CYGNA
ENERGY SERVICES
101 California Street, Suite 1000, San Francisco, CA 94111-5894 415/397-5600

May 6, 1985
84042.029

Mr. J.W. Beck
Manager-Licensing
Texas Utilities Generating Company
Skyway Tower
400 North Olive Street, L.B. 81
Dallas, Texas 75201

Subject: Reissuing of Cygna letters 84042.035 and 84042.036
Comanche Peak Steam Electric Station
Independent Assessment Program
Texas Utilities Generating Company
Job No. 84042

References: (1) N.H. Williams (Cygna) letter to J.B. George (TUGCO), "Stability of Pipe Supports," 84042.035, dated February 19, 1985

(2) N.H. Williams (Cygna) letter to J.W. Beck (TUGCO) "Phase 3 Open Items - Cinching of U-Bolts," 84042.036, dated March 25, 1985

Dear Mr. Beck:

We are reissuing the above referenced letters since they were inadvertently logged in Cygna's ASLB files rather than the Phase 3 outgoing correspondence files. Accordingly, replacement letters are attached bearing the log numbers 84042.027 and 84042.028 for references (1) and (2), respectively. Please replace the referenced letters in your files with the enclosed versions.

Very truly yours,

N.H. Williams

N.H. Williams
Project Manager

NHW/ajb

8505280472 850506
PDR ADOCK 05000445
A PDR

Enclosures

cc: Mr. J. Redding (TUGCO)
Mr. J. Finneran (TUGCO)
Ms. J. van Amerongen (EBASCO/TUGCO)
Mr. S. Treby (USNRC)
Mr. V. Noonan (USNRC)
Mr. S. Burwell (USNRC)
Mr. R. Ballard (Gibbs & Hill)

Z222
1/1 See Attached Dist

5/16/85

TO: DOCUMENT CONTROL

FROM: S. B. Burwell x27038

SUBJECT: Cygna Review (Phase 3) Comanche Peak

Attached is the following document:
CYGNA - May 6, 1985 letter to J. W. Beck from N. H. Williams Letter No. 84042.029 reissuing letters issued with wrong file nos.

Please distribute as follows:

Reg File
NRC PDR
LPDR
NTIS
NSIC
Region IV
Region IV: D. Hunnicutt

LB#1/DL - S. B. Burwell (4)
MEB/DE - D. Terao
SGEB/DE - F. Rinaldi
QUAB/IE - J. Spraul
EGCB/IE - J. Fair
OELD - S. Treby
EQB/DE - G. Bagchi
EQB/DE - V. Noonan
ORB 3/DL - C. Trammell
D/DET - L. Shao
ICSB/DSI - J. Calvo

CYGNA
ENERGY SERVICES
101 California Street, Suite 1000, San Francisco, CA 94111-5894 415/397-5600

February 19, 1985
84042.027

Mr. J. B. George
Project General Manager
Texas Utilities Generating Company
Comanche Peak Steam Electric Station
Highway FM 201
Glen Rose, Texas 76043

Subject: Stability of Pipe Supports
Texas Utilities Generating Company
Comanche Peak Steam Electric Station
Independent Assessment Program
Job No. 84042

References:

(1) N.H. Williams (Cygna) letter to V. Noonan (U.S. NRC), "Open Items Associated with Walsh/Doyle Allegations," 84042.22, dated January 18, 1985.

(2) N.H. Williams (Cygna) letter to V. Noonan (U.S. NRC), "Revision to Open Items Schedule," 84056.055, February 14, 1985.

(3) Affidavit of John C. Finneran Jr. regarding Stability of Pipe Supports and Piping Systems, dated June 17, 1984.

(4) Cygna Phase 3 Final Report TR-84042-1, Rev. 1, November 20, 1984.

Dear Mr. George:

As committed to in Reference 1 and subsequently revised in Reference 2, Cygna has completed an evaluation of the pipe support stability issue. This evaluation considered the support designs reviewed by Cygna as part of Phases 2, 3 and 4 as well as TUGCO's position described in Reference 3. Since stability is a very complex issue, we will summarize our position in six parts: (1) Definition of Stability, (2) Dynamic Versus Static Stability, (3) System Stability, (4) Commentary on TUGCO's Position, (5) Classification of Cygna Review Scope, and (6) Conclusions.

CYGNA ENERGY SERVICES

Definition of Stability

Prior to performing an evaluation of this issue, criteria were developed to define what constitutes an unstable pipe support. Individual pipe supports can be classified into two broad categories: (1) supports which, in the total absence of the pipe, are stable, and (2) supports which, in the total absence of the pipe, are unstable. Implicit in our definition for the second category is the fact that the instability is a rigid body type which may be completely removed or accommodated by proper attachment to the pipe. That is, by restraining certain degrees of freedom at the attachment to the pipe, such as with a pipe clamp, the instability may be removed. Alternatively, by limiting the motion following instability through the presence of the pipe and adjacent supports, the instability may also be eliminated. Since there is no stability issue with respect to supports of the first category, only supports of the second category need be discussed.

In order for a support of the second category to be stable, there are two requirements to be met, one involving force transfer between the pipe and support and the other involving the geometric relationship between the pipe and support. The force requirement is met if adequate forces, which develop instantaneously and can be relied upon by design, exist between the pipe and the support hardware to resist the factored load. The following definitions are provided for clarity:

> develop instantaneously (immediately): Resisting forces are activated at the same instant that piping loads are applied. An example of forces which cannot develop immediately are binding forces which require a rigid body motion of the support (rotation, translation) to become effective.
>
> by design: The mechanism for and magnitude of the resisting forces are calculatable and known, or have been evaluated extensively by test or by use in the specific application.
>
> factored load: Applied load times a safety factor.

In addition to the above described force requirement, the geometric relationship between the support and the pipe must remain within set limits during the operational life of the plant. If sufficient clamping forces between the pipe and support are not present, small pipe movements may cause large changes in the position of the support relative to the pipe. Piping system vibration occurring during start-up, normal operation or shut-down can cause the support to move (rotate, translate) relative to the pipe. This support movement is unfavorable if, for a support initially perpendicular to the pipe, the direction of pipe

movement in the absence of the support is such that the displaced centerline of the pipe intersects the arc made by the rigid body motion of the pipe center within the support. The new position of the support on the pipe may be well outside the displacement (eccentricity) envelope for which it was designed and for which stability has been assured. Since the support did not restrain the movement of the pipe during this process, adjacent supports must now resist an additional load for which they may not be adequate. Therefore, a sufficient condition for individual pipe support stability of the second category is a design in which, upon the application of the factored load from the pipe, adequate resisting forces can be developed immediately and the position of the support attachment on the pipe does not move relative to the pipe with time.

Considering the definition presented above, we will now discuss some specialized situations in which the instantaneous development of resisting forces required for stability does not occur. For these designs momentary instability (of the rigid body type) could be tolerated, provided that it can be demonstrated that sufficient forces eventually develop to completely remove the instability (i.e., stop the motion and allow the support to function as designed). For example, when considering the instability of a support which requires the development of binding forces to ultimately maintain stability, one could assume the support does not act and then determine the resulting pipe deflection in the released direction. If that deflection is a sufficient multiple (say 4) of the deflection required to develop the necessary binding forces, it then becomes appropriate to further investigate the ability of the support to resist both the binding force and the applied load. During such an investigation, it is essential to demonstrate that the binding force mechanism possesses both sufficient strength and stiffness. In other words, while certain designs may exhibit sufficient strength to develop and resist the necessary binding forces, they may not posssess sufficient stiffness to limit the rigid body displacement and thus resist the applied load. The alternative to this approach is to limit the consequences of the instability. This could be accomplished by showing that the piping and remaining supports are acceptable in the absence of the unstable support. In either approach, before the design can be considered satisfactory, pipe stresses and other support reactions must be checked for the new displacements occurring at the support and the pipe must be checked for the effects of the binding forces.

Dynamic Versus Static Stability

The preceeding discussion addresses only stability due to statically applied loading. The question arises as to whether a support could be unstable statically under the application of maximum load, yet stable when the same load is applied dynamically. This is a very complex analytic problem to resolve which is further complicated by the fact that the maximum loading on a pipe

support is generally some combination of static and dynamic loads. Cygna is unaware of any established precedent for the acceptance of statically unstable supports based on dynamic arguments. In some cases dynamic loading can contribute to pipe support instability rather than helping to preclude it. The time phasing of static and applied seismic (random) forces can either exacerbate or alleviate individual support instability. Therefore, to demonstrate analytically that a statically unstable support is dynamically stable would require an extensive evaluation using large nonlinear dynamic models and time-history analyses. Add to this the variety of possible geometric configurations and input motions that must be considered, as well as the existence of static system preload (dead load plus thermal), and the problem becomes extremely costly to evaluate. This is a particularly unfavorable approach in view of the potentially inconclusive nature of the results.

For many of the same reasons stated above, any testing program developed to prove dynamic stability would also have to be very extensive. Tests which are severely displacement limited and sinusoidal (non-random) in nature can only prove that a support is stable under small amplitude displacement sinusoidal input. Such tests would not necessarily demonstrate stability under conditions which reflect the real nature of the random input motion.

System Stability

Generally, the term system stability is associated with the arrangement of a structure's restraint configuration such that it is not possible for the structure to undergo rigid body motion. We will refer to this as geometric stability. With respect to piping systems, geometric stability is assured when a pipe stress computer analysis is successfully executed. This computer analysis would have detected a system of supports which does not restrain each of the three translational and three rotational global degrees of freedom. Encountering such a geometrically unstable system is an extremely rare situation since almost all piping systems contain some type of anchor (e.g., equipment nozzle, penetration, structural anchor, etc.).

When discussing system stability as it relates to pipe support stability, the major concern is the ability of the piping system to provide the appropriate stabilizing restraint for each support. This type of global stability can only be assured if each support is individually stable in its own right, either through its design (supports of the first category) or by adequate attachment to the pipe (supports of the second category). If individual support stability is not assured, system stability is not guaranteed. The instability of one support can trigger the progressive instability of adjacent supports by causing the limits of the forces and displacements to which the adjacent supports were originally designed to be exceeded. This may result in the formation of plastic

CYGNA
ENERGY SERVICES

hinges in the pipe (due to overload) which in turn may develop into a collapse mechanism. This situation would not, however, prevent successful execution of a linear, elastic pipe stress computer analysis.

Demonstration of system stability by removal of an unstable support from the system and subsequently showing that each remaining support can resist the new forces is not sufficient by itself. In addition, it should be shown that removing the unstable support does not affect the stability of other supports. That is, overall system stability should be reevaluated in the absence of the removed support.

Commentary on TUGCO's Position

Cygna has reviewed the Reference (3) Affidavit using the criteria described above. The Affidavit (pages 2-8) discusses system stability and its relation to individual support stability. In it, TUGCO states:

> "In addition, if the total support scheme does not provide proper multidirection support required by the piping configuration, the analyst will be unable to successfully run the piping analysis computer program, (see Tr. 12025 (Bjorkman testimony)). In summary, the piping analyst assures the stability of the piping system by limiting deflections, which negates any need to assess stability separately."

Cygna agrees with the first statement, since this is our basic definition of geometric stability. The second statement, however, does not follow. A piping analyst does not limit deflections to those required to assure system stability, since, in general, these deflections are not known. Rather, the analyst inputs each support as a restrained node and reports the resulting deformations to the designer for consideration. Therefore, the issue is not piping system stability, but rather the stability of the individual support itself. The key point is whether the individual support can resist the applied load within the initial eccentricities and displacement limits imposed upon it.

The stability issue is best illustrated in Figure 1(c) of the Affidavit, (page 4). The concern is not whether an adjacent support can provide a horizontal reaction component (since it is already known by analysis that it can and the system is geometrically stable), but rather whether the clamp (U-bolt) can provide sufficient resisting forces to prevent rotation of the clamp (U-bolt) about the pipe or slippage along the pipe axis. If the clamp (U-bolt) cannot provide sufficient resisting torque, the individual support is unstable and system stability as well as progressive support instability must be re-evaluated.

CYGNA ENERGY SERVICES

Of the specific support configurations discussed in the Affidavit, the most unique is the box frame with zero-inch gap attached to a single strut or snubber (Affidavit, page 9). This is unusual because it relies solely on the relative thermal expansion between the pipe and frame during normal operation to create clamping forces. The resulting frictional forces which resist support rotation around the pipe and translation along the axis of the pipe would stabilize the support. The lower bound value of stabilizing frictional force which exists over the operational life of the plant was never determined either analytically or by test. Furthermore, since clamping forces do not exist at ambient conditions, it is possible for the support to move (rotate and translate) relative to the pipe. This movement of the support could be caused by normal vibration during start-up, operation or shut-down, combined with pipe thermal translation compatible within the rigid body displacement envelope of the support. Subsequent to this movement the support may be in a position on the pipe which is outside of the displacement range for which it was designed and for which stability could be assured. Furthermore, due to the compatible rigid body motion of the pipe and support, the support would be unable to restrain the thermal movement (load) for which it was designed and adjacent supports would have to resist this load -- a load for which they were not designed. This situation may also develop at temperatures above ambient since the maintenance of zero gap over the life of the plant could be difficult to achieve. For these reasons, Cygna classifies these supports, without modification, as unstable.

In Figure 4 of the Affidavit (page 13) three methods are shown which have been utilized to modify the box frame supports to improve their stability. Two of these methods, "indexed lugs" and "additional struts" only provide rotational stability. They do not prevent translation of the support along the axis of the pipe with time. Therefore both of these modification schemes result in supports which must still be classified as unstable. The third modification scheme, the addition of cinched U-bolts, can prevent both rotation and translation of the support provided it can develop sufficient lower bound clamping forces. Since the final evaluation on the use of cinched U-bolts has not been completed, the acceptability of supports with this configuration remains an open issue at this time.

Cygna classifies all single struts with U-bolts and a thermal gap (Affidavit, page 15) as unstable since the stability of this type of support has never been analytically or experimentally demonstrated. Cygna understands that all of these supports have been modified in an effort to enhance stability (Affidavit, page 18). These modifications consist of either cinching the U-bolts or adding supplementary steel that would prevent the rotation of the U-bolt crosspiece. Cygna believes we have addressed those supports for which supplementary steel was added to create "stability bumpers" in Reference (4) Observation PS-02. Cygna found these bumpers unacceptable since there were no calculations to

CYGNA ENERGY SERVICES

demonstrate that they possessed sufficient strength and stiffness to maintain stability. The stability of the supports which were modified by cinching the U-bolts remains open as part of the U-bolt analysis/testing program.

Double strutted frames (Affidavit, page 19) supporting two or more pipes were not encountered during any of the Cygna review phases. However, Cygna did find examples of double strutted frames supporting a single pipe and double strutted trapeze supports with U-bolts, which are configurations similar to those discussed in the Affidavit. As previously discussed for single strutted frames, both the double strutted frames and trapeze supports with uncinched U-bolts suffer from the problem of not having the demonstrated ability to maintain their relative position on the pipe over time. In addition, the double struts cannot be relied upon to resist compressive load until the frame (U-bolt) has rotated about an axis parallel to the struts and has bound itself in a cocked position against the pipe. Neither the stiffness requirements of the frame (U-bolt) necessary to maintain a stable position nor the binding forces and displacements required to restrict the unstability have been evaluated. Cygna therefore classifies these supports as unstable.

In the case of double strutted trapeze supports with cinched U-bolts, the most likely mode of instability is that due to rotation of the support about an axis parallel to the struts. If the frictional resistance between the pipe and the trapeze crosspiece is not sufficient, the frictional bond will be broken and the entire destabilizing twisting moment must be resisted by the bending strength (and stiffness) of the U-bolt binding against the pipe. Since neither the frictional forces nor the U-bolt have been evaluated for their capability to resist this nonlinear destabilizing moment, Cygna classifies this configuration as unstable.

The stability of a single strut or snubber with a cinched U-bolt (Affidavit, page 27) is directly related to the resolution of the issue of U-bolts used as pipe clamps. Until the resolution of that issue, which includes the satisfactory determination that lower bound preloads can provide the clamping force necessary to resist the factored piping loads, Cygna considers all such supports to the unstable.

Classification of Cygna Review Scope

Cygna has examined the 226 pipe supports within the Phases 2, 3 and 4 review scope. Thirty-seven supports were identified as supports which, in the total absence of the pipe, are stable. Of the remaining 189 supports which in the absence of the pipe would be unstable, 124 possess sufficient positive attachment to the pipe to ensure stability. The 65 potentially unstable supports may be classified as follows:

- Single strut with box frame or cinched U-bolt (23)
- Double strut trapeze with cinched U-bolt (25)
- Multi-strut box frame (8)
- Single strut with uncinched U-bolt, stability bumpers (2)
- Double strut, double trunnion with cinched U-bolt (1)
- Double strut trapeze with box frame (2)
- Double strut trapeze with uncinched U-bolt (3)
- Triple strut box frame (1)

There are two reasons for classifying these supports as unstable: 1) the unconventional methods used to develop the restraining forces between the pipe and the support, and 2) the lack of any demonstration that the restraining forces developed by these supports are sufficient to maintain the support's stability. Supports which are designed with cinched U-bolts to provide the necessary positive connection to the pipe may be reclassified as stable if the U-bolt testing/ analysis program and the application of the results to the individual supports in question is found to be acceptable. It should be noted, however, that this program does not address the stability of supports which do not use U-bolts, nor does it evaluate the twisting strength of U-bolts used in trapeze supports.

Conclusions

Throughout this letter, Cygna has applied a very rigorous definition of rigid body instability. Cygna recognizes from a practical standpoint that many of these potentially unstable designs may actually perform their intended function. However, we also recognize that the inability to quantify the actual behavior which may help stabilize the support in practice necessitates that stability be viewed under more idealized conditions. For that reason the individually unstable supports identified above, and any similar configurations throughout the plant, should be evaluated using one of the following approaches:

- Modify to provide adequate restraint at the pipe/support connection

- Demonstrate system stability in the presence of the unstable supports

- Quantitatively show that the individual supports are stable

CYGNA ENERGY SERVICES

Please call to discuss any questions or clarification necessary since this is a complex subject.

Very truly yours,

N.H. Williams
Project Manager

NHW/ajb

cc: S. Treby (U.S. NRC)
S. Burwell (U.S. NRC)
V. Noonan (U.S. NRC)
D. Wade (TUGCO)
J. van Amerongen (EBASCO/TUGCO)
R. Ballard (G&H)
J. Ellis (CASE)
D. Pigott (Orrick, Herrington & Sutcliff)
J. Finneran (TUGCO)

CYGNA
ENERGY SERVICES
101 California Street, Suite 1000, San Francisco, CA 94111-5894
415/397-5600

March 25, 1985
84042.028

Mr. J.W. Beck
Manager - Licensing
Texas Utilities Generating Company
Skyway Tower
400 North Olive Street
L.B. 81
Dallas, Texas 75201

Subject: Phase 3 Open Items - Cinching of U-Bolts
Texas Utilities Generating Company
Comanche Peak Steam Electric Station
Independent Assessment Program
Job No. 84042

References: See Attachment 1 for a List of References

Dear Mr. Beck:

As committed to in References 1 and 2, Cygna has reviewed all the information provided by TUGCO on the U-bolt cinching evaluation program. This information consists of the documents listed in References 3, 4, 5, 7, 8, 10 and 11 only. Cygna has previously issued questions on the testing/analysis program in References 6 and 9. We have reviewed both our earlier questions and all data supplied by TUGCO. A summary of our remaining questions is contained in this letter.

Throughout our review of this program, Cygna has asked questions which are interrelated. For example, questions 6, 12, 18, and 19 from Reference 6 were discussed as a single issue during the TUGCO/EBASCO/Cygna meeting on September 13, 1984. Thus, it is not possible to address any individual question without considering the implications of the response on other questions. Cygna's underlying concerns, which must be addressed in any response, are:

(1) Has the test considered the worst orientation of the U-bolt/strut when attempting to demonstrate stability?

(2) Does the test show that the U-bolt is capable of maintaining the support in a stable configuration at the minimum preload over the operating life of the plant?

(3) Has TUGCO established a torque vs. preload relationship which will ensure that the torque used in the plant will guarantee the minimum preload required for stability?

CYGNA
ENERGY SERVICES

(4) Has TUGCO shown that the stresses in the pipe due to the maximum possible U-bolt load (for the torque chosen) are acceptable under all conditions of temperature, pressure, and applied load?

Cygna's remaining questions and concerns related to each of these four areas are detailed in Attachment 2 to this letter. After receiving additional information (References 10 and 11), Cygna reviewed the entire set of references once more to determine if all our concerns had been addressed. In this attempt to trace the path from the testing through the analysis and finally to the actual in-plant data, Cygna has concluded that we are unable to close out the four basic concerns at this time. We suggest that while we are transmitting these questions via letter, a meeting may be the most expeditious way to discuss these questions and to provide any required clarification.

This letter completes Cygna's commitment listed under Item 1 of the Open Items List attached to Reference 1 and subsequently updated by Reference 2. If you have any questions or wish to discuss the subject, please call.

Very truly yours,

N.H. Williams

N.H. Williams
Project Manager

NHW/ajb

Enclosures

cc: Mrs. J. Ellis
Mr. S. Treby
Mr. S. Burwell
Mr. V. Noonan
Mr. J. Redding