Bechtel Associates Professional Corporation

Inter-office Memorandum

To	L.H. Curtis	Date	August 1, 1980
Subject	Midland - Units 1 & 2	From	B.R. Klein
		Of	Plant Design
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Attached with this is a report which evaluates the general acceptability of the effects of settlement in several buried service piping systems in the proximity of the diesel generator building. The report is a partial response to several FSAR questions (16 through 20 and 34), under 10CRF50.54(f).

The NRC questions as presented are a general mix of system settlement and one or more effects related to the settlement question. Our intent in this report is to address the fact of settlement in the buried piping and the acceptability of the effects of it in the systems, only. We have concluded that if the settlement effect in the systems is acceptable, only then can local conditions be identified and, where necessary, local modifications carried out for correction. Only one such condition has been identified to date.

In the event our argument for acceptability of the settlement condition is not favorably received, an entirely new approach to the problem will be required. In that case, the identification and recommendation of modifications for local effects will, of a necessity, require a new assessment as well.

We are proceeding on an effort to identify and, if necessary, determine what corrective work may be required in local area penetration and connection points, assuming the conditions noted in our report will prove to be acceptable.

B.R. Klein

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BRK/JAL/cg
Attachment

BURIED PIPING SETTLEMENT CONDITIONS

Midland Plant - Units 1 & 2

1. Introduction

This report is concerned with the effects of settlement in several buried service piping systems that are routed underground in the proximity of, and between, the diesel generator building, the auxiliary building and the service water pump structure. A number of 'questions' have been raised by the NRC, both with respect to system performance and future service integrity; these may be noted in FSAR questions 16 through 20, and question 34, which are related to the requirements of 10CFR50.54(f).

It is intended that this report will provide an engineering rationale for the general acceptance of both the present condition of these buried systems and the future service conditions that may be expected within the predicted limits of maximum additional settlement. This report does not provide specific responses to the current NRC questions noted above but is intended to provide a reference basis for response by the project licensing group.

2. Report Scope

This final analysis review is addressed and is primarily related to NRC questions 17 and 19 which directly apply to those service systems listed in Table 17-1 and, partially, to those listed in Table 19-1. The scope of this final investigation is related only to the 26"/36"-OHBC-16 Service Water System which is typical of most of the systems in configuration. Further, it is routed throughout the yard area of concern and is the system most susceptable to settlement, both from the effects of soil loading and least resistance to axial strain. Given this, it is assumed that if the acceptability condition of this system can be demonstrated, the settlement condition of all systems should be acceptable as well.

This following table lists the parameters substantiating the statement in the previous paragraph. This includes the five piping sizes used in the systems with which there is a concern here.

Size	Lbs/Ft	Ft^2/Ft	Lbs/Ft^2	$Am - in^2$	Lbs/in^2	Lbs/Ft^3
36"	565	4.7	120	42.0	13.5	80.0
26"	319	3.4	94	30.2	10.6	86.6
18"	172	2.4	73	20.8	8.3	97.2
10"	75	1.4	53	11.9	6.3	118.4
8"	51	1.1	45	8.4	6.1	123.7

a) This table indicates the following: column 1 lists unit weights, including the weight of both the pipe and water contents.

b) Column 2 lists one-half of the pipe surface area which, when combined with the unit loads (from column 1), provides the 'bed' loading of each pipe size listed in column 3. For a given bedding soil resistance, and the greatest top surface exposed to overbearing loads, it is assumed that the largest sizes will be most susceptable to settlement. The relative density values noted in column 6, however, tend to weaken this argument; see Para. 3.c.

c) As a corollary to this, it is assumed that when settlement occurs between two fixed points, a system will tend to elongate, axially. A system's resistance to elongation strain will be related to both the weight of pipe and contents and the net external loading effect. Using the piping load (in column 1) and the cross-sectional metal area of the piping (column 4), the relative unit tensile loading is determined and listed in column 5. This indicates that the greatest unit loading exists (the least resistance to strain) in the largest sizes.

The scope of this final investigation is further limited to the general question of settlement and the effects of it in a buried piping system undergoing a transitory change in geometry as a result of the settlement. Specific local effects, other than in the piping itself, will be addressed separately pending the acceptance of this report.

3. Evaluation Assumptions

Several basic assumptions are made here without which any analytical approach will be meaningless. These are:

a) The original, as-built, installed elevation profiles of these piping systems are not known. Given this fact, it is necessary that the piping is assumed to have been originally placed at the theoretical elevations indicated on the design drawings.

b) The difference in the original design elevations and those noted in the most recent survey represents a settlement that will be assumed to have occurred under the deadweight condition of the piping and the overbearing load of the trench fill above the piping.

c) Given the semi-fluid density of the past reported soil conditions (approaching that of water), the systems would have had the capability of settling under their own filled-weight conditions. Note column 6 of the data table which indicates filled-system densities of 80.0 to 123.7 lbs/ft^3.

4. System Analytical Approach

There are no established analytical techniques for a rigorous evaluation of the stressed condition of the settled piping systems with which there is a concern here. There is a great deal of uncertainty as to the nature of the operating mechanisms which caused the translation of the piping from an essentially level, stress-free condition (at the assumed design elevation), to a settled condition of varying elevation with a pronounced degree of point-to-point strain. This can be noted in the Service Water System elevation profile presented on drawing SK-M-2458. It can be seen on the profile that, ostensibly, the total system has settled in varying degrees and, that the net effect has produced a series of elevation inflection points on the profile curve. On the basis of this observation, it can be shown that several conclusions may be reached which lend to a simplified evaluation of the system condition:

a) The total piping system may be divided into a number of 'sections,' each of which can be analyzed independently with respect to the actual deformation or strain existent in the section under review. An example of such a condition is illustrated in Figure 1.

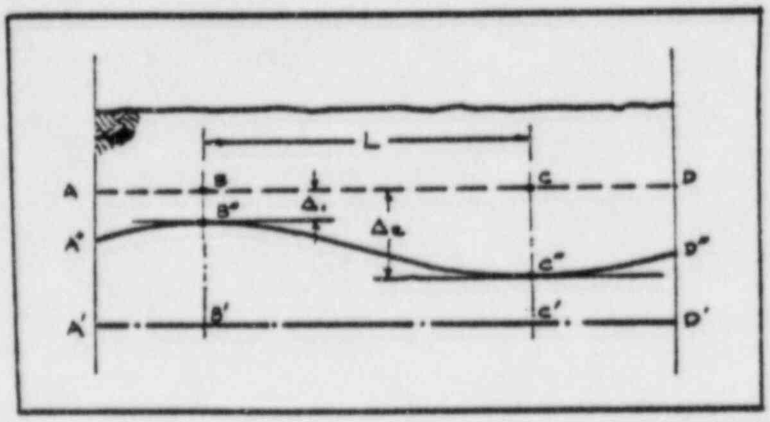

Figure 1

b) In this example, a portion of the total system is shown between points A and D. The piping was designed and placed between those points in a level, unstrained condition and, therefore, it assumed to be in a stress-free condition. It is also reasonable to assume that if the total piping system, including its end-connection points, had uniformly settled to any lower elevation, say between points A' and D', no part of the system would be in a strained condition and therefore would remain stress-free.

c) This example addresses the fact that the system has settled in a non-uniform fashion, leaving portions of the system in a strained condition, as indicated between points A" and D". Here, our concern is not with how much settlement has occurred but, rather, with the differential effects between any two closely related points in the system; in this case, the 'section' between points B" and C", which are separated by a distance of L feet, and have been subjected to a differential settlement condition of $(\Delta_2 - \Delta_1)$ inches.

d) In the evaluation of this piping, the overall system was divided into subsystems, or sections, as indicated above, based upon the profile data shown on drawing SK-M-2458. This simplified approach assumes that the subsystems between inflection points can be evaluated as a fixed-end beam condition with one end free to displace ($\Delta_2 - \Delta_1$), under a uniformly distributed load which is the end affect of bed resistance, dead load, over-bearing load and lateral soil friction-resistance.

e) Two stress effects may be noted from these assumed conditions:

- The longitudinal bending stress which will occur as a result of the differential displacement; this can be expressed as:

$$S_b = \frac{DE\Delta}{36L^2} \qquad (1)$$

- The stress effects of axial elongation which will occur in length L, between points B and C in the displaced length of B" to C". This can be expressed as:

$$S_a = \frac{0.0085E\Delta^2}{L^2} \qquad (2)$$

where (in both expressions above):

S_a = Axial elongation stress, psi
S_b = Longitudinal bending stress, psi
D = Piping O.D., inches
E = Modulus of Elasticity, psi
Δ = Vertical Span displacement, inches
L = Beam length, feet.

f) The axial strain, or change in length due to end displacement of the fixed-end beam, can be expressed as:

$$\Delta L = \frac{0.102\Delta^2}{L}, \text{ inches (see above for terms)} \qquad (3)$$

g) The bending unit strain, at the point of maximum moment and stress, can be expressed as:

$$\epsilon = \frac{S_b}{E}, \text{ inches/inch} \qquad (4)$$

5. Typical System Effects

Given the relationships in Para. 4, above, a typical worst condition can be examined. One such condition would be that of a 5" vertical displacement in a 75 foot span of 26" pipe. Using 27.9 X 10^6 for E, for carbon steel at ambient conditions:

a) Using Equation (1), the displacement bending stress will be:

$$S = \frac{26 \times 27.9 \times 10^6 \times 5}{36 \times (75)^2} = \underline{17,911} \text{ psi}$$

b) Using Equation (2), the axial elongation stress will be:

$$S = \frac{0.0085 \times 27.9 \times 10^6 (5)^2}{(75)^2} = \underline{1,054} \text{ psi}$$

c) Using Equation (3), the total change in length (B" to C"), or axial strain, will be:

$$\Delta L = \frac{0.102\ (25)}{75} = \underline{0.034} \text{ inches}$$

d) Using Equation (4), the unit strain at the point of maximum bending moment will be:

$$\epsilon = \frac{17,911}{27.9 \times 10^6} = \underline{0.000642} \text{ inches/inch}$$

$$= 0.064 \text{ percent strain}$$

6. Conclusions

Several conclusions may be reached based on this study and the results tabulated in Table 17-2 of the FSAR Question Responses.

a) The bending stresses related to the differential displacements vary widely throughout the length of each system, no doubt resulting from the variable quality of soil compaction and water entrainment. It is expected that, while most of the settlement has occurred, up to 3" of additional settlement may occur over the lifetime of the installation (see Afifi to Curtis, 3/6/80). There are no data indicating the distribution of this additional settlement with respect to what portion of it may contribute to differential settlement within a section, rather than to the uniform settlement of a total section.

b) Considering the above, it is expected that within the conservative approach of the beam analogy used in this analysis, that maximum longitudinal bending stresses in some cases may exceed the values listed in Table 17-2, or that in the example of this report, and may possibly reach or exceed twice the yield stress of the material.

c) Table 17-2 implies an allowable stress limit of that defined in Equation 10a of ASME Section III, Division 1, Subsection NC, which is defined as a limit for "the effects of any single nonrepeated anchor movement..." with the bending moment defined (by example) as that caused by predicted building settlement. There are no arguments with applying (10a) as a conservatively safe limit but the application of both $3S_c$ (approximately 1.88 Sy), and a stress intensification factor (for a single, half-cycle occurrence), is considered here to be both excessively conservative and in direct contradiction with the stress and strain limitations permitted in both the cold and hot forming operations permitted in NC-4200. There, for example, a 5D bend in 26" pipe size will produce a unit strain of approximately 0.10 inches/inch in the outer surface (as compared to 0.000642 inches/inch in the example here), and a stress level of 1 to 3 million psi, depending upon temperature, as compared to probably 2Sy, or less, in these settled piping systems.

d) For the settled piping systems of concern on this project, it is proposed that the stress effects of settlement in the general run of the systems, both in the present condition and for predicted future settlement, be considered safely acceptable. Further, that all local effects of settlement (i.e., at subgrade building penetrations) be identified and uniquely evaluated for the necessity of either piping repair, or the addition of Code-qualified flexible couplings.

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Plant Design
August 1, 1980

JAL/cg