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PACIFIC GAS AND ELECTRIC COMPANY

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June 8, 1984

PGandE Letter No.: DCL-84-220

Mr. John B. Martin, Regional Administrator
U. S. Nuclear Regulatory Commission, Region V
1450 Maria Lane, Suite 210
Walnut Creek, CA 94596-5368

Re: Docket No. 50-275, OL-DPR-76
Diablo Canyon Unit 1
Safety-Related Bolting

Dear Mr. Martin:

During a site inspection by NRC Region V between May 14 and 25, 1984, the NRC requested information relative to the oversize hole condition in bolted connections in safety-related structures and components. The requested information is enclosed.

Kindly acknowledge receipt of this material on the enclosed copy of this letter and return it in the enclosed addressed envelope.

Sincerely,

W. A. Raymond

for J. O. Schuyler

Enclosure

cc: T. W. Bishop
D. G. Eisenhut
G. W. Knighton
H. E. Schierling
Service List

PGandE Letter No.: DCL-84-220

ENCLOSURE

OVERSIZE HOLES IN BOLTED CONNECTIONS SAFETY-RELATED STRUCTURES AND COMPONENTS

INTRODUCTION

During a site inspection by NRC Region V between May 14 and 25, 1984, the issue of oversize holes in bolted connections was examined by the NRC inspection team.

During this inspection the NRC requested the following information:

1. Describe the categories of installations which contain oversize holes and the methods used to obtain required joint integrity.

2. Describe the practice of packing wire in oversized holes, the extent this practice was applied, and justification which demonstrates compliance with the required joint integrity.

This enclosure responds to these questions.

OVERSIZE AND SLOTTED HOLES

OVERVIEW

During the course of plant construction when bolt hole sizes were determined to exceed the AISC standard, General Construction (GC) contacted Project Engineering to obtain resolution either on a case by case basis or, in the case of pipe supports, on a generic basis. In some cases the area between the bolt and the hole was filled using plastic steel, steel rods, or shim stock. However, more often, the connection was modified by either: (1) using plate washers and cover plates; (2) repairing excess gaps by welding and drilling to the correct size; (3) reaming or drilling the holes and using larger size bolts; or (4) replacing the bolted connection with a welded connection.

To identify the categories of installations in which oversize holes were encountered during construction and the method used to obtain joint integrity, GC generated discrepancy reports and reviewed the installation procedures. The following categories of installations were found to have, in some cases, required resolution of oversize holes.

1. Pipe Supports
2. Miscellaneous Structural Steel
3. Pipe Rupture Restraints Inside Containment
4. Electrical Raceway Supports

The following sections detail the approach adopted to resolve the question of oversized holes at various installations and provide justification for the approach adopted. The practice of packing voids between the bolt and bolt hole with wire is detailed in the Pipe Rupture Restraint Section and is limited to pipe rupture restraints inside containment.

PIPE SUPPORTS

Oversize holes in pipe support fabrication and installation of pipe support base plates have been observed during plant construction. These situations were corrected by use of washers where no shear load was present or, by installation of cover plates. The use of washers was discontinued after 1975 and all installations were done using only fish plates. The use of washers and cover plates restored the oversize conditions to the standards specified in the design documents.

MISCELLANEOUS STRUCTURAL STEEL

Structural steel contractors, including suppliers of base plates such as Murphy Pacific, American Bridge, Endurance Metal Products, Guy F. Atkinson, and H. P. Foley Company, were required to meet specification requirements for hole sizes as defined in Specification Nos. 8831XR, 8833, 8833XR, 8837, and 5422. The work performed under these specifications was required to conform to the AISC criteria.

In cases where the identified bolt holes were outside the criteria set forth in the specifications, one of the following corrective actions was taken:

a. Holes were reamed to AISC requirements and oversize bolts were used.
b. The holes were plug welded and redrilled or reamed to AISC specification.
c. Bolted connections were replaced with welded connections.
d. Base plate bolt holes were corrected by putting in shim stocks or using plastic grout.

PIPE RUPTURE RESTRAINTS INSIDE CONTAINMENT

The rupture restraint base plates are anchored to wall or floor concrete. In cases where the base plate holes were oversized, the gaps were filled with steel rods to enable the bolts to transfer the load to concrete. These were determined to be limited to rupture restraints installed inside containment (Reference drawing #447253, Rev. 4) A total of 246 anchor bolts were affected.

Six rupture restraints having 15 oversized anchor bolt holes were identified as being the typical cases and the amount of steel rods packed into the oversized holes was documented.

Details of this resolution are presented in Attachment 1 along with technical justification of this arrangement.

The review of rupture restraint documents shows that when steel rod was used on rupture restraint base plates installed inside the containment, it was recorded on process sheets. Twenty packages out of a total population of 222 rupture restraints installed outside the containment were reviewed, and it was found that the process sheets did not indicate that steel rod was used in these restraints.

ELECTRICAL RACEWAY SUPPORTS

H. P. Foley Company work involved Specification No. 8802 dealing with electrical raceway support and equipment. PGandE drawing #050030 for raceway supports requires the use of the largest size bolt permissible. Equipment mounting was controlled by PGandE drawing #050053 which required that the bolt shall be the largest that the hole would accept, i.e., for 7/16-in. hole, 3/8-in. bolt; for 9/16-in. hole, 1/2-in. anchor bolt; etc.

Attachment

Attachment

PIPE RUPTURE RESTRAINTS INSIDE CONTAINMENT

BASEPLATE OVERSIZE HOLE - ROD PACKING DETAIL

1. Statement of Concern

A concern has been raised regarding the acceptability of the shear transfer detail used for oversize baseplate anchor bolt holes. This detail, defined on drawing #447253 Rev. 4 (Zone A9), specifies the use of A36 steel rod (1/4-in. max. diameter) to fill the space between the baseplate and anchor bolt.

2. Background

The shear transfer detail using A36 rod packing is confined to rupture restraints located inside containment. Application of this detail is specified on drawing #447253 Rev. 4. The oversize hole packing was applied to the Embedment "Class" A, B, and C embedments.[1] Two hundred and forty-six anchor bolts use this detail.

The detailing practice used by the steel fabricator shop was to oversize the baseplate in accordance with the AISC "Detailing for Steel Construction" manual. Table 7-1 of that manual recommends the following:

Table 7-1. Recommended Hole Sizes for Anchor Bolts

Bolt size	Hole size
3/4" to 1" incl.	Diameter + 5/16"
Over 1" to 2" incl.	Diameter + 1/2"
Over 2"	Diameter + 1"

The above AISC table recommends the anchor bolt hole sizes for normal building construction. Since the Project specification required conformance to the AISC criteria, the steel fabrication with oversize holes was within the specified limits. However, the rod packing detail was developed to provide a positive mechanism to transfer shear from the baseplate to the anchor bolt. The shear is transfered by bearing between the baseplate and the rod packing/anchor bolt shank. This detail was

1 The term Embedment Class refers to the type of embedment detail used and is not related to safety class.

approved by engineering for use in the installation of rupture restraints inside containment.

DCP understands the current concerns regarding the rod packing shear transfer detail to be:

a. The adequacy of the rod packing under the bearing loads imposed under design conditions, and

b. Possible relative movement between the baseplate and anchor bolt due to rod packing compaction.

3. Field Survey

DCP construction personnel conducted a document survey and interviewed knowledgable construction personnel to verify the extent of the rod packing detail. The use of rod packing was noted on construction process sheets. A review of rupture restraint documentation confirmed the use of this detail inside containment. A review of 20 of the 222 outside containment restraint packages revealed no use of this procedure.

Pullman Power Products and PGandE General Construction (GC) personnel with historic knowledge of the rupture restraint installation were interviewed by GC management personnel. Interviewed personnel confirmed that the rod packing detail was confirmed to inside containment application.

4. Field Evaluation

Engineering defined a representative sample of inside containment rupture restraints for field inspection of anchor bolt packing. The sample selected included the Priority Code "C" restraints (critical to Civil) specified by the "Procedure for Measuring Hot Gaps on Rupture Restraints" (Procedure P-37, Revision 1).

The field inspection sample was modified by limiting inspection to:

a. Restraints that were accessible without the installation of scaffolding, and restraints which did not represent an excessive safety hazard to personnel.

b. Restraints and/or bolts which did not require disassembly or rigging for nut removal.

Fifteen bolts were inspected. Thirteen restraints were in the Priority Code "C" category. Eleven of the 13 restraints were anchored to concrete using the rod packing detail. Only 6 of the 11 restraints could be accessed without scaffolding. Fifteen nuts could be removed from these six restraints without disassembly of structural components.

An initial inspection on May 29 and 30, 1984, identified five "worst case" rod packing cases. "Worst Case" bolts were those with visibly loose rod packing and/or voids. A followup field inspection was made on June 1, 1984, to measure bolt offsets and rod packing densities. The results of the June 1 inspection were used for a quantitative engineering evaluation.

5. <u>Engineering Evaluation</u>

Engineering evaluated the following aspects of the rod packing detail:

- Rod packing ultimate bearing capacity compared to anchor bolt ultimate strength design limits for shear.

- Worst case baseplate displacement relative to the anchor bolt associated with rod packing compaction.

a. Bearing Capacity - Rod Packing Material

The rod packing material is confined between the bolt body, baseplate, washer/nut and the wall/floor slab. Local deforming or flattening of a rod is considered self-limiting. Local contact forces which result in plastic deformation of the rods will result in increased contact area. The limiting case is full flattening of the rod.

Normal bearing stress on the rod material was evaluated for the limit state case of rods completely flattened to 100% compaction. The predicted normal bearing stress, for bolts at the design shear force limit ranges from 37% of the faulted allowable bearing stress for 1-in. bolts to 60% of the allowable for 3-in. bolts. The allowable bearing stress was computed in accordance with the AISC Section 1.5.2.2 bearing stress criteria, factored for the faulted pipe break condition.

b. Baseplate Displacement

Baseplate displacement can occur due to loose packing (construction packing tolerance allowed up to 1/8-in. gaps) and due to deformation of the rod material. The worst case displacement was predicted by:

- Computing the density of the rod packing as measured in the field.

- Assuming complete compaction of the rod material between the bolt and baseplate, i.e., the rod material is fully plastically deformed to a zero void state.

Even in the fully displaced state there would be some amount of void left in the interspaces between the compacted rods. However, based upon a conservative estimate of the assumed condition of no void, the maximum predicted displacement of the baseplate relative to the anchor bolt would be 1/4 in.

The worst effect of baseplate relative displacement occurs when one bolt is in initial contact with the baseplate and the other bolt is separated by loose rod packing (see Figure 5-1). In the illustrated case, Bolt B will resist the shear load immediately. Bolt A will gradually resist shear as the rod packing compacts. As Bolt B deforms, Bolt A will increasingly resist shear.

The embedded anchor bolts for restraints inside containment are ductile. Embedment depth is sufficiently deep to develop the full tensile design strength of the bolt. Research has indicated that deeply embeded bolts (with respect to tensile compacity) are also ductile in shear. Illustrations of bolt ductility are found in:

- The Ollgaard, Slutter and Fisher, "Shear Strength of Stud Connectors in Lightweight and Normal-weight Concrete," AISC Engineering Journal, April 1971.

- Fisher and Struik, Guide to Design Criteria for Bolted and Riveted Joints, Section 4.2.2 "Bolts Subjected to Shear," 1974.

The Ollgaard AISC Engineering Journal experimental investigation studies the behaviour of steel stud connnectors embedded in concrete and loaded in shear. Ollgaard observed that 5/8-in. and 3/4-in. diameter shear studs achieve maximum strength at laternal displacements of 0.23 in. to 0.42 in.. Ollgaard further observed that the studs exhibit "substantial inelastic deformation before failure", and that "at ultimate load there was no sudden failure evident." These results indicate that the concrete anchors can still provide the required shear resistance at displacements of 3/8 to 1/2 of the bolt's diameter. The worst case projection of bolt displacement associated with loose rod packing is equivalent to 1/6 to 1/8 of the bolt's diameter.

The Fisher Criteria for Bolted and Riveted Joints reports on the shear deformation behaviour of A325 and A490 bolts in steel-to-steel connections. The typical shear-deformation curve for standard A325 and A490 bolts show shear deformations of about 3/16 in. at ultimate. It is expected that the rupture restraint bolts, which are larger than typical structural bolts, have higher deformations at ultimate strength.

In summary, the inherent ductility of bolting material in steel-to-steel connections and embedded in concrete, allows relative base plate to anchor bolt displacements in excess of 1/4 in. while retaining the connections load carrying capacity.

6. Summary

Bolt holes for rupture restraints baseplates inside containment were oversized for installation. The spaces between the baseplate and anchor bolt were packed with rod material to provide a positive shear transfer mechanism. Field inspection and engineering evaluation indicate that the baseplate may displace up to 3/16 in. to 1/4 in. relative to the anchor bolt. Shear deformations of this magnitude are considered acceptable based on overall structural system ductility and the nature of rupture restraint "one time" loading. Bearing force on the rod packing material was evaluated and considered acceptable. In summary, the rod packing shear transfer detail specified by drawing 447253, Rev. 4 is adequate for its intended function.

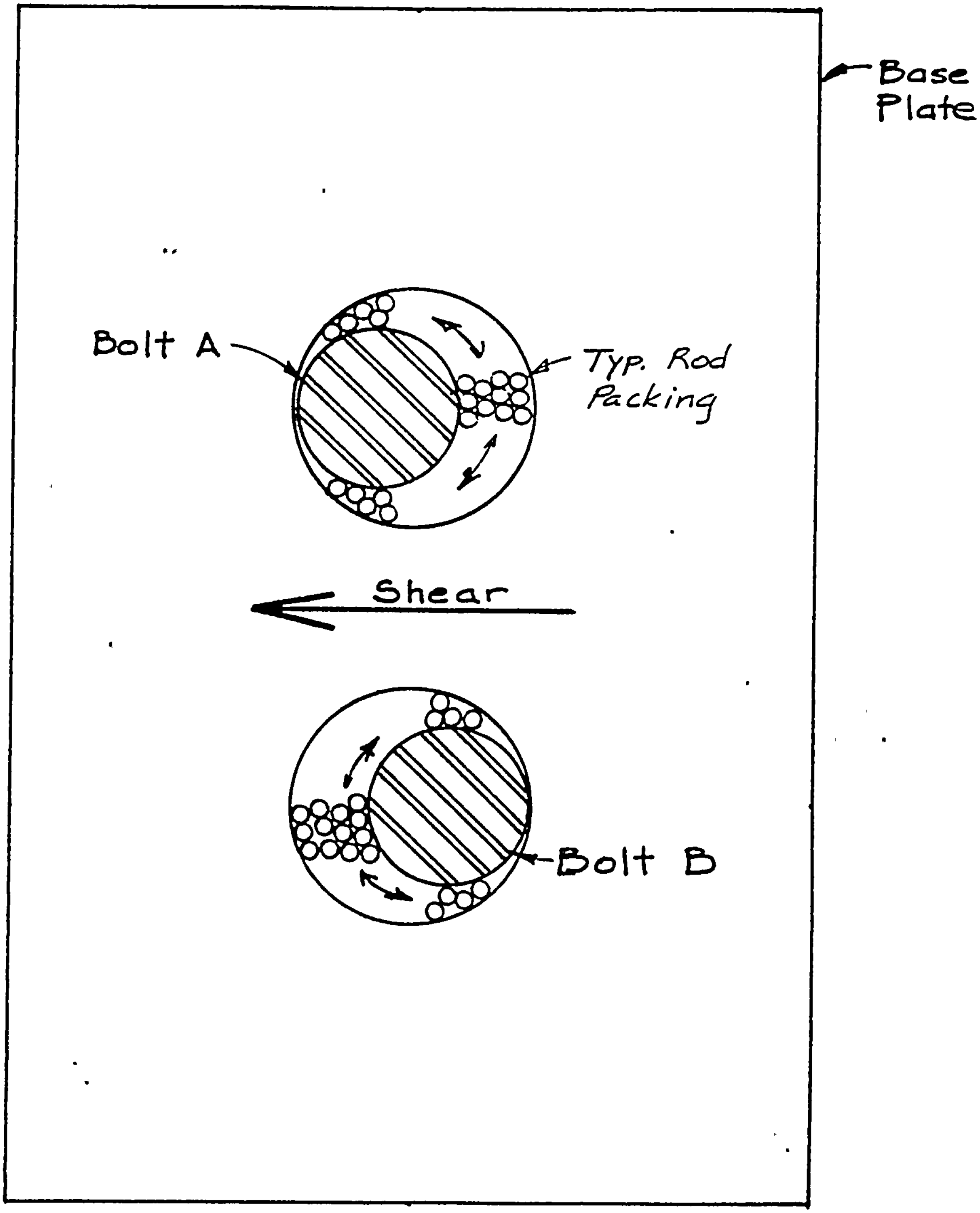
PACIFIC GAS AND ELECTRIC COMPANY
BECHTEL POWER CORPORATION

DIABLO CANYON PROJECT
CALCULATION SHEET

SHEET NO. ______ OF ______
CALC. NO. ______
REV. NO. ______

SUBJECT Figure 5-1

MADE BY ______ DATE ______ CHECKED BY ______ DATE ______ JOB NO. 15320



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