

**Enclosure 1 – SED Incident Investigation Report, dated
February 25, 2017**

Confidential Incident Investigation Report

**CALIFORNIA PUBLIC UTILITIES COMMISSION
Safety and Enforcement Division
Electric Safety and Reliability Branch**

Incident Investigation Report

Report Date: 2/25/2017

Incident Number: E20151018-01

Utility: PG&E

Date and Time of the Incident: 10/18/2015, 7:00:00 AM

Location of the Incident: Moss Landing Substation, Moss Landing
County: Monterey

Summary of Incident:

On October 18, 2015, PG&E's Tower 61/128 supporting two 230 kV circuits collapsed, causing an outage to 55,000 customers. PG&E restored service to all customers on the same day. The SED Staff investigation found that PG&E used the incorrect batter angle for all four concrete footings and "stub angles" which resulted in a low safety factor and caused the tower to fail and fall down to the ground.

Fatality / Injury: There were no injuries or fatalities reported.

Property Damage: Excess of \$50,000

Utility Facilities involved: Moss Landing-Metcalf #1 and #2, 230 kV Circuits

Witnesses:

	<i>Name</i>	<i>Title</i>	<i>Phone</i>
1	Jamie Lau	CPUC Investigator	(415)-703-2233
2	██████████	PG&E Safety Compliance	██████████
3	██████████	PG&E Consulting Engineer	██████████
4	Brian McDonald	Exponent Principal Engineer	(650)-688-6946
5	██████████	PG&E Tower Foreman	██████████

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6	██████████	PG&E Towerman	██████████
7	██████████	PG&E Crane Operator	██████████

Evidence:

	<i>Source</i>	<i>Description</i>
1	██████████	PG&E Reports and Responses to CPUC
2	Jamie Lau	Field observations on 10/20/2015
3	Jamie Lau	Lab observations on 10/21/2015
4	██████████	Interview dated on 2/18/2016
5	██████████	Phone call dated on 3/3/2016
6	Jamie Lau	Tower Demonstration dated 3/21/2016
7	Jamie Lau	Field observations on 4/5/2016
8	PG&E	Moss Landing Tower Collapse Direct Cause Analysis, first report
9	PG&E	Moss Landing Tower Collapse Root Cause Analysis, second report

Observations and Findings:

In March 2015, PG&E began the construction of Tower 61/268 as part of its substation upgrade project.

Tower 61/268 was located north of PG&E's Moss Landing Substation, just outside of the substation fence. The tower was designed to support two 230 kV Moss Landing-Metcalf transmission circuits, Number 1 and Number 2 (see Figure 1).

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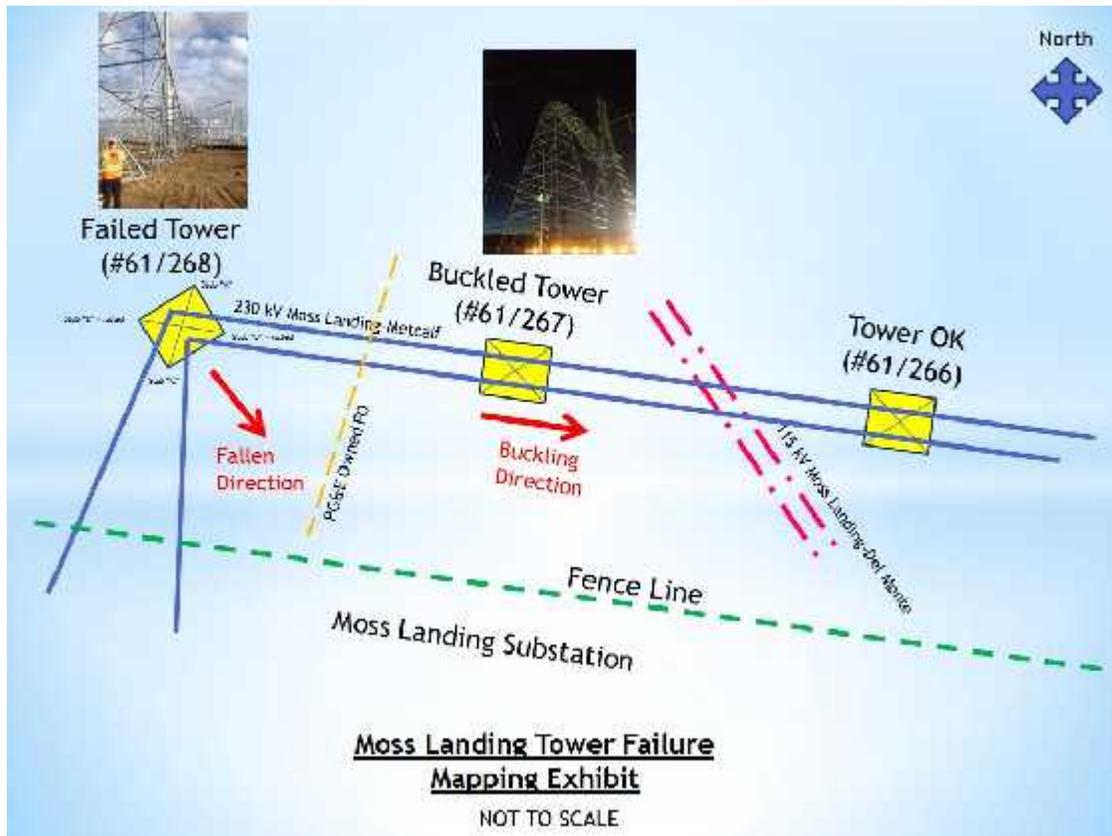


Figure 1

Tower 61/268 was a PG&E Type “G95” steel lattice, double circuit tower (see Figure 2). The last updated G95 tower design plans were in 1950 and they were hand drawn.

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Figure 3: (a) Example of a batter board, (b) its use, (c) close-up of the bottom of a tower, detailing the concrete footing, stub angle, and tower leg.

In March 2015, PG&E began the foundation construction of Tower 61/268. The tower crew was led by Foreman [REDACTED] and crew members Towerman [REDACTED], Crane Operator [REDACTED], and Utility Worker [REDACTED]. [REDACTED] had prior experience with tower construction; however, it was his first time installing a G95 tower.

On March 17, 2015, the tower crew met for a morning tailboard, and [REDACTED] reviewed Record 621915 (see Figure 4) for the dimensions to craft a batter board. The record was an 11-by-17-inch, reduce-sized photocopy of the original plan.

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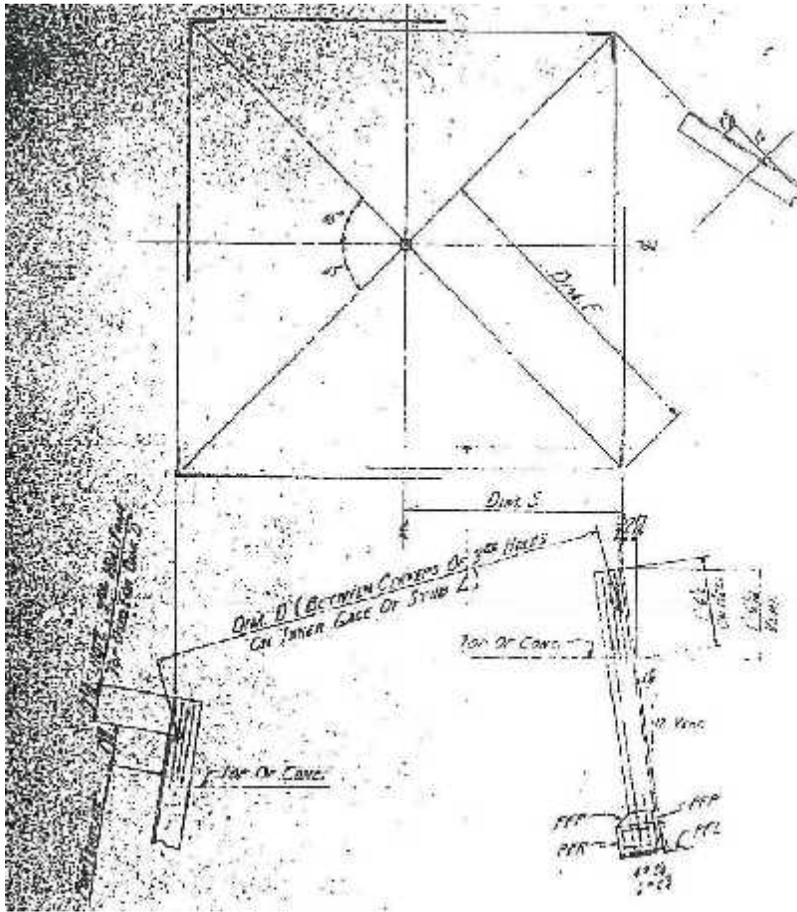


Figure 4 – Stub Angles from PG&E Record 621915

██████████ instructed ██████████ to make the batter board, and verbally provided the dimensions to ██████████, who recorded the dimensions on a pocket notebook, and with ██████████ assistance, started making the batter board shortly after receiving ██████████ work order.

Record 621915 had two batter dimensions for the concrete footing and stub angles (collectively referred to as “foundation stubs”): the “heel batter” and the “face batter.” The heel batter had a lower slope – 2-5/8 inch by 12-inch – while the face batter had a higher slope – 1-7/8 inch by 12-inch (see Figure 5). The batter board is supposed to be crafted based on the heel batter and not the face batter.

¹ During the batter board making process, ██████████ did not participate in cutting or taking measurements of the batter board. ██████████ did help with inserting the lumber into the truck vise, which was for securing the lumber in place while cutting. ██████████ observed the batter board making process as part of his training program.

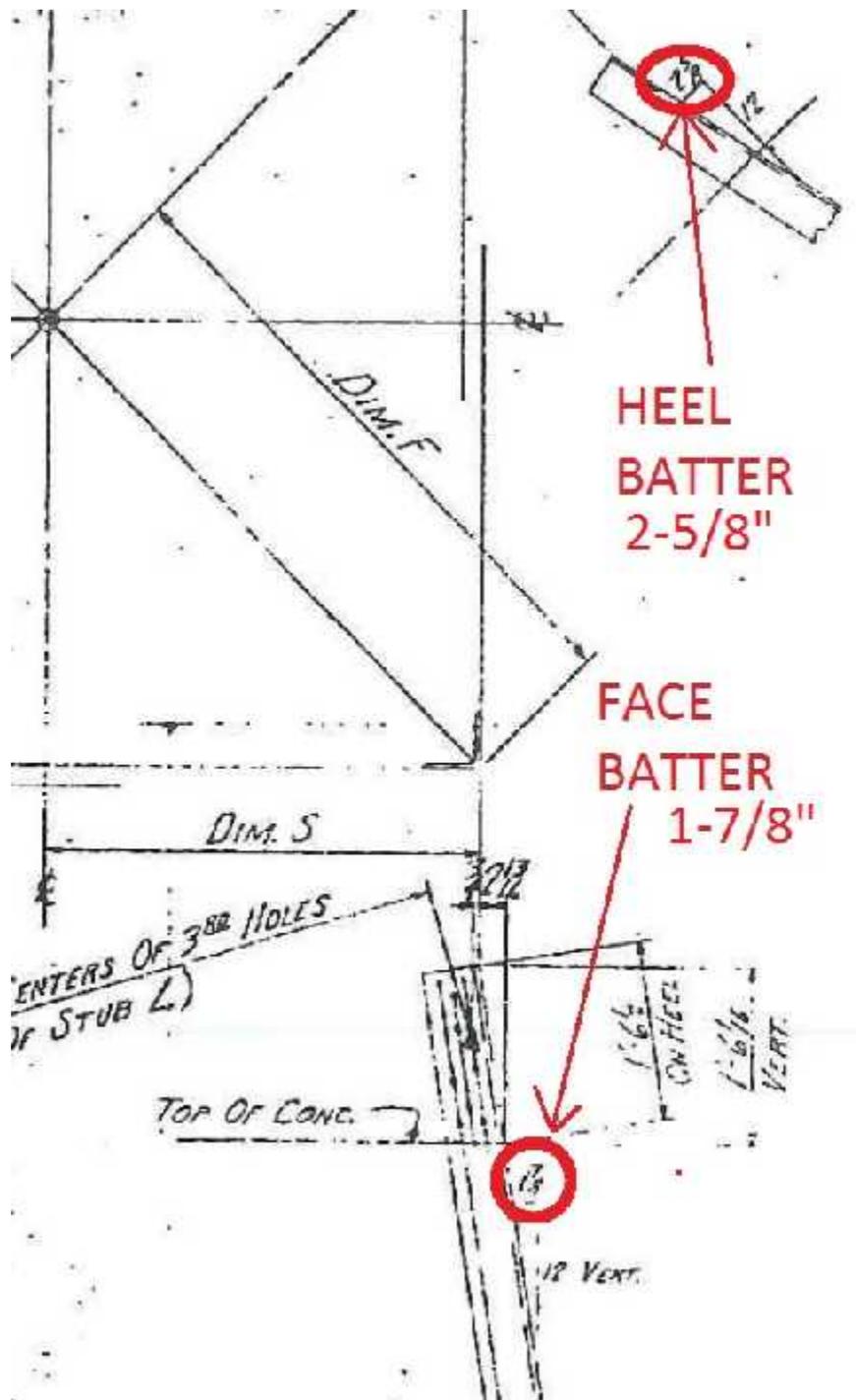


Figure 5 – Heel batter vs. face batter

██████████ made the batter board on a truck located near the project trailer. Using the recorded notes as a reference, he drew the cut lines on a 2-by-4-inch lumber, and used an electrical skill saw to cut the lumber according to the cut lines. After cutting the

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lumber, [REDACTED] used a measuring tape to verify and confirm the dimensions against his recorded notes and proceeded to attach a torpedo level to the batter board using an adhesive tape (see Figure 3).

[REDACTED] presented the finished batter board to [REDACTED], who used a measuring tape to verify the board's dimensions against the ones on Record 621915.

On March 18, 2015, the tower crew used the batter board to angle the auger in preparation for digging the four foundation holes.

On March 19, 2015, [REDACTED] was on vacation; his foreman role was substituted by [REDACTED]. Using the same batter board, the tower crew dug all four foundation holes and angled the foundation stubs. The stubs' height and angles were adjusted through the adjustment knobs on a "ring template" (see Figure 6). The templates were set on the soil through shallow anchors.



Figure 6 – Sample of a template ring holding a foundation stub

The tower crew poured concrete into the holes after the stubs were placed into the desired position. During the concrete pouring process, the crew repeatedly verified the stub angles by using the batter board. The poured concrete was left to cure until April 7,

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2015, when all four ring templates were removed.

On April 7, 2015, [REDACTED] was back to work as the Foreman of the tower crew.

Between April 7 and 8, 2015, the crew installed the 17.5-foot tower body extension. The body extension elements included tower legs, and diagonal, vertical and horizontal “lacing” members. The erection sequence included the following steps [corresponding to the images in Figure 7 below]: (1) loosely bolt four tower legs to the stubs; (2) assemble diagonal lacing members to a gusset plate; (3) connect or “lace” Legs A and B with pre-assembled lacing members; (4) install additional lacing members, followed by a horizontal “stringer” and vertical “strut”.

The lacing sequence (steps 2 – 4) would then be repeated between Legs D and C, Legs B to C, and then Legs D to A to complete all four sides of the tower.

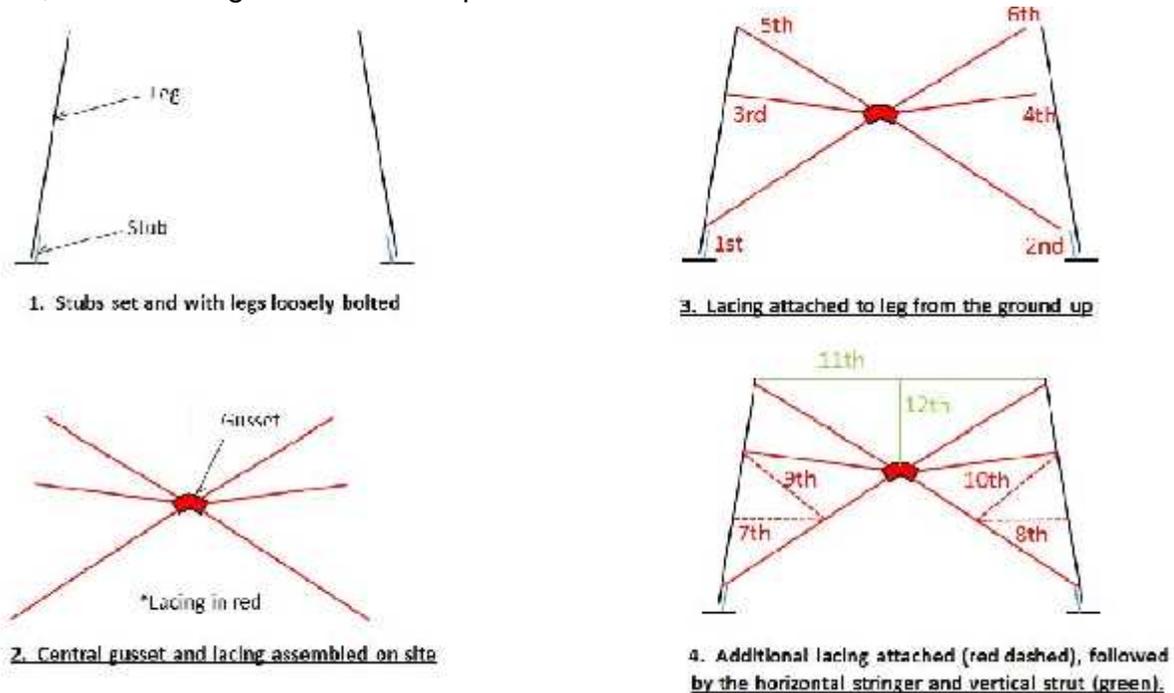


Figure 7 – Tower Body Installation Process

During the tower body installation, [REDACTED] found the pre-assembled lacing members were about one inch off when connecting to the tower legs. The crew was able to bend the tower legs with their arms to fit (or force fit) the pre-assembled lacing members.

While connecting the horizontal stringer between Legs D and A (the last side of the tower to be laced), [REDACTED] saw a gap of two to four inches between the two legs and stringer (see Figure 8 and 9). Due to the significant gap, the crew was not able to

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use their arms to force fit. The crew decided to use a chain hoist (see Figure 10) to pull Legs D and A to close the gap to the stringer.

██████████ believes that a gap under 6 inches was acceptable to be force fit; however, anything over 6 inches would require manager's attention.

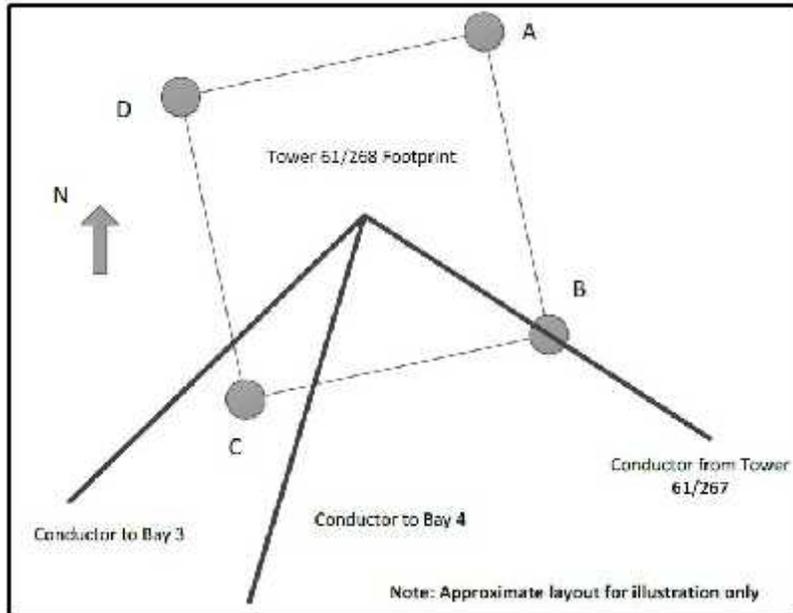


Figure 8 – Tower Legs Identification

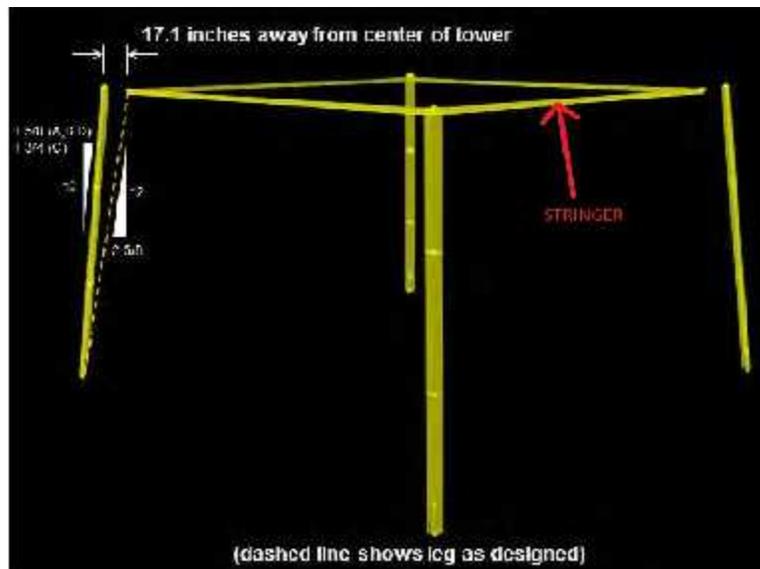


Figure 9 - Stringer

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Figure 10 – Example of a chain Hoist

On September 9, 2015, a PG&E tower crew that consisted of [REDACTED], [REDACTED], [REDACTED], and [REDACTED], visually inspected the tower, including the foundation stubs, before stringing conductors on the tower. They did not find any visible crack on the foundation stubs.

After the tower installation, the batter board was discarded, and on October 11, 2015, PG&E's line crew installed conductors on the tower.

On October 18, 2015 at 0700 hours, a Dynegy employee from the adjacent Moss Landing Power Plant noted Tower 61/128 collapsed and immediately notified PG&E (see Figure 11). PG&E reported the incident to CPUC at 0909 hours. Service to 55,000 customers was affected and restored by 2359 hours on the same day.

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Figure 11 – Collapsed Tower 61/268

Besides the collapsed Tower 61/268, the adjacent Tower 61/267 buckled at its midsection due to longitudinal load imbalance from the collapsed tower (see Figure 12). Following the incident, PG&E inspected Tower 61/267 and determined it was not the source of failure. Tower 61/267 was later repaired and put back in service.



Figure 12 – Buckled Tower 61/267

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On October 20, 2015, SED staff (Staff) visited the incident location and discovered that the collapsed tower was gathered in a pile near the pre-collapsed Tower 61/128 location. The foundation stubs were transported to a lab for failure analysis.

On October 21, 2015, Staff visited the lab where the stubs were being materially analyzed and noticed that Stub D and Stub B had rust on their cracked surface (see Figure 13). This suggests that sometime after the tower was installed, a stress fracture occurred on Stub D and Stub B. This stress fracture could have been caused by the bending moment created when the tower leg was forcefully aligned and bolted onto the foundation stub.

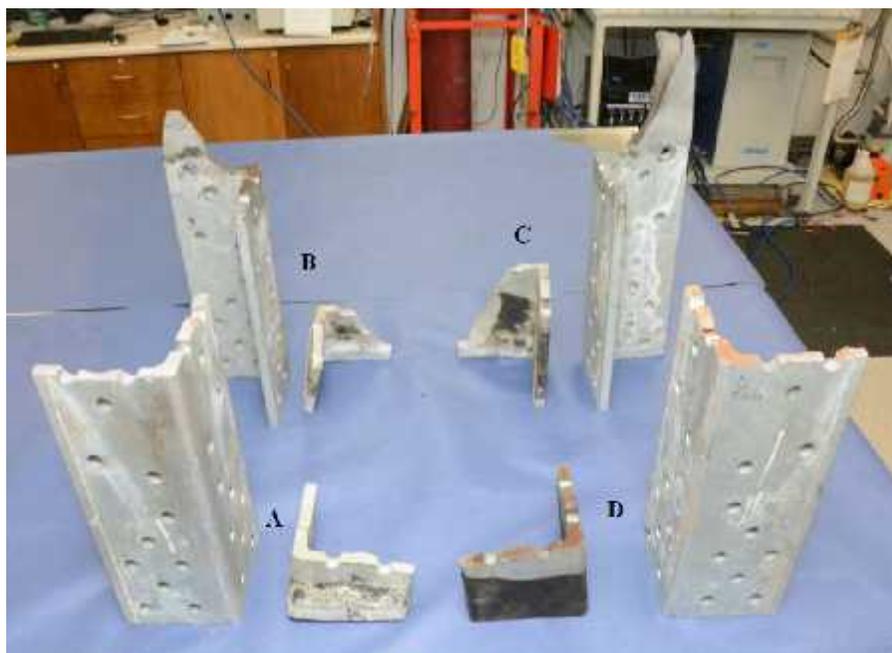


Figure 13 – Stub A through D

Tower 61/128's designed safety factor (without the force fit) was 2.0²; GO 95 requires such towers to be designed with a minimum safety factor of 1.5.

PG&E's first Tower Collapse Direct-Cause Analysis report, dated December 31, 2015, concluded that the tower collapsed due to all four foundation stubs not being aligned properly as indicated in the design plans. The stubs were designed to have a heel batter of 2-5/8 inches by 12-inches, but the as-measured heel batter was 1-5/8 inches by 12

² Tower 61/128's designed minimum safety factor for the foundation was its "drilled pier uplift resistance", which is 2.0; in this case, the tower did not fail under this mode, but failed as a result of excessive bending moment at the stubs' critical sections (along the bottom bolt holes), which caused the actual safety factor to be less than 2.

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inches for Stubs B, C and D, and 1-6/8 inches by 12 inches for Stub A³. Thus, the foundation stubs were misaligned.

As a result of the misaligned stubs, the attached tower legs did not fit well with other components of the 17-5-foot tower body extension during assembly. In order to close the gaps, the PG&E crew connected the tower segments by force fit; in doing so, the tower legs produced bending moments in the stub angles which exceeded their stress limits, eventually cracked, and caused tower to collapse.

On February, 18, 2016, [REDACTED] indicated to Staff that he recalled [REDACTED] instructing [REDACTED] to make a "1-7/8-inch batter board"; instead of "2-5/8-inch"⁴ as prescribed by PG&E's Record 621915.

On March 3, 2016, [REDACTED] indicated to the Staff that although he had no recollection of doing so, he believed that he might have mistaken the face batter with the heel batter on the same drawing, and provided the mistaken dimension to [REDACTED] in making the batter board.

On April 5, 2016, Staff re-visited the incident location and noticed that the collapsed Tower 61/128 was replaced by two tubular steel poles (see Figure 14) at a nearby location.

³ Immediately after the tower collapsed, PG&E chipped away foot concrete around all four stubs so that samples of the stubs could be removed for testing and to expose sufficient stub to measure its location and orientation. PG&E believes Stub A's 1/8-inch heel batter deviation was due to impact of the hammer used to chip the concrete, and did not predate the tower collapse.

⁴ In a follow-up interview with [REDACTED] dated May 9, 2016, Staff questioned how he could recall a specific dimension from nine-months ago. [REDACTED] indicated "1-7/8-inch" stood out for him because that was the only "1-7/8-inch tower" he had done in year 2015. Also, he indicated that batter boards in the one-inch range are usually used on "115 kV jobs", so using one on a 230 kV tower also stood out for him.

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Figure 14 – New tubular steel poles replacement

PG&E's second report, Tower Collapse Root-Cause Analysis dated April 5, 2016, concluded that the tower collapse was initiated by misaligned stubs "due to a human error in determining the drawing heel batter; and the subsequent communication of this incorrect heel batter to the crew for use in setting the stub angles." However, PG&E was not able to identify the specific human error and miscommunication events that have caused the misaligned stubs.

On May 4, 2016, in a data request response, PG&E indicated that the safety factor for the failed foundation stubs was actually 0.62, upon installation of the 230 kV circuits. The actual built safety factor of the foundation stubs did not meet GO 95, Rule 44.1, Table 4's minimum requirement of 1.5 for Grade "A", steel tower construction.

PG&E's addendum to the Tower Collapse Root-Cause Analysis report dated August 17, 2016, stated that a human error was "made at some point during the tower erection process (from construction receiving job package to installation of the stub angles)". Also, there was "most likely a misreading or miscommunication related to the stub angles and that during the construction process, the correct batter angles were not obtained."

In a letter dated September 15, 2016, PG&E indicated that it was not able to determine the specific reason of the misaligned stubs because of the questionable reliability of information being recalled by the tower crew, and the lack of documented evidence to review. PG&E did not have a practice of documenting work performed and capturing as-built dimensions.

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GO 95, Rule 44.1, Installation and Reconstruction, states in part,

Lines and elements of lines, upon installation or reconstruction, shall provide as a minimum the safety factors specified in Table 4.

GO 95, Rule 44.1 requires the minimum safety factor of a steel tower of Grade “A” construction, including its foundation, to be 1.5. PG&E did not construct Tower 61/128’s foundation stubs to meet GO 95’s minimum safety factor. After installation of the 230 kV circuits, the tower foundation stubs had an actual safety factor of 0.62.

Go 95, Rule 31.1, Design, Construction and Maintenance, states in part,

Electrical supply and communication systems shall be designed, constructed, and maintained for their intended use, regard being given to the conditions under which they are to be operated, to enable the furnishing of safe, proper, and adequate service.

Tower 61/268’s foundation stubs should have had a heel batter of 2-5/8 inches by 12-inches, but the as-measured heel batter was 1-5/8 inches by 12-inches, resulting in a significant discrepancy. Therefore, PG&E did not construct its transmission tower foundation safely and adequately.

Preliminary Statement of Pertinent General Order, Public Utilities Code Requirements, and/or Federal Requirements:

<i>General Order</i>	<i>GO Rule</i>	<i>Violation</i>
1 GO95	44.1	Yes
2 GO95	31.1	Yes

Conclusion:

The SED Staff investigation found that PG&E is in violation of GO 95, Rule 31.1, for misaligning the stubs that supported the tower, thus, not constructing the transmission tower safely and adequately. PG&E also violated GO 95, Rule 44.1, for not constructing the transmission tower foundation with a minimum safety factor of 1.5.