PUNA GEOTHERMAL VENTURE

REVIEW AND RESPONSE TO THE ELEMENT I REPORT

INDEPENDENT TECHNICAL INVESTIGATION OF THE PUNA GEOTHERMAL VENTURE UNPLANNED STEAM RELEASE, JUNE 12 AND 13, 1991, PUNA, HAWAII

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PGV Response to the Element I Executive Summary.

Puna Geothermal Venture (PGV) agrees with the Element I Report conclusion that the geothermal resource encountered in the KS-8 well, although quite hot, is manageable through the use of modern well drilling and production technology. However, PGV does not agree that the KS-8 well uncontrolled flow event occurred because of inadequacies in PGV's drilling plan and procedures. PGV believes that it occurred because the drilling encountered a high temperature and high pressure geothermal resource at a depth that was more shallow than anticipated. PGV's previous experiences with the KS-7 well caused PGV to make significant changes to the drilling program implemented for KS-8, and the KS-8 well drilling program was prepared to handle any resource of similar characteristics (see PGV Response G). However, the temperatures and pressures of the geothermal resource encountered by the KS-8 well were substantially higher than those encountered in the KS-7 well.

PGV concurs that there were a number of indicators preceding the KS-8 "kick" (defined by the Element I Report as "the intrusion of formation liquids or gas into a well bore which results in an increase in pit volume which, without corrective measures, can result in an uncontrolled flow from the well") and "uncontrolled flow event" (defined as "the uncontrolled flow of well fluids and/or well fluids from the well bore to the surface, or into lower-pressured subsurface zones") which could have led PGV to make certain decisions which would have substantially reduced the possibility that the KS-8 well kick would have turned into an uncontrolled flow event. However, there were also a significant number of additional indicators which led PGV to evaluate the situation differently. (See PGV Responses I and Z).

~~PGV concurs with the Element I Report that the kick resulted from the drill bit encountering a substantially over-pressured geothermal resource, with bottom-hole pressures sufficient to lift the entire column of moderately weighted drilling mud.~~ However, PGV believes that all currently available information demonstrates that the kick, and subsequent uncontrolled flow event, of well KS-8 were not created by the condition, assumed by the Element I Report, of heavy drilling mud entering the fracture and thus leaving the well bore partially void of confining drilling fluid. ~~Accordingly, PGV believes that the proper course for future drilling in the Kilauea East Rift Zone will be to drill with mud that is sufficiently heavy in weight to~~

[redacted] See PGV Response J.

In retrospect, PGV also agrees that the 9-5/8" casing should have been set somewhere near the 3,177-foot depth. However, at the time the decision was made not to run the casing at 3,177 feet, numerous geologic indicators (see PGV Responses I and Z) did not show that PGV would encounter the type of geothermal resource that was, in fact, encountered. PGV was clearly recognizing, as the events were unfolding, the numerous conflicting indicators of the status of the geothermal well. These conflicting indicators did not, in PGV's evaluation, show the need for setting the casing at 3,177 feet. In addition, as stated in PGV Response I, this casing was <u>not</u> necessary to ensure proper anchoring of the blowout prevention equipment (BOPE), nor would setting any casing at any depth have prevented the kick.

PGV disagrees with the Element I Report statement that sufficient cold water pumped down the well bore would certainly be able to completely kill the well during the uncontrolled flow event. [redacted] (see PGV Response J).

PGV generally accepts the recommendations of the Element I Report. Please see PGV Responses P through Y and Attachment 1 for a discussion of the actions already taken, or planned to be taken, in response to these recommendations and the results of PGV's own internal investigation. However, PGV believes that none of the Element I Report findings or recommended equipment or procedural changes would have prevented the kick of well KS-8.

A. Page 4, List of Persons Interviewed by Investigation Team.

As a point of clarification, Norman J. Clark, Project Manager; William J. Teplow, Field Manager; and B. J. Livesay, Consultant, were never formally interviewed by the review panel regarding the KS-8 well uncontrolled flow event. Each of these individuals attended initial, informal group meetings with the review panel, but had no subsequent formal contact with the team.

B. Page 5, paragraph 6; and page 6, paragraphs 1, 2 and 3, regarding drilling permits.

The Department of Health (DOH) issued an Underground Injection Control (UIC) Authority to Construct (ATC) permit for up to three (3) dedicated geothermal injection wells and up to nine (9) production/injection wells for the PGV project.

DOH does not normally issue UIC ATC permits for production wells, but may issue UIC ATC permits for wells which may be converted from production to injection.

The information provided to the DOH with the application for the UIC ATC permit in June, 1989 consisted of two alternative designs for the injection wells: Alternative 1, an injection well design identical to the general production well design (with the addition of an internal hang-down liner); and Alternative 2, a dedicated injection well design. DOH does not request detailed information regarding the drilling program in its application forms for a UIC ATC permit, and such information was not submitted to the DOH by PGV.

C. Page 6, paragraph 6, well KS-7 uncontrolled flow event.

At the time of the KS-7 uncontrolled flow event, the annular preventer did not serve as the sole BOPE. The BOPE stack employed on the KS-7 well at the time of the event consisted of a rotating head, spacer spool, annular preventer, double ram preventer, mud cross, banjo box, and single ram preventer.

D. Page 7, paragraph 2, regarding the status of the KS-8 well on June 7, 1991.

Because the carbon dioxide response point in the mudloggers trailer was set at the background level of 330 ppm, PGV can only say that the carbon dioxide measured prior to this date was not greater than the background level of 330 ppm.

E. Page 8, paragraph 3, quoting from the PGV report "Geothermal Well KS-8 Uncontrolled Flow Event and Well Design Review".

At the time of the June 12, 1991 meeting described in the Element I Report which led to the decision to continue drilling, PGV had certain information available to consider in making this decision. This included all of the information collected on the KS-3 and KS-7 wells. Also considered was all available information on the current status of the KS-8 well, including the flow of drilling mud out of the wellbore, the gains in mud volume while pulling stands, and the gas entries while circulating "bottoms up". In addition, PGV was aware that there were no obvious mineralogic precursors of significant temperatures found in any of the cuttings, and that the mud temperature return history and the measured temperature profile curves for KS-8 much more closely resembled that of the cooler KS-3 well, rather than the hotter KS-7 well. This latter information indicated to PGV that temperatures in the KS-8 well were in the range of 450°F, rather than the 630°F subsequently encountered at a depth of 3,488 feet. Moreover, the installation of the 9-5/8" casing was not necessary to assure a good anchor for the BOPE prior to further drilling (see PGV Response I). Based on all this information, PGV made the decision to continue drilling deeper before setting the 9-5/8" casing, but to closely watch the selected indicators (listed in the referenced paragraph in the Element I Report) while drilling to specifically determine the point at which to set the casing. See PGV Response I for additional information.

F. Page 10, paragraph 10, referring to the current status of well KS-8.

Although surface pressures measured at the wellhead have been as low as 5 psi or lower since the well has been shut in, low wellhead pressures are temporary events. The much more typical wellhead pressure since shut in has been around 900 psi. PGV believes that this sustained high wellhead pressure, combined with the very high bottom hole pressures measured through the drill pipe after the shut-in, demonstrate that the KS-8 well has encountered a resource which is significantly above the pressure encountered in KS-7 or KS-3.

G. Page 11, paragraphs 3 and 4, discussing the differences in the drilling program between KS-7 and KS-8.

It is incorrect to state that the experiences of KS-7 did not result in a change to the drilling program used for KS-8. KS-7 was drilled using the "Alternative 2" well design contained in the DOH UIC permit application. KS-7 was drilled with a 17-½" hole with 13-3/8" casing down to 1,020'. A 12-¼" hole was being drilled at the time of the kick in KS-7.

Because of the elevated pressures encountered in KS-7, and the possibility that KS-8 might be used as a production well, PGV elected to use the stronger "Alternative 1" (production well) well design from the DOH UIC permit application. This design called for 20" casing cemented in 26" hole to approximately 1,000 feet; 13-3/8" casing cemented in 17-½" hole to approximately 2,200 feet; and 9-5/8" casing cemented in 12-¼" hole to approximately 4,000 feet. The "Alternative 1" design for the KS-8 well was also improved by the use of higher strength casing in the upper portions of the hole.

In addition, the drilling plan for the KS-8 well was modified so that the well would intersect, at a depth below 4,000 feet, the near-vertical fracture that KS-7 encountered at a depth of 1,678 feet. This KS-8 point of intersection would occur after the cementing of the three (3) strings of casing described above. Based on the experience of KS-7, supplies of material to increase the weight of the drilling mud (barite) were stockpiled on site for the drilling of KS-8, and it was decided that the degree of mineralization in the drill cuttings was to be used to determine the casing set point. Coupled with an awareness of the potential for shallow fractures based on the experiences from KS-7, these appeared to be all the major changes necessary for drilling the KS-8 well.

H. Page 11, paragraph 6, discussing the reservoir conditions encountered by KS-8.

PGV concurs that the temperature measurements taken on June 21, 1991 through the drill pipe in KS-8 indicate that the temperatures and pressures encountered in the fracture were far above those represented by a simple, normal hydrostatic situation, indicating that the KS-8 well encountered a relatively shallow geothermal resource which is significantly over-pressured relative to normal hydrostatic pressure at that depth.

Please see Attachment 1 for a complete summary of the actions taken, or planned to be taken, to bring the KS-8 well into full control by PGV, consistent with the recommendations of the review panel and the conclusions of PGV's own internal investigation.

I. Page 11, paragraph 8, and page 12, paragraphs 1 and 2, regarding the "numerous 'red flags'" and PGV's decision to drill to a depth of 4,000 feet.

PGV does not agree that the factors enumerated in paragraph 8 of page 11 and paragraphs 1 and 2 of page 12 of the Element I Report can be taken in isolation as "red flags" or a "serious problem" that in themselves were sufficient to indicate the impending kick or uncontrolled flow event. As discussed below and in PGV Responses E and Z, PGV was aware of the enumerated information, but was also aware of significant information (such as measured temperatures and the lack of mineralization) which indicated that the KS-8 well was not acting like the KS-7 well. At that time, PGV believed that all prudent measures were being taken.

In retrospect, PGV agrees that the 9-5/8" casing should have been set somewhere near the 3,177-foot depth, as this would have isolated the fluids entering the well bore behind the casing. However, the decision to not run casing at 3,177 feet, but to continue to drill, was based on a number of factors which, at the time of the decision, did not indicate the necessity of setting casing at that time. See PGV Response E. There were no obvious mineralogic precursors of significant temperatures recognized in the cuttings, and the mud temperature return history and the measured temperature profile curves for the KS-8 well much more closely resembled that of the cooler KS-3 well, rather than the hotter KS-7 well (indicating that temperatures were in the range of 450°F, rather than the 630°F subsequently encountered at a depth of 3,488 feet). Further, PGV did not believe that the small flow of geothermal fluid into the wellbore (as indicated by the flow of drilling mud at the surface) was a problem serious enough to immediately require that the 9-5/8" casing be run. PGV was aware of the conditions encountered in the KS-3 and KS-7 wells, and believes that it was prepared to handle the consequences of drilling into the resource conditions found in the KS-3 and KS-7 wells. However, the temperatures and pressures encountered in the KS-8 resource were subsequently found to be substantially higher than those encountered in the KS-7 or KS-3 wells at a comparable depth.

The installation of the 9-5/8" casing was not necessary to assure a good anchor for the BOPE prior to further drilling. In conformance with the then current drilling program and accepted geothermal drilling practices, the 9-5/8" casing was to be cemented in place, and the top of this casing was to be secured in an expansion spool, which would allow the casing to move up and down. The anchor for the BOPE while drilling below the 9-5/8' casing is still the 13-3/8" casing head with the 9-5/8" casing cemented inside of the 13-3/8" casing.

J. Page 12, paragraphs 3 and 4, discussion regarding drill mud weight and cold water supply.

PGV believes that sufficient information is now available to demonstrate that the geothermal resource encountered by the KS-8 well is different, although not unique, from the "typical" geothermal reservoirs experienced by the review panel. World-wide, other examples may be found in the Philippines, Indonesia, Japan and possibly other active volcanic terrains. The KS-8 reservoir contains geothermal fluid which is over-pressured relative to a column of water from the surface which is temperature equilibrated to the surrounding rock. Therefore, whether drilling with air, cold water or drilling mud, the geothermal fluid would rapidly and aggressively enter the well bore <u>unless</u> the cumulative weight of the column of drilling fluid exceeded that of the pressure of the reservoir.

Geothermal well drilling is typically done with a column of drilling fluid (either liquid or air, or a combination of both) which, by design, either (i) allows some inflow of geothermal fluid into the well bore (known as "under-pressured" drilling, because the bottom-hole weight of the drilling fluid is "under", or less than, the pressure of the geothermal reservoir at the bottom of the hole; this system is used when drilling geothermal wells throughout The Geysers geothermal steam field), or (ii) prevents the geothermal fluid from entering the well bore (known as "over-pressured" drilling, which is used for most of the other geothermal areas in the world). Whether drilling under-pressured or over-pressured, encountering any geothermal resource at a higher pressure than the weight of the drilling fluid opposite the entry will immediately result in the commencement of flow of that geothermal resource into the well bore. The amount of fluid which enters the well bore and the rate at which it enters is dependent upon the difference in pressures between the reservoir and the fluid in the well bore and the "productivity" (i.e., ability to produce fluid into the well bore) of the geothermal resource entry.

Because typical geothermal reservoirs are at most only slightly over-pressured, the weight of the fluid in the well bore necessary to prevent backflowing of geothermal fluid from the reservoir into the well bore need not be much heaver than that of a column of water which is equilibrated at the temperature of the adjacent rock. Frequently, either cool or cold water (which is denser, and thus heavier, than the warmer water found in the geothermal reservoir) or a slightly weighted drilling mud is sufficiently heavy at the bottom of the hole to prevent any back flow of geothermal fluid into the well bore. Only if the weight of the fluid in the drilling column is heavy enough to force back the geothermal resource into the reservoir and emptied part or all of the well bore, would a significant flow of geothermal resource come back into the well bore as a kick. Even under these circumstances, the wellhead pressures seen by the BOPE from a typical geothermal resource would be relatively low.

The Element I Report assumes that the weight of the drilling mud used at the time of the kick, in excess of 10.6 pounds per gallon (ppg), contributed to the uncontrolled flow event because the drilling mud left the hole to enter the fracture, thus allowing the geothermal fluid to enter the well bore and escape to the surface. The Element I Report also assumes that kicks in geothermal wells such as experienced in KS-8 are usually controlled with the use of cold or cool water. PGV agrees that geothermal wells drilled into typical geothermal reservoirs (which are either under-pressured relative to hydrostatic (ground water) pressures (such as is the case for the entire Geysers geothermal steam field)), or are only slightly over-pressured relative to hydrostatic pressures (as is the case in most geothermal fields in California and Nevada), are usually controlled with the use of cold or cool water. However, the geothermal resource encountered by KS-8 is different from those typical geothermal resources mentioned in the Element I Report.

As described above (see PGV Response E), the flowing bottom hole pressure of KS-8 is approximately 1,950+ psi (at a depth of approximately 3,488 feet). However, the initial bottom hole pressure of KS-8 may have been as high as 2,200 psi. This means that <u>any</u> drilling fluid with a weight less than approximately 12.2 ppg would not have been able to control the initial pressure of the geothermal resource, and would have been immediately thrust back up the well bore, followed by the geothermal resource. This thrust of geothermal resource up the well bore constitutes the kick. The lighter the weight of the fluid in the drilling column, the easier the geothermal fluid would have thrust the drilling fluid back up the well bore. PGV believes that it is unlikely that any amount of cold or cool water pumped down hole would have been able to prevent this geothermal fluid kick. Water is necessary to help cool and temporarily control the well during the current operations, but by itself probably cannot completely kill the well without also the use of heavy drilling mud and/or cement. See PGV Response T.

K. Page 12, paragraph 6, item 1 of the Analysis of Blowout Equipment.

The mud cooler provided by the contractor is designed to drop the mud temperatures by 10 to 15°F. It was necessary to shut down the mud cooler for cleaning with each drill pipe connection at the time of the uncontrolled flow event only because the cooler was handling significant quantities of lost circulation material which was added to the drilling mud to plug off zones in the reservoir into which the drilling mud was leaking and which clogged the nozzles of the cooler. This limitation was recognized, and PGV was preparing to install the mud cooler of a different design from the other drilling rig when the kick occurred.

L. Page 12, paragraph 8, discussions regarding indicators available to the driller.

None of the actions undertaken by the driller resulted from information passed on to the driller from the mudlogger. The driller was watching the monitor in the doghouse when the kick occurred. Upon observing critical readings, he went over to the brake and started to pick up the Kelly so that he could close the BOPE.

M. Page 13, paragraph 1, discussion regarding supply of cool, fresh water.

As discussed above in PGV Response J, PGV believes that this geothermal resource can be cooled and controlled, but not completely "killed", by the use of large volumes of cool or cold water. Even if pumping large volumes of water down the well bore could control the well, PGV believes that the use of cool or cold water, rather than the available 100°F water, is unnecessary. The weight difference between a 3,500-foot column of water of 75°F and a column of 100°F water is inconsequential (amounting to approximately 6 psi), and the difference in the heat absorption capacity (to the point of flashing) is only 2.6 percent. PGV has completed a second water well to increase the available supply of water.

N. Page 13, paragraphs 2 and 3, discussions regarding size of the choke line.

Because none of the permits issued by the regulatory agencies permitted venting of geothermal fluid, the choke line was neither sized to handle the flow of geothermal fluid, nor was a silencer or muffler on the end of the choke manifold line at the time of the kick.

O. Page 13, paragraph 4, discussion regarding supervisory personnel.

Please see Attachment 1 for a discussion of the actions taken to strengthen the onsite management of the drilling rigs.

P. Page 13, paragraph 5, Recommendations.

PGV concurs that specific parameters for well design and possible modification during drilling must be made on a well-by-well basis, often as demanded by the subsurface conditions encountered during the drilling process. See also Attachment 1 for a discussion of the actions already taken, or planned to be taken, in response to these recommendations and the results of PGV's own internal investigation.

Q. Page 13 and 14, Recommendations for Upper Portions of Well, Recommendations 1 and 2.

PGV concurs that the philosophy expressed in Recommendation 1 regarding flexibility, and expressed in Recommendation 2 regarding implementing closer observations for temperature rise and/or hydrothermal alteration mineralogy, is correct and necessary. However, PGV believes it may be impractical, in real time, to follow Recommendation 2.b. Please see Attachment 1 for a more complete description of PGV's monitoring program.

R. Page 14, Recommendation 1 for equipment modifications and additional equipment.

PGV agrees that a larger flow relief line from the BOPE stack is appropriate, and proposed this modification to the review panel during their investigations. However, it should be noted that should a kick occur, geothermal fluid would still be vented through this stack, although for only a short period of time.

S. Page 14, Recommendation 2 for equipment modifications and additional equipment.

Although it is not clearly indicated on the referenced Figure 8, PGV intends to install a "silencer" or muffler at the discharge end of the 13-3/8" flow relief line. In addition, PGV will install a hydrogen sulfide abatement system, similar to that used during the well flow tests, to abate hydrogen sulfide should the flow diverter line ever be used.

T. Page 14, Recommendations 3 and 4 for equipment modifications and additional equipment.

PGV agrees with these recommendations, but believes that it is unlikely that any amount of cool water pumped down the well will be sufficient by itself to kill a well which encounters reservoir pressures such as those encountered in KS-8. Water is necessary to help cool and temporarily control the well during the current operations, but cannot completely kill the well without also the use of heavy drilling mud and/or cement. See PGV Response J.

U. Page 14, Recommendation 5 for equipment modifications and additional equipment.

PGV concurs with the recommendation that another mud cooler, less likely to clog, be added to the system. PGV has already acquired one such unit. However, PGV does not believe that the temperature of the drilling mud was, in any way, related to the kick or uncontrolled flow event.

V. Page 15, Recommendation 6 for equipment modifications and additional equipment.

PGV concurs that a Visulogger and pit rise alarm installed on the rig floor would assist the driller in timely reacting to any changes in the well status. Appropriate monitoring devices have been installed by PGV on the rig floor.

W. Page 15, paragraph 2, discussing alternate BOPE stack arrangements.

PGV concurs and, as noted in the above paragraph 2, had made these same recommendations to the review panel.

X. Pages 15 and 16, Recommendations for State Regulatory Agencies.

PGV concurs with the five recommendations made by the review panel for state regulatory agencies. PGV would point out, however, that neither the "National Geothermal Drilling Organization" (probably the Geothermal Drilling Organization or National Geothermal Association) nor the American Society for Testing of Materials are organizations set up to review current operations or establish procedural standards for drilling geothermal wells. As such, PGV believes that such a review is not appropriate.

Y. Page 16, Recommendations for Supervisory Personnel.

PGV has reviewed these recommendations, and has altered its procedures to ensure that adequate supervision is available at all times. PGV is also undertaking additional training of PGV drilling personnel. See also Attachment 1.

Z. Page 16, Conclusion.

PGV believes that it acted prudently and responsibly in its decision making process leading up to the kick and uncontrolled flow event of the KS-8 well, based on the information that was available to it at the time that these decisions were made (see PGV Response E). In retrospect, certain information might have been collectively interpreted differently, which could possibly have led PGV to case the well at the 3,177 foot depth. This may then have prevented the kick from developing into an uncontrolled flow event. As discussed above in PGV Response J, PGV believes that, although the water would have helped to cool and control the KS-8 well, no amount of water of any temperature would have been able to fully kill the well. However, through implementation of the recommendations of the review panel and the additional improvements developed by PGV, PGV certainly concurs with the conclusion of the review panel that "drilling of geothermal wells in the Kilauea East Rift Zone may proceed safely."

**LIST OF ACTIONS TAKEN BY
PUNA GEOTHERMAL VENTURE (PGV) CONSISTENT
WITH THE RECOMMENDATIONS OF THE
TECHNICAL INVESTIGATIVE REPORTS
AND THE CONCLUSIONS OF PGV'S OWN
INTERNAL INVESTIGATION**

The following is a list of actions taken, or begun, by PGV consistent with the recommendations of the Technical Investigative Reports and the conclusions of PGV's own internal investigation with respect to the June 12, 1991, steam release.

I. DRILLING PROCEDURES AND SUPERVISION

A. CASING PROGRAM

The casing must be set as close to the top of the high temperature reservoir as possible without setting casing in the high temperature reservoir. The method of determining the setting depth must remain flexible and react to a series of setting criteria. Mineralization of cuttings must be used in conjunction with other criteria. Temperature in excess of 425° F may be one of the reliable indicators for the top of the formation. Also, increases in CO_2 and H_2S in conjunction with temperature increases are indicators that the wellbore is close to a producing interval and that casing should be run.

Temperature surveys in the form of maximum reading thermometers will be run at determined intervals to measure current values of bottom hole temperatures. When approaching the resource these will be run every 30 feet.

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refer to pg. 14 item 2(a), below 500' depth

B. MUD WEIGHT

The Hawaii Department of Health Authority to Construct (air quality) permit for the PGV well field requires that mud drilling be utilized and the mud weight be sufficient to control pressures of the resource. The mud weight that is required to control formation fluid pressures will vary with depth. Mud will be weighted up if and as required by the conditions of the well.

C. SUPERVISION

The chain of responsibility for the rig actions cover the situation during all operations. The driller is the first point of control when drilling the well.

has this been submitted?

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Attachment 1
to
Element I Report

To strengthen the on-site management of the rigs, the Parker Drilling Co. (PDC) tool pushers are now working on a 12 hour rotation for the current critical operations on KS-8. This will be reinstituted whenever required. The pusher and/or rig supervisor will be on the rig floor during all critical operations and during all crew changes. Drilling supervision has increased to two people and will be scheduled on a rotation basis of either 12 or 24-hour duration.

D. TRAINING EFFORTS

As a part of the normal training for drilling a geothermal well, all personnel were trained in H_2S safety. Also, well control schools have been held for the drilling personnel. These schools will be repeated as necessary.

As a foundation for training, formal standard drilling orders are in preparation and will be in place prior to any future drilling. These standard drilling orders will be the basis for on-the-job training and for more site-specific formal training.

A project-specific well control school tailored for geothermal resources will be prepared and all drilling and key personnel will be trained again. Short seminars will be used to emphasize certain elements of the operation where needed. The seminars will be tailored to the features of the resource and area. All on-site training will be logged on the daily tour sheet.

II. EQUIPMENT MODIFICATIONS AND ADDITIONS

A. MONITORING EQUIPMENT

A redesign or the monitoring and communication system now provides for instant contact between the mud logger, the rig floor, the mud pits, tool pushers trailer and the PGV rig supervisors trailer. The type and number of contact stations has been increased to shorten the distance to a reporting station. Additional alarm systems have been installed to sound pit level variations, H_2S levels and any other trend value that can be an indictor of problems. A Visulogger-style drillers display has been installed with monitor alarms which are controlled from the drillers station. As part of the monitoring changes, a wireline service with equipment to work in the temperatures encountered will be employed.

B. WATER SUPPLY

Additional water supply for well control purposes has been provided by drilling water well MW-3. The well and pump are designed to deliver 1,200 gpm continuously to the drilling operation. The flow is piped directly to the area adjacent to Well Pad A and Well Pad D. Reserve pit storage at each well pad will provide drilling water and additional control fluids. By combining the output from well MW-1, well MW-3, on-site storage and mud systems, it is now possible to provide up to 2,100 gpm water for over 15 hours and 1,470 gpm water indefinitely for well control.

C. MUD SYSTEM

1. MUD COOLER: A Kern Steel Geo-Cooler has been installed and is part of the current drilling system.

2. MUD PUMP CAPACITY: Additional mud pump capacity is being supplied by PDC. The additional pumping capacity will be used in kill operations on KS-8 and be on emergency standby. The two PDC Rig 231 Continental-Emsco F-1000 pumps provide adequate flowrate and pressure for normal drilling operation.

3. DRILLING FLUID SYSTEM CAPACITY: Additional mud mixing and storage capacity has been installed or is in transit to the site. The additional equipment is being supplied by PDC.

The total usable capacity will be 4,275 bbls. There will be a large multiple of hole volume available as surface storage for mud. Using PGV present practice as to hole size and casing size, the hole volume is 650 bbls. The surface storage of 4,275 bbls would then give a multiple of over six to one. This volume ratio will provide for mud mixing, movement and storage of mud pills as required and provide a larger volume for conditioning the mud on the fly during drilling. Manifolding will be designed and fabricated to facilitate mud movement.

D. BLOW OUT PREVENTION SYSTEM

1. The 13 5/8-inch 5M BOP stack has been changed for use in drilling the 12 1/4" hole and smaller.

The left column shows the existing BOP stack and the right column illustrates the BOP stack that will be used in the future.

EXISTING STACK	MODIFIED STACK
Wellhead 13 5/8-inch 900 Series 13 5/8-inch	Wellhead 13 5/8-inch 1500 Series
DSA Flange 900 Series to 1500 Series	DSA Flange 1500 Series 13 3/8-inch to 1500 Series 13 5/8-inch
Single Gate BOP Cameron 5000 #	Double Gate BOP Cameron Type V 5000 #
Side Outlet Spool	Fabricated banjo-box with 13 5/8-inch side outlet
	Attached to side outlet Cameron Singles Gate BOP with 150 psi rupture disk
Double Gate BOP Cameron Type V 5000 #	Cameron Type V 5000 # Double Gate BOP
Annular BOP 5000	Annular BOP 5000 #
Spacer Spool	Spacer spool
Rotating Head	Rotating head

A set of variable rams for use in the upper double gate is included in the equipment being brought to Hawaii. The variable ram will seal around any size or shape of pipe in the ram area and will close effectively around a hexagonal kelly. The annular preventer will also close around the kelly.

2. The BOP stack that will be used in drilling the 17 1/2-inch hole to the casing point for the 13 3/8-inch has been changed to the following:

<u>20" BOP STACK</u>

20-inch 3000 # well head

20-inch Cameron 2000 # double gate BOP

20-inch Hydril Type MAP 21 1/4-inch 2000 # annular.

This stack arrangement will increase the ability to control unforeseen intrusions between the 13 3/8-inch and 20-inch casing points.

3. A large diameter vent line off the 13 5/8-inch 5000 # stack will be installed. A weldneck flange that will accommodate the 150 psi rupture disk will be installed. The vent line will be anchored and a rigid support system will be built for this line. The relief line will also carry the exhaust point further from the rig floor to reduce interference with the activities on the rig floor when taking a kick. A noise muffler and H_2S abatement system will be affixed to the terminal end of the vent line.

The PDC Rig 231 as presently configured has six stations on the Koomey BOPE control unit. The new BOP stack will require seven stations and a spare, for a total of eight stations. The addition of two Koomey stations may require extra accumulator capacity. The additional two stations will be added, and if needed, additional accumulator capacity will be added to the system.

4. In the choke manifold, One hydraulically controlled remote operator is installed on the bypass line in the choke system. This is in parallel to the 13 3/8-inch bypass line discussed as part of the stack. The choke bodies will be moved further from the rig floor and will have silencers affixed to the end sections.

E. WELL HEAD DESIGN CHANGES

The 13 3/8-inch casing is the foundation of the preventer system as well as the production or injection wellhead. The 9 5/8-inch casing is suspended through the 13 3/8-inch by 9 5/8-inch expansion spool and cemented inside the 13 3/8-inch casing.

The design of the KS-8 wellhead originally was to be 13 3/8-inch wellhead, 13 3/8-inch by 9 5/8-inch expansion spool, 10-inch master valve and 10-inch wellhead valve, and then the piping system to the powerplant. All of this original design was 900 Series 13 3/8-inch wellhead equipment.

It is anticipated that the wells will be produced choked. This will cause the wellhead operating temperature to be higher than originally expected. Therefore, the 1500 Series wellhead assemblies will be used on production wells.

The wellhead design for KS-8 will be all 1500 Series equipment. After well control is accomplished on KS-8 and casing has been run, the 13 3/8-inch 900 Series well head will be removed and a 13 3/8-inch 1500 Series wellhead will be welded on to the 13 3/8-inch casing. The other components for the stack will be 1500 Series. All of this equipment is onsite.

The 1500 Series assemblies will be used for each production well unless and until it is determined that 900 Series will be sufficient for the pressure and temperature encountered.