Response to Data Request

Response to SED Data Request-63

Prepared for:

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CPUC Legal Division

Purpose:

Blade response to the CPUC Data Request SED 63 related to the Reply Testimony of Mr. L. William Abel on behalf of SoCalGas.

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1 Background

The Legal Division of the California Public Utilities Commission issued a Data Request to Blade Energy Partners (Blade) on April 2, 2020. Data Request No: SED 63 is related the Preliminary Investigation of Southern California Gas Company's Aliso Canyon Storage Facility.

The CPUC questions (from file: "I1906016 SED DR 63 Final.pdf") are included verbatim followed by the Blade responses to the questions.

The passages are from the document titled: Chapter III, Prepared Reply Testimony of L. William Abel on behalf of Southern California Gas Company (U 904 G) (file name: "3_Ch. III - Abel (A Final).pdf").

2 Questions and Responses

2.1 Question 1

1. On page 12, "Blade's modeling simply represents an academic exercise to calculate the kill fluid density and pump rate that theoretically *could have* killed SS-25, and fails to account for several important safety considerations that impacted Boots & Coots' well kill efforts. First, as Boots & Coots explained to SED during SED's August 2018 examination, the first step upon arriving at a well control event is to secure the area and ensure the safety of personnel. [Footnote omitted.]. Indeed, as discussed in SoCalGas' opening testimony, safety is a paramount consideration in any well control operation, and the response to the SS-25 leak was no different—extensive measures were implemented to mitigate the risk of ignition. [Footnote omitted]. Second, in designing a well kill plan, a well control company must take extreme caution not to implement a well kill operation that may worsen the leak, and thereby increase the risk of ignition, or jeopardize the success of subsequent kill attempts. Boots & Coots appropriately considered these factors, and made adjustments to its kill operations accordingly." With this passage on mind, please answer:

2.1.1 Questions and Blade Responses

a. Does Blade agree that, "Blade's modeling simply represents an academic exercise to calculate the kill fluid density and pump rate that theoretically could have killed SS-25?"

No.

b. If Blade disagrees with this statement, please state the reasons for disagreeing.

Blade's efforts to model the kill operations were not an academic exercise—it was specifically to ascertain why the top kill well-control efforts were unsuccessful and why it took 111 days to stop the gas from the Aliso Canyon gas storage reservoir from escaping to the atmosphere. As discussed in the Blade Report [1] (page 229), Blade conducted a transient kill simulation study to evaluate the likelihood of success of the actual kill attempts. Blade intentionally used the same field data that were available to the onsite well control personnel during the time of well kill operations for this evaluation. According to Blade's modeling, all the SS-25 kill attempts were predicted to be unsuccessful.

It is not clear to Blade how Boots and Coots selected the pump rates and kill fluid densities for each kill attempt. The kill fluid densities did not change materially until kill attempt #7.

c. Does Blade take the position that its modeling would have successfully killed well SS-25?

Because of the modeling and kill attempt operational uncertainties, no one can guarantee a successful well kill strictly based on modeling results. Modeling to determine a plan for the pumping operations is the first important component of a well kill plan. The modeling uses available data and reasonable engineering assumptions for unknown data. In fact, the advantage of modeling is that it allows for evaluation of uncertainties in the data and assumptions. The second component of a kill operation is to carry out the pumping operations according to the plan developed through modeling. If the modeling results are flawed, or if the pumping operation does not go as planned, a well kill attempt will likely be unsuccessful.

Blade takes the position that kill modeling is necessary to properly plan a kill operation where early success in killing the well is of high importance. Such modeling could include transient kill modeling or other analytical approaches that take into account pressure, kill fluid properties, flow rates and restrictions in the flow path. There was no evidence provided to Blade that kill modeling or other analytical approaches were undertaken for kill attempts #1 through #6.

Furthermore, Blade contends that by the time of kill attempt #2, the complexity of the kill operation should have been well understood. Twenty days were available to gather data on the well conditions during the time interval between kill attempts #1 and #2. Diagnostic logs were run in the well showing temperature anomalies and possible leak depths. By then it was clear that there was a leak in the 7 in. casing at some shallow depth; and this was documented in the daily reports. This time period was adequate to conduct kill modeling. Gas was flowing from the reservoir up through the 7 in. casing × 2 7/8 in. tubing annulus and then outside of the 7 in. casing. The gas was escaping into the surrounding formation and some was migrating to the surface. This was not a standard top kill operation based on the available data.

The following are examples of data and assumptions that could have been made regarding the leak severity, leak depth, and flow path:

- The SoCalGas SS-25 daily report for October 24, 2015 [2] stated “At this time, It [sic] appears that we had a wellhead seal leak and/or a very shallow 7” production casing leak.”
- The temperature log run on November 8, 2015 [3], showed cooling anomalies at 365 ft and 890 ft indicating the possible depths of gas expansion and cooling associated with a leak.
- The Boots & Coots daily report on November 13, 2015 (Add Energy Report [4], page 89, AC_BLD_0031392), stating that after pumping junk shots down the 2 7/8 in. × 7 in. annulus, brine was observed after 5 bbl were pumped.
- Both Add Energy [4] (page 9, AC_BLD_0031312) and Blade [5] (page 51) estimated the SS-25 gas flow rate using data that was available at the time of the leak. Add Energy stated on page 7, “This estimated flow rate is not dependent of the flow path from the bottom of the tubing to surface, but only calculated based on pressures and the inflow performance relation (IPR) estimated from well tests.”

A kill design is based on the well parameters such as geometry, flow path restrictions, and gas flow rate as well as the kill parameters including kill fluid density, pump rate, fluid volume, and surface pump pressure. Kill modeling is an effective way of accounting for these variables and their uncertainties and then screening well kill plans to determine which plans may be successful and which are likely to be unsuccessful thereby maximizing the chances of success. Kill modeling is safer, more efficient, and less risky than pumping multiple unsuccessful kill attempts. The risk of unsuccessful kill attempts includes damage to the site and the well’s surface equipment that can limit additional kill attempts. The modeling allows learnings from each kill attempt to be incorporated into the next one. The seven unsuccessful kill attempts at SS-25 resulted in a large and deep crater around the wellhead and conductor casing creating a hazardous condition and required waiting for the relief well to stop the gas flow from SS-25 to the atmosphere.

Question 1 includes a comment on safety considerations and the following statement:

> Second, in designing a well kill plan, a well control company must take extreme caution not to implement a well kill operation that may worsen the leak, and thereby increase the risk of ignition, or jeopardize the success of subsequent kill attempts.

Blade agrees with this statement. This is exactly why kill modeling is a necessary component of designing a successful well kill plan. However, evidence indicates that this did not happen at SS-25. The use of higher density fluids, as predicted by the kill modeling, would not have compromised safety during the kill attempts. Specifically, kill attempt #2 resulted in the formation of the crater around the wellhead and conductor. Similarly designed, unsuccessful kill attempts continued after kill attempt #2. During kill attempt #6, the flow line from the 7 in. casing and tubing head broke, monitoring devices were damaged, and the pump line to the casing head broke. The pump line tee broke off because of wellhead movement and the 11 3/4 in. × 7 in. annulus valve backed out during kill attempt #7 allowing the annulus to vent gas at surface and enlarge the crater. The additional kill attempts continued even when the well and surface conditions had deteriorated from after kill attempt #2.

Blade was provided with what appear to be some graphical results of modeling for kill attempt #7, the final SS-25 top kill attempt on December 22, 2015 [6] [7]. Kill modelling was not mentioned in the August 8, 2018, Examination Under Oath of Mr. Danny Walzel and Mr. James Kopecky [8] (pages SED 00635 – SED 00786). It is clearly stated in this document that Boot & Coots did not calculate the well flow rate which is a key variable needed for developing a kill plan (pages SED 00736 – SED 00737).

It appears from data provided to Blade that kill modeling was performed in preparation for kill attempt #7, unlike the lack of any modeling prior to the previous six kill attempts. But by this time the surface conditions had deteriorated from previous attempts and wellhead movement and safety concerns prevented the kill fluids from being pumped according the plan. Kill attempt #7 appeared to come close to killing the well, but it was terminated because of undesirable movement of the wellhead and pump lines that broke during the job. It is important to note that the kill attempt #7 fluid densities were similar to the results from the Blade transient kill models for the previous kill attempts.

d. If so, what is the factual basis for such a position?

   As discussed in Question 1 c, modeling by itself cannot ensure a successful well kill.

e. Were the adjustments to kill operations that Mr. Abel mentions disclosed to Blade during its Root Cause Analysis?

   Blade had access to historical kill data including:

   - Some pre-job procedures
   - SoCalGas daily operations reports
   - Boots & Coots daily operations reports
   - Halliburton post-job reports
   - DOGGR daily operations summary reports

   However, the rationale and the factors considered in designing the kill attempts were not made available to Blade.

   The subject of kill modeling was raised many times with SoCalGas during the RCA. Multiple data requests were sent to SoCalGas regarding the kill attempts, rationale behind the kill attempts, and associated kill data. Consequently, Blade requested a discussion meeting and suggested the Boots & Coots personnel who were onsite and were associated with planning and executing the kill attempts join the discussion meeting [9]. Such a meeting never occurred.

f. If so, did Blade consider whether Boots & Coots appropriately considered all factors and made correct adjustments to its kill operations?

As discussed in the response to Question 1 e, the rationale for the well kill adjustments were not disclosed to Blade.

Although requested, Blade did not have direct access to the Boots & Coots personnel to determine if Boots & Coots appropriately considered all factors and made correct adjustments to its kill operations. Our review of the Boots & Coots well kill plans for attempts #2 – 6 did not document the rationale for the kill attempts. The 2018 Boots & Coots Examination Under Oath [8] did not have the details required to ascertain whether Boots & Coots considered all factors.

In Blade's view, kill attempt #7 had significant adjustments to the kill plan from previous kill attempts, and it was similar to the results of the Blade modeling.

g. Provide any documents and necessary additional context to support the answers provided.

Two documents were provided by SoCalGas to Blade that appear to be graphical results of kill modeling. These graphs appear to be generated within Schlumberger's *Drillbench* software. This is industry standard well control modeling software and the same software that Blade used in its kill analysis. Images of the documents are included in Figure 1 and Figure 2.

Figure 2 shows an AOF (absolute open flow) of 25 MMscf7/D and a gas flow rate of 15 MMscf/D. Blade estimated the well was flowing approximately 57 MMscf/D on December 22, 2015, [5] *SS-25 Well Nodal-Analysis with Uncontrolled Leak Estimation*, page 51. The final kill attempt #7 was pumped on December 22, 2015.

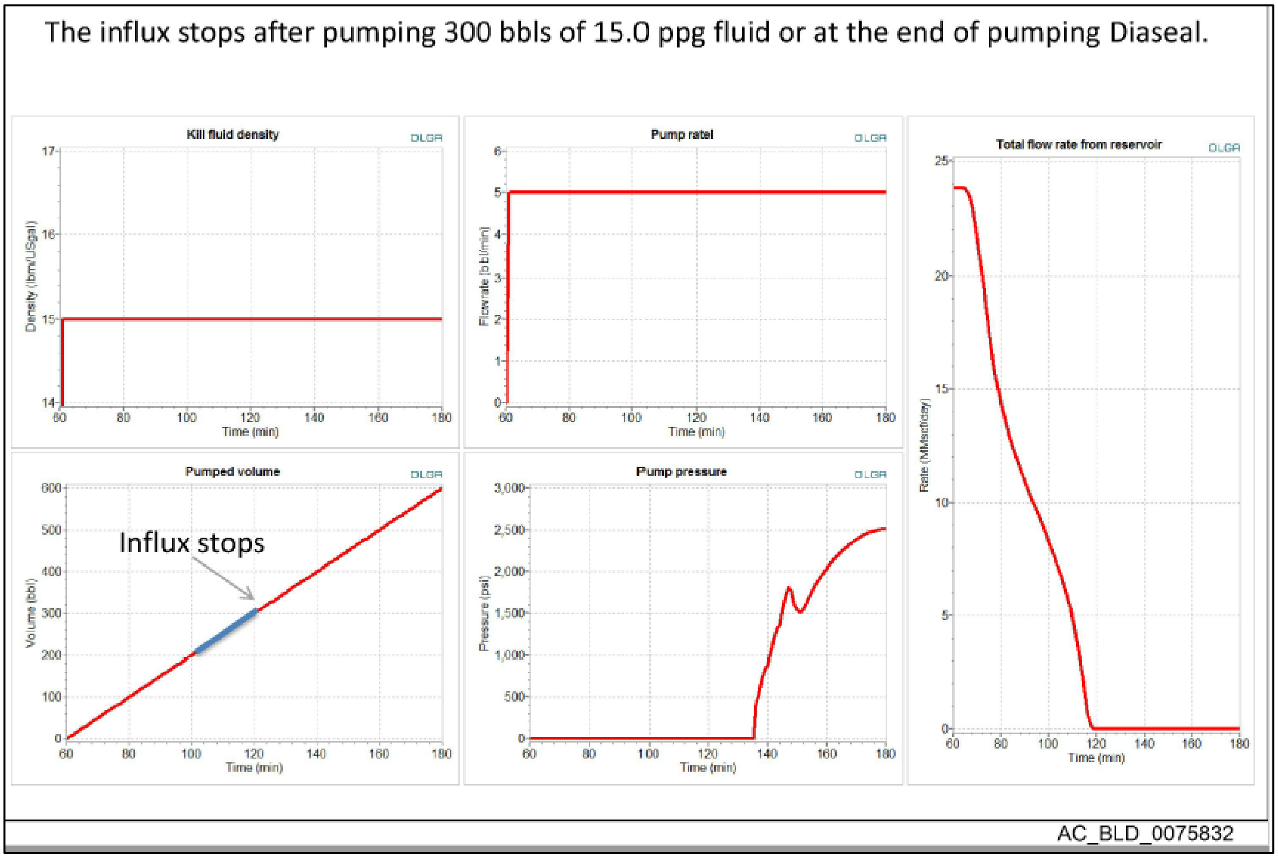

Figure 1: Kill Modeling Graphical Results

Snapshot of pumping 15.0 ppg WBM at the rate of 3 bpm

Basis of simulation:		Results:	
Reservoir pressure:	2,200 psi	Gas flow rate:	15 MMscfd
AOF:	25 MMscfd	Max pump pressure:	1,450 psi
SITP:	1,400 psi	Kill fluid volume:	65 bbls
Depth of exit point:	450 ft MD	Fracture occurs:	105 bbls
Restriction at exit point:	Yes	Top of fluid level in the annulus:	5,500 ft MD
Kill fluid density:	15.0 ppg		
Kill fluid viscosity:	25 cP		

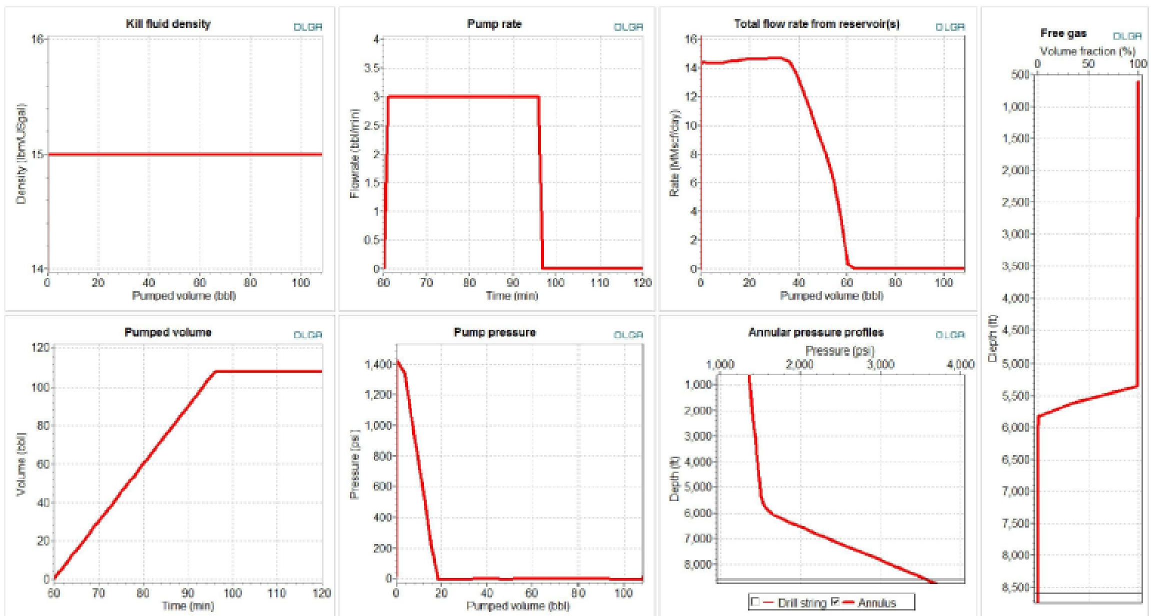

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Figure 2: Kill Modeling Graphical Results

2.2 Question 2

2. Please refer to the following passage on page 12 of Mr. Abel's testimony: Mr. Walzel testified that while the SS-25 wellhead equipment was rated to 5,000 PSI, given the unknown condition of the leak, Boots & Coots set a "safety limit" or "safety factor" well below the working pressure of the equipment. [Footnote omitted]. I believe that it was prudent for Boots & Coots to have set a safety factor so as not to risk damaging the wellhead." With this passage in mind, please answer:

2.2.1 Questions and Blade Responses

a. Does Blade's modeling consider risk to damaging the wellhead?

Yes. Blade considered the wellhead rated working pressure of 5,000 psi. The Blade kill simulations for all of the kill attempts resulted in a maximum predicted pump pressure of 3,644 psi for kill attempt #2 with decreasing maximum pump pressure for subsequent kill attempts because the reservoir pressure was declining with time. The maximum predicted pump pressure of 3,644 psi is below the "safety limit" set by Boots and Coots of 4,000 psi. The field was on withdrawal during the kill attempts so the reservoir pressure was dropping.

b. What is Blade's view as to whether this alleged "safety factor" below the working pressure of the equipment was prudent so as not to risk damaging the wellhead?

Blade agrees that it is prudent to use a safety factor to avoid damage to the wellhead and surface equipment. Blade's simulations showed that the wellhead pressures would not have exceeded 3,644 psi with the higher fluid densities. The model results honored the wellhead safety factor.

c. In Blade's view, given what could have been known about the condition of well SS-25 and other related factors by Boots & Coots at the time of its well kill attempts, could Boots & Coots have known whether the pump rate and fluid density it used was inadequate to kill well SS-25?

Yes, well kill modeling would have demonstrated that the pump rate and fluid density were inadequate to kill well SS-25.

Data were available on October 23, 2015, October 24, 2015 (when the first kill attempt was pumped), and November 8, 2015 (when a temperature, pressure, and spinner survey was run). These data could have been used for kill modeling to determine whether the planned kill attempt was likely to kill the well. A summary of the data available includes the following:

- October 23, 2015: The wellbore geometry was known, i.e., casing internal diameter, tubing outside and inside diameter, packer depth, ported mandrel with slots depth, perforations depth, etc. It could have been assumed that the flow path was from the perforations, up the casing, through the tubing to the ported mandrel slots, exit the slots, up the 7 in. casing × 2 7/8 in. tubing annulus until the flow exited the 7 in. casing leak into the surface casing × production casing annulus. The tubing was shut in at surface diverting the flow up the annulus. The gas at surface during kill attempt #1 indicated the leak was shallow enough to broach to surface. The flowing casing pressure of approximately 270 psi on October 23, 2015, gave information on the back pressure the leak was flowing against without needing to know the exact flow path of the gas to surface.
- October 23, 2015: The reservoir pressure was available from the pressure monitoring well SS-5 and the historical SS-25 well test data were available. As described in the Blade Report [1] pages 127 – 134, the well test data could have been used to determine the well deliverability based on the bottom hole pressure (BHP) to estimate the gas flow rate. The flow rate decreased with time because the field was being produced to reduce the BHP.
- October 23, 2015: While the size of the hole in the casing was unknown, the area of the casing × tubing annulus cross section could have been used as the size of the hole in the casing as a worst case (which in fact turned out to be correct because the 7 in. casing was parted).
- October 24, 2015: Kill attempt #1 reported gas at surface after pumping 89 bbl of fluid down the casing. This indicated a shallow leak as documented in the SoCalGas SS-25 daily report for October 24, 2015 [2] "At this time, It appears that we had a wellhead seal leak and/or a very shallow 7" production casing leak."
- November 8, 2015: A production log survey [3] (temperature, pressure, and spinner) was run and it showed cooling anomalies at approximately 365 ft and at 890 ft. Assumptions for modeling could have used these two depths as possible leak depths. The analysis from the temperature survey was dated November 12, 2015. As it turned out the leak was at 892 ft, the lower temperature anomaly depth. Blade modeled a leak at 440 ft and determined the

parameters to kill the well at a 440 ft leak were approximately the same as a leak at 892 ft [10] SS-25 Transient Well Kill Analysis, page 35.

- November 13, 2015: Junk shots were pumped during kill attempt #2. After 5 bbl of brine was pumped down the annulus, brine was observed from the fissures (Add Energy Report [4], page 89).

Blade believes that kill modeling using the well data described in Question 2 c. would have shown that the reported fluids pumped (volume, density, and rate) during kill attempts #2 through 6 would not have killed the well. A summary of the Blade analysis of the actual kill attempts are included in a supplementary report [10] *SS-25 Transient Well Kill Analysis*, page 20.

2.3 Question 3

3. Please refer to the following passage on page 13 of Mr. Abel's testimony, "Further, Boots & Coots' pumping operations were implemented not only in consideration of the pressure rating of the surface equipment, but also based on observation of the wellhead's physical response to pumping operations. Mr. Walzel described that during certain pumping operations, the SS-25 wellhead was "moving around a lot," which at times caused Boots & Coots to slow or stop pumping operations an [sic], in one case, broke the flow lines on the 7 inch tubing and casing, and the nipple on the wellhead. [Footnote omitted] While it does not appear that Blade's modeling accounted for these safety considerations, Boots & Coots appropriately tailored its kill operations—in real-time—to limit the potential risk of further damaging the well and compromising safety."

2.3.1 Questions and Blade Responses

a. Does Blade agree that Blade's modeling did not account for the considerations such as those identified above?

Blade's modeling assumed the fluids would be pumped at the rates, volumes, and density that would kill the well according to the kill modeling. It should be noted that any interruption in the planned pumping schedule such as slowing or stopping pumping will likely result in an unsuccessful kill attempt. Modeling results are the basis of pre-job planning. Safety considerations encountered during the kill attempts may interrupt and abort an attempt. However, the usage of heavier fluids, planned using the modeling results, may have reduced the well head movement.

Although requested, Blade did not have direct access to the Boots & Coots personnel to determine what Boots & Coots had considered and the rationale for kill operations. The 2018 Boots & Coots Examination Under Oath [8] did not have the details required to ascertain whether Boots & Coots considered all factors.

b. If not, did SoCalGas provide Blade with this information when Blade was doing its Root Cause Analysis?

Information that Boots & Coots appropriately tailored its kill operations—in real-time—to limit the potential risk of further damaging the well and compromising safety was not provided to Blade. As discussed in Question 1 e., Blade requested data regarding kill planning, modeling, and operations many times, but such data were not provided.

Safety considerations always take precedence when carrying out the field operations. The planning of a kill operation includes the modeling results to know how to plan the equipment, the personnel, the physical layout, and the fluids for the field operations. Safety considerations are normally discussed at the pre-job meeting in the field. While the pumping is underway, changes in the plan can occur if things are not going according the plan or if there is a reason to change the operation because of a safety consideration. Events like wellhead movement and broken lines are reasons why the pumping plan could change.

It also needs to be pointed out that the modeling is based on an assumed pump rate and fluid density to maintain a bottom hole pressure because of fluid friction and, if the pump rate is reduced or stopped, the loss of friction pressure may allow the well to start flowing again. If this happens, the kill attempt is likely to be unsuccessful. The well, surface equipment, and pumping equipment need to be in a condition that allows the pumping operation to continue without interruption to have a chance of a successful kill. A review of data from kill attempts #2 through 6 reported no indications that safety issues would have compromised the ability to kill the well with heavier fluids at the pump rates resulting from the Blade modeling.

This shows the importance of using kill modeling, which considers the normal variables and accounts for other limitations, to provide results that maximize the chances of success to kill the well on the first attempt. The well and surface conditions are usually going to be the best for the earlier kill attempts.

c. If not, did Blade provide SoCalGas with the opportunity to provide Blade with this information when Blade was doing its Root Cause Analysis?

Blade made multiple data requests for data related to kill operations and kill modeling in addition to a request for a face-to-face meeting with the Boots & Coots personnel with first-hand knowledge of the SS-25 kill operations. A meeting with Blade and Boots & Coots could not be arranged. This was discussed in Question 1 e.

d. Provide any context necessary in support of these answers.

Blade data requests to SoCalGas related to killing the SS-25 well includes the following:

- Data Request February 11, 2016 [11]
- Data Request May 4, 2016 [12]
- Data Request June 29, 2018 [13]
- Data Request August 29, 2018 [14]
- Data Request October 26, 2018 [15]
- Data Request December 19, 2018 [9]
- Data Request January 2, 2019 [16]

2.4 Question 4

4. Please refer to the following passage on page 13 of Mr. Abel's testimony: "Second, Blade had the benefit of gathering more precise data points that were not available to Boots & Coots while planning, modeling, and executing its well kill attempts: 1) the precise depth and severity of damage to the production casing, and 2) the flow path of the gas from the 7" casing leak to the surface. Indeed, computer modeling is sensitive to the well geometry (i.e., leak depth, severity, and flow path), which means that more precise information will produce more accurate modeling outputs. However, precise flow path geometry is typically unavailable during an active leak response. . .While Blade was able to determine that the production casing had completely parted 892 feet after extracting and examining the

7” casing, Boots & Coots could only estimate the flow path geometry based on real-time observation and analysis of pumping operations. Second, after extracting the 7” casing, Blade had the advantage of using a video camera to analyze the 11-3/4” casing an observe holes—which Blade determined were the “likely consequence of the axial rupture” of the 7” casing. [Footnote omitted.]. The existence of holes in the surface casing is significant because it impacts the flow path of the leak and, in turn, the accuracy of the transient modeling. Accordingly, while Blade was able to extract the 7” casing to gather additional data to incorporate into its modeling, Boots & Coots could not have done the same. The practical impact of this disparity in information is that Blade’s modeling was refined by additional data points that were not available to Boots & Coots.” With this passage in mind, please answer.

2.4.1 Questions and Blade Responses

a. Does Blade agree that each of the points raised in this passage were available to Blade, but Boots & Coots could not have gathered such information at the time it was attempting the well kills of SS-25?

    No.

b. If not, which data points does Blade view that Boots & Coots could have attained?

    Assumptions regarding the leak path and leak depth were made within a few days of the leak event on October 23, 2015, and likely within hours because a wellbore schematic (WBS) with well details information was needed for kill planning. Examples of the evolution of wellbore schematics prepared post October 23, 2015, include wellbore schematics from SoCalGas, a Boots & Coots WBS from a December 16, 2015, presentation, a WBS from an Add Energy Report released in February, 2016, (work done prior to February), and a Blade WBS with final data. Log surveys run on November 8, 2015, were also available that indicated possible leak depths. A review of these documents shows there were no material changes to the leak path and there would be no impact on modeling results. Refer to Figure 3 through Figure 8.

    Precise data of the leak location and leak path were not needed for transient kill modeling.

Figure 3 shows a rough sketch of SS-25 with an indication of the leak flow path to surface [17] (page 79, AC_CPUC_0000101). Figure 4 shows more details of the suspected gas flow path. The sketches indicate a leak in the 7 in. production casing with the leak path outside the 11 3/4 in. casing to surface [18].

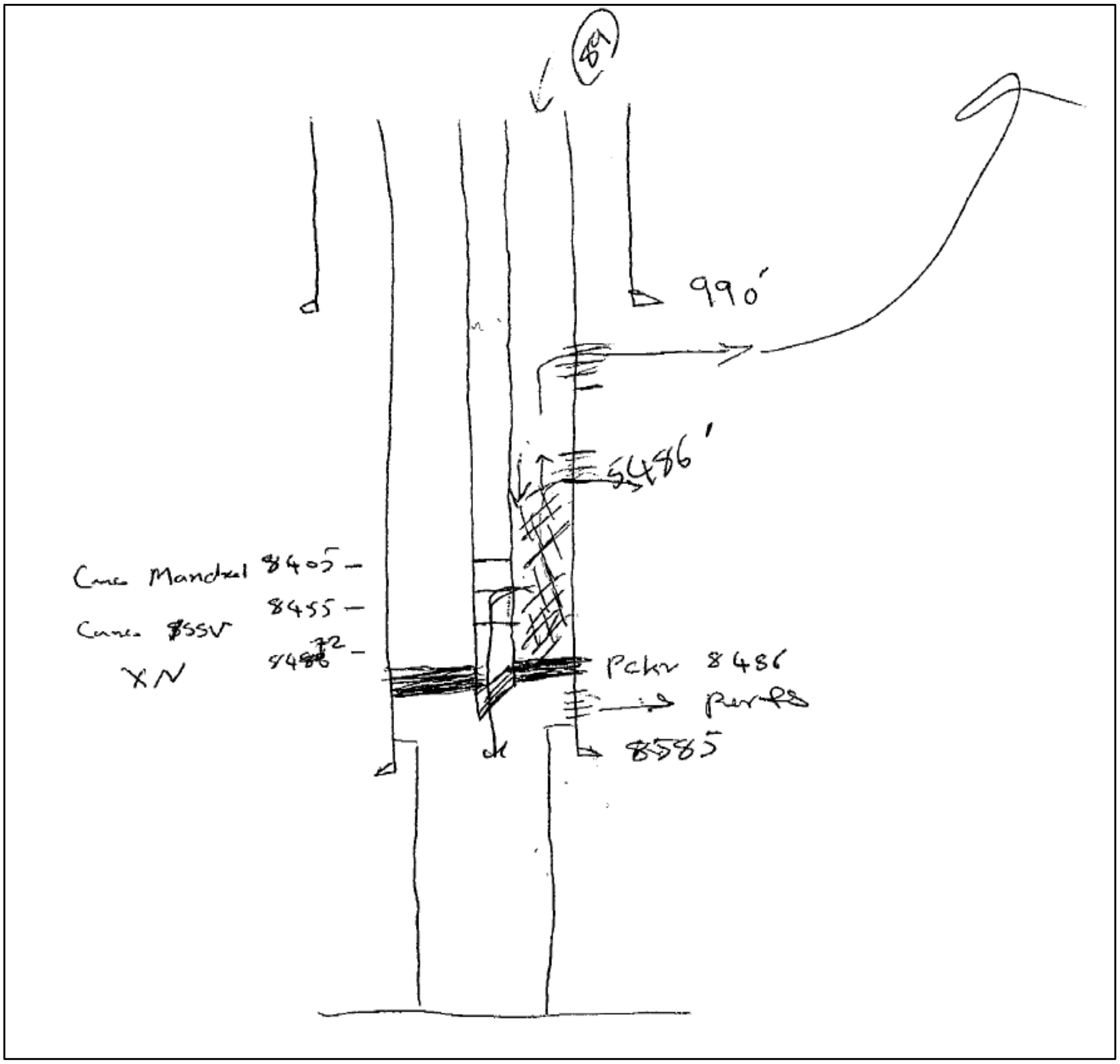

Figure 3: SoCalGas Wellbore Schematic of SS-25 (circa October 24, 2015)

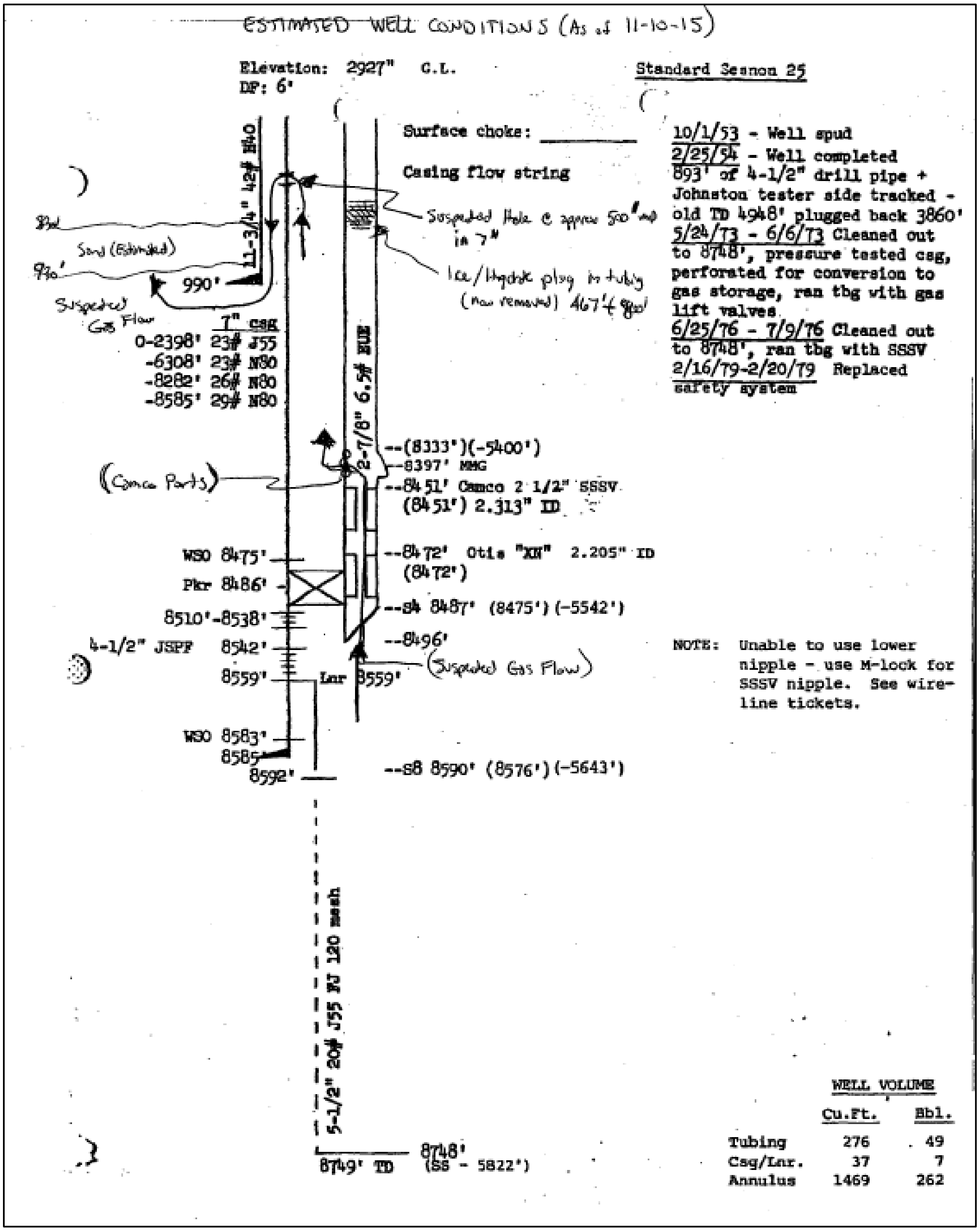

Figure 4: SoCalGas Wellbore Schematic of SS-25 (November 10, 2015)

On November 8, 2015, a production log including temperature, pressure, and spinner surveys was run [3]. It showed temperature anomalies with comments and a possible leak depth at 890 ft near the 11 3/4 in. shoe depth (Figure 5). The leak depth turned out to be correct and was confirmed when the casing was recovered.

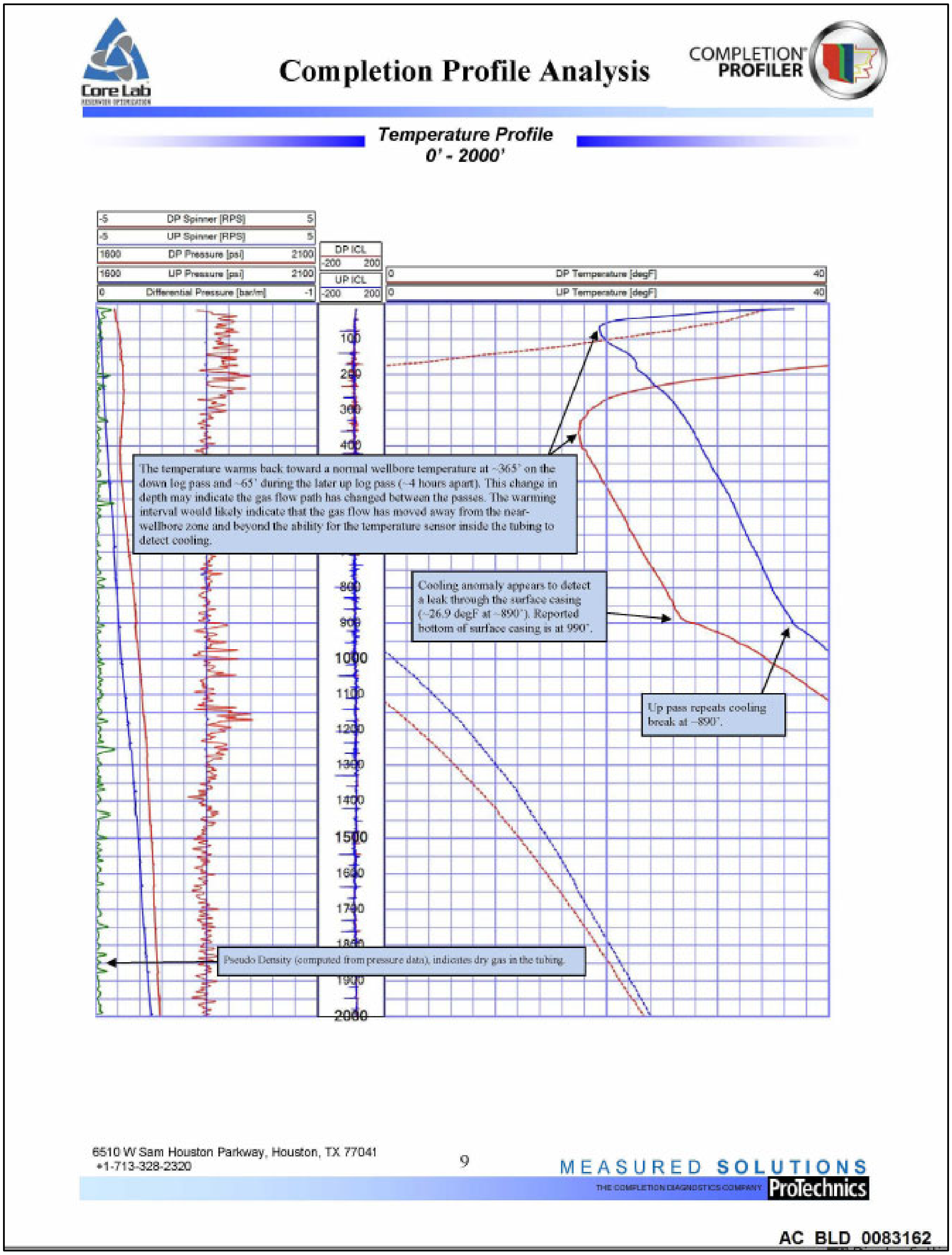

Figure 5: Temperature Profile (November 8, 2015)

Figure 7 shows the Boots & Coots version of the WBS with gas flow paths from a presentation dated December 16, 2015 [19].

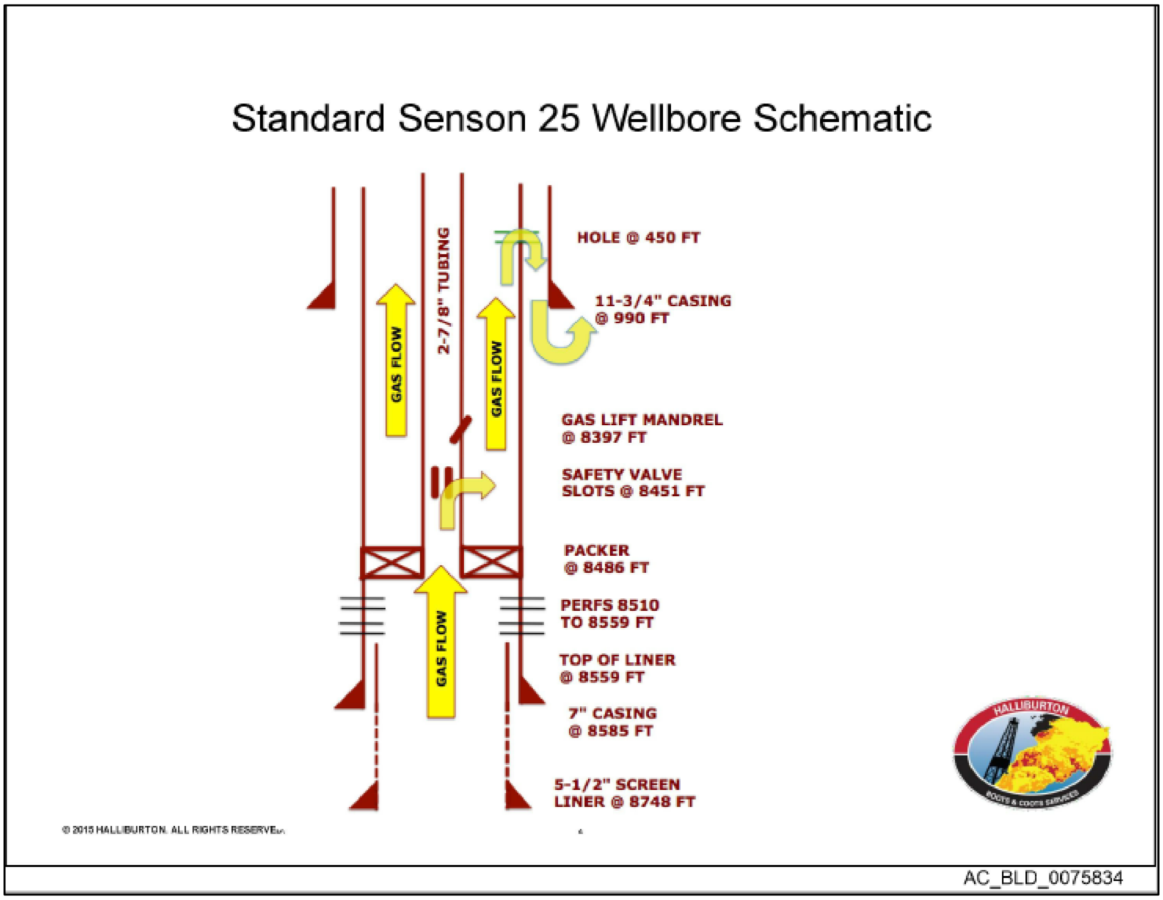

Figure 6: Boots & Coots Wellbore Schematic (December 16, 2015)

Figure 7 shows the WBS from the Add Energy Report released in February 2016 [4] (page 34, AC_BLD_0031337). The gas flow paths are indicated by the red arrows. A leak depth at 440 ft was estimated by Add Energy.

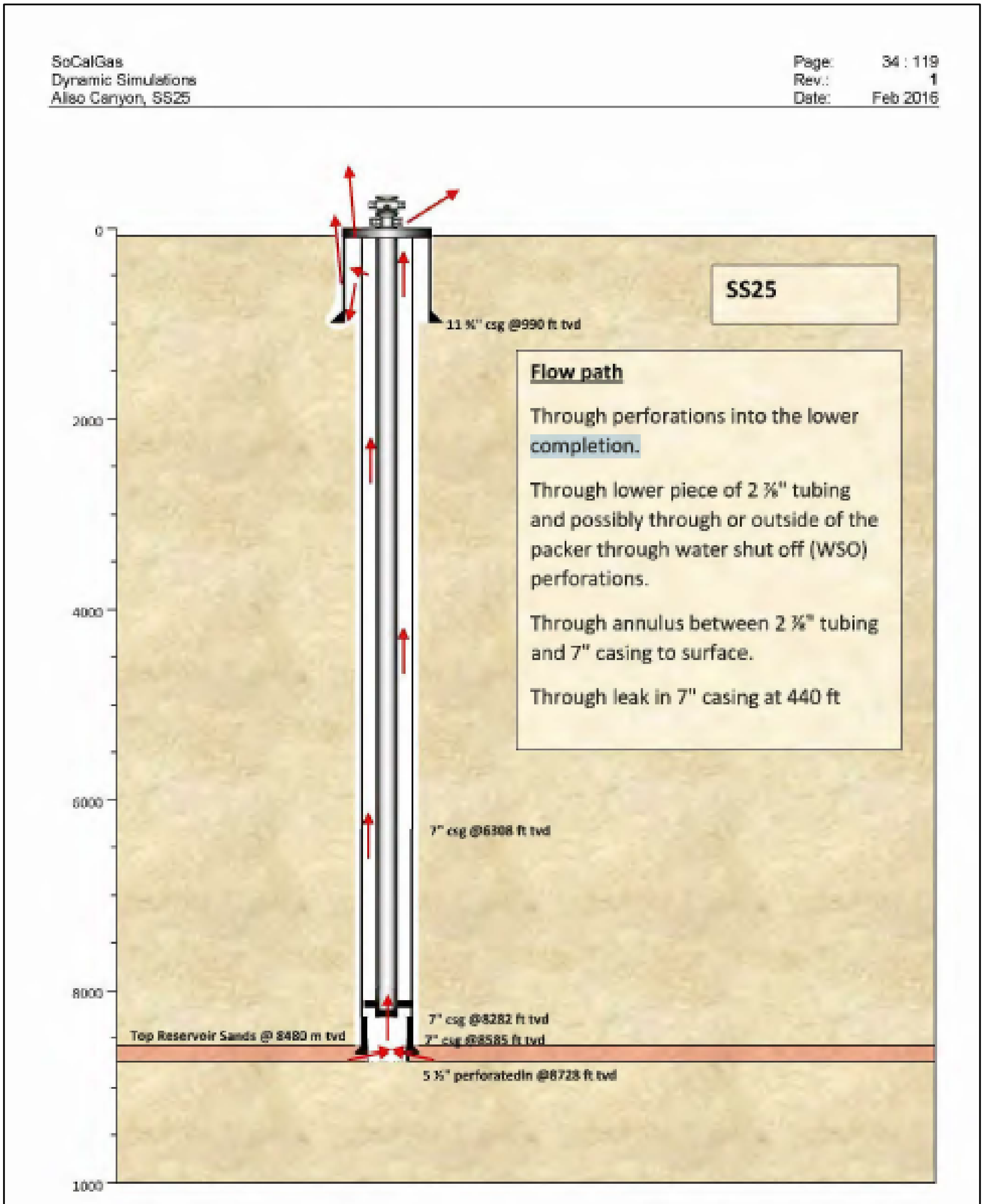

Figure 3.3: Schematic of potential flow path in annulus between 7" csg and 2 ⅞" tbg

Figure 7: Add Energy Wellbore Schematic

Figure 8 shows the WBS for SS-25 prepared by Blade with the parted 7 in. casing at 892 ft.

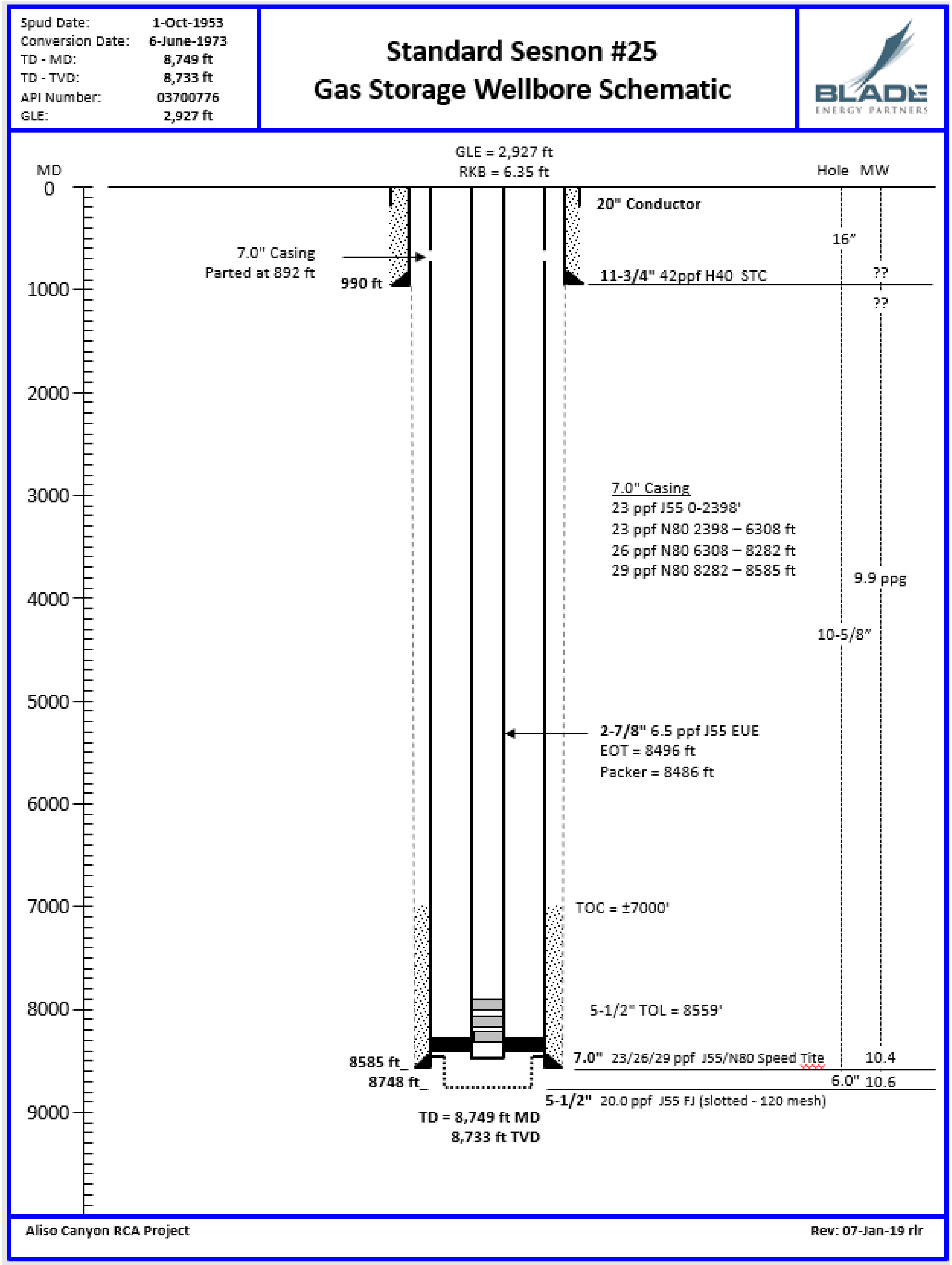

Figure 8: Blade Wellbore Schematic

An estimate of the depth of the leak was available from the temperature survey run on November 8, 2015 [3]. The survey showed temperature anomalies at 890 ft and 365 ft (Figure 5). Blade modeling shows flow from either depth resulted in no change in the pump rate and fluid density required to kill the well [10] *SS-25 Transient Well Kill Analysis*, page 35. The severity of the leak could have been assumed as the cross-sectional area of the casing × tubing annulus which turned out to be correct with parted 7 in. casing. The flow path pressure restriction from the leak to surface was inferred by Blade based on the 7 in. casing surface flowing pressure of approximately 270 psi on October 23, 2015. The 7 in. casing flowing pressure takes into account the restrictions in the flow path to surface and the holes in the surface casing were not relevant.

The holes in the 11 3/4 in. casing were discovered in August 2018 after the 7 in. casing was extracted. The majority of the Blade kill modeling was done in 2016, some two years before the holes were discovered. The Blade kill modeling has never considered the holes in the 11 3/4 in. casing directly. The effect of the holes on the flow and pressure from the leak depth to surface is accounted for in the flowing casing pressure. The flowing casing pressure was known at the time of the event on October 23, 2015. Knowing the existence of the 11 3/4 in. holes was not relevant and was immaterial for the modeling.

The Add Energy Report [4] in 2016, had correctly predicted the flow path, ". . . the pressure in the outer annulus reached the fracture pressure of the 11 3/4" casing shoe with the consequence that flow paths were created outside of this casing to surface." (Add Energy Report page 9, AC_BLD_0031312) In the absence of any additional data, Add Energy had a near correct interpretation of the leak path, leak rates, and even the complexities of the hydrates forming. The Add Energy Report includes a discussion of potential flow paths (page 32, AC_BLD_0031335) where a possible shallow hole in the 11 3/4 in. casing is mentioned two times. Add Energy didn't have any of the benefits that Blade had with the actual physical failure, subsequent inspection and temperature logging data, nor any downhole video camera data. Notably, Add Energy estimated a flow rate 80 MMSCF/d at the time of the first kill attempt; they stated the methodology as, "(This estimated flow rate is not dependent of the flow path from the bottom of the tubing to surface, but only calculated based on pressures and the inflow performance relation (IPR) estimated from well tests)." (Add Energy Report page 7, AC_BLD_0031310). Add Energy's findings were not groundbreaking academic research but were an obvious extensions of industry standard modeling. Further, the Add Energy Report also assumed a shallow 7 in. casing leak location.

The knowledge of the exact 7 in. casing leak location and the presence of 11 3/4 in. holes does not impact the modeling. All of the required data was available during the kill attempts to conduct such modeling.

c. If Blade lists an answer to question 4b, explain why Boots & Coots could have attained these data points.

   A key parameter required for kill modeling with realistic results, not mentioned in the passage, is the SS-25 gas flow rate. The gas flow rate, and the other data mentioned in Question 4 b. were available with reasonable certainty to conduct kill modeling. The data needed for modeling, including the estimate of the gas flow rate, a key parameter for kill modeling, are discussed in detail in response to Question 2 c.

d. In Blade's view, with the data that Boots & Coots had at the time it was attempting to kill well SS-25, could Boots & Coots successfully have killed well SS-25?

   Yes, assuming that available data and reasonable assumptions had been used for the kill modeling (and assuming that the pumping was carried out according to plan developed through modeling), Boots & Coots could likely have killed SS-25. By "reasonable" we mean that assumptions were made based on engineering analysis, experience, and judgment. In addition, uncertainties in the input data should have been evaluated using the modeling to determine the sensitivities to a given parameter. Conservative assumptions are normally made in designing kill plans to improve the chances for a successful outcome.

Blade evaluated each kill attempt using reasonable assumptions of bottom hole pressure and gas flow rate and modeling showed the well could have been killed with 12 ppg or 15 ppg drilling fluid pumped between 5 and 10 bpm depending on the specific kill attempt. The bottom hole pressure was changing with time, correspondingly, the kill parameters changed. Details of the kill scenarios are included in the Blade supplementary report *SS-25 Transient Well Kill Analysis* [10] (pages 27 – 31).

The Blade modeling planned killing the well with weighted drilling fluid which is better suited to prevent gas migration and leak-off into the formation than the low-density clear fluid that was used in kill attempts #2 – 6. Boots & Coots used 15 ppg drilling fluid in the final kill attempt #7 which was consistent with the Blade modeling results. This is discussed in the supplementary report SS-25 Transient Well Kill Analysis [10] (page 38).

e. If so, on which attempt?

Kill attempt #2 (the first Boots & Coots attempt) or kill attempt #3 were possible to achieve a successful kill assuming proper modeling was done with valid input data and a successful pumping operation according to the modeling results. This is discussed in the Blade Report [1] (page 4). A pumping operation with no interruptions is extremely important to prevent the well from flowing once it was killed during the kill operation. If the pumping fluid friction pressure is lost or reduced during the kill operation, the kill attempt will likely fail. It should be noted that operational uncertainties are not accounted for in modeling.

f. If the answer to Question 4 d is yes, why?

The well and site were in the best condition of all of the kill attempts for kill attempt #2. However, the SoCalGas November 13, 2015, daily report [2] shows there was a pump shut down during the job which interrupted the planned kill operation and resulted in an unsuccessful kill attempt.

Unfortunately, the surface conditions deteriorated during and after kill attempt #2. A quote from a DOGGR report [20] describes the damage caused by the kill attempt.

> Overall, this was the day that the well actually blew out in the conventional sense. Previously, it was not clear that the well was in a blowout situation. But after this pumping job, a blowout vent opened 20’ from the wellbore and began shooting debris 75’ into the air.

g. In Blade’s view, with the data that Boots & Coots had and could have attained at the time it was attempting to kill well SS-25, could Boots & Coots successfully have killed well SS-25?

See Question 4 d.

h. If so, on which attempt?

See Question 4 e.

i. If the answer to question g is yes, why?

See Question 4 f.

2.5 Question 5

5. Please refer to the following passage of page 14 of Mr. Abel’s testimony.

Lastly, Blade's model disregarded other key variables in pertinent well control operations. Blade's primary design variables were fluid density and pump rate. Other parameters such as viscosity, fluid stability, availability, and toxicity must also be considered. Further, not only must a kill operation stop the gas flow, the well must be stable when the kill fluid column is in a static state (i.e., after pumping stops). The pressure profile and corresponding tubular and wellbore integrity (which changes with depth) must also be considered and not exceeded. Because the Blade Report did not analyze these additional parameters, it is unknown if the fluid characteristics proposed by Blade (and alleged by SED) would have killed the well.

With this passage in mind, please answer:

2.5.1 Questions and Blade Responses

a. Does Blade agree that its model disregarded other key variables in pertinent well control operations?

No.

b. Why or why not?

The parameters fluid stability, availability, and toxicity are not input data to a kill model. Blade used fluid viscosity in the modeling analysis. Fluid viscosity is an important parameter used to estimate the friction pressure calculations which affect the pressure profile in the fluid flow path in the wellbore and the surface pump pressure.

c. Provide additional context and facts as necessary.

Fluid stability is important to ensure the solids in the weighted kill fluid (drilling fluid) remain suspended when the fluid is static. This would be a requirement that would be part of the specifications and requirements communicated to the supplier of the kill fluid when the fluid is ordered. The fluid properties would be confirmed before the fluid was pumped to ensure stability and other properties. This is a common requirement when dealing with fluids where the density is controlled by adding solids to the fluid.

Fluids with the proper density and flow properties are available from numerous suppliers. The kill fluids being discussed are also referred to as drilling fluid and are commonly used in oilfield drilling and workover operations. The fluid used by Boots & Coots in kill attempt #7 was 15 ppg water-based fluid that was procured and made available for the kill attempt. Blade identified similar densities for fluids for kill #2 through #6. A well kill model would have revealed that 12 ppg or 15 ppg fluid could have been used earlier in the kill attempts. As discussed in Question 4 d, using a drilling fluid as the kill fluid has several advantages over a clear fluid related to preventing gas migration and fluid leak-off into the formation.

Boots & Coots pumped barite pills as part of kill attempts #3, 4, and 5. However, because the well was not killed, the gas flow prevented the barite from settling and forming a competent plug or bridge in the annulus. A barite pill needs several hours in a static condition to settle.

It is not clear why toxicity is mentioned. It is not something that affects the modeling or the killing operations. Water-based fluids are commonly made up of non-toxic materials and there would be no reason to include toxic materials in a kill fluid.

d. Does Blade agree that "it is unknown if the fluid characteristics proposed by Blade (and alleged by SED) would have killed the well?

Yes, because the fluid characteristics along with the fluid densities and pump rates modeled by Blade were not used in a kill attempt and operational uncertainties are not reflected in modeling.

e. Why or why not?

The main parameter of the fluid used to kill a well is density with sufficient additives to maintain a stable fluid at surface and downhole conditions. The fluids proposed based on the Blade modeling included water-based fluids with 12 ppg or 15 ppg density and are standard-commonly available fluids with known flow properties.

f. Provide additional context and facts as necessary.

Not only are the fluid characteristics important; as discussed, the requirement for a successful well kill is to determine the fluid density and pump rate required to kill the well by stopping the influx of gas and then pumping the kill fluid in the same manner that it was modeled. If there are interruptions in the pumping, the kill is likely to be unsuccessful.

2.6 Question 6

6. Please refer to the following passage of pages 14 and 15 of Mr. Abel's testimony.

In sum, Blade's post-hoc transient modeling was an academic exercise that cannot fairly be compared to Boots & Coots' task of working on site under real-time constraints, and dealing with practical, field-level concerns (e.g., severe weather, wellhead condition, and safety of personnel). Even assuming Blade's transient modeling generated reasonable outputs, there is no basis for SED to claim that Boots & Coots should have killed SS-25 sooner—particularly as early as the second attempt (on November 13, approximately 3 weeks after the leak commenced)—when Blade needed 5-6 weeks to model a well kill, [Footnote omitted] not including time spent on the investigation and casing removal. Boots & Coots' approach of increasing pump rate and fluid density over well kill attempts 2 through 7 reflects a measured and logical process that did not compromise the safety in the process of bringing the well under control.

With this passage in mind, please answer:

2.6.1 Questions and Blade Responses

a. Does Blade view that its transient modeling generated reasonable outputs?

Yes.

b. Why?

Blade used available data (as described in the response to Question 2 c.) to construct its model. This model demonstrated that the well could be killed using 12 ppg or 15 ppg fluids pumped at reasonable rates.

c. Does Blade maintain that there is a basis for the claim that Boots & Coots should have killed SS-25 sooner?

Blade is not in a position to determine if Boots & Coots should have killed SS-25 sooner.

d. Why or why not?

As discussed previously, there are two components of a well kill required to result in a successful outcome. The first is a plan based on available data and reasonable assumptions if data is not available. Blade contends that because of the obvious complexity of the well control situation, kill modeling was needed to develop a plan that maximized the chances of a successful kill. The second part is implementation of the pumping operations in the field. The fluid density and fluid pump rate have to match or exceed the plan and pumping must be completed without interruptions. When both components are done correctly, there is a good chance the kill will be successful. If either component is not right, a failed kill attempt is likely.

e. Does Blade maintain that there is a basis for the claim that Boots & Coots should have killed SS-25 as early as the second attempt, even if Blade needed 5 to 6 weeks to model a well kill (excluding investigation and casing removal time)?

The statement that Blade needed 5 to 6 weeks to model a well kill was taken out of context.

The accurate statement is "So for us [Blade] it took much longer; four, five, six weeks to analyze all of the seven kills." [21] (page 1058:14 – 16). Blade modeling included a detailed assessment of gas flowrates and history matching. This level of accuracy was not required for kill modeling prior to kill attempts.

Blade believes that more accurate kill modeling, using data available as early as the second kill attempt, would have led to a better well kill plan. Such modeling would have taken less than a week to complete. *Drillbench* software is intended to be used prior to well kill operations. A properly designed well kill plan, if implemented correctly, would have increased the chances of success. However, operational uncertainties are not reflected in modeling.

f. Why or why not?

See Question 6 d.

g. Even if Blade needed 5 to 6 weeks to model a well kill, does Blade maintain that Boots & Coots needed that long to do its own transient modeling at the time of the SS-25 incident?

No and again, the statement that Blade needed 5 to 6 weeks to model a well kill was taken out of context as discussed in Question 6 e.

h. Why or why not?

Blade is not in a position to know how long it would take Boots & Coots to do transient modeling. However, for engineers familiar with the *Drillbench* software could conduct such analysis with reasonable assumptions within a few days.

The data obtained by Blade for modeling was collected through numerous data requests over an extended time period.

i. Does Blade agree that Boots & Coots approach of increasing pump rate and fluid density over well kill attempts 2 through 7 reflects a measured and logical process that did not compromise the safety in the process of bringing the well under control?

Not necessarily.

j. If Blade disagrees with any portion of Mr. Abel's statement mentioned in question 6i, please identify each such portion.

Blade disagrees with the following portions of Mr. Abel's statement:

- "In sum, Blade's post-hoc transient modeling was an academic exercise that cannot fairly be compared to Boots & Coots' task of working on site under real-time constraints, and dealing with practical, field-level concerns (e.g., severe weather, wellhead condition, and safety of personnel)."

- "Even assuming Blade's transient modeling generated reasonable outputs, there is no basis for SED to claim that Boots & Coots should have killed SS-25 sooner—particularly as early as the second attempt (on November 13, approximately 3 weeks after the leak commenced)—when Blade needed 5-6 weeks to model a well kill, [Footnote omitted] not including time spent on the investigation and casing removal."
- "Boots & Coots' approach of increasing pump rate and fluid density over well kill attempts 2 through 7 reflects a measured and logical process that did not compromise the safety in the process of bringing the well under control."

k. Please explain why Blade disagrees with each portion of Mr. Abel's statement identified in response to Question 6 j.

For the first bullet point of Question 6 j., see our answers to Question 1 b.

For the second bullet point of Question 6 j., see our answers to Question 6 e.

For the third bullet point of Question 6 j., our answer is as follows:

Based on kill attempt data and reports provided to Blade, the fluid density did not increase during kill attempts #2 through 6. The majority of the kill fluid pumped was 9.4 ppg brine and 8.34 ppg fresh water with some 18 ppg barite pills. This assertion is supported by Mr. Walzel with Boots & Coots. He stated ". . . I think the fluid weights stayed the same." in the *SED CPUC Opening Testimony Supporting Attachments* document [8] (page SED 00717:18 – 19). The fluid density did increase to 15 ppg for kill attempt #7. The data does show the pump rate increased from 8 to 9 bpm for kill attempts #2, 3, and 4 to 13 bpm for kill attempts #5 and 6. The pump rate for kill attempt #7 was 5.8 bpm.

As discussed in the Blade Report [1] (page 4), "Based on the data reviewed by Blade, the well-control company appeared to have designed the kill attempts solely by calculating a kill fluid density that was higher than the static bottom hole pressure." The result was that the well was not killed and the surface conditions continued to deteriorate. The well was brought under control in February 2016 from the relief well, not from top kill attempts in November and December of 2015.

l. Provide additional context and facts in support of the question 6 responses as necessary.

Not applicable. See the discussion in Question 6 a – k responses.

3 References

[1] Blade Energy Partners, "Root Cause Analysis of the Uncontrolled Hydrocarbon Release from Aliso Canyon SS-25," 2019.

[2] SoCalGas, "Daily Report 10-23-2015 thru 11-15-2015.pdf," 2015.

[3] SoCalGas, "SS-25 Completion Profiler, AC_BLD_0083154.pdf," 2015.

[4] Add Energy, "Dynamic Simulations Aliso Canyon SS25, AC_BLD_003304-AC_BLD_0031422, February 16, 2016 (C042 AC_BLD_0031304 Optimized Add Energy.pdf)".

[5] Blade Energy Partners, "SS-25 Well Nodal-Analysis with Uncontrolled Leak Estimation RCA Report Volume 3 - Post-SS-25 Leak Events.pdf," 2019.

[6] Unknown, "Kill Attempt Modeling, AC_BLD_0075832, (no date) (AC_BLD_0075832.pdf)".

[7] Unknown, "Kill Attempt Modeling, AC_BLD_0075853, (no date) (AC_BLD_0075853.pdf)".

[8] SED California Public Utilities Commission, "I1906016 (PUBLIC) SED Opening Testimony - Supporting Attachments.pdf".

[9] Blade Energy Partners, "Data Request December 19, 2018 (Request for Factual Data Verification Discussion December 19th, 2018-Boots_Coots.pdf)," 2018.

[10] Blade Energy Partners, "SS-25 Transient Well Kill Analysis RCA Report Volume 3 - Post-SS-25 Leak Events.pdf," 2019.

[11] Blade Energy Partners, "B012 RCA Info Request to SoCalGas, February 11th 2016.pdf," 2016.

[12] Blade Energy Partners, "B064 RCA Info Request to SoCalGas, May 4th 2016_additional kill data from SS25.pdf," 2016.

[13] Blade Energy Partners, "Request for Factual Data Verification Discussion June 29th, 2018.pdf," 2018.

[14] Blade Energy Partners, "RCA Follow-up Request to SoCalGas, August 29th 2018 Factual Meeting followup-1.pdf," 2018.

[15] Blade Energy Partners, "RCA Info Request to SoCalGas, October 26, 2018.pdf," 2018.

[16] Blade Energy Partners, "RCA Info Request to SoCalGas, January 2, 2019 final.pdf," 2019.

[17] SoCalGas, "SS-25 Well Documentation (from SoCalGas)_N.pdf".

[18] SoCalGas, "SS-25 Well Schematic_11-10-15.pdf," 2015.

[19] Boots & Coots, "Boots and Coots Presentation Dec 16 2015 AC_BLD_0075833.pdf," 2015.

[20] Division of Oil, Gas, and Geothermal Resources, "SS-25 Chronology Summary (STANDARD SESNON 25 Chronology Summary-1 from DOGGR.docx)".

[21] "Porter Ranch - FULL Deposition Transcript of Ravi M. Krishnamurthy, Ph. D., Vol. III, on 11-22-19 with EXHIBITS (00550786xBCD99).PDF," 2019.