	12680.87	17489.61	T	17489.61	T
26.0	1.52286	0.6206E+05	6463.24	11034.82	17498.06	T	17498.06	T
32.0	1.54384	0.6098E+05	8276.18	9222.58	17498.76	T	17498.76	T
42.0	1.59551	0.5269E+05	10727.69	6770.69	17498.38	T	17498.38	T
58.0	1.71407	0.3275E+05	13326.66	4172.77	17499.43	T	17499.43	T
75.0	1.86871	0.1044E+05	14929.35	2570.52	17499.87	T	17499.87	T
80.0	1.91593	0.4117E+04	15259.99	2239.97	17499.96	T	17499.96	T
85.0	0.93042	0.0000E+00	15453.80	2046.15	17499.96	B	17499.96	T
90.0	1.04310	0.0000E+00	15453.77	2046.15	17499.92	B	17499.92	T
95.0	1.16222	0.0000E+00	15453.75	2046.15	17499.90	B	17499.90	T
100.0	1.28778	0.0000E+00	15453.74	2046.15	17499.89	B	17499.89	T
110.0	1.55823	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
120.0	1.85443	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
135.0	2.34703	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
140.0	2.52411	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
150.0	2.89759	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
160.0	3.29683	0.0000E+00	15453.83	2046.15	17499.98	B	17499.98	T
170.0	3.72183	0.0000E+00	15453.81	2046.15	17499.96	B	17499.96	T
175.0	3.94400	0.0000E+00	15453.83	2046.15	17499.99	B	17499.99	T
200.0	5.15144	0.0000E+00	15453.84	2046.15	17500.00	B	17500.00	T
240.0	7.41831	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
270.0	9.38906	0.0000E+00	15453.83	2046.15	17499.98	B	17499.98	T
300.0	11.59180	0.0000E+00	15453.83	2046.15	17499.99	B	17499.99	T
350.0	15.77868	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T

DB= 40.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00004	0.1607E+05	302.56	14149.16	14451.71	T	14451.71	T
10.0	2.00073	0.3733E+05	1369.82	16104.86	17474.68	T	17474.68	T
16.0	2.00426	0.5223E+05	3137.85	14339.03	17476.88	T	17476.88	T
21.0	2.01118	0.5930E+05	4808.74	12680.87	17489.61	T	17489.61	T
26.0	2.02286	0.6206E+05	6463.24	11034.82	17498.06	T	17498.06	T
32.0	2.04384	0.6098E+05	8276.18	9222.58	17498.76	T	17498.76	T
42.0	2.09551	0.5269E+05	10727.69	6770.69	17498.38	T	17498.38	T
58.0	2.21407	0.3275E+05	13326.66	4172.77	17499.43	T	17499.43	T
75.0	2.36871	0.1044E+05	14929.35	2570.52	17499.87	T	17499.87	T
80.0	2.41593	0.4117E+04	15259.99	2239.97	17499.96	T	17499.96	T
85.0	0.93040	0.0000E+00	15453.69	2046.15	17499.84	B	17499.84	T
90.0	1.04309	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
95.0	1.16221	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
100.0	1.28777	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
110.0	1.55820	0.0000E+00	15453.76	2046.15	17499.92	B	17499.92	T
120.0	1.85440	0.0000E+00	15453.81	2046.15	17499.96	B	17499.96	T
135.0	2.34699	0.0000E+00	15453.80	2046.15	17499.95	B	17499.95	T
140.0	2.52407	0.0000E+00	15453.82	2046.15	17499.97	B	17499.97	T
150.0	2.89755	0.0000E+00	15453.84	2046.15	17500.00	B	17500.00	T

160.0	3.29678	0.0000E+00	15453.81	2046.15	17499.97	B	17499.97	T
170.0	3.72178	0.0000E+00	15453.82	2046.15	17499.97	B	17499.97	T
175.0	3.94394	0.0000E+00	15453.82	2046.15	17499.97	B	17499.97	T
200.0	5.15136	0.0000E+00	15453.83	2046.15	17499.98	B	17499.98	T
240.0	7.41820	0.0000E+00	15453.83	2046.15	17499.98	B	17499.98	T
270.0	9.38893	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
300.0	11.59164	0.0000E+00	15453.84	2046.15	17500.00	B	17500.00	T
350.0	15.77846	0.0000E+00	15453.85	2046.15	17500.00	B	17500.00	T

DB= 41.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50004	0.1607E+05	302.56	14149.16	14451.71	T	14451.71	T
10.0	2.50073	0.3733E+05	1369.82	16104.86	17474.68	T	17474.68	T
16.0	2.50426	0.5223E+05	3137.85	14339.03	17476.88	T	17476.88	T
21.0	2.51118	0.5930E+05	4808.74	12680.87	17489.61	T	17489.61	T
26.0	2.52286	0.6206E+05	6463.24	11034.82	17498.06	T	17498.06	T
32.0	2.54384	0.6098E+05	8276.18	9222.58	17498.76	T	17498.76	T
42.0	2.59551	0.5269E+05	10727.69	6770.69	17498.38	T	17498.38	T
58.0	2.71407	0.3275E+05	13326.66	4172.77	17499.43	T	17499.43	T
75.0	2.86871	0.1044E+05	14929.35	2570.52	17499.87	T	17499.87	T
80.0	2.91593	0.4117E+04	15259.99	2239.97	17499.96	T	17499.96	T
85.0	0.93039	0.0000E+00	15453.75	2046.15	17499.90	B	17499.90	T
90.0	1.04307	0.0000E+00	15453.77	2046.15	17499.92	B	17499.92	T
95.0	1.16219	0.0000E+00	15453.79	2046.15	17499.95	B	17499.95	T
100.0	1.28775	0.0000E+00	15453.82	2046.15	17499.98	B	17499.98	T
110.0	1.55818	0.0000E+00	15453.79	2046.15	17499.94	B	17499.94	T
120.0	1.85437	0.0000E+00	15453.78	2046.15	17499.93	B	17499.93	T
135.0	2.34696	0.0000E+00	15453.82	2046.15	17499.98	B	17499.98	T
140.0	2.52403	0.0000E+00	15453.79	2046.15	17499.95	B	17499.95	T
150.0	2.89750	0.0000E+00	15453.80	2046.15	17499.95	B	17499.95	T
160.0	3.29674	0.0000E+00	15453.85	2046.15	17500.00	B	17500.00	T
170.0	3.72173	0.0000E+00	15453.83	2046.15	17499.99	B	17499.99	T
175.0	3.94389	0.0000E+00	15453.84	2046.15	17500.00	B	17500.00	T
200.0	5.15129	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
240.0	7.41810	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
270.0	9.38880	0.0000E+00	15453.84	2046.15	17500.00	B	17500.00	T
300.0	11.59147	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
350.0	15.77823	0.0000E+00	15453.84	2046.15	17500.00	B	17500.00	T

DB= 42.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00004	0.1607E+05	302.56	14149.16	14451.71	T	14451.71	T
10.0	3.00073	0.3733E+05	1369.82	16104.86	17474.68	T	17474.68	T
16.0	3.00426	0.5223E+05	3137.85	14339.03	17476.88	T	17476.88	T
21.0	3.01118	0.5930E+05	4808.74	12680.87	17489.61	T	17489.61	T
26.0	3.02286	0.6206E+05	6463.24	11034.82	17498.06	T	17498.06	T
32.0	3.04384	0.6098E+05	8276.18	9222.58	17498.76	T	17498.76	T
42.0	3.09551	0.5269E+05	10727.69	6770.69	17498.38	T	17498.38	T
58.0	3.21407	0.3275E+05	13326.66	4172.77	17499.43	T	17499.43	T
75.0	3.36871	0.1044E+05	14929.35	2570.52	17499.87	T	17499.87	T
80.0	3.41593	0.4117E+04	15259.99	2239.97	17499.96	T	17499.96	T
85.0	0.93038	0.0000E+00	15453.80	2046.15	17499.95	B	17499.95	T
90.0	1.04306	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
95.0	1.16217	0.0000E+00	15453.75	2046.15	17499.90	B	17499.90	T
100.0	1.28773	0.0000E+00	15453.80	2046.15	17499.96	B	17499.96	T
110.0	1.55816	0.0000E+00	15453.81	2046.15	17499.96	B	17499.96	T
120.0	1.85435	0.0000E+00	15453.83	2046.15	17499.99	B	17499.99	T
135.0	2.34693	0.0000E+00	15453.85	2046.15	17500.00	B	17500.00	T
140.0	2.52400	0.0000E+00	15453.83	2046.15	17499.98	B	17499.98	T
150.0	2.89746	0.0000E+00	15453.81	2046.15	17499.96	B	17499.96	T
160.0	3.29669	0.0000E+00	15453.83	2046.15	17499.99	B	17499.99	T
170.0	3.72167	0.0000E+00	15453.81	2046.15	17499.96	B	17499.96	T
175.0	3.94383	0.0000E+00	15453.83	2046.15	17499.98	B	17499.98	T
200.0	5.15121	0.0000E+00	15453.82	2046.15	17499.97	B	17499.97	T
240.0	7.41799	0.0000E+00	15453.83	2046.15	17499.99	B	17499.99	T
270.0	9.38866	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T
300.0	11.59131	0.0000E+00	15453.84	2046.15	17500.00	B	17500.00	T
350.0	15.77800	0.0000E+00	15453.84	2046.15	17499.99	B	17499.99	T

Table B.6 Maximum Allowable Borehole Deviation Based on Liner Insertion Stresses in Boreholes Drilled with a Steerable Bit

This section of Appendix B lists the output file from PROGRAM DEVIAT2 for maximum allowable borehole deviation based on liner insertion stresses during liner insertion operations with simultaneous drilling in horizontal and vertical boreholes drilled with a steerable bit.

The following parameter values were used in computing these results:

L_b = 26 ft (vertical borehole)
= 32, 42, 58, 75, 270, and 350 feet (horizontal boreholes)

d_b = 36.5, 37, 38, 39, 40, 41, and 42 inches

F_b = 470,000 lb (simultaneous drilling)

L = 0 to L_b .

Other parameter values were fixed as listed in Section 5.2.

RUN WITH DEVIAT1.FOR
 LINER INSERTION LOADING SPECIFIED
 MINIMUM ALLOWABLE LINER RAD'JS OF CURVATURE= 65.74 FT (BASED ON CONTAINER CLEARANCE)
 CRITICAL BUCKLING STRESS BASED ON BENDING= 0.2114E+06 PSI
 CRITICAL BUCKLING STRESS BASED ON COMPRESSION= 0.2039E+06 PSI
 FS= 4.00
 FB= 470000.00 LBF

LB= 26.000 FEET (VERTICAL)

DB= 36.500 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25015	0.7033E+05	1080.64	16298.70	17379.35	T	8950.85	I
10.0	0.25178	0.1043E+06	3204.16	14262.38	17466.54	T	9038.05	I
16.0	0.25753	0.1077E+06	5294.59	12194.11	17488.71	T	9060.21	I
21.0	0.26573	0.9949E+05	6420.44	11079.25	17499.70	T	9071.20	I
26.0	0.27683	0.8942E+05	7144.11	10352.67	17496.78	T	9068.28	I

DB= 37.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50015	0.7033E+05	1080.64	16298.70	17379.35	T	8950.85	I
10.0	0.50178	0.1043E+06	3204.16	14262.38	17466.54	T	9038.05	I
16.0	0.50753	0.1077E+06	5294.59	12194.11	17488.71	T	9060.21	I
21.0	0.51573	0.9949E+05	6420.44	11079.25	17499.70	T	9071.20	I
26.0	0.52683	0.8942E+05	7144.11	10352.67	17496.78	T	9068.28	I

DB= 38.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00015	0.7033E+05	1080.64	16298.70	17379.35	T	8950.85	I
10.0	1.00178	0.1043E+06	3204.16	14262.38	17466.54	T	9038.05	I
16.0	1.00753	0.1077E+06	5294.59	12194.11	17488.71	T	9060.21	I
21.0	1.01573	0.9949E+05	6420.44	11079.25	17499.70	T	9071.20	I
26.0	1.02683	0.8942E+05	7144.11	10352.67	17496.78	T	9068.28	I

DB= 39.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50015	0.7033E+05	1080.64	16298.70	17379.35	T	8950.85	I
10.0	1.50178	0.1043E+06	3204.16	14262.38	17466.54	T	9038.05	I
16.0	1.50753	0.1077E+06	5294.59	12194.11	17488.71	T	9060.21	I
21.0	1.51573	0.9949E+05	6420.44	11079.25	17499.70	T	9071.20	I
26.0	1.52683	0.8942E+05	7144.11	10352.67	17496.78	T	9068.28	I

DB= 40.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00015	0.7033E+05	1080.64	16298.70	17379.35	T	8950.85	I
10.0	2.00178	0.1043E+06	3204.16	14262.38	17466.54	T	9038.05	I
16.0	2.00753	0.1077E+06	5294.59	12194.11	17488.71	T	9060.21	I
21.0	2.01573	0.9949E+05	6420.44	11079.25	17499.70	T	9071.20	I
26.0	2.02683	0.8942E+05	7144.11	10352.67	17496.78	T	9068.28	I

DB= 41.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50015	0.7033E+05	1080.64	16298.70	17379.35	T	8950.85	I
10.0	2.50178	0.1043E+06	3204.16	14262.38	17466.54	T	9038.05	I
16.0	2.50753	0.1077E+06	5294.59	12194.11	17488.71	T	9060.21	I
21.0	2.51573	0.9949E+05	6420.44	11079.25	17499.70	T	9071.20	I
26.0	2.52683	0.8942E+05	7144.11	10352.67	17496.78	T	9068.28	I

DB= 42.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00015	0.7033E+05	1080.64	16298.70	17379.35	T	8950.85	I
10.0	3.00178	0.1043E+06	3204.16	14262.38	17466.54	T	9038.05	I
16.0	3.00753	0.1077E+06	5294.59	12194.11	17488.71	T	9060.21	I
21.0	3.01573	0.9949E+05	6420.44	11079.25	17499.70	T	9071.20	I
26.0	3.02683	0.8942E+05	7144.11	10352.67	17496.78	T	9068.28	I

LB= 32.000 FEET (HORIZONTAL)

DB= 36.500 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25012	0.5580E+05	867.07	16178.78	17045.84	T	4753.70	I
10.0	0.25155	0.8985E+05	2799.86	14680.93	17480.79	T	5972.04	I
16.0	0.25686	0.9659E+05	4848.33	12650.73	17499.06	T	7077.10	I
21.0	0.26466	0.9073E+05	6026.48	11469.05	17495.53	T	7749.43	I
26.0	0.27540	0.8219E+05	6828.90	10670.49	17499.39	T	8260.57	I
32.0	0.29187	0.7182E+05	7459.29	10039.13	17498.42	T	8735.21	I

DB= 37,000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50012	0.5580E+05	867.07	16178.78	17045.84	T	4753.70	I
10.0	0.50155	0.8985E+05	2799.86	14680.93	17480.79	T	5972.04	I
16.0	0.50686	0.9659E+05	4848.33	12650.73	17499.06	T	7077.10	I
21.0	0.51466	0.9073E+05	6026.48	11469.05	17495.53	T	7749.43	I
26.0	0.52540	0.8219E+05	6828.90	10670.49	17499.39	T	8260.57	I
32.0	0.54187	0.7182E+05	7459.29	10039.13	17498.42	T	8735.21	I

DB= 38,000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00012	0.5580E+05	867.07	16178.78	17045.84	T	4753.70	I
10.0	1.00155	0.8985E+05	2799.86	14680.93	17480.79	T	5972.04	I
16.0	1.00686	0.9659E+05	4848.33	12650.73	17499.06	T	7077.10	I
21.0	1.01466	0.9073E+05	6026.48	11469.05	17495.53	T	7749.43	I
26.0	1.02540	0.8219E+05	6828.90	10670.49	17499.39	T	8260.57	I
32.0	1.04187	0.7182E+05	7459.29	10039.13	17498.42	T	8735.21	I

DB= 39,000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50012	0.5580E+05	867.07	16178.78	17045.84	T	4753.70	I
10.0	1.50155	0.8985E+05	2799.86	14680.93	17480.79	T	5972.04	I
16.0	1.50686	0.9659E+05	4848.33	12650.73	17499.06	T	7077.10	I
21.0	1.51466	0.9073E+05	6026.48	11469.05	17495.53	T	7749.43	I
26.0	1.52540	0.8219E+05	6828.90	10670.49	17499.39	T	8260.57	I
32.0	1.54187	0.7182E+05	7459.29	10039.13	17498.42	T	8735.21	I

DB= 40,000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00012	0.5580E+05	867.07	16178.78	17045.84	T	4753.70	I
10.0	2.00155	0.8985E+05	2799.86	14680.93	17480.79	T	5972.04	I
16.0	2.00686	0.9659E+05	4848.33	12650.73	17499.06	T	7077.10	I
21.0	2.01466	0.9073E+05	6026.48	11469.05	17495.53	T	7749.43	I
26.0	2.02540	0.8219E+05	6828.90	10670.49	17499.39	T	8260.57	I
32.0	2.04187	0.7182E+05	7459.29	10039.13	17498.42	T	8735.21	I

DB= 41,000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50012	0.5580E+05	867.07	16178.78	17045.84	T	4753.70	I
10.0	2.50155	0.8985E+05	2799.86	14680.93	17480.79	T	5972.04	I
16.0	2.50686	0.9659E+05	4848.33	12650.73	17499.06	T	7077.10	I
21.0	2.51466	0.9073E+05	6026.48	11469.05	17495.53	T	7749.43	I
26.0	2.52540	0.8219E+05	6828.90	10670.49	17499.39	T	8260.57	I
32.0	2.54187	0.7182E+05	7459.29	10039.13	17498.42	T	8735.21	I

DB= 42,000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00012	0.5580E+05	867.07	16178.78	17045.84	T	4753.70	I
10.0	3.00155	0.8985E+05	2799.86	14680.93	17480.79	T	5972.04	I
16.0	3.00686	0.9659E+05	4848.33	12650.73	17499.06	T	7077.10	I
21.0	3.01466	0.9073E+05	6026.48	11469.05	17495.53	T	7749.43	I
26.0	3.02540	0.8219E+05	6828.90	10670.49	17499.39	T	8260.57	I
32.0	3.04187	0.7182E+05	7459.29	10039.13	17498.42	T	8735.21	I

LB= 42,000 FEET (HORIZONTAL)

DB= 36,500 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25009	0.4174E+05	651.07	16059.57	16710.64	T	4478.10	I
10.0	0.25127	0.7345E+05	2295.86	15152.47	17448.33	T	5703.81	I
16.0	0.25598	0.8400E+05	4229.58	13259.30	17488.88	T	6762.63	I
21.0	0.26327	0.8194E+05	5459.13	12040.84	17499.97	T	7467.97	I
26.0	0.27356	0.7606E+05	6338.96	11157.95	17496.91	T	8014.35	I
32.0	0.28965	0.6785E+05	7069.06	10430.37	17499.42	T	8540.59	I
42.0	0.32475	0.5512E+05	7798.64	9700.26	17498.90	T	9245.21	I

DB= 37,000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50009	0.4174E+05	651.07	16059.57	16710.64	T	4478.10	I
10.0	0.50127	0.7345E+05	2295.86	15152.47	17448.33	T	5703.81	I
16.0	0.50598	0.8400E+05	4229.58	13259.30	17488.88	T	6762.63	I
21.0	0.51327	0.8194E+05	5459.13	12040.84	17499.97	T	7467.97	I
26.0	0.52356	0.7606E+05	6338.96	11157.95	17496.91	T	8014.35	I
32.0	0.53965	0.6785E+05	7069.06	10430.37	17499.42	T	8540.59	I
42.0	0.57475	0.5512E+05	7798.64	9700.26	17498.90	T	9245.21	I

DB= 38.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00009	0.4174E+05	651.07	16059.57	16710.64	T	4478.10	I
10.0	1.00127	0.7345E+05	2295.86	15152.47	17448.33	T	5703.81	I
16.0	1.00598	0.8400E+05	4229.58	13259.30	17488.88	T	6762.63	I
21.0	1.01327	0.8194E+05	5459.13	12040.84	17499.97	T	7467.97	I
26.0	1.02356	0.7606E+05	6338.96	11157.95	17496.91	T	8014.35	I
32.0	1.03965	0.6785E+05	7069.06	10430.37	17499.42	T	8540.59	I
42.0	1.07475	0.5512E+05	7798.64	9700.26	17498.90	T	9245.21	I

DB= 39.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50009	0.4174E+05	651.07	16059.57	16710.64	T	4478.10	I
10.0	1.50127	0.7345E+05	2295.86	15152.47	17448.33	T	5703.81	I
16.0	1.50598	0.8400E+05	4229.58	13259.30	17488.88	T	6762.63	I
21.0	1.51327	0.8194E+05	5459.13	12040.84	17499.97	T	7467.97	I
26.0	1.52356	0.7606E+05	6338.96	11157.95	17496.91	T	8014.35	I
32.0	1.53965	0.6785E+05	7069.06	10430.37	17499.42	T	8540.59	I
42.0	1.57475	0.5512E+05	7798.64	9700.26	17498.90	T	9245.21	I

DB= 40.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00009	0.4174E+05	651.07	16059.57	16710.64	T	4478.10	I
10.0	2.00127	0.7345E+05	2295.86	15152.47	17448.33	T	5703.81	I
16.0	2.00598	0.8400E+05	4229.58	13259.30	17488.88	T	6762.63	I
21.0	2.01327	0.8194E+05	5459.13	12040.84	17499.97	T	7467.97	I
26.0	2.02356	0.7606E+05	6338.96	11157.95	17496.91	T	8014.35	I
32.0	2.03965	0.6785E+05	7069.06	10430.37	17499.42	T	8540.59	I
42.0	2.07475	0.5512E+05	7798.64	9700.26	17498.90	T	9245.21	I

DB= 41.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50009	0.4174E+05	651.07	16059.57	16710.64	T	4478.10	I
10.0	2.50127	0.7345E+05	2295.86	15152.47	17448.33	T	5703.81	I
16.0	2.50598	0.8400E+05	4229.58	13259.30	17488.88	T	6762.63	I
21.0	2.51327	0.8194E+05	5459.13	12040.84	17499.97	T	7467.97	I
26.0	2.52356	0.7606E+05	6338.96	11157.95	17496.91	T	8014.35	I
32.0	2.53965	0.6785E+05	7069.06	10430.37	17499.42	T	8540.59	I
42.0	2.57475	0.5512E+05	7798.64	9700.26	17498.90	T	9245.21	I

DB= 42.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00009	0.4174E+05	651.07	16059.57	16710.64	T	4478.10	I
10.0	3.00127	0.7345E+05	2295.86	15152.47	17448.33	T	5703.81	I
16.0	3.00598	0.8400E+05	4229.58	13259.30	17488.88	T	6762.63	I
21.0	3.01327	0.8194E+05	5459.13	12040.84	17499.97	T	7467.97	I
26.0	3.02356	0.7606E+05	6338.96	11157.95	17496.91	T	8014.35	I
32.0	3.03965	0.6785E+05	7069.06	10430.37	17499.42	T	8540.59	I
42.0	3.07475	0.5512E+05	7798.64	9700.26	17498.90	T	9245.21	I

LB= 58.000 FEET (HORIZONTAL)

DB= 36.500 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25007	0.3237E+05	507.07	16627.16	17134.23	T	4617.89	I
10.0	0.25099	0.5705E+05	1791.86	15666.94	17458.80	T	5457.04	I
16.0	0.25497	0.6956E+05	3519.42	13972.90	17492.32	T	6409.28	I
21.0	0.26151	0.7081E+05	4711.77	12755.35	17496.12	T	7106.86	I
26.0	0.27112	0.6792E+05	5689.25	11807.38	17496.63	T	7689.37	I
32.0	0.28654	0.6229E+05	6522.38	10976.15	17498.52	T	8266.80	I
42.0	0.32089	0.5207E+05	7404.76	10094.05	17498.81	T	9048.22	I
58.0	0.39583	0.3829E+05	8129.30	9370.61	17499.91	T	10146.35	I

DB= 37.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50007	0.3237E+05	507.07	16627.16	17134.23	T	4617.89	I
10.0	0.50099	0.5705E+05	1791.86	15666.94	17458.80	T	5457.04	I
16.0	0.50497	0.6956E+05	3519.42	13972.90	17492.32	T	6409.28	I
21.0	0.51151	0.7081E+05	4740.77	12755.35	17496.12	T	7106.86	I
26.0	0.52112	0.6792E+05	5689.25	11807.38	17496.63	T	7689.37	I
32.0	0.53654	0.6229E+05	6522.38	10976.15	17498.52	T	8266.80	I
42.0	0.57089	0.5207E+05	7404.76	10094.05	17498.81	T	9048.22	I
58.0	0.64583	0.3829E+05	8129.30	9370.61	17499.91	T	10146.35	I

DB= 38.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00007	0.3237E+05	507.07	16627.16	17134.23	T	4617.89	I
10.0	1.00099	0.5705E+05	1791.86	15666.94	17458.80	T	5457.04	I
16.0	1.00497	0.6956E+05	3519.42	13972.90	17492.32	T	6409.28	I
21.0	1.01151	0.7081E+05	4740.77	12755.35	17496.12	T	7106.86	I
26.0	1.02112	0.6792E+05	5689.25	11807.38	17496.63	T	7689.37	I
32.0	1.03654	0.6229E+05	6522.38	10976.15	17498.52	T	8266.80	I
42.0	1.07089	0.5207E+05	7404.76	10094.05	17498.81	T	9048.22	I
58.0	1.14583	0.3829E+05	8129.30	9370.61	17499.91	T	10146.35	I

DB= 39.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50007	0.3237E+05	507.07	16627.16	17134.23	T	4617.89	I
10.0	1.50099	0.5705E+05	1791.86	15666.94	17458.80	T	5457.04	I
16.0	1.50497	0.6956E+05	3519.42	13972.90	17492.32	T	6409.28	I
21.0	1.51151	0.7081E+05	4740.77	12755.35	17496.12	T	7106.86	I
26.0	1.52112	0.6792E+05	5689.25	11807.38	17496.63	T	7689.37	I
32.0	1.53654	0.6229E+05	6522.38	10976.15	17498.52	T	8266.80	I
42.0	1.57089	0.5207E+05	7404.76	10094.05	17498.81	T	9048.22	I
58.0	1.64583	0.3829E+05	8129.30	9370.61	17499.91	T	10146.35	I

DB= 40.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00007	0.3237E+05	507.07	16627.16	17134.23	T	4617.89	I
10.0	2.00099	0.5705E+05	1791.86	15666.94	17458.80	T	5457.04	I
16.0	2.00497	0.6956E+05	3519.42	13972.90	17492.32	T	6409.28	I
21.0	2.01151	0.7081E+05	4740.77	12755.35	17496.12	T	7106.86	I
26.0	2.02112	0.6792E+05	5689.25	11807.38	17496.63	T	7689.37	I
32.0	2.03654	0.6229E+05	6522.38	10976.15	17498.52	T	8266.80	I
42.0	2.07089	0.5207E+05	7404.76	10094.05	17498.81	T	9048.22	I
58.0	2.14583	0.3829E+05	8129.30	9370.61	17499.91	T	10146.35	I

DB= 41.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50007	0.3237E+05	507.07	16627.16	17134.23	T	4617.89	I
10.0	2.50099	0.5705E+05	1791.86	15666.94	17458.80	T	5457.04	I
16.0	2.50497	0.6956E+05	3519.42	13972.90	17492.32	T	6409.28	I
21.0	2.51151	0.7081E+05	4740.77	12755.35	17496.12	T	7106.86	I
26.0	2.52112	0.6792E+05	5689.25	11807.38	17496.63	T	7689.37	I
32.0	2.53654	0.6229E+05	6522.38	10976.15	17498.52	T	8266.80	I
42.0	2.57089	0.5207E+05	7404.76	10094.05	17498.81	T	9048.22	I
58.0	2.64583	0.3829E+05	8129.30	9370.61	17499.91	T	10146.35	I

DB= 42.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00007	0.3237E+05	507.07	16627.16	17134.23	T	4617.89	I
10.0	3.00099	0.5705E+05	1791.86	15666.94	17458.80	T	5457.04	I
16.0	3.00497	0.6956E+05	3519.42	13972.90	17492.32	T	6409.28	I
21.0	3.01151	0.7081E+05	4740.77	12755.35	17496.12	T	7106.86	I
26.0	3.02112	0.6792E+05	5689.25	11807.38	17496.63	T	7689.37	I
32.0	3.03654	0.6229E+05	6522.38	10976.15	17498.52	T	8266.80	I
42.0	3.07089	0.5207E+05	7404.76	10094.05	17498.81	T	9048.22	I
58.0	3.14583	0.3829E+05	8129.30	9370.61	17499.91	T	10146.35	I

LB= 75.000 FEET (HORIZONTAL)

DB= 36.500 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25005	0.2300E+05	363.07	16005.02	16368.09	T	4162.82	I
10.0	0.25080	0.4592E+05	1449.86	15992.34	17442.20	T	5277.74	I
16.0	0.25421	0.5869E+05	2985.05	14501.67	17486.71	T	6139.28	I
21.0	0.26009	0.6183E+05	4161.17	13333.30	17494.48	T	6816.25	I
26.0	0.26903	0.6096E+05	5132.75	12365.37	17498.11	T	7411.85	I
32.0	0.28373	0.5726E+05	6028.43	11469.53	17497.96	T	8019.55	I
42.0	0.31721	0.4916E+05	7029.25	10470.43	17499.68	T	8860.90	I
58.0	0.39136	0.3695E+05	7890.12	9609.41	17499.53	T	10026.57	I
75.0	0.49368	0.2673E+05	8343.31	9156.57	17499.88	T	10970.30	I

DB= 37.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50005	0.2300E+05	363.07	16005.02	16368.09	T	4162.82	I
10.0	0.50080	0.4592E+05	1449.86	15992.34	17442.20	T	5277.74	I
16.0	0.50421	0.5869E+05	2985.05	14501.67	17486.71	T	6139.28	I
21.0	0.51009	0.6183E+05	4161.17	13333.30	17494.48	T	6816.25	I
26.0	0.51903	0.6096E+05	5132.75	12365.37	17498.11	T	7411.85	I
32.0	0.53373	0.5726E+05	6028.43	11469.53	17497.96	T	8019.55	I

42.0	0.56721	0.4916E+05	7029.25	10470.43	17499.68	T	8860.90	I
58.0	0.64136	0.3695E+05	7890.12	9609.41	17499.53	T	10026.57	I
75.0	0.74368	0.2673E+05	8343.31	9156.57	17499.88	T	12960.97	I

DB= 38.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00005	0.2300E+05	363.07	16005.02	16368.09	T	4162.82	I
10.0	1.00080	0.4592E+05	1449.86	15992.34	17442.20	T	5277.74	I
16.0	1.00421	0.5869E+05	2985.05	14501.67	17486.71	T	6139.28	I
21.0	1.01009	0.6183E+05	4161.17	13333.30	17494.48	T	6816.25	I
26.0	1.01903	0.6096E+05	5132.75	12365.37	17498.11	T	7411.85	I
32.0	1.03373	0.5726E+05	6028.43	11469.53	17497.96	T	8019.55	I
42.0	1.06721	0.4916E+05	7029.25	10470.43	17499.68	T	8860.90	I
58.0	1.14136	0.3695E+05	7890.12	9609.41	17499.53	T	10026.57	I
75.0	1.24368	0.2673E+05	8343.31	9156.57	17499.88	T	12960.97	I

DB= 39.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50005	0.2300E+05	363.07	16005.02	16368.09	T	4162.82	I
10.0	1.50080	0.4592E+05	1449.86	15992.34	17442.20	T	5277.74	I
16.0	1.50421	0.5869E+05	2985.05	14501.67	17486.71	T	6139.28	I
21.0	1.51009	0.6183E+05	4161.17	13333.30	17494.48	T	6816.25	I
26.0	1.51903	0.6096E+05	5132.75	12365.37	17498.11	T	7411.85	I
32.0	1.53373	0.5726E+05	6028.43	11469.53	17497.96	T	8019.55	I
42.0	1.56721	0.4916E+05	7029.25	10470.43	17499.68	T	8860.90	I
58.0	1.64136	0.3695E+05	7890.12	9609.41	17499.53	T	10026.57	I
75.0	1.74368	0.2673E+05	8343.31	9156.57	17499.88	T	12960.97	I

DB= 40.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00005	0.2300E+05	363.07	16005.02	16368.09	T	4162.82	I
10.0	2.00080	0.4592E+05	1449.86	15992.34	17442.20	T	5277.74	I
16.0	2.00421	0.5869E+05	2985.05	14501.67	17486.71	T	6139.28	I
21.0	2.01009	0.6183E+05	4161.17	13333.30	17494.48	T	6816.25	I
26.0	2.01903	0.6096E+05	5132.75	12365.37	17498.11	T	7411.85	I
32.0	2.03373	0.5726E+05	6028.43	11469.53	17497.96	T	8019.55	I
42.0	2.06721	0.4916E+05	7029.25	10470.43	17499.68	T	8860.90	I
58.0	2.14136	0.3695E+05	7890.12	9609.41	17499.53	T	10026.57	I
75.0	2.24368	0.2673E+05	8343.31	9156.57	17499.88	T	12960.97	I

DB= 41.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50005	0.2300E+05	363.07	16005.02	16368.09	T	4162.82	I
10.0	2.50080	0.4592E+05	1449.86	15992.34	17442.20	T	5277.74	I
16.0	2.50421	0.5869E+05	2985.05	14501.67	17486.71	T	6139.28	I
21.0	2.51009	0.6183E+05	4161.17	13333.30	17494.48	T	6816.25	I
26.0	2.51903	0.6096E+05	5132.75	12365.37	17498.11	T	7411.85	I
32.0	2.53373	0.5726E+05	6028.43	11469.53	17497.96	T	8019.55	I
42.0	2.56721	0.4916E+05	7029.25	10470.43	17499.68	T	8860.90	I
58.0	2.64136	0.3695E+05	7890.12	9609.41	17499.53	T	10026.57	I
75.0	2.74368	0.2673E+05	8343.31	9156.57	17499.88	T	12960.97	I

DB= 42.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00005	0.2300E+05	363.07	16005.02	16368.09	T	4162.82	I
10.0	3.00080	0.4592E+05	1449.86	15992.34	17442.20	T	5277.74	I
16.0	3.00421	0.5869E+05	2985.05	14501.67	17486.71	T	6139.28	I
21.0	3.01009	0.6183E+05	4161.17	13333.30	17494.48	T	6816.25	I
26.0	3.01903	0.6096E+05	5132.75	12365.37	17498.11	T	7411.85	I
32.0	3.03373	0.5726E+05	6028.43	11469.53	17497.96	T	8019.55	I
42.0	3.06721	0.4916E+05	7029.25	10470.43	17499.68	T	8860.90	I
58.0	3.14136	0.3695E+05	7890.12	9609.41	17499.53	T	10026.57	I
75.0	3.24368	0.2673E+05	8343.31	9156.57	17499.88	T	12960.97	I

LB=270.000 FEET (HORIZONTAL)

DB= 36.500 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25001	0.4254E+04	75.07	13922.54	13997.61	T	2833.58	I
10.0	0.25025	0.1370E+05	459.86	16939.91	17399.77	T	4761.53	I
16.0	0.25153	0.2037E+05	1100.67	16374.40	17475.07	T	5191.28	I
21.0	0.25418	0.2445E+05	1748.93	15743.51	17492.44	T	5609.11	I
26.0	0.25890	0.2720E+05	2435.41	15056.88	17492.29	T	6060.27	I
32.0	0.26793	0.2902E+05	3251.09	14248.04	17499.13	T	6631.46	I
42.0	0.29209	0.2930E+05	4465.99	13032.01	17498.00	T	7578.43	I
58.0	0.35463	0.2592E+05	5924.78	11575.16	17499.94	T	9067.48	I
75.0	0.44940	0.2058E+05	6926.35	10573.29	17499.64	T	11165.67	I
80.0	0.48194	0.1896E+05	7144.02	10355.68	17499.70	T	10614.84	I

85.0	0.51630	0.1735E+05	7335.18	10164.70	17499.89	T	10153.69	I
90.0	0.55230	0.1577E+05	7503.36	9996.60	17499.96	T	9760.68	I
95.0	0.58976	0.1422E+05	7651.67	9848.15	17499.83	T	9420.14	I
100.0	0.64416	0.1362E+05	7729.91	9769.96	17499.87	D	9308.37	I
110.0	0.78849	0.1328E+05	7819.72	9680.23	17499.95	D	9398.18	I
120.0	0.95059	0.1239E+05	7921.56	9578.36	17499.91	D	9500.02	I
135.0	1.22537	0.1045E+05	8071.53	9428.41	17499.94	D	9649.99	I
140.0	1.32599	0.9713E+04	8118.26	9381.74	17499.99	D	9696.72	I
150.0	1.53850	0.8160E+04	8205.27	9294.71	17499.98	D	9783.73	I
160.0	1.76718	0.6547E+04	8283.58	9216.38	17499.96	D	9862.04	I
170.0	2.01184	0.4909E+04	8353.56	9146.42	17499.98	D	9932.03	I
175.0	2.14011	0.4088E+04	8385.63	9114.36	17499.99	D	9964.09	I
200.0	2.84023	0.2896E+02	8520.53	8979.46	17499.99	D	10098.99	I
240.0	4.09037	0.0000E+00	8521.36	8978.62	17499.98	B	10099.82	I
270.0	5.17692	0.0000E+00	8521.36	8978.62	17499.98	B	10099.83	I

DB= 37.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50001	0.4254E+04	75.07	13922.54	13997.61	T	2833.58	I
10.0	0.50025	0.1370E+05	459.86	16939.91	17399.77	T	4761.53	I
16.0	0.50153	0.2037E+05	1100.67	16374.40	17475.07	T	5191.28	I
21.0	0.50418	0.2445E+05	1748.93	15743.51	17492.44	T	5609.11	I
26.0	0.50890	0.2720E+05	2435.41	15056.88	17492.29	T	6060.27	I
32.0	0.51793	0.2902E+05	3251.09	14248.04	17499.13	T	6631.46	I
42.0	0.54209	0.2930E+05	4465.99	13032.01	17498.00	T	7578.43	I
58.0	0.60463	0.2592E+05	5924.78	11575.16	17499.94	T	9067.48	I
75.0	0.69940	0.2058E+05	6926.35	10573.29	17499.64	T	14100.97	I
80.0	0.73194	0.1896E+05	7144.02	10355.68	17499.70	T	15302.39	I
85.0	0.76630	0.1735E+05	7335.18	10164.70	17499.89	T	14305.97	I
90.0	0.80230	0.1577E+05	7503.36	9996.60	17499.96	T	13464.41	I
95.0	0.83976	0.1422E+05	7651.67	9848.15	17499.83	T	12744.27	I
100.0	0.87852	0.1270E+05	7783.21	9716.73	17499.95	T	12120.72	I
110.0	0.95916	0.9792E+04	8004.00	9495.83	17499.83	T	11090.80	I
120.0	1.04273	0.7035E+04	8180.71	9319.26	17499.98	T	10267.88	I
135.0	1.25953	0.5300E+04	8293.19	9206.74	17499.93	D	9871.65	I
140.0	1.35758	0.5051E+04	8311.69	9188.24	17499.93	D	9890.15	I
150.0	1.56648	0.4307E+04	8354.52	9145.45	17499.98	D	9932.99	I
160.0	1.79211	0.3329E+04	8400.46	9099.50	17499.96	D	9978.93	I
170.0	2.03417	0.2195E+04	8446.31	9053.64	17499.96	D	10024.77	I
175.0	2.16129	0.1588E+04	8468.65	9031.33	17499.98	D	10047.11	I
200.0	2.84050	0.0000E+00	8521.38	8978.62	17500.00	B	10099.84	I
240.0	4.09036	0.0000E+00	8521.38	8978.62	17499.99	B	10099.84	I
270.0	5.17690	0.0000E+00	8521.37	8978.62	17499.98	B	10099.83	I

DB= 38.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00001	0.4254E+04	75.07	13922.54	13997.61	T	2833.58	I
10.0	1.00025	0.1370E+05	459.86	16939.91	17399.77	T	4761.53	I
16.0	1.00153	0.2037E+05	1100.67	16374.40	17475.07	T	5191.28	I
21.0	1.00418	0.2445E+05	1748.93	15743.51	17492.44	T	5609.11	I
26.0	1.00890	0.2720E+05	2435.41	15056.88	17492.29	T	6060.27	I
32.0	1.01793	0.2902E+05	3251.09	14248.04	17499.13	T	6631.46	I
42.0	1.04209	0.2930E+05	4465.99	13032.01	17498.00	T	7578.43	I
58.0	1.10463	0.2592E+05	5924.78	11575.16	17499.94	T	9067.48	I
75.0	1.19940	0.2058E+05	6926.35	10573.29	17499.64	T	14100.97	I
80.0	1.23194	0.1896E+05	7144.02	10355.68	17499.70	T	15826.29	I
85.0	1.26630	0.1735E+05	7335.18	10164.70	17499.89	T	17662.92	T
90.0	1.30230	0.1577E+05	7503.36	9996.60	17499.96	T	19610.87	T
95.0	1.33976	0.1422E+05	7651.67	9848.15	17499.83	T	19392.64	T
100.0	1.37852	0.1270E+05	7783.21	9716.73	17499.95	T	18120.86	T
110.0	1.45916	0.9792E+04	8004.00	9495.83	17499.83	T	16049.58	I
120.0	1.54273	0.7035E+04	8180.71	9319.26	17499.98	T	14434.62	I
135.0	1.67001	0.5316E+04	8384.94	9115.01	17499.95	T	12574.45	I
140.0	1.71210	0.4945E+04	8440.61	9059.36	17499.96	T	12060.74	I
150.0	1.59775	0.0000E+00	8521.36	8978.62	17499.98	B	10099.82	I
160.0	1.81789	0.0000E+00	8521.37	8978.62	17499.99	B	10099.83	I
170.0	2.05223	0.0000E+00	8521.37	8978.62	17499.99	B	10099.83	I
175.0	2.17473	0.0000E+00	8521.38	8978.62	17500.00	B	10099.84	I
200.0	2.84047	0.0000E+00	8521.35	8978.62	17499.97	B	10099.82	I
240.0	4.09033	0.0000E+00	8521.38	8978.62	17500.00	B	10099.84	I
270.0	5.17686	0.0000E+00	8521.37	8978.62	17499.99	B	10099.83	I

DB= 39.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50001	0.4254E+04	75.07	13922.54	13997.61	T	2833.58	I
10.0	1.50025	0.1370E+05	459.86	16939.91	17399.77	T	4761.53	I
16.0	1.50153	0.2037E+05	1100.67	16374.40	17475.07	T	5191.28	I
21.0	1.50418	0.2445E+05	1748.93	15743.51	17492.44	T	5609.11	I
26.0	1.50890	0.2720E+05	2435.41	15056.88	17492.29	T	6060.27	I
32.0	1.51793	0.2902E+05	3251.09	14248.04	17499.13	T	6631.46	I
42.0	1.54209	0.2930E+05	4465.99	13032.01	17498.00	T	7578.43	I

58.0	1.60463	0.2592E+05	5924.78	11575.16	17499.94	T	9067.48	I
75.0	1.69940	0.2058E+05	6926.35	10573.29	17499.64	T	14100.97	I
80.0	1.73194	0.1896E+05	7144.02	10355.68	17499.70	T	15826.29	I
85.0	1.76630	0.1735E+05	7335.18	10164.70	17499.89	T	17662.92	T
90.0	1.80230	0.1577E+05	7503.36	9996.60	17499.96	T	19610.87	T
95.0	1.83976	0.1422E+05	7651.67	9848.15	17499.83	T	21670.12	T
100.0	1.87852	0.1270E+05	7783.21	9716.73	17499.95	T	23840.69	T
110.0	1.95916	0.9792E+04	8004.00	9495.83	17499.83	T	21008.51	T
120.0	2.04273	0.7035E+04	8180.71	9319.26	17499.98	T	18601.47	T
135.0	2.17001	0.3169E+04	8384.94	9115.01	17499.95	T	15866.75	I
140.0	2.21210	0.1945E+04	8440.61	9059.36	17499.96	T	15122.07	I
150.0	1.59774	0.0000E+00	8521.37	8978.62	17499.99	B	10099.84	I
160.0	1.81787	0.0000E+00	8521.35	8978.62	17499.96	B	10099.81	I
170.0	2.05221	0.0000E+00	8521.35	8978.62	17499.97	B	10099.81	I
175.0	2.17471	0.0000E+00	8521.37	8978.62	17499.99	B	10099.83	I
200.0	2.84045	0.0000E+00	8521.36	8978.62	17499.98	B	10099.82	I
240.0	4.09029	0.0000E+00	8521.36	8978.62	17499.98	B	10099.83	I
270.0	5.17682	0.0000E+00	8521.37	8978.62	17499.99	B	10099.83	I

DB= 40.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00001	0.4254E+04	75.07	13922.54	13997.61	T	2833.58	I
10.0	2.00025	0.1370E+05	459.86	16939.91	17399.77	T	4761.53	I
16.0	2.00153	0.2037E+05	1100.67	16374.40	17475.07	T	5191.28	I
21.0	2.00418	0.2445E+05	1748.93	15743.51	17492.44	T	5609.11	I
26.0	2.00890	0.2720E+05	2435.41	15056.88	17492.29	T	6060.27	I
32.0	2.01793	0.2902E+05	3251.09	14248.04	17499.13	T	6631.46	I
42.0	2.04209	0.2930E+05	4465.99	13032.01	17498.00	T	7578.43	I
58.0	2.10463	0.2592E+05	5924.78	11575.16	17499.94	T	9067.48	I
75.0	2.19940	0.2058E+05	6926.35	10573.29	17499.64	T	14100.97	I
80.0	2.23194	0.1896E+05	7144.02	10355.68	17499.70	T	15826.29	I
85.0	2.26630	0.1735E+05	7335.18	10164.70	17499.89	T	17662.92	T
90.0	2.30230	0.1577E+05	7503.36	9996.60	17499.96	T	19610.87	T
95.0	2.33976	0.1422E+05	7651.67	9848.15	17499.83	T	21670.12	T
100.0	2.37852	0.1270E+05	7783.21	9716.73	17499.95	T	23840.69	T
110.0	2.45916	0.9792E+04	8004.00	9495.83	17499.83	T	25967.67	T
120.0	2.54273	0.7035E+04	8180.71	9319.26	17499.98	T	22768.48	T
135.0	2.67001	0.3169E+04	8384.94	9115.01	17499.95	T	19159.16	T
140.0	2.71210	0.1945E+04	8440.61	9059.36	17499.96	T	18183.48	T
150.0	1.59772	0.0000E+00	8521.34	8978.62	17499.95	B	10099.80	I
160.0	1.81786	0.0000E+00	8521.37	8978.62	17499.99	B	10099.83	I
170.0	2.05220	0.0000E+00	8521.38	8978.62	17500.00	B	10099.84	I
175.0	2.17469	0.0000E+00	8521.36	8978.62	17499.98	B	10099.82	I
200.0	2.84043	0.0000E+00	8521.37	8978.62	17499.99	B	10099.83	I
240.0	4.09026	0.0000E+00	8521.37	8978.62	17499.99	B	10099.83	I
270.0	5.17678	0.0000E+00	8521.37	8978.62	17499.99	B	10099.83	I

DB= 41.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50001	0.4254E+04	75.07	13922.54	13997.61	T	2833.58	I
10.0	2.50025	0.1370E+05	459.86	16939.91	17399.77	T	4761.53	I
16.0	2.50153	0.2037E+05	1100.67	16374.40	17475.07	T	5191.28	I
21.0	2.50418	0.2445E+05	1748.93	15743.51	17492.44	T	5609.11	I
26.0	2.50890	0.2720E+05	2435.41	15056.88	17492.29	T	6060.27	I
32.0	2.51793	0.2902E+05	3251.09	14248.04	17499.13	T	6631.46	I
42.0	2.54209	0.2930E+05	4465.99	13032.01	17498.00	T	7578.43	I
58.0	2.60463	0.2592E+05	5924.78	11575.16	17499.94	T	9067.48	I
75.0	2.69940	0.2058E+05	6926.35	10573.29	17499.64	T	14100.97	I
80.0	2.73194	0.1896E+05	7144.02	10355.68	17499.70	T	15826.29	I
85.0	2.76630	0.1735E+05	7335.18	10164.70	17499.89	T	17662.92	T
90.0	2.80230	0.1577E+05	7503.36	9996.60	17499.96	T	19610.87	T
95.0	2.83976	0.1422E+05	7651.67	9848.15	17499.83	T	21670.12	T
100.0	2.87852	0.1270E+05	7783.21	9716.73	17499.95	T	23840.69	T
110.0	2.95916	0.9792E+04	8004.00	9495.83	17499.83	T	28515.76	T
120.0	3.04273	0.7035E+04	8180.71	9319.26	17499.98	T	26935.71	T
135.0	3.17001	0.3169E+04	8384.94	9115.01	17499.95	T	22451.69	T
140.0	3.21210	0.1945E+04	8440.61	9059.36	17499.96	T	21245.02	T
150.0	1.59771	0.0000E+00	8521.35	8978.62	17499.97	B	10099.81	I
160.0	1.81784	0.0000E+00	8521.34	8978.62	17499.96	B	10099.80	I
170.0	2.05218	0.0000E+00	8521.36	8978.62	17499.98	B	10099.82	I
175.0	2.17467	0.0000E+00	8521.35	8978.62	17499.97	B	10099.81	I
200.0	2.84041	0.0000E+00	8521.38	8978.62	17499.99	B	10099.84	I
240.0	4.09023	0.0000E+00	8521.37	8978.62	17499.99	B	10099.84	I
270.0	5.17674	0.0000E+00	8521.37	8978.62	17499.99	B	10099.83	I

DB= 42.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00001	0.4254E+04	75.07	13922.54	13997.61	T	2833.58	I
10.0	3.00025	0.1370E+05	459.86	16939.91	17399.77	T	4761.53	I
16.0	3.00153	0.2037E+05	1100.67	16374.40	17475.07	T	5191.28	I
21.0	3.00418	0.2445E+05	1748.93	15743.51	17492.44	T	5609.11	I

26.0	3.00890	0.2720E+05	2435.41	15056.88	17492.29	T	6060.27	I
32.0	3.01793	0.2902E+05	3251.09	14248.04	17499.13	T	6631.46	I
42.0	3.04209	0.2930E+05	4465.99	13032.01	17498.00	T	7578.43	I
58.0	3.10463	0.2592E+05	5924.78	11575.16	17499.94	T	9067.48	I
75.0	3.19940	0.2058E+05	6926.35	10573.29	17499.64	T	14100.97	I
80.0	3.23194	0.1896E+05	7144.02	10355.68	17499.70	T	15826.29	I
85.0	3.26630	0.1735E+05	7335.18	10164.70	17499.89	T	17662.92	T
90.0	3.30230	0.1577E+05	7503.36	9996.60	17499.96	T	19610.87	T
95.0	3.33976	0.1422E+05	7651.67	9848.15	17499.83	T	21670.12	T
100.0	3.37852	0.1270E+05	7783.21	9716.73	17499.95	T	23840.69	T
110.0	3.45916	0.9792E+04	8004.00	9495.83	17499.83	T	28515.76	T
120.0	3.54273	0.7035E+04	8180.71	9319.26	17499.98	T	31103.20	T
135.0	3.67001	0.3169E+04	8384.94	9115.01	17499.95	T	25744.40	T
140.0	3.71210	0.1945E+04	8440.61	9059.36	17499.96	T	24306.70	T
150.0	1.59770	0.0000E+00	8521.36	8978.62	17499.98	B	10099.82	I
160.0	1.81783	0.0000E+00	8521.36	8978.62	17499.98	B	10099.82	I
170.0	2.05216	0.0000E+00	8521.35	8978.62	17499.96	B	10099.81	I
175.0	2.17466	0.0000E+00	8521.37	8978.62	17499.99	B	10099.84	I
200.0	2.84038	0.0000E+00	8521.35	8978.62	17499.97	B	10099.81	I
240.0	4.09020	0.0000E+00	8521.38	8978.62	17500.00	B	10099.84	I
270.0	5.17670	0.0000E+00	8521.37	8978.62	17499.99	B	10099.83	I

LB=350.000 FEET (HORIZONTAL)

DB= 36.500 INCHES

L (FT)	DELM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25001	0.4254E+04	75.07	15550.40	15625.47	T	3647.51	I
10.0	0.25019	0.1019E+05	351.86	16814.76	17166.62	T	4590.95	I
16.0	0.25121	0.1579E+05	875.67	16574.57	17450.24	T	5066.36	I
21.0	0.25337	0.1933E+05	1418.32	16073.45	17491.77	T	5443.47	I
26.0	0.25731	0.2190E+05	2012.04	15485.82	17497.86	T	5851.37	I
32.0	0.26504	0.2386E+05	2743.08	14756.42	17499.50	T	6377.64	I
42.0	0.28650	0.2488E+05	3895.58	13603.46	17499.04	T	7293.75	I
58.0	0.34455	0.2289E+05	5385.42	12114.54	17499.96	T	9535.17	I
75.0	0.43557	0.1866E+05	6483.79	11015.96	17499.74	T	11338.32	I
80.0	0.46726	0.1728E+05	6731.15	10768.58	17499.72	T	10807.28	I
85.0	0.50088	0.1588E+05	6951.02	10548.81	17499.83	T	10365.27	I
90.0	0.53625	0.1448E+05	7146.69	10353.30	17499.99	T	9990.60	I
95.0	0.57318	0.1308E+05	7320.99	10178.99	17499.98	T	9667.38	I
100.0	0.61994	0.1220E+05	7439.27	10060.58	17499.85	D	9485.43	I
110.0	0.75981	0.1202E+05	7535.29	9964.70	17499.99	D	9581.45	I
120.0	0.91802	0.1128E+05	7650.14	9849.76	17499.91	D	9696.30	I
135.0	1.18843	0.9559E+04	7825.02	9674.95	17499.97	D	9871.17	I
140.0	1.28714	0.8884E+04	7880.40	9619.56	17499.97	D	9926.56	I
150.0	1.49713	0.7442E+04	7984.63	9515.31	17499.95	D	10030.79	I
160.0	1.72363	0.5925E+04	8079.44	9420.51	17499.95	D	10125.60	I
170.0	1.96639	0.4368E+04	8164.85	9335.13	17499.98	D	10211.01	I
175.0	2.09380	0.3582E+04	8204.18	9295.80	17499.98	D	10250.33	I
200.0	2.78617	0.0000E+00	8358.36	9141.62	17499.98	B	10404.52	I
240.0	4.01213	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I
270.0	5.07789	0.0000E+00	8358.37	9141.62	17499.99	B	10404.52	I
300.0	6.26906	0.0000E+00	8358.37	9141.62	17499.99	B	10404.53	I
350.0	8.53304	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I

DB= 37.000 INCHES

L (FT)	DELM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50001	0.4254E+04	75.07	15550.40	15625.47	T	3647.51	I
10.0	0.50019	0.1019E+05	351.86	16814.76	17166.62	T	4590.95	I
16.0	0.50121	0.1579E+05	875.67	16574.57	17450.24	T	5066.36	I
21.0	0.50337	0.1933E+05	1418.32	16073.45	17491.77	T	5443.47	I
26.0	0.50731	0.2190E+05	2012.04	15485.82	17497.86	T	5851.37	I
32.0	0.51504	0.2386E+05	2743.08	14756.42	17499.50	T	6377.64	I
42.0	0.53650	0.2488E+05	3895.58	13603.46	17499.04	T	7293.75	I
58.0	0.59455	0.2289E+05	5385.42	12114.54	17499.96	T	9535.17	I
75.0	0.68557	0.1866E+05	6483.79	11015.96	17499.74	T	14568.66	I
80.0	0.71726	0.1728E+05	6731.15	10768.58	17499.72	T	15494.83	I
85.0	0.75088	0.1588E+05	6951.02	10548.81	17499.83	T	14517.55	I
90.0	0.78625	0.1448E+05	7146.69	10353.30	17499.99	T	13694.33	I
95.0	0.82318	0.1308E+05	7320.99	10178.99	17499.98	T	12991.50	I
100.0	0.86149	0.1171E+05	7476.67	10023.30	17499.97	T	12384.05	I
110.0	0.94149	0.9014E+04	7741.14	9758.83	17499.97	T	11383.25	I
120.0	1.02468	0.6424E+04	7955.09	9544.79	17499.88	T	10585.15	I
135.0	1.23039	0.4607E+04	8101.32	9398.63	17499.95	D	10147.47	I
140.0	1.32662	0.4390E+04	8122.14	9377.80	17499.94	D	10168.30	I
150.0	1.53224	0.3713E+04	8171.91	9328.05	17499.96	D	10218.07	I
160.0	1.75502	0.2798E+04	8226.61	9273.35	17499.96	D	10272.76	I
170.0	1.99460	0.1723E+04	8282.01	9217.97	17499.99	D	10328.17	I
175.0	2.12059	0.1143E+04	8309.18	9190.80	17499.98	D	10355.33	I
200.0	2.78616	0.0000E+00	8358.36	9141.62	17499.98	B	10404.52	I
240.0	4.01211	0.0000E+00	8358.37	9141.62	17499.99	B	10404.52	I
270.0	5.07787	0.0000E+00	8358.37	9141.62	17499.99	B	10404.52	I
300.0	6.26904	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I

350.0	8.53301	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I
DB= 38.000 INCHES								
L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00001	0.4254E+04	75.07	15550.40	15625.47	T	3647.51	I
10.0	1.00019	0.1019E+05	351.86	16814.76	17166.62	T	4590.95	I
16.0	1.00121	0.1579E+05	875.67	16574.57	17450.24	T	5066.36	I
21.0	1.00337	0.1933E+05	1418.32	16073.45	17491.77	T	5443.47	I
26.0	1.00731	0.2190E+05	2012.04	15485.82	17497.86	T	5851.37	I
32.0	1.01504	0.2386E+05	2743.08	14756.42	17499.50	T	6377.64	I
42.0	1.03650	0.2488E+05	3895.58	13603.46	17499.04	T	7293.75	I
58.0	1.09455	0.2289E+05	5385.42	12114.54	17499.96	T	9535.17	I
75.0	1.18557	0.1866E+05	6483.79	11015.96	17499.74	T	14568.66	I
80.0	1.21726	0.1728E+05	6731.15	10768.58	17499.72	T	16293.98	I
85.0	1.25088	0.1588E+05	6951.02	10548.81	17499.83	T	18130.61	T
90.0	1.28625	0.1448E+05	7146.69	10353.30	17499.99	T	20078.56	T
95.0	1.32318	0.1308E+05	7320.99	10178.99	17499.98	T	19639.88	T
100.0	1.36149	0.1171E+05	7476.67	10023.30	17499.97	T	18384.19	T
110.0	1.44149	0.9014E+04	7741.14	9758.83	17499.97	T	16342.03	I
120.0	1.52468	0.6424E+04	7955.09	9544.79	17499.88	T	14751.89	I
135.0	1.65185	0.2737E+04	8205.58	9294.31	17499.89	T	12922.57	I
140.0	1.69401	0.1559E+04	8274.47	9225.51	17499.98	T	12417.67	I
150.0	1.56719	0.0000E+00	8358.38	9141.62	17499.99	B	10404.53	I
160.0	1.78311	0.0000E+00	8358.34	9141.62	17499.96	B	10404.50	I
170.0	2.01297	0.0000E+00	8358.35	9141.62	17499.97	B	10404.51	I
175.0	2.13313	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I
200.0	2.78614	0.0000E+00	8358.37	9141.62	17499.99	B	10404.52	I
240.0	4.01208	0.0000E+00	8358.37	9141.62	17499.99	B	10404.52	I
270.0	5.07783	0.0000E+00	8358.37	9141.62	17499.99	B	10404.52	I
300.0	6.26899	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I
350.0	8.53294	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I

DB= 39.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50001	0.4254E+04	75.07	15550.40	15625.47	T	3647.51	I
10.0	1.50019	0.1019E+05	351.86	16814.76	17166.62	T	4590.95	I
16.0	1.50121	0.1579E+05	875.67	16574.57	17450.24	T	5066.36	I
21.0	1.50337	0.1933E+05	1418.32	16073.45	17491.77	T	5443.47	I
26.0	1.50731	0.2190E+05	2012.04	15485.82	17497.86	T	5851.37	I
32.0	1.51504	0.2386E+05	2743.08	14756.42	17499.50	T	6377.64	I
42.0	1.53650	0.2488E+05	3895.58	13603.46	17499.04	T	7293.75	I
58.0	1.59455	0.2289E+05	5385.42	12114.54	17499.96	T	9535.17	I
75.0	1.68557	0.1866E+05	6483.79	11015.96	17499.74	T	14568.66	I
80.0	1.71726	0.1728E+05	6731.15	10768.58	17499.72	T	16293.98	I
85.0	1.75088	0.1588E+05	6951.02	10548.81	17499.83	T	18130.61	T
90.0	1.78625	0.1448E+05	7146.69	10353.30	17499.99	T	20078.56	T
95.0	1.82318	0.1308E+05	7320.99	10178.99	17499.98	T	22137.82	T
100.0	1.86149	0.1171E+05	7476.67	10023.30	17499.97	T	24308.38	T
110.0	1.94149	0.9014E+04	7741.14	9758.83	17499.97	T	21300.96	T
120.0	2.02468	0.6424E+04	7955.09	9544.79	17499.88	T	18918.75	T
135.0	2.15185	0.2737E+04	8205.58	9294.31	17499.89	T	16214.87	I
140.0	2.19401	0.1559E+04	8274.47	9225.51	17499.98	T	15479.00	I
150.0	1.56717	0.0000E+00	8358.33	9141.62	17499.95	B	10404.49	I
160.0	1.78310	0.0000E+00	8358.36	9141.62	17499.98	B	10404.51	I
170.0	2.01296	0.0000E+00	8358.38	9141.62	17499.99	B	10404.53	I
175.0	2.13311	0.0000E+00	8358.36	9141.62	17499.98	B	10404.52	I
200.0	2.78612	0.0000E+00	8358.37	9141.62	17499.99	B	10404.53	I
240.0	4.01205	0.0000E+00	8358.37	9141.62	17499.99	B	10404.53	I
270.0	5.07779	0.0000E+00	8358.37	9141.62	17499.99	B	10404.52	I
300.0	6.26894	0.0000E+00	8358.38	9141.62	17499.99	B	10404.53	I
350.0	8.53287	0.0000E+00	8358.37	9141.62	17499.99	B	10404.53	I

DB= 40.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00001	0.4254E+04	75.07	15550.40	15625.47	T	3647.51	I
10.0	2.00019	0.1019E+05	351.86	16814.76	17166.62	T	4590.95	I
16.0	2.00121	0.1579E+05	875.67	16574.57	17450.24	T	5066.36	I
21.0	2.00337	0.1933E+05	1418.32	16073.45	17491.77	T	5443.47	I
26.0	2.00731	0.2190E+05	2012.04	15485.82	17497.86	T	5851.37	I
32.0	2.01504	0.2386E+05	2743.08	14756.42	17499.50	T	6377.64	I
42.0	2.03650	0.2488E+05	3895.58	13603.46	17499.04	T	7293.75	I
58.0	2.09455	0.2289E+05	5385.42	12114.54	17499.96	T	9535.17	I
75.0	2.18557	0.1866E+05	6483.79	11015.96	17499.74	T	14568.66	I
80.0	2.21726	0.1728E+05	6731.15	10768.58	17499.72	T	16293.98	I
85.0	2.25088	0.1588E+05	6951.02	10548.81	17499.83	T	18130.61	T
90.0	2.28625	0.1448E+05	7146.69	10353.30	17499.99	T	20078.56	T
95.0	2.32318	0.1308E+05	7320.99	10178.99	17499.98	T	22137.82	T
100.0	2.36149	0.1171E+05	7476.67	10023.30	17499.97	T	24308.38	T
110.0	2.44149	0.9014E+04	7741.14	9758.83	17499.97	T	26260.12	T
120.0	2.52468	0.6424E+04	7955.09	9544.79	17499.88	T	23085.76	T
135.0	2.65185	0.2737E+04	8205.58	9294.31	17499.89	T	19507.28	T

140.0	2.69401	0.1559E+04	8274.47	9225.51	17499.98	T	18540.42	T
150.0	1.56716	0.0000E+00	8358.34	9141.62	17499.96	B	10404.50	I
160.0	1.78309	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I
170.0	2.01294	0.0000E+00	8358.36	9141.62	17499.98	B	10404.51	I
175.0	2.13309	0.0000E+00	8358.35	9141.62	17499.97	B	10404.51	I
200.0	2.78610	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I
240.0	4.01202	0.0000E+00	8358.37	9141.62	17499.99	B	10404.53	I
270.0	5.07775	0.0000E+00	8358.37	9141.62	17499.99	B	10404.52	I
300.0	6.26889	0.0000E+00	8358.37	9141.62	17499.99	B	10404.53	I
350.0	8.53281	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I

DB= 41.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50001	0.4254E+04	75.07	15550.40	15625.47	T	3647.51	I
10.0	2.50019	0.1019E+05	351.86	16814.76	17166.62	T	4590.95	I
16.0	2.50121	0.1579E+05	875.67	16574.57	17450.24	T	5066.36	I
21.0	2.50337	0.1933E+05	1418.32	16073.45	17491.77	T	5443.47	I
26.0	2.50731	0.2190E+05	2012.04	15485.82	17497.86	T	5851.37	I
32.0	2.51504	0.2386E+05	2743.08	14756.42	17499.50	T	6377.64	I
42.0	2.53650	0.2488E+05	3895.58	13603.46	17499.04	T	7293.75	I
58.0	2.59455	0.2289E+05	5385.42	12114.54	17499.96	T	9535.17	I
75.0	2.68557	0.1866E+05	6483.79	11015.96	17499.74	T	14568.66	I
80.0	2.71726	0.1728E+05	6731.15	10768.58	17499.72	T	16293.98	I
85.0	2.75088	0.1588E+05	6951.02	10548.81	17499.83	T	18130.61	T
90.0	2.78625	0.1448E+05	7146.69	10353.30	17499.99	T	20078.56	T
95.0	2.82318	0.1308E+05	7320.99	10178.99	17499.98	T	22137.82	T
100.0	2.86149	0.1171E+05	7476.67	10023.30	17499.97	T	24308.38	T
110.0	2.94149	0.9014E+04	7741.14	9758.83	17499.97	T	28983.45	T
120.0	3.02468	0.6424E+04	7955.09	9544.79	17499.88	T	31420.47	T
135.0	3.15185	0.2737E+04	8205.58	9294.31	17499.89	T	26092.51	T
140.0	3.19401	0.1559E+04	8274.47	9225.51	17499.98	T	24663.63	T
150.0	1.56715	0.0000E+00	8358.36	9141.62	17499.98	B	10404.51	I
160.0	1.78307	0.0000E+00	8358.35	9141.62	17499.97	B	10404.50	I
170.0	2.01293	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I
175.0	2.13308	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I
200.0	2.78607	0.0000E+00	8358.35	9141.62	17499.97	B	10404.51	I
240.0	4.01199	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I
270.0	5.07771	0.0000E+00	8358.37	9141.62	17499.98	B	10404.52	I
300.0	6.26884	0.0000E+00	8358.37	9141.62	17499.99	B	10404.53	I
350.0	8.53274	0.0000E+00	8358.37	9141.62	17499.99	B	10404.53	I

DB= 42.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00001	0.4254E+04	75.07	15550.40	15625.47	T	3647.51	I
10.0	3.00019	0.1019E+05	351.86	16814.76	17166.62	T	4590.95	I
16.0	3.00121	0.1579E+05	875.67	16574.57	17450.24	T	5066.36	I
21.0	3.00337	0.1933E+05	1418.32	16073.45	17491.77	T	5443.47	I
26.0	3.00731	0.2190E+05	2012.04	15485.82	17497.86	T	5851.37	I
32.0	3.01504	0.2386E+05	2743.08	14756.42	17499.50	T	6377.64	I
42.0	3.03650	0.2488E+05	3895.58	13603.46	17499.04	T	7293.75	I
58.0	3.09455	0.2289E+05	5385.42	12114.54	17499.96	T	9535.17	I
75.0	3.18557	0.1866E+05	6483.79	11015.96	17499.74	T	14568.66	I
80.0	3.21726	0.1728E+05	6731.15	10768.58	17499.72	T	16293.98	I
85.0	3.25088	0.1588E+05	6951.02	10548.81	17499.83	T	18130.61	T
90.0	3.28625	0.1448E+05	7146.69	10353.30	17499.99	T	20078.56	T
95.0	3.32318	0.1308E+05	7320.99	10178.99	17499.98	T	22137.82	T
100.0	3.36149	0.1171E+05	7476.67	10023.30	17499.97	T	24308.38	T
110.0	3.44149	0.9014E+04	7741.14	9758.83	17499.97	T	28983.45	T
120.0	3.52468	0.6424E+04	7955.09	9544.79	17499.88	T	31420.47	T
135.0	3.65185	0.2737E+04	8205.58	9294.31	17499.89	T	26092.51	T
140.0	3.69401	0.1559E+04	8274.47	9225.51	17499.98	T	24663.63	T
150.0	1.56714	0.0000E+00	8358.37	9141.62	17499.99	B	10404.52	I
160.0	1.78306	0.0000E+00	8358.37	9141.62	17499.99	B	10404.52	I
170.0	2.01291	0.0000E+00	8358.36	9141.62	17499.98	B	10404.52	I
175.0	2.13306	0.0000E+00	8358.36	9141.62	17499.98	B	10404.52	I
200.0	2.78605	0.0000E+00	8358.36	9141.62	17499.98	B	10404.51	I
240.0	4.01196	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I
270.0	5.07767	0.0000E+00	8358.36	9141.62	17499.98	B	10404.52	I
300.0	6.26879	0.0000E+00	8358.37	9141.62	17499.99	B	10404.52	I
350.0	8.53268	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I

Table B.7 Maximum Allowable Borehole Deviation Based on Liner Insertion Stresses in Boreholes Drilled with a Steerable Bit

This section of Appendix B lists the output file from PROGRAM DEVIAT2 for maximum allowable borehole deviation based on liner insertion stresses during liner insertion operations with no simultaneous drilling in horizontal and vertical boreholes drilled with a steerable bit.

The following parameter values were used in computing these results:

L_b = 26 ft (vertical borehole)
= 32, 42, 58, 75, 270, and 350 feet (horizontal boreholes)

d_b = 36.5, 37, 38, 39, 40, 41, and 42 inches

F_b = 0 (no simultaneous drilling)

L = 0 to L_b .

Other parameter values were fixed as listed in Section 5.2.

RUN 1H DEVIAT1.FOR
 LINER INSERTION LOADING SPECIFIED
 MINIMUM ALLOWABLE LINER RADIUS OF CURVATURE= 65.74 FT (BASED ON CONTAINER CLEARANCE)
 CRITICAL BUCKLING STRESS BASED ON BENDING= 0.2114E+06 PSI
 CRITICAL BUCKLING STRESS BASED ON COMPRESSION= 0.2039E+06 PSI
 FS= 4.00
 FB= 0.00 LBF

LB= 26.000 FEET (VERTICAL)

DB= 36.500 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25029	0.1359E+06	2088.64	15211.36	17300.00	T	17300.00	T
10.0	0.25344	0.2015E+06	6192.16	11274.21	17466.37	T	17466.37	T
16.0	0.26454	0.2079E+06	10223.50	7271.15	17494.65	T	17494.65	T
21.0	0.28034	0.1919E+06	12383.71	5112.77	17496.48	T	17496.48	T
26.0	0.30177	0.1725E+06	13784.94	3712.80	17497.74	T	17497.74	T

DB= 37.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50029	0.1359E+06	2088.64	15211.36	17300.00	T	17300.00	T
10.0	0.50344	0.2015E+06	6192.16	11274.21	17466.37	T	17466.37	T
16.0	0.51454	0.2079E+06	10223.50	7271.15	17494.65	T	17494.65	T
21.0	0.53034	0.1919E+06	12383.71	5112.77	17496.48	T	17496.48	T
26.0	0.55177	0.1725E+06	13784.94	3712.80	17497.74	T	17497.74	T

DB= 38.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00029	0.1359E+06	2088.64	15211.36	17300.00	T	17300.00	T
10.0	1.00344	0.2015E+06	6192.16	11274.21	17466.37	T	17466.37	T
16.0	1.01454	0.2079E+06	10223.50	7271.15	17494.65	T	17494.65	T
21.0	1.03034	0.1919E+06	12383.71	5112.77	17496.48	T	17496.48	T
26.0	1.05177	0.1725E+06	13784.94	3712.80	17497.74	T	17497.74	T

DB= 39.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50029	0.1359E+06	2088.64	15211.36	17300.00	T	17300.00	T
10.0	1.50344	0.2015E+06	6192.16	11274.21	17466.37	T	17466.37	T
16.0	1.51454	0.2079E+06	10223.50	7271.15	17494.65	T	17494.65	T
21.0	1.53034	0.1919E+06	12383.71	5112.77	17496.48	T	17496.48	T
26.0	1.55177	0.1725E+06	13784.94	3712.80	17497.74	T	17497.74	T

DB= 40.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00029	0.1359E+06	2088.64	15211.36	17300.00	T	17300.00	T
10.0	2.00344	0.2015E+06	6192.16	11274.21	17466.37	T	17466.37	T
16.0	2.01454	0.2079E+06	10223.50	7271.15	17494.65	T	17494.65	T
21.0	2.03034	0.1919E+06	12383.71	5112.77	17496.48	T	17496.48	T
26.0	2.05177	0.1725E+06	13784.94	3712.80	17497.74	T	17497.74	T

DB= 41.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50029	0.1359E+06	2088.64	15211.36	17300.00	T	17300.00	T
10.0	2.50344	0.2015E+06	6192.16	11274.21	17466.37	T	17466.37	T
16.0	2.51454	0.2079E+06	10223.50	7271.15	17494.65	T	17494.65	T
21.0	2.53034	0.1919E+06	12383.71	5112.77	17496.48	T	17496.48	T
26.0	2.55177	0.1725E+06	13784.94	3712.80	17497.74	T	17497.74	T

DB= 42.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00029	0.1359E+06	2088.64	15211.36	17300.00	T	17300.00	T
10.0	3.00344	0.2015E+06	6192.16	11274.21	17466.37	T	17466.37	T
16.0	3.01454	0.2079E+06	10223.50	7271.15	17494.65	T	17494.65	T
21.0	3.03034	0.1919E+06	12383.71	5112.77	17496.48	T	17496.48	T
26.0	3.05177	0.1725E+06	13784.94	3712.80	17497.74	T	17497.74	T

LB= 32.000 FEET (HORIZONTAL)

DB= 36.500 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25024	0.1120E+06	1731.07	15494.79	17225.86	T	9489.95	I
10.0	0.25299	0.1742E+06	5391.86	12060.82	17452.68	T	11468.23	I
16.0	0.26325	0.1880E+06	9341.30	8155.15	17496.44	T	13536.52	I
21.0	0.27835	0.1773E+06	11614.24	5879.90	17494.14	T	14756.86	I
26.0	0.29917	0.1614E+06	13158.19	4340.11	17498.30	T	15638.91	I
32.0	0.33121	0.1421E+06	14374.52	3123.94	17498.47	T	16407.09	I

DB= 37.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50024	0.1120E+06	1731.07	15494.79	17225.86	T	9489.95	I
10.0	0.50299	0.1742E+06	5391.86	12060.82	17452.68	T	11468.23	I
16.0	0.51325	0.1880E+06	9341.30	8155.15	17496.44	T	13536.52	I
21.0	0.52835	0.1773E+06	11614.24	5879.90	17494.14	T	14756.86	I
26.0	0.54917	0.1614E+06	13158.19	4340.11	17498.30	T	15638.91	I
32.0	0.58121	0.1421E+06	14374.52	3123.94	17498.47	T	16407.09	I

DB= 38.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00024	0.1120E+06	1731.07	15494.79	17225.86	T	9489.95	I
10.0	1.00299	0.1742E+06	5391.86	12060.82	17452.68	T	11468.23	I
16.0	1.01325	0.1880E+06	9341.30	8155.15	17496.44	T	13536.52	I
21.0	1.02835	0.1773E+06	11614.24	5879.90	17494.14	T	14756.86	I
26.0	1.04917	0.1614E+06	13158.19	4340.11	17498.30	T	15638.91	I
32.0	1.08121	0.1421E+06	14374.52	3123.94	17498.47	T	16407.09	I

DB= 39.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50024	0.1120E+06	1731.07	15494.79	17225.86	T	9489.95	I
10.0	1.50299	0.1742E+06	5391.86	12060.82	17452.68	T	11468.23	I
16.0	1.51325	0.1880E+06	9341.30	8155.15	17496.44	T	13536.52	I
21.0	1.52835	0.1773E+06	11614.24	5879.90	17494.14	T	14756.86	I
26.0	1.54917	0.1614E+06	13158.19	4340.11	17498.30	T	15638.91	I
32.0	1.58121	0.1421E+06	14374.52	3123.94	17498.47	T	16407.09	I

DB= 40.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00024	0.1120E+06	1731.07	15494.79	17225.86	T	9489.95	I
10.0	2.00299	0.1742E+06	5391.86	12060.82	17452.68	T	11468.23	I
16.0	2.01325	0.1880E+06	9341.30	8155.15	17496.44	T	13536.52	I
21.0	2.02835	0.1773E+06	11614.24	5879.90	17494.14	T	14756.86	I
26.0	2.04917	0.1614E+06	13158.19	4340.11	17498.30	T	15638.91	I
32.0	2.08121	0.1421E+06	14374.52	3123.94	17498.47	T	16407.09	I

DB= 41.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50024	0.1120E+06	1731.07	15494.79	17225.86	T	9489.95	I
10.0	2.50299	0.1742E+06	5391.86	12060.82	17452.68	T	11468.23	I
16.0	2.51325	0.1880E+06	9341.30	8155.15	17496.44	T	13536.52	I
21.0	2.52835	0.1773E+06	11614.24	5879.90	17494.14	T	14756.86	I
26.0	2.54917	0.1614E+06	13158.19	4340.11	17498.30	T	15638.91	I
32.0	2.58121	0.1421E+06	14374.52	3123.94	17498.47	T	16407.09	I

DB= 42.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00024	0.1120E+06	1731.07	15494.79	17225.86	T	9489.95	I
10.0	3.00299	0.1742E+06	5391.86	12060.82	17452.68	T	11468.23	I
16.0	3.01325	0.1880E+06	9341.30	8155.15	17496.44	T	13536.52	I
21.0	3.02835	0.1773E+06	11614.24	5879.90	17494.14	T	14756.86	I
26.0	3.04917	0.1614E+06	13158.19	4340.11	17498.30	T	15638.91	I
32.0	3.08121	0.1421E+06	14374.52	3123.94	17498.47	T	16407.09	I

LB= 42.000 FEET (HORIZONTAL)

DB= 36.500 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25019	0.8860E+05	1371.07	16101.64	17472.71	T	9433.38	I
10.0	0.25246	0.1432E+06	4437.86	13023.96	17461.82	T	10995.80	I
16.0	0.26156	0.1638E+06	8153.02	9338.42	17491.44	T	12939.88	I
21.0	0.27565	0.1602E+06	10512.19	6982.39	17494.58	T	14206.06	I
26.0	0.29562	0.1496E+06	12212.92	5285.12	17498.04	T	15166.15	I
32.0	0.32690	0.1344E+06	13616.91	3882.57	17499.47	T	16028.79	I
42.0	0.39555	0.1111E+06	15023.13	2476.32	17499.46	T	17071.98	I

DB= 37.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50019	0.8860E+05	1371.07	16101.64	17472.71	T	9433.38	I
10.0	0.50246	0.1432E+06	4437.86	13023.96	17461.82	T	10995.80	I
16.0	0.51156	0.1638E+06	8153.02	9338.42	17491.44	T	12939.88	I
21.0	0.52565	0.1602E+06	10512.19	6982.39	17494.58	T	14206.06	I
26.0	0.54562	0.1496E+06	12212.92	5285.12	17498.04	T	15166.15	I
32.0	0.57690	0.1344E+06	13616.91	3882.57	17499.47	T	16028.79	I
42.0	0.64555	0.1111E+06	15023.13	2476.32	17499.46	T	17071.98	I

DB= 38.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00019	0.8860E+05	1371.07	16101.64	17472.71	T	9433.38	I
10.0	1.00246	0.1432E+06	4437.86	13023.96	17461.82	T	10995.80	I
16.0	1.01156	0.1638E+06	8153.02	9338.42	17491.44	T	12939.88	I
21.0	1.02565	0.1602E+06	10512.19	6982.39	17494.58	T	14206.06	I
26.0	1.04562	0.1496E+06	12212.92	5285.12	17498.04	T	15166.15	I
32.0	1.07690	0.1344E+06	13616.91	3882.57	17499.47	T	16028.79	I
42.0	1.14555	0.1111E+06	15023.13	2476.32	17499.46	T	17071.98	I

DB= 39.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50019	0.8860E+05	1371.07	16101.64	17472.71	T	9433.38	I
10.0	1.50246	0.1432E+06	4437.86	13023.96	17461.82	T	10995.80	I
16.0	1.51156	0.1638E+06	8153.02	9338.42	17491.44	T	12939.88	I
21.0	1.52565	0.1602E+06	10512.19	6982.39	17494.58	T	14206.06	I
26.0	1.54562	0.1496E+06	12212.92	5285.12	17498.04	T	15166.15	I
32.0	1.57690	0.1344E+06	13616.91	3882.57	17499.47	T	16028.79	I
42.0	1.64555	0.1111E+06	15023.13	2476.32	17499.46	T	17071.98	I

DB= 40.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00019	0.8860E+05	1371.07	16101.64	17472.71	T	9433.38	I
10.0	2.00246	0.1432E+06	4437.86	13023.96	17461.82	T	10995.80	I
16.0	2.01156	0.1638E+06	8153.02	9338.42	17491.44	T	12939.88	I
21.0	2.02565	0.1602E+06	10512.19	6982.39	17494.58	T	14206.06	I
26.0	2.04562	0.1496E+06	12212.92	5285.12	17498.04	T	15166.15	I
32.0	2.07690	0.1344E+06	13616.91	3882.57	17499.47	T	16028.79	I
42.0	2.14555	0.1111E+06	15023.13	2476.32	17499.46	T	17071.98	I

DB= 41.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50019	0.8860E+05	1371.07	16101.64	17472.71	T	9433.38	I
10.0	2.50246	0.1432E+06	4437.86	13023.96	17461.82	T	10995.80	I
16.0	2.51156	0.1638E+06	8153.02	9338.42	17491.44	T	12939.88	I
21.0	2.52565	0.1602E+06	10512.19	6982.39	17494.58	T	14206.06	I
26.0	2.54562	0.1496E+06	12212.92	5285.12	17498.04	T	15166.15	I
32.0	2.57690	0.1344E+06	13616.91	3882.57	17499.47	T	16028.79	I
42.0	2.64555	0.1111E+06	15023.13	2476.32	17499.46	T	17071.98	I

DB= 42.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00019	0.8860E+05	1371.07	16101.64	17472.71	T	9433.38	I
10.0	3.00246	0.1432E+06	4437.86	13023.96	17461.82	T	10995.80	I
16.0	3.01156	0.1638E+06	8153.02	9338.42	17491.44	T	12939.88	I
21.0	3.02565	0.1602E+06	10512.19	6982.39	17494.58	T	14206.06	I
26.0	3.04562	0.1496E+06	12212.92	5285.12	17498.04	T	15166.15	I
32.0	3.07690	0.1344E+06	13616.91	3882.57	17499.47	T	16028.79	I
42.0	3.14555	0.1111E+06	15023.13	2476.32	17499.46	T	17071.98	I

LB= 58.000 FEET (HORIZONTAL)

DB= 36.500 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25014	0.6517E+05	1011.07	16386.87	17397.94	T	9215.99	I
10.0	0.25191	0.1109E+06	3447.86	13964.47	17412.33	T	10476.05	I
16.0	0.25960	0.1358E+06	6774.89	10709.43	17484.32	T	12247.25	I
21.0	0.27226	0.1388E+06	9128.52	8367.98	17496.50	T	13515.18	I
26.0	0.29090	0.1338E+06	10956.12	6543.37	17499.49	T	14538.47	I
32.0	0.32087	0.1237E+06	12556.95	4941.22	17498.16	T	15498.15	I
42.0	0.38803	0.1052E+06	14255.79	3243.00	17498.79	T	16687.97	I
58.0	0.53638	0.8048E+05	15649.81	1850.13	17499.93	T	18120.87	T

DB= 37.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50014	0.6517E+05	1011.07	16386.87	17397.94	T	9215.99	I
10.0	0.50191	0.1109E+06	3447.86	13964.47	17412.33	T	10476.05	I
16.0	0.50960	0.1358E+06	6774.89	10709.43	17484.32	T	12247.25	I
21.0	0.52226	0.1388E+06	9128.52	8367.98	17496.50	T	13515.18	I
26.0	0.54090	0.1338E+06	10956.12	6543.37	17499.49	T	14538.47	I
32.0	0.57087	0.1237E+06	12556.95	4941.22	17498.16	T	15498.15	I
42.0	0.63803	0.1052E+06	14255.79	3243.00	17498.79	T	16687.97	I
58.0	0.78638	0.8048E+05	15649.81	1850.13	17499.93	T	18120.87	T

DB= 38,000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00014	0.6517E+05	1011.07	16386.87	17397.94	T	9215.99	I
10.0	1.00191	0.1109E+06	3447.86	13964.47	17412.33	T	10476.05	I
16.0	1.00960	0.1358E+06	6774.89	10709.43	17484.32	T	12247.25	I
21.0	1.02226	0.1388E+06	9128.52	8367.98	17496.50	T	13515.18	I
26.0	1.04090	0.1338E+06	10956.12	6543.37	17499.49	T	14538.47	I
32.0	1.07087	0.1237E+06	12556.95	4941.22	17498.16	T	15498.15	I
42.0	1.13803	0.1052E+06	14255.79	3243.00	17498.79	T	16687.97	I
58.0	1.28638	0.8048E+05	15649.81	1850.13	17499.93	T	18120.87	T

DB= 39,000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50014	0.6517E+05	1011.07	16386.87	17397.94	T	9215.99	I
10.0	1.50191	0.1109E+06	3447.86	13964.47	17412.33	T	10476.05	I
16.0	1.50960	0.1358E+06	6774.89	10709.43	17484.32	T	12247.25	I
21.0	1.52226	0.1388E+06	9128.52	8367.98	17496.50	T	13515.18	I
26.0	1.54090	0.1338E+06	10956.12	6543.37	17499.49	T	14538.47	I
32.0	1.57087	0.1237E+06	12556.95	4941.22	17498.16	T	15498.15	I
42.0	1.63803	0.1052E+06	14255.79	3243.00	17498.79	T	16687.97	I
58.0	1.78638	0.8048E+05	15649.81	1850.13	17499.93	T	18120.87	T

DB= 40,000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00014	0.6517E+05	1011.07	16386.87	17397.94	T	9215.99	I
10.0	2.00191	0.1109E+06	3447.86	13964.47	17412.33	T	10476.05	I
16.0	2.00960	0.1358E+06	6774.89	10709.43	17484.32	T	12247.25	I
21.0	2.02226	0.1388E+06	9128.52	8367.98	17496.50	T	13515.18	I
26.0	2.04090	0.1338E+06	10956.12	6543.37	17499.49	T	14538.47	I
32.0	2.07087	0.1237E+06	12556.95	4941.22	17498.16	T	15498.15	I
42.0	2.13803	0.1052E+06	14255.79	3243.00	17498.79	T	16687.97	I
58.0	2.28638	0.8048E+05	15649.81	1850.13	17499.93	T	18120.87	T

DB= 41,000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50014	0.6517E+05	1011.07	16386.87	17397.94	T	9215.99	I
10.0	2.50191	0.1109E+06	3447.86	13964.47	17412.33	T	10476.05	I
16.0	2.50960	0.1358E+06	6774.89	10709.43	17484.32	T	12247.25	I
21.0	2.52226	0.1388E+06	9128.52	8367.98	17496.50	T	13515.18	I
26.0	2.54090	0.1338E+06	10956.12	6543.37	17499.49	T	14538.47	I
32.0	2.57087	0.1237E+06	12556.95	4941.22	17498.16	T	15498.15	I
42.0	2.63803	0.1052E+06	14255.79	3243.00	17498.79	T	16687.97	I
58.0	2.78638	0.8048E+05	15649.81	1850.13	17499.93	T	18120.87	T

DB= 42,000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00014	0.6517E+05	1011.07	16386.87	17397.94	T	9215.99	I
10.0	3.00191	0.1109E+06	3447.86	13964.47	17412.33	T	10476.05	I
16.0	3.00960	0.1358E+06	6774.89	10709.43	17484.32	T	12247.25	I
21.0	3.02226	0.1388E+06	9128.52	8367.98	17496.50	T	13515.18	I
26.0	3.04090	0.1338E+06	10956.12	6543.37	17499.49	T	14538.47	I
32.0	3.07087	0.1237E+06	12556.95	4941.22	17498.16	T	15498.15	I
42.0	3.13803	0.1052E+06	14255.79	3243.00	17498.79	T	16687.97	I
58.0	3.28638	0.8048E+05	15649.81	1850.13	17499.93	T	18120.87	T

LB= 75,000 FEET (HORIZONTAL)

DB= 36,500 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25011	0.5111E+05	795.07	16652.12	17447.19	T	9132.62	I
10.0	0.25155	0.8985E+05	2799.86	14654.16	17454.02	T	10172.90	I
16.0	0.25814	0.1149E+06	5748.33	11742.31	17490.63	T	11737.13	I
21.0	0.26952	0.1215E+06	8010.15	9488.74	17498.90	T	12957.20	I
26.0	0.28684	0.1203E+06	9875.05	7621.34	17496.39	T	13996.39	I
32.0	0.31543	0.1139E+06	11600.70	5899.05	17499.74	T	15020.82	I
42.0	0.38086	0.9948E+05	13524.15	3975.71	17499.86	T	16322.69	I
58.0	0.52761	0.7785E+05	15180.54	2319.14	17499.69	T	17886.11	T
75.0	0.75025	0.6236E+05	16005.28	1494.67	17499.95	D	16752.61	I

DB= 37,000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50011	0.5111E+05	795.07	16652.12	17447.19	T	9132.62	I
10.0	0.50155	0.8985E+05	2799.86	14654.16	17454.02	T	10172.90	I
16.0	0.50814	0.1149E+06	5748.33	11742.31	17490.63	T	11737.13	I
21.0	0.51952	0.1215E+06	8010.15	9488.74	17498.90	T	12957.20	I
26.0	0.53684	0.1203E+06	9875.05	7621.34	17496.39	T	13996.39	I
32.0	0.56543	0.1139E+06	11600.70	5899.05	17499.74	T	15020.82	I

42.0	0.63086	0.9948E+05	13524.15	3975.71	17499.86	T	16322.69	I
58.0	0.77761	0.7785E+05	15180.54	2319.14	17499.69	T	17886.11	T
75.0	0.98458	0.6018E+05	16052.11	1447.85	17499.96	T	19361.12	T

DB= 38.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00011	0.5111E+05	795.07	16652.12	17447.19	T	9132.62	I
10.0	1.00155	0.8985E+05	2799.86	14654.16	17454.02	T	10172.90	I
16.0	1.00814	0.1149E+06	5748.33	11742.31	17490.63	T	11737.13	I
21.0	1.01952	0.1215E+06	8010.15	9488.74	17498.90	T	12957.20	I
26.0	1.03684	0.1203E+06	9875.05	7621.34	17496.39	T	13996.39	I
32.0	1.06543	0.1139E+06	11600.70	5899.05	17499.74	T	15020.82	I
42.0	1.13086	0.9948E+05	13524.15	3975.71	17499.86	T	16322.69	I
58.0	1.27761	0.7785E+05	15180.54	2319.14	17499.69	T	17886.11	T
75.0	1.48458	0.6018E+05	16052.11	1447.85	17499.96	T	19361.12	T

DB= 39.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50011	0.5111E+05	795.07	16652.12	17447.19	T	9132.62	I
10.0	1.50155	0.8985E+05	2799.86	14654.16	17454.02	T	10172.90	I
16.0	1.50814	0.1149E+06	5748.33	11742.31	17490.63	T	11737.13	I
21.0	1.51952	0.1215E+06	8010.15	9488.74	17498.90	T	12957.20	I
26.0	1.53684	0.1203E+06	9875.05	7621.34	17496.39	T	13996.39	I
32.0	1.56543	0.1139E+06	11600.70	5899.05	17499.74	T	15020.82	I
42.0	1.63086	0.9948E+05	13524.15	3975.71	17499.86	T	16322.69	I
58.0	1.77761	0.7785E+05	15180.54	2319.14	17499.69	T	17886.11	T
75.0	1.98458	0.6018E+05	16052.11	1447.85	17499.96	T	19361.12	T

DB= 40.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00011	0.5111E+05	795.07	16652.12	17447.19	T	9132.62	I
10.0	2.00155	0.8985E+05	2799.86	14654.16	17454.02	T	10172.90	I
16.0	2.00814	0.1149E+06	5748.33	11742.31	17490.63	T	11737.13	I
21.0	2.01952	0.1215E+06	8010.15	9488.74	17498.90	T	12957.20	I
26.0	2.03684	0.1203E+06	9875.05	7621.34	17496.39	T	13996.39	I
32.0	2.06543	0.1139E+06	11600.70	5899.05	17499.74	T	15020.82	I
42.0	2.13086	0.9948E+05	13524.15	3975.71	17499.86	T	16322.69	I
58.0	2.27761	0.7785E+05	15180.54	2319.14	17499.69	T	17886.11	T
75.0	2.48458	0.6018E+05	16052.11	1447.85	17499.96	T	19361.12	T

DB= 41.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50011	0.5111E+05	795.07	16652.12	17447.19	T	9132.62	I
10.0	2.50155	0.8985E+05	2799.86	14654.16	17454.02	T	10172.90	I
16.0	2.50814	0.1149E+06	5748.33	11742.31	17490.63	T	11737.13	I
21.0	2.51952	0.1215E+06	8010.15	9488.74	17498.90	T	12957.20	I
26.0	2.53684	0.1203E+06	9875.05	7621.34	17496.39	T	13996.39	I
32.0	2.56543	0.1139E+06	11600.70	5899.05	17499.74	T	15020.82	I
42.0	2.63086	0.9948E+05	13524.15	3975.71	17499.86	T	16322.69	I
58.0	2.77761	0.7785E+05	15180.54	2319.14	17499.69	T	17886.11	T
75.0	2.98458	0.6018E+05	16052.11	1447.85	17499.96	T	19361.12	T

DB= 42.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00011	0.5111E+05	795.07	16652.12	17447.19	T	9132.62	I
10.0	3.00155	0.8985E+05	2799.86	14654.16	17454.02	T	10172.90	I
16.0	3.00814	0.1149E+06	5748.33	11742.31	17490.63	T	11737.13	I
21.0	3.01952	0.1215E+06	8010.15	9488.74	17498.90	T	12957.20	I
26.0	3.03684	0.1203E+06	9875.05	7621.34	17496.39	T	13996.39	I
32.0	3.06543	0.1139E+06	11600.70	5899.05	17499.74	T	15020.82	I
42.0	3.13086	0.9948E+05	13524.15	3975.71	17499.86	T	16322.69	I
58.0	3.27761	0.7785E+05	15180.54	2319.14	17499.69	T	17886.11	T
75.0	3.48458	0.6018E+05	16052.11	1447.85	17499.96	T	19361.12	T

LB=270.000 FEET (HORIZONTAL)

DB= 36.500 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25003	0.1363E+05	219.07	16384.77	16603.83	T	8422.94	I
10.0	0.25048	0.2717E+05	873.86	16339.12	17212.98	T	9089.38	I
16.0	0.25296	0.4082E+05	2106.14	15372.04	17478.18	T	9909.81	I
21.0	0.25808	0.4912E+05	3340.77	14139.88	17480.64	T	10613.37	I
26.0	0.26724	0.5499E+05	4656.12	12839.64	17495.76	T	11386.61	I
32.0	0.28477	0.5912E+05	6211.24	11285.28	17496.53	T	12324.49	I
42.0	0.33196	0.6082E+05	8534.36	8964.21	17498.56	T	13827.14	I
58.0	0.45547	0.5619E+05	11320.50	6179.36	17499.85	T	15956.17	I
75.0	0.64653	0.4795E+05	13234.51	4265.18	17499.69	T	15925.21	I
80.0	0.72350	0.4660E+05	13565.59	3934.29	17499.88	D	15532.74	I

85.0	0.82710	0.4700E+05	13737.25	3762.55	17499.79	D	15618.52	I
90.0	0.93974	0.4690E+05	13922.00	3577.85	17499.85	D	15710.92	I
95.0	1.06122	0.4643E+05	14110.30	3389.62	17499.92	D	15805.11	I
100.0	1.19136	0.4567E+05	14296.19	3203.78	17499.97	D	15898.08	I
110.0	1.47700	0.4358E+05	14647.74	2852.20	17499.94	D	16226.20	I
120.0	1.79561	0.4103E+05	14963.15	2536.77	17499.92	D	16541.61	I
135.0	2.33362	0.3682E+05	15365.00	2134.96	17499.96	D	16943.46	I
140.0	2.52868	0.3539E+05	15481.26	2018.73	17499.99	D	17059.73	I
150.0	2.94202	0.3252E+05	15690.22	1809.76	17499.97	D	17268.68	I
160.0	3.38604	0.2970E+05	15871.39	1628.58	17499.97	D	17449.85	I
170.0	3.86046	0.2695E+05	16028.79	1471.21	17500.00	D	17607.25	T
175.0	4.10899	0.2561E+05	16099.67	1400.32	17499.99	D	17678.13	T
200.0	5.46405	0.1924E+05	16390.92	1109.08	17499.99	D	17969.38	T
240.0	8.01842	0.1019E+05	16703.10	796.88	17499.98	D	18281.56	T
270.0	10.24399	0.4177E+04	16859.97	640.02	17499.99	D	18438.43	T

DB= 37.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50003	0.1363E+05	219.07	16384.77	16603.83	T	8422.94	I
10.0	0.50048	0.2717E+05	873.86	16339.12	17212.98	T	9089.38	I
16.0	0.50296	0.4082E+05	2106.14	15372.04	17478.18	T	9909.81	I
21.0	0.50808	0.4912E+05	3340.77	14139.88	17480.64	T	10613.37	I
26.0	0.51724	0.5499E+05	4656.12	12839.64	17495.76	T	11386.61	I
32.0	0.53477	0.5912E+05	6211.24	11285.28	17496.53	T	12324.49	I
42.0	0.58196	0.6082E+05	8534.36	8964.21	17498.56	T	13827.14	I
58.0	0.70547	0.5619E+05	11320.50	6179.36	17499.85	T	15956.17	I
75.0	0.89653	0.4795E+05	13234.51	4265.18	17499.69	T	17952.18	T
80.0	0.96328	0.4543E+05	13650.46	3849.38	17499.83	T	18516.40	T
85.0	1.03444	0.4293E+05	14015.49	3484.42	17499.90	T	18923.21	T
90.0	1.10980	0.4048E+05	14336.69	3163.18	17499.88	T	18023.05	T
95.0	1.18916	0.3809E+05	14620.31	2879.60	17499.91	T	17389.96	I
100.0	1.27231	0.3577E+05	14871.43	2628.44	17499.88	T	16846.12	I
110.0	1.52446	0.3467E+05	15118.50	2381.39	17499.89	D	16696.96	I
120.0	1.83674	0.3395E+05	15305.99	2193.96	17499.95	D	16884.45	I
135.0	2.36727	0.3167E+05	15586.66	1913.28	17499.94	D	17165.12	I
140.0	2.56026	0.3072E+05	15674.71	1825.23	17499.93	D	17253.17	I
150.0	2.96999	0.2867E+05	15839.49	1660.49	17499.98	D	17417.95	I
160.0	3.41096	0.2648E+05	15988.30	1511.69	17500.00	D	17566.77	T
170.0	3.88277	0.2423E+05	16121.53	1378.43	17499.96	D	17700.00	T
175.0	4.13015	0.2311E+05	16182.69	1317.28	17499.97	D	17761.15	T
200.0	5.48056	0.1753E+05	16440.56	1059.41	17499.97	D	18019.02	T
240.0	8.03010	0.9183E+04	16727.55	772.44	17499.99	D	18306.02	T
270.0	10.25328	0.3461E+04	16875.39	624.60	17499.99	D	18453.85	T

DB= 38.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00003	0.1363E+05	219.07	16384.77	16603.83	T	8422.94	I
10.0	1.00048	0.2717E+05	873.86	16339.12	17212.98	T	9089.38	I
16.0	1.00296	0.4082E+05	2106.14	15372.04	17478.18	T	9909.81	I
21.0	1.00808	0.4912E+05	3340.77	14139.88	17480.64	T	10613.37	I
26.0	1.01724	0.5499E+05	4656.12	12839.64	17495.76	T	11386.61	I
32.0	1.03477	0.5912E+05	6211.24	11285.28	17496.53	T	12324.49	I
42.0	1.08196	0.6082E+05	8534.36	8964.21	17498.56	T	13827.14	I
58.0	1.20547	0.5619E+05	11320.50	6179.36	17499.85	T	15956.17	I
75.0	1.39653	0.4795E+05	13234.51	4265.18	17499.69	T	17952.18	T
80.0	1.46328	0.4543E+05	13650.46	3849.38	17499.83	T	18516.40	T
85.0	1.53444	0.4293E+05	14015.49	3484.42	17499.90	T	19078.09	T
90.0	1.60980	0.4048E+05	14336.69	3163.18	17499.88	T	19640.81	T
95.0	1.68916	0.3809E+05	14620.31	2879.60	17499.91	T	19640.12	T
100.0	1.77231	0.3577E+05	14871.43	2628.44	17499.88	T	22846.28	T
110.0	1.94918	0.3136E+05	15293.56	2206.40	17499.96	T	20909.19	T
120.0	2.13875	0.2724E+05	15630.96	1869.00	17499.97	T	19401.34	T
135.0	2.44318	0.2158E+05	16021.19	1478.74	17499.93	T	17665.14	T
140.0	2.62344	0.2140E+05	16061.73	1438.24	17499.97	D	17640.19	T
150.0	3.02592	0.2096E+05	16137.99	1361.96	17499.95	D	17716.45	T
160.0	3.46078	0.2004E+05	16222.05	1277.91	17499.96	D	17800.51	T
170.0	3.92741	0.1881E+05	16307.11	1192.87	17499.98	D	17885.57	T
175.0	4.17248	0.1810E+05	16348.77	1151.21	17499.98	D	17927.23	T
200.0	5.51360	0.1411E+05	16539.91	960.09	17500.00	D	18118.37	T
240.0	8.05345	0.7163E+04	16776.44	723.54	17499.98	D	18354.90	T
270.0	10.27186	0.2028E+04	16906.22	593.77	17499.99	D	18484.68	T

DB= 39.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50003	0.1363E+05	219.07	16384.77	16603.83	T	8422.94	I
10.0	1.50048	0.2717E+05	873.86	16339.12	17212.98	T	9089.38	I
16.0	1.50296	0.4082E+05	2106.14	15372.04	17478.18	T	9909.81	I
21.0	1.50808	0.4912E+05	3340.77	14139.88	17480.64	T	10613.37	I
26.0	1.51724	0.5499E+05	4656.12	12839.64	17495.76	T	11386.61	I
32.0	1.53477	0.5912E+05	6211.24	11285.28	17496.53	T	12324.49	I
42.0	1.58196	0.6082E+05	8534.36	8964.21	17498.56	T	13827.14	I

58.0	1.70547	0.5619E+05	11320.50	6179.36	17499.85	T	15956.17	I
75.0	1.89653	0.4795E+05	13234.51	4265.18	17499.69	T	17952.18	T
80.0	1.96328	0.4543E+05	13650.46	3849.38	17499.83	T	18516.40	T
85.0	2.03444	0.4293E+05	14015.49	3484.42	17499.90	T	19078.09	T
90.0	2.10980	0.4048E+05	14336.69	3163.18	17499.88	T	19640.81	T
95.0	2.18916	0.3809E+05	14620.31	2879.60	17499.91	T	21670.12	T
100.0	2.27231	0.3577E+05	14871.43	2628.44	17499.88	T	23840.69	T
110.0	2.44918	0.3136E+05	15293.56	2206.40	17499.96	T	25868.15	T
120.0	2.63875	0.2724E+05	15630.96	1869.00	17499.97	T	23568.21	T
135.0	2.94318	0.2158E+05	16021.19	1478.74	17499.93	T	20957.44	T
140.0	3.04912	0.1981E+05	16127.53	1372.40	17499.92	T	20246.53	T
150.0	3.26630	0.1645E+05	16312.57	1187.42	17500.00	T	18998.65	T
160.0	3.51061	0.1360E+05	16455.86	1044.17	17499.99	D	18034.32	T
170.0	3.97204	0.1338E+05	16492.66	1007.22	17499.97	D	18071.12	T
175.0	4.21481	0.1310E+05	16514.87	985.13	17500.00	D	18093.33	T
200.0	5.54663	0.1069E+05	16639.24	860.76	17499.99	D	18217.70	T
240.0	8.07680	0.5143E+04	16825.34	674.65	17499.98	D	18403.80	T
270.0	10.29044	0.5955E+03	16937.06	562.94	17500.00	D	18515.52	T

DB= 40.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00003	0.1363E+05	219.07	16384.77	16603.83	T	8422.94	I
10.0	2.00048	0.2717E+05	873.86	16339.12	17212.98	T	9089.38	I
16.0	2.00296	0.4082E+05	2106.14	15372.04	17478.18	T	9909.81	I
21.0	2.00808	0.4912E+05	3340.77	14139.88	17480.64	T	10613.37	I
26.0	2.01724	0.5499E+05	4656.12	12839.64	17495.76	T	11386.61	I
32.0	2.03477	0.5912E+05	6211.24	11285.28	17496.53	T	12324.49	I
42.0	2.08196	0.6082E+05	8534.36	8964.21	17498.56	T	13827.14	I
58.0	2.20547	0.5619E+05	11320.50	6179.36	17499.85	T	15956.17	I
75.0	2.39653	0.4795E+05	13234.51	4265.18	17499.69	T	17952.18	T
80.0	2.46328	0.4543E+05	13650.46	3849.38	17499.83	T	18516.40	T
85.0	2.53444	0.4293E+05	14015.49	3484.42	17499.90	T	19078.09	T
90.0	2.60980	0.4048E+05	14336.69	3163.18	17499.88	T	19640.81	T
95.0	2.68916	0.3809E+05	14620.31	2879.60	17499.91	T	21670.12	T
100.0	2.77231	0.3577E+05	14871.43	2628.44	17499.88	T	23840.69	T
110.0	2.94918	0.3136E+05	15293.56	2206.40	17499.96	T	28515.76	T
120.0	3.13875	0.2724E+05	15630.96	1869.00	17499.97	T	27735.26	T
135.0	3.44318	0.2158E+05	16021.19	1478.74	17499.93	T	24249.87	T
140.0	3.54912	0.1981E+05	16127.53	1372.40	17499.92	T	23307.97	T
150.0	3.76630	0.1645E+05	16312.57	1187.42	17500.00	T	21665.48	T
160.0	3.98888	0.1329E+05	16467.14	1032.85	17499.98	T	20276.34	T
170.0	4.21480	0.1031E+05	16597.48	902.50	17499.97	T	19079.30	T
175.0	4.32833	0.8878E+04	16655.05	844.89	17499.94	T	18538.36	T
200.0	5.57966	0.7273E+04	16738.57	761.43	17500.00	D	18317.03	T
240.0	8.10015	0.3124E+04	16874.23	625.75	17499.98	D	18452.69	T
270.0	10.29806	0.0000E+00	16949.86	550.13	17499.99	B	18528.33	T

DB= 41.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50003	0.1363E+05	219.07	16384.77	16603.83	T	8422.94	I
10.0	2.50048	0.2717E+05	873.86	16339.12	17212.98	T	9089.38	I
16.0	2.50296	0.4082E+05	2106.14	15372.04	17478.18	T	9909.81	I
21.0	2.50808	0.4912E+05	3340.77	14139.88	17480.64	T	10613.37	I
26.0	2.51724	0.5499E+05	4656.12	12839.64	17495.76	T	11386.61	I
32.0	2.53477	0.5912E+05	6211.24	11285.28	17496.53	T	12324.49	I
42.0	2.58196	0.6082E+05	8534.36	8964.21	17498.56	T	13827.14	I
58.0	2.70547	0.5619E+05	11320.50	6179.36	17499.85	T	15956.17	I
75.0	2.89653	0.4795E+05	13234.51	4265.18	17499.69	T	17952.18	T
80.0	2.96328	0.4543E+05	13650.46	3849.38	17499.83	T	18516.40	T
85.0	3.03444	0.4293E+05	14015.49	3484.42	17499.90	T	19078.09	T
90.0	3.10980	0.4048E+05	14336.69	3163.18	17499.88	T	19640.81	T
95.0	3.18916	0.3809E+05	14620.31	2879.60	17499.91	T	21670.12	T
100.0	3.27231	0.3577E+05	14871.43	2628.44	17499.88	T	23840.69	T
110.0	3.44918	0.3136E+05	15293.56	2206.40	17499.96	T	28515.76	T
120.0	3.63875	0.2724E+05	15630.96	1869.00	17499.97	T	31902.54	T
135.0	3.94318	0.2158E+05	16021.19	1478.74	17499.93	T	27142.45	T
140.0	4.04912	0.1981E+05	16127.53	1372.40	17499.92	T	26369.53	T
150.0	4.26630	0.1645E+05	16312.57	1187.42	17500.00	T	24332.41	T
160.0	4.48888	0.1329E+05	16467.14	1032.85	17499.98	T	22620.30	T
170.0	4.71480	0.1031E+05	16597.48	902.50	17499.97	T	21155.59	T
175.0	4.82833	0.8878E+04	16655.05	844.89	17499.94	T	20497.69	T
200.0	5.61268	0.3854E+04	16837.88	662.10	17499.98	D	18416.34	T
240.0	8.12350	0.1104E+04	16923.13	576.86	17499.99	D	18501.59	T
270.0	10.29790	0.0000E+00	16949.87	550.13	17499.99	B	18528.33	T

DB= 42.000 INCHES

L (FT)	DELBM (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00003	0.1363E+05	219.07	16384.77	16603.83	T	8422.94	I
10.0	3.00048	0.2717E+05	873.86	16339.12	17212.98	T	9089.38	I
16.0	3.00296	0.4082E+05	2106.14	15372.04	17478.18	T	9909.81	I
21.0	3.00808	0.4912E+05	3340.77	14139.88	17480.64	T	10613.37	I

26.0	3.01724	0.5499E+05	4656.12	12839.64	17495.76	T	11386.61	I
32.0	3.03477	0.5912E+05	6211.24	11285.28	17496.53	T	12324.49	I
42.0	3.08196	0.6082E+05	8534.36	8964.21	17498.56	T	13827.14	I
58.0	3.20547	0.5619E+05	11320.50	6179.36	17499.85	T	15956.17	I
75.0	3.39653	0.4795E+05	13234.51	4265.18	17499.69	T	17952.18	T
80.0	3.46328	0.4543E+05	13650.46	3849.38	17499.83	T	18516.40	T
85.0	3.53444	0.4293E+05	14015.49	3484.42	17499.90	T	19078.09	T
90.0	3.60980	0.4048E+05	14336.69	3163.18	17499.88	T	19640.81	T
95.0	3.68916	0.3809E+05	14620.31	2879.60	17499.91	T	21670.12	T
100.0	3.77231	0.3577E+05	14871.43	2628.44	17499.88	T	23840.69	T
110.0	3.94918	0.3136E+05	15293.56	2206.40	17499.96	T	28515.76	T
120.0	4.13875	0.2724E+05	15630.96	1869.00	17499.97	T	33636.07	T
135.0	4.44318	0.2158E+05	16021.19	1478.74	17499.93	T	30835.20	T
140.0	4.54912	0.1981E+05	16127.53	1372.40	17499.92	T	29431.26	T
150.0	4.76630	0.1645E+05	16312.57	1187.42	17500.00	T	26999.47	T
160.0	4.98888	0.1329E+05	16467.14	1032.85	17499.98	T	24964.35	T
170.0	5.21480	0.1031E+05	16597.48	902.50	17499.97	T	23231.95	T
175.0	5.32833	0.8878E+04	16655.05	844.89	17499.94	T	22457.09	T
200.0	5.89018	0.2225E+04	16885.22	614.77	17499.99	T	19249.03	T
240.0	8.13621	0.0000E+00	16949.87	550.13	17499.99	B	18528.33	T
270.0	10.29774	0.0000E+00	16949.87	550.13	17499.99	B	18528.33	T

LB=350.000 FEET (HORIZONTAL)

DB= 36.500 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.25002	0.8940E+04	147.07	14180.71	14327.78	T	7248.91	I
10.0	0.25038	0.2132E+05	693.86	16768.59	17462.45	T	9124.11	I
16.0	0.25235	0.3209E+05	1677.23	15820.32	17497.56	T	9705.05	I
21.0	0.25652	0.3925E+05	2704.03	14790.65	17494.68	T	10302.03	I
26.0	0.26415	0.4470E+05	3833.34	13660.82	17494.15	T	10974.42	I
32.0	0.27917	0.4911E+05	5226.87	12272.94	17499.81	T	11833.94	I
42.0	0.32107	0.5221E+05	7423.13	10076.29	17499.42	T	13271.96	I
58.0	0.43567	0.5025E+05	10261.04	7238.37	17499.41	T	15426.22	I
75.0	0.61902	0.4413E+05	12354.19	5145.36	17499.55	T	15778.42	I
80.0	0.68401	0.4208E+05	12825.16	4674.67	17499.83	D	15162.50	I
85.0	0.78262	0.4275E+05	12998.49	4501.45	17499.94	D	15249.22	I
90.0	0.89052	0.4294E+05	13192.83	4306.99	17499.81	D	15346.32	I
95.0	1.00755	0.4276E+05	13396.70	4103.25	17499.95	D	15448.33	I
100.0	1.13351	0.4228E+05	13602.01	3897.83	17499.84	D	15648.17	I
110.0	1.41164	0.4071E+05	13999.57	3500.35	17499.92	D	16045.72	I
120.0	1.72376	0.3859E+05	14364.43	3135.54	17499.98	D	16410.59	I
135.0	2.25367	0.3492E+05	14838.62	2661.35	17499.97	D	16884.78	I
140.0	2.44640	0.3363E+05	14977.56	2522.38	17499.93	D	17023.71	I
150.0	2.85559	0.3102E+05	15229.31	2270.66	17499.97	D	17275.46	I
160.0	3.29602	0.2841E+05	15449.48	2050.52	17499.99	D	17495.63	I
170.0	3.76731	0.2584E+05	15642.07	1857.92	17499.98	D	17688.22	T
175.0	4.01443	0.2457E+05	15729.21	1770.75	17499.96	D	17775.36	T
200.0	5.36371	0.1851E+05	16089.96	1410.03	17499.99	D	18136.12	T
240.0	7.91185	0.9741E+04	16481.16	1018.82	17499.98	D	18527.31	T
270.0	10.13427	0.3851E+04	16679.44	820.54	17499.99	D	18725.60	T
300.0	12.59252	0.0000E+00	16786.87	713.13	17500.00	B	18833.02	T
350.0	17.14103	0.0000E+00	16786.87	713.13	17499.99	B	18833.02	T

DB= 37.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	0.50002	0.8940E+04	147.07	14180.71	14327.78	T	7248.91	I
10.0	0.50038	0.2132E+05	693.86	16768.59	17462.45	T	9124.11	I
16.0	0.50235	0.3209E+05	1677.23	15820.32	17497.56	T	9705.05	I
21.0	0.50652	0.3925E+05	2704.03	14790.65	17494.68	T	10302.03	I
26.0	0.51415	0.4470E+05	3833.34	13660.82	17494.15	T	10974.42	I
32.0	0.52917	0.4911E+05	5226.87	12272.94	17499.81	T	11833.94	I
42.0	0.57107	0.5221E+05	7423.13	10076.29	17499.42	T	13271.96	I
58.0	0.68567	0.5025E+05	10261.04	7238.37	17499.41	T	15426.22	I
75.0	0.86902	0.4413E+05	12354.19	5145.36	17499.55	T	17511.95	T
80.0	0.93396	0.4207E+05	12825.83	4674.13	17499.96	T	18104.15	T
85.0	1.00349	0.3997E+05	13244.42	4255.26	17499.68	T	18692.44	T
90.0	1.07742	0.3787E+05	13617.14	3882.69	17499.83	T	18007.91	T
95.0	1.15552	0.3579E+05	13949.38	3550.61	17499.98	T	17410.38	I
100.0	1.23756	0.3373E+05	14245.93	3253.93	17499.87	T	16896.83	I
110.0	1.46989	0.3227E+05	14577.33	2922.55	17499.88	D	16623.48	I
120.0	1.77460	0.3184E+05	14788.18	2711.81	17499.99	D	16834.33	I
135.0	2.29562	0.2997E+05	15114.92	2385.01	17499.93	D	17161.07	I
140.0	2.48588	0.2914E+05	15219.36	2280.61	17499.97	D	17265.51	I
150.0	2.89069	0.2729E+05	15416.60	2083.38	17499.98	D	17462.75	I
160.0	3.32739	0.2528E+05	15596.62	1903.34	17499.96	D	17642.77	T
170.0	3.79550	0.2319E+05	15759.22	1740.75	17499.97	D	17805.37	T
175.0	4.04121	0.2213E+05	15834.24	1665.75	17499.99	D	17880.39	T
200.0	5.38472	0.1683E+05	16153.10	1346.89	17499.99	D	18199.25	T
240.0	7.92680	0.8745E+04	16512.42	987.57	17499.99	D	18558.57	T
270.0	10.14621	0.3142E+04	16699.22	800.78	17500.00	D	18745.37	T
300.0	12.59242	0.0000E+00	16786.87	713.13	17499.99	B	18833.02	T

350.0 17.14090 0.0000E+00 16786.87 713.13 17500.00 B 18833.03 T

DB= 38.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.00002	0.8940E+04	147.07	14180.71	14327.78	T	7248.91	I
10.0	1.00038	0.2132E+05	693.86	16768.59	17462.45	T	9124.11	I
16.0	1.00235	0.3209E+05	1677.23	15820.32	17497.56	T	9705.05	I
21.0	1.00652	0.3925E+05	2704.03	14790.65	17494.68	T	10302.03	I
26.0	1.01415	0.4470E+05	3833.34	13660.82	17494.15	T	10974.42	I
32.0	1.02917	0.4911E+05	5226.87	12272.94	17499.81	T	11833.94	I
42.0	1.07107	0.5221E+05	7423.13	10076.29	17499.42	T	13271.96	I
58.0	1.18567	0.5025E+05	10261.04	7238.37	17499.41	T	15426.22	I
75.0	1.36902	0.4413E+05	12354.19	5145.36	17499.55	T	17511.95	T
80.0	1.43396	0.4207E+05	12825.83	4674.13	17499.96	T	18104.15	T
85.0	1.50349	0.3997E+05	13244.42	4255.26	17499.68	T	18692.44	T
90.0	1.57742	0.3787E+05	13617.14	3882.69	17499.83	T	20078.56	T
95.0	1.65552	0.3579E+05	13949.38	3550.61	17499.98	T	22137.82	T
100.0	1.73756	0.3373E+05	14245.93	3253.93	17499.87	T	22896.98	T
110.0	1.91263	0.2975E+05	14749.84	2750.01	17499.85	T	21014.42	T
120.0	2.10089	0.2596E+05	15157.71	2342.23	17499.95	T	19553.54	T
135.0	2.40408	0.2065E+05	15635.02	1864.95	17499.97	T	17875.39	T
140.0	2.56483	0.2015E+05	15702.91	1797.07	17499.99	D	17749.07	T
150.0	2.96088	0.1983E+05	15791.14	1708.82	17499.96	D	17837.29	T
160.0	3.39014	0.1903E+05	15890.96	1608.99	17499.95	D	17937.11	T
170.0	3.85189	0.1791E+05	15993.57	1506.43	17500.00	D	18039.72	T
175.0	4.09475	0.1725E+05	16044.24	1455.74	17499.98	D	18090.39	T
200.0	5.42674	0.1348E+05	16279.38	1220.60	17499.98	D	18325.53	T
240.0	7.95669	0.6753E+04	16574.92	925.06	17499.98	D	18621.08	T
270.0	10.17007	0.1725E+04	16738.74	761.25	17499.99	D	18784.89	T
300.0	12.59222	0.0000E+00	16786.86	713.13	17499.99	B	18833.02	T
350.0	17.14063	0.0000E+00	16786.87	713.13	17499.99	B	18833.02	T

DB= 39.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	1.50002	0.8940E+04	147.07	14180.71	14327.78	T	7248.91	I
10.0	1.50038	0.2132E+05	693.86	16768.59	17462.45	T	9124.11	I
16.0	1.50235	0.3209E+05	1677.23	15820.32	17497.56	T	9705.05	I
21.0	1.50652	0.3925E+05	2704.03	14790.65	17494.68	T	10302.03	I
26.0	1.51415	0.4470E+05	3833.34	13660.82	17494.15	T	10974.42	I
32.0	1.52917	0.4911E+05	5226.87	12272.94	17499.81	T	11833.94	I
42.0	1.57107	0.5221E+05	7423.13	10076.29	17499.42	T	13271.96	I
58.0	1.68567	0.5025E+05	10261.04	7238.37	17499.41	T	15426.22	I
75.0	1.86902	0.4413E+05	12354.19	5145.36	17499.55	T	17511.95	T
80.0	1.93396	0.4207E+05	12825.83	4674.13	17499.96	T	18104.15	T
85.0	2.00349	0.3997E+05	13244.42	4255.26	17499.68	T	18692.44	T
90.0	2.07742	0.3787E+05	13617.14	3882.69	17499.83	T	20078.56	T
95.0	2.15552	0.3579E+05	13949.38	3550.61	17499.98	T	22137.82	T
100.0	2.23756	0.3373E+05	14245.93	3253.93	17499.87	T	24308.38	T
110.0	2.41263	0.2975E+05	14749.84	2750.01	17499.85	T	25973.38	T
120.0	2.60089	0.2596E+05	15157.71	2342.23	17499.95	T	23720.41	T
135.0	2.90408	0.2065E+05	15635.02	1864.95	17499.97	T	21167.70	T
140.0	3.00977	0.1897E+05	15766.15	1733.84	17499.99	T	20473.31	T
150.0	3.22664	0.1576E+05	15995.29	1504.69	17499.98	T	19254.84	T
160.0	3.45289	0.1278E+05	16185.31	1314.65	17499.96	D	18231.47	T
170.0	3.90827	0.1262E+05	16227.89	1272.10	17499.99	D	18274.04	T
175.0	4.14829	0.1237E+05	16254.24	1245.73	17499.97	D	18300.40	T
200.0	5.46876	0.1012E+05	16405.67	1094.32	17499.99	D	18451.82	T
240.0	7.98659	0.4761E+04	16637.45	862.55	17500.00	D	18683.61	T
270.0	10.19394	0.3083E+03	16778.27	721.73	17500.00	D	18824.43	T
300.0	12.59203	0.0000E+00	16786.87	713.13	17500.00	B	18833.02	T
350.0	17.14036	0.0000E+00	16786.87	713.13	17499.99	B	18833.02	T

DB= 40.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.00002	0.8940E+04	147.07	14180.71	14327.78	T	7248.91	I
10.0	2.00038	0.2132E+05	693.86	16768.59	17462.45	T	9124.11	I
16.0	2.00235	0.3209E+05	1677.23	15820.32	17497.56	T	9705.05	I
21.0	2.00652	0.3925E+05	2704.03	14790.65	17494.68	T	10302.03	I
26.0	2.01415	0.4470E+05	3833.34	13660.82	17494.15	T	10974.42	I
32.0	2.02917	0.4911E+05	5226.87	12272.94	17499.81	T	11833.94	I
42.0	2.07107	0.5221E+05	7423.13	10076.29	17499.42	T	13271.96	I
58.0	2.18567	0.5025E+05	10261.04	7238.37	17499.41	T	15426.22	I
75.0	2.36902	0.4413E+05	12354.19	5145.36	17499.55	T	17511.95	T
80.0	2.43396	0.4207E+05	12825.83	4674.13	17499.96	T	18104.15	T
85.0	2.50349	0.3997E+05	13244.42	4255.26	17499.68	T	18692.44	T
90.0	2.57742	0.3787E+05	13617.14	3882.69	17499.83	T	20078.56	T
95.0	2.65552	0.3579E+05	13949.38	3550.61	17499.98	T	22137.82	T
100.0	2.73756	0.3373E+05	14245.93	3253.93	17499.87	T	24308.38	T
110.0	2.91263	0.2975E+05	14749.84	2750.01	17499.85	T	28983.45	T
120.0	3.10089	0.2596E+05	15157.71	2342.23	17499.95	T	27887.46	T
135.0	3.40408	0.2065E+05	15635.02	1864.95	17499.97	T	24460.13	T

140.0	3.50977	0.1897E+05	15766.15	1733.84	17499.99	T	23534.75	T
150.0	3.72664	0.1576E+05	15995.29	1504.69	17499.98	T	21921.67	T
160.0	3.94916	0.1272E+05	16187.86	1312.13	17499.99	T	20557.86	T
170.0	4.17522	0.9838E+04	16350.96	1149.00	17499.96	T	19382.66	T
175.0	4.28890	0.8447E+04	16423.30	1076.68	17499.98	T	18851.56	T
200.0	5.51077	0.6769E+04	16531.93	968.04	17499.97	D	18578.08	T
240.0	8.01648	0.2769E+04	16699.96	800.03	17500.00	D	18746.12	T
270.0	10.19900	0.0000E+00	16786.86	713.13	17499.98	B	18833.01	T
300.0	12.59183	0.0000E+00	16786.86	713.13	17499.99	B	18833.02	T
350.0	17.14010	0.0000E+00	16786.87	713.13	17500.00	B	18833.03	T

DB= 41.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	2.50002	0.8940E+04	147.07	14180.71	14327.78	T	7248.91	I
10.0	2.50038	0.2132E+05	693.86	16768.59	17462.45	T	9124.11	I
16.0	2.50235	0.3209E+05	1677.23	15820.32	17497.56	T	9705.05	I
21.0	2.50652	0.3925E+05	2704.03	14790.65	17494.68	T	10302.03	I
26.0	2.51415	0.4470E+05	3833.34	13660.82	17494.15	T	10974.42	I
32.0	2.52917	0.4911E+05	5226.87	12272.94	17499.81	T	11833.94	I
42.0	2.57107	0.5221E+05	7423.13	10076.29	17499.42	T	13271.96	I
58.0	2.68567	0.5025E+05	10261.04	7238.37	17499.41	T	15426.22	I
75.0	2.86902	0.4413E+05	12354.19	5145.36	17499.55	T	17511.95	T
80.0	2.93396	0.4207E+05	12825.83	4674.13	17499.96	T	18104.15	T
85.0	3.00349	0.3997E+05	13244.42	4255.26	17499.68	T	18692.44	T
90.0	3.07742	0.3787E+05	13617.14	3882.69	17499.83	T	20078.56	T
95.0	3.15552	0.3579E+05	13949.38	3550.61	17499.98	T	22137.82	T
100.0	3.23756	0.3373E+05	14245.93	3253.93	17499.87	T	24308.38	T
110.0	3.41263	0.2975E+05	14749.84	2750.01	17499.85	T	28983.45	T
120.0	3.60089	0.2596E+05	15157.71	2342.23	17499.95	T	32054.74	T
135.0	3.90408	0.2065E+05	15635.02	1864.95	17499.97	T	27752.70	T
140.0	4.00977	0.1897E+05	15766.15	1733.84	17499.99	T	26596.32	T
150.0	4.22664	0.1576E+05	15995.29	1504.69	17499.98	T	24588.60	T
160.0	4.44916	0.1272E+05	16187.86	1312.13	17499.99	T	22901.81	T
170.0	4.67522	0.9838E+04	16350.96	1149.00	17499.96	T	21458.95	T
175.0	4.78890	0.8447E+04	16423.30	1076.68	17499.98	T	20810.89	T
200.0	5.55279	0.3416E+04	16658.23	841.76	17499.99	D	18704.38	T
240.0	8.04636	0.7773E+03	16762.46	737.52	17499.98	D	18808.61	T
270.0	10.19885	0.0000E+00	16786.87	713.13	17500.00	B	18833.03	T
300.0	12.59164	0.0000E+00	16786.87	713.13	17500.00	B	18833.03	T
350.0	17.13983	0.0000E+00	16786.87	713.13	17499.99	B	18833.02	T

DB= 42.000 INCHES

L (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
5.0	3.00002	0.8940E+04	147.07	14180.71	14327.78	T	7248.91	I
10.0	3.00038	0.2132E+05	693.86	16768.59	17462.45	T	9124.11	I
16.0	3.00235	0.3209E+05	1677.23	15820.32	17497.56	T	9705.05	I
21.0	3.00652	0.3925E+05	2704.03	14790.65	17494.68	T	10302.03	I
26.0	3.01415	0.4470E+05	3833.34	13660.82	17494.15	T	10974.42	I
32.0	3.02917	0.4911E+05	5226.87	12272.94	17499.81	T	11833.94	I
42.0	3.07107	0.5221E+05	7423.13	10076.29	17499.42	T	13271.96	I
58.0	3.18567	0.5025E+05	10261.04	7238.37	17499.41	T	15426.22	I
75.0	3.36902	0.4413E+05	12354.19	5145.36	17499.55	T	17511.95	T
80.0	3.43396	0.4207E+05	12825.83	4674.13	17499.96	T	18104.15	T
85.0	3.50349	0.3997E+05	13244.42	4255.26	17499.68	T	18692.44	T
90.0	3.57742	0.3787E+05	13617.14	3882.69	17499.83	T	20078.56	T
95.0	3.65552	0.3579E+05	13949.38	3550.61	17499.98	T	22137.82	T
100.0	3.73756	0.3373E+05	14245.93	3253.93	17499.87	T	24308.38	T
110.0	3.91263	0.2975E+05	14749.84	2750.01	17499.85	T	28983.45	T
120.0	4.10089	0.2596E+05	15157.71	2342.23	17499.95	T	34103.76	T
135.0	4.40408	0.2065E+05	15635.02	1864.95	17499.97	T	31045.45	T
140.0	4.50977	0.1897E+05	15766.15	1733.84	17499.99	T	29658.04	T
150.0	4.72664	0.1576E+05	15995.29	1504.69	17499.98	T	27255.65	T
160.0	4.94916	0.1272E+05	16187.86	1312.13	17499.99	T	25245.87	T
170.0	5.17522	0.9838E+04	16350.96	1149.00	17499.96	T	23535.31	T
175.0	5.28890	0.8447E+04	16423.30	1076.68	17499.98	T	22770.29	T
200.0	5.85204	0.1946E+04	16713.59	786.41	17500.00	T	19602.32	T
240.0	8.05795	0.0000E+00	16786.86	713.13	17499.98	B	18833.01	T
270.0	10.19869	0.0000E+00	16786.87	713.13	17500.00	B	18833.03	T
300.0	12.59144	0.0000E+00	16786.87	713.13	17499.99	B	18833.02	T
350.0	17.13956	0.0000E+00	16786.87	713.13	17499.99	B	18833.02	T

Table B.8 Maximum Allowable Borehole Deviation Based on Liner Insertion Stresses in Boreholes Drilled with a Non-Steerable Bit

This section of Appendix B lists the output file from PROGRAM DEVIAT1 for maximum allowable borehole deviation based on liner insertion stresses during liner insertion operations with simultaneous drilling in horizontal and vertical boreholes drilled with a non-steerable bit.

The following parameter values were used in computing these results:

L_b = 26 ft (vertical borehole)

L_b = 32, 42, 58, 75, 270, and 350 feet (horizontal boreholes)

d_b = 36.5, 37, 38, 39, 40, 41, and 42 inches

F_b = 470,000 lb (simultaneous drilling).

Other parameter values were fixed as listed in Section 5.2.

RUN WITH DEVIAT2.FOR
 LINER INSERTION LOADING SPECIFIED
 MINIMUM ALLOWABLE LINER RADIUS OF CURVATURE= 65.74 FT (BASED ON CONTAINER CLEARANCE)
 CRITICAL BUCKLING STRESS BASED ON BENDING= 0.2114E+06 PSI
 CRITICAL BUCKLING STRESS BASED ON COMPRESSION= 0.2039E+06 PSI
 FS= 4.00
 FB= 470000.00 LBF

LB= 26.000 FEET (VERTICAL)

DB (IN)	RB (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	1635.2	2.48033	0.2502E+05	7994.84	9505.15	17499.99	T	9071.50	I
37.00	905.3	4.47996	0.2502E+05	7994.82	9505.15	17499.96	T	9071.47	I
38.00	478.3	8.47735	0.2502E+05	7994.74	9505.14	17499.87	T	9071.38	I
39.00	325.1	12.47060	0.2502E+05	7994.65	9505.12	17499.77	T	9071.28	I
40.00	246.2	16.45777	0.2502E+05	7994.73	9505.14	17499.87	T	9071.37	I
41.00	198.2	20.43685	0.2501E+05	7994.16	9505.06	17499.22	T	9070.73	I
42.00	165.8	24.40601	0.2501E+05	7994.52	9505.11	17499.62	T	9071.13	I

LB= 32.000 FEET

DB (IN)	RB (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	2250.0	2.73065	0.1927E+05	8176.81	9323.19	17500.00	T	9368.68	I
37.00	1298.8	4.73038	0.1927E+05	8176.80	9323.19	17499.98	T	9368.66	I
38.00	703.8	8.72855	0.1927E+05	8176.77	9323.18	17499.95	T	9368.63	I
39.00	482.7	12.72391	0.1927E+05	8176.73	9323.18	17499.91	T	9368.59	I
40.00	367.3	16.71519	0.1927E+05	8176.75	9323.18	17499.93	T	9368.61	I
41.00	296.5	20.70106	0.1927E+05	8176.55	9323.16	17499.70	T	9368.40	I
42.00	248.6	24.68025	0.1927E+05	8176.31	9323.13	17499.44	T	9368.14	I

LB= 42.000 FEET

DB (IN)	RB (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	3234.0	3.27266	0.1423E+05	8373.44	9126.56	17500.00	T	9989.18	I
37.00	2007.3	5.27246	0.1423E+05	8373.43	9126.56	17499.99	T	9989.18	I
38.00	1141.5	9.27125	0.1423E+05	8373.42	9126.56	17499.98	T	9989.17	I
39.00	797.5	13.26833	0.1423E+05	8373.41	9126.56	17499.96	T	9989.15	I
40.00	612.9	17.26295	0.1423E+05	8373.43	9126.56	17499.98	T	9989.17	I
41.00	497.7	21.25434	0.1423E+05	8373.34	9126.55	17499.89	T	9989.08	I
42.00	419.0	25.24177	0.1423E+05	8373.33	9126.55	17499.88	T	9989.07	I

LB= 58.000 FEET

DB (IN)	RB (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	4575.0	4.41175	0.9254E+04	8555.05	8944.95	17500.00	T	10175.19	I
37.00	3148.0	6.41159	0.9254E+04	8555.05	8944.95	17500.00	T	11572.60	I
38.00	1938.6	10.41078	0.9254E+04	8555.04	8944.95	17499.99	T	11572.60	I
39.00	1400.6	14.40898	0.9254E+04	8555.04	8944.95	17499.99	T	11572.60	I
40.00	1096.4	18.40579	0.9254E+04	8555.02	8944.95	17499.97	T	11572.60	I
41.00	900.7	22.40081	0.9254E+04	8555.01	8944.95	17499.96	T	11572.60	I
42.00	764.4	26.39367	0.9254E+04	8555.02	8944.95	17499.98	T	11572.60	I

LB= 75.000 FEET

DB (IN)	RB (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	5222.5	6.46234	0.7018E+04	8616.64	8883.36	17500.00	D	9055.10	I
37.00	4259.1	7.92406	0.5851E+04	8666.89	8833.11	17500.00	T	11004.25	I
38.00	2830.4	11.92341	0.5851E+04	8666.89	8833.11	17500.00	T	16337.74	I
39.00	2119.5	15.92210	0.5851E+04	8666.89	8833.11	17499.99	T	19222.22	T
40.00	1694.0	19.91989	0.5851E+04	8666.89	8833.11	17500.00	T	19222.22	T
41.00	1410.8	23.91652	0.5851E+04	8666.87	8833.11	17499.98	T	19222.22	T
42.00	1208.8	27.91179	0.5851E+04	8666.88	8833.11	17499.99	T	19222.22	T

LB=270.000 FEET

DB (IN)	RB (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	5280.9	82.80945	0.0000E+00	8521.38	8978.62	17500.00	B	10099.84	I
37.00	5280.9	82.80913	0.0000E+00	8521.38	8978.62	17500.00	B	10099.84	I
38.00	5280.9	82.80847	0.0000E+00	8521.38	8978.62	17500.00	B	10099.84	I
39.00	5281.0	82.80782	0.0000E+00	8521.38	8978.62	17500.00	B	10099.84	I
40.00	5281.0	82.80717	0.0000E+00	8521.38	8978.62	17500.00	B	10099.84	I
41.00	5281.0	82.80651	0.0000E+00	8521.38	8978.62	17500.00	B	10099.84	I
42.00	5281.1	82.80586	0.0000E+00	8521.38	8978.62	17500.00	B	10099.84	I

LB=350.000 FEET

DB (IN)	RB (FT)	DELB (IN)	P (LB)	SB (PSI)	SI (PSI)	SIG (PSI)	CONTACT	SIGTH (PSI)	REST
36.50	5383.8	136.47161	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I
37.00	5383.9	136.47108	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I
38.00	5383.9	136.47003	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I
39.00	5383.9	136.46898	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I
40.00	5384.0	136.46791	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I
41.00	5384.0	136.46686	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I
42.00	5384.1	136.46581	0.0000E+00	8358.38	9141.62	17500.00	B	10404.53	I

APPENDIX C

COMPARISON OF PARAMETER VALUES USED IN THIS STUDY
WITH THOSE IN THE REFERENCE INFORMATION BASE

This appendix provides a comparison of parameter values used in this analysis with corresponding values in the Reference Information Base (RIB).

TABLE C.1
COMPARISON OF PARAMETER VALUES

<u>Parameter</u>	<u>Value Used in Analysis</u>	<u>RIB Version 02.002</u>		<u>Remarks</u>
		<u>Value</u>	<u>Subsection</u>	
Liner outside diameter	36 in	None		
Liner inside diameter	35 in	None		
Liner mean radius	17.75 in	None		
Liner thickness	0.5 in	None		
Liner elastic modulus	30×10^6 psi	None		
Liner weight/volume	489 lb/ft ³	None		
Liner Poisson's ratio	0.29	None		
Liner ultimate strength	70 kpsi	None		
Liner/rock friction coefficient	0.6	None		
Vertical borehole diameter (spent fuel borehole)	36.5 in 37.0 in 38.0 in 39.0 in 40.0 in 41.0 in 42.0 in	29 in	2.2.2.8	Equipment designs may require larger dia. borehole than that in RIB.
Horizontal borehole diameter (spent fuel borehole)	36.5 in 37.0 in 38.0 in 39.0 in 40.0 in 41.0 in 42.0 in	37 in	2.2.1.8	Equipment designs may require larger dia. borehole than that in RIB.
Waste container skid weight	1,774 lb	None		
Waste container skid length	16.7 ft	None		

TABLE C.1
COMPARISON OF PARAMETER VALUES
(continued)

<u>Parameter</u>	<u>Value Used in Analysis</u>	<u>RIB Version 02.002</u>		<u>Remarks</u>
		<u>Value</u>	<u>Subsection</u>	
Effective waste container weight (spent fuel container)	14,985 lb	6,437 - 13,211 lb	2.1.1.2	Value used assumes the heaviest container and includes the weight of the skid.
Effective waste container length (spent fuel container)	16.7 ft (200.5 in)	187.5 in	2.1.1.2	Value used includes body of skid
Effective waste container diameter (spent fuel container)	28.75 in	26.0 in	2.2.1.2	Value used is for hybrid container and includes thickness of skid.
Vertical borehole length (spent fuel borehole)	26 ft	25 ft	2.2.2.8	Value used in analysis is now under con-
			sideration	
Horizontal borehole length (spent fuel borehole)	32 ft 42 ft 58 ft 75 ft 270 ft 350 ft	363 ft	2.2.1.8	Values used in analysis are now under consideration.
Safety factor against liner rupture	4.0	None		
Drilling thrust force	470,000 lb	None		

TABLE C.1
COMPARISON OF PARAMETER VALUES
(continued)

<u>Parameter</u>	Value Used in <u>Analysis</u>	<u>RIB Version 02.002</u>		<u>Remarks</u>
		<u>Value</u>	<u>Subsection</u>	
Maximum borehole wall temperature	441°F (227°C)	157°C	3.1.1.4	RIB value is for 363-ft horizontal borehole; value used is for the vertical borehole (SNL, 1987c)
Initial liner temperature	68°F (20°C)	20.3°C	1.3.1.7	RIB value is the representative undisturbed temperature of the repository horizon.
Liner thermal expansion coefficient	$6.5 \times 10^{-6} / ^\circ\text{F}$	None		
Tuff thermal expansion coefficient (thermal/mechanical unit TSw2)	$4.9 \times 10^{-6} / ^\circ\text{F}$ $8.8 \times 10^{-6} / ^\circ\text{K}$	$8.8 \times 10^{-6} / ^\circ\text{K}$	1.3.1.3	RIB value is mean pretransition value.
Intact rock unconfined compressive strength (thermal/mechanical unit TSw2)	24.1 kpsi (166 MPa)	166±65 MPa	1.3.1.4	Mean RIB value used.

APPENDIX D

SITE AND ENGINEERING PROPERTIES DATA BASE INFORMATION

This report contains no data taken from or that should be included in the Yucca Mountain Site and Engineering Properties Data Base (SEPDB).

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