STATE OF HAWAII
GEOTHERMAL ACTION PLAN

ELEMENT III, PART I

INDEPENDENT AIR AND NOISE PROGRAM REVIEW CONCERNING THE JUNE 1991 UNCONTROLLED VENTING OF THE PUNA GEOTHERMAL VENTURES KS-8 GEOTHERMAL WELL

SUBMITTED TO: Honorable Lorraine R. Inouye, Mayor
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1.0 Executive Summary

Review by the Element III, third party team began on July 1, 1991 and consisted of Mr. Robert L. Reynolds and Dr. Wilson Goddard, assisted by LCAQMD[1] staff members Mr. Ross Kauper and Mr. John Thompson.

The scope of the project included: 1) a review of the air and noise monitoring program as implemented at the Puna Geothermal Venture project during the "KS-8 uncontrolled vent of June 12-14, 1991", with a special emphasis on making recommendations for extent, equipment, location, quality of data assurance and management changes; 2) a precursory appraisal of issued ATC[2] and GRP[3], complaint response and regulatory practices to assess compliance and effectiveness of control technologies given the new information; 3) suggestions on how to better anticipate, mitigate and manage possible future similar events from an air quality and noise perspective with the public input and technology considerations; and 4) to develop an accident scenario and emission profile independently for use in Part II of this report in which a micro meterological assessment, and determination of correlation with health and measured aerometric values is presented.

Emissions of noise and air pollutants caused widespread complaints and concerns. Some residents in the local area were evacuated as a safety precaution, advisories were issued and ambient measurements of noise and H2S indicated levels markedly above those anticipated in the issued permits as limits or believed to be acceptable. The emergency response plan interacted with the DOH[4] role in monitoring and making recommmendations for actions taken to manage the event.

There are seven air monitoring stations presently operated by three semi-independent parties. The three independent efforts of PGV[5], DOH•CAB[6] and DOH•ASAB[7] need to be combined into a single monitoring program directed by a committee of agency, industry and active environmentalists (see section 4).

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[1]LCAQMD - Lake County Air Quality Management District, a California special District that enforces federal, state and local air and noise regulation with extensive geothermal.experience.

[2]ATC - Authority to Construct permit issued by the DOH pursuant to federal and state law for the protection of air quality.

[3]GRP - Geothermal Resource permit issued by the County of Hawaii for the protection of the public, and specifically in this case regulation of noise.

[4]DOH - Hawaii Department of Health

[5]PGV - Puna Geothermal Venture, the owner or permit holder. Used Interchangeably with Ormat Energy Systems International in this report.

[6]DOH•CAB - The Clean Air Branch of the Hawaii Department of Health

[7]DOH•ASAB - The Air Surveillance and Analysis Branch of the Hawaii Department of Health

Two background stations and other stations have provided data establishing a near zero background. The number of stations, seven is in excess to what should be necessary for compliance monitoring. The program should direct a greater amount of resources to other areas of the air program; most specifically, source testing and characterization of emissions, abatement technology application and compliance testing, and ambient monitoring for components other than hydrogen sulfide (H2S[8]).

Several stations need to correct noted equipment, quality assurance and audit deficiencies, primarily DOH•CAB stations.

Though recommended changes in air monitoring stations are made, it is clear considerable data was provided by the air monitoring in place to establish exceeds of the 100 ppbv limit. Air monitoring stations with a couple of noted exceptions produced reasonably reliable and meaningful data. PGV's monitoring effort follows their issued ATC. The field monitoring effort by DOH and PGV was extensive and provided reasonable and believable data.

There was little or no mitigation proposed or sought during the uncontrolled venting to control air or noise emissions. This process lead to venting in a manner that increased impacts on local residential areas. Recommendations are made to have in place a wet cyclone or similar device for noise, H2S and particulate abatement.

There was no attempt to specifically estimate or measure net emissions of H2S and other components. This made management of the event cumbersome and the impact of unknown emissions difficult to estimate at the time of the accident or with hindsight. No drift or particulate samples were collected, though both are believed to have been emitted to the air in substantial amounts and a sample submitted by a public member raises concern. Insufficient information exists to accurately estimate emissions. It is recommended that testing become a normal part of management during venting, that DOH gain the ability to perform simpler teseting for H2S and that Condition 20 of the ATC be implemented promptly to measure trace toxic components. That such information to be gained by testing be used to trip toxic ambient monitoring requirements, review of potential plant reliability or corrosion problems, as well a review for potential abatement and improved management for any components of concern.

The ATC permits are extensive and criticized as regards: specific ambient air monitoring standard requirements which are too lax and not tied to an emissions

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8 H2S - hydogen sulfide gas the odorous and poisonous gas commonly referred to throughout this report.

rate, operate on a sliding breakdown or upset that is determined by PGV activities; allow natural (background) emissions effects that deviate significantly from EPA and typical air agency procedures to accommodate monitoring influenced by natural uncontrolled events; characterizing emissions timely; and are lax in requiring and substantiating BACT choices and claimed efficiencies.

The GRP required noise limits were exceeded by more than 25 dBA on a semi continuous basis during the event. The GRP required monitoring was reviewed for utility at determining compliance with limitations, and recommendations are made to clarify the permit and noise data measurement and reporting presently utilized.

Additional equipment for the purposes of emissions testing, inventory and ambient monitoring is recommended.

2.0 Recommendations

2.1 Air Monitoring Network

1. If background is consistently near zero, as indicated by this review, the use of background monitoring sites should be discontinued, and the cost savings for background monitoring should be redirected to source control, evaluation and high quality portable field monitors. The number of stations (7) exceeds that necessary for compliance determination.

2. Unify the air monitoring efforts into a single comprehensive program managed and audited by the state, but which receives and follows input and policy from a committee consisting of active environmentalists, industry and agency people. The existing DOH and contractor staff could share responsibility for the operation. The following attributes should be added:

- The monitoring program expanded to verify the concentrations of other potentially toxic pollutants indicated by reservoir and process chemistry. Examples include lead, chrome, mercury, boron, nickel, and arsenic.
- Each permanent H2S air monitoring station should have a meteorological measurement system and remote access (modem) capability incorporated. They should be password protected but access automated for those needing and using the information.
- A uniform functional, as short as possible, sampling intake, manifold, and monitor intake line should be used and cleaned regularly.
- Add a multi-sensor 30 to 40 meter meteorological tower to provide information relative to atmospheric stability, multi-level temperature gradients and wind fields, preferably at the Irvine site.
- A quality assurance program be implemented at all stations with independent DOH staff performing quarterly audits. The existing SAIC quality assurance program, or the GAMP program should be used as a basis to develop a single

quality assurance program, but also correcting the noted deficiencies in reporting and audit approaches (see discussion sections).

• Two additional field portable H2S monitors (Jerome equivalent) be made available by the developer and properly maintained for use by DOH and/or other responding agency. One should be portable and configured for sample initiation by the public with automatic data recording. Local firemen and other agencies likely to respond to a hazardous H2S event should have one or more safety systems for use with each responding crew which give numerical readout and audio alarm.

• Recommended Actions at existing stations are summarized below and further discussed in section 6.

Recommendations Applicable (see below Key)

Station / Recommend Key->	1	2	3	4	5	6	7	8	9	10	11
Alvarez Station (CAB)	X	X	X	X	X	X	X		X		X
Wade Station (CAB)	X	X	X	X	X	X	X		X		X
Leilani Station(ASAB)			X	X	X		X	X	X	X	X
Nanawale Station (ASAB)			X	X	X		X	X	X	X	X
Ormat (PGV) SW				X		X	X		X		X
Ormat (PGV) SE				X		X	X	X	X		X
Woods Station (PGV)				X		X	X	X	X		X

<u>Recommendations Key (not necessarily priority ordered):</u>

1. Manifold, intake probe and sample line replacement or modification to remove condensation needed immediately.
2. Immediate and independent gas phase audit is needed (full probe preferred at all stations).
3. Improvement in written station procedures, data handling and station equipment diagram needed soon.
4. Manifold, intake probe and sample line regular cleaning.
5. Establish a station log and perhaps monitor log that remains with the station and equipment.
6. Offset chart zero by 10% and carefully document drift if accuracy in the 2-6 ppb range is to be claimed. Establish tolerances in the QA program that reflect the desired low concentration accuracy.
7. Add password level remote access integration into the QA and data reduction of station data. Provide password level controlled immediate access to agencies desiring and needing information.
8. Add meteorological measurement ability.
9. Calibrate and audit station at a lower range of H_2S than presently utilized.
10. Add functional data loggers (CAB is presently preferred)
11. Prepare monthly tables showing hourly averages and peak daily H_2S values, and DOH should clearly identify station location, name and operator.

3. Specific to the short term utilization of the present monitoring station resources; reference Map A shows a preliminary proposed station redistribution and possible reduction in number for discussion. It is recommended to occur only with a shifting of those resources to the control technology assessment and source testing effort, and can rationally be delayed until after power plant startup and shakedown if such is to occur in the immediate future. Only one station at a time should be relocated. If in fact the public or others are in disagreement, tracer releases under varied meteorologic conditions should be performed to identify locations and weather patterns of maximum impact prior to moving stations. Field portable monitoring could be used to partially substitute, and more thought as to the actual and expected emissions scenarios of the project need to be developed to influence this decision.

- Retain only (1) one background station at Nanawale (Flower Rd.) . Drop the PGV Woods Station.
- Relocate the PGV Southeast Station more to the southwest to avoid heavy agricultural influence and provide for increased community coverage.
- Relocate the Alvarez Station approximately 2000 ft. north or drop.
- Retain the Irvine Station for met data only and add multi-level measurement capability for wind and temperature.

<u>2.2 Geothermal Resources Permit and Noise Monitoring</u>

1. Clarification of the GRP requirements reflected in this review should be performed. One government office should be designated to receive and investigate complaints of noise. They should be available to any person that would choose to complain to them instead of PGV. Anonymous complaints should be taken, and investigated if practical.

2. At least one mobile/portable unmanned monitor with shelter and modem access, that can be used at complainant homes and is capable of determining compliance should be made available to Hawaii County or others.

3. Spot checks should be performed more frequently by an agency staff to add credibility. More frequent site inspections of PGV's effort and periodic comparison of calibrators could also add to the credibility and acceptance of the noise monitoring program.

4. The present noise standards should be evaluated for effectiveness by reviewing all complaints and their resolution. Typically, noise assessments for source and BACT determinations are specialized. The Planning Director should, if he believes it is necessary, seek expert opinion on BACT assessments from an

independent consultant paid for by PGV but contracted with and reporting to the County.

5. The monitoring effort should be directed to resolve complaints and identify source problem solutions.

6. There is too great an emphasis on monitoring sound and part of this effort is recommended to be directed at specific problem noise identification.

7. Determinations of BACT should be sensitive to the worker safety aspects, and not allow early choices of equipment to dictate subsequent noise control steps that unreasonably create a choice between a safety and noise problem.

2.3 Permit and Compliance Review Recommendations

1. The 100 ppbv one hour average limitation (AAQS) be evaluated from the experience of this incident and review. Evaluations of remaining health complaints should be performed by DOH as promptly as practical.

2. One government office be designated to receive and investigate noise and air quality complaints believed to result from the project. The present practice of recording tape messages, reading back and referring complaint directly to PGV should cease.

3. Resource characterizations required under Condition 20 of the ATC be performed as soon as practical and evaluated on a timely basis to better understand and estimate emissions, and determine if project design problems may result from any unexpected resource characteristic.

4. DOH staff should, actively participate in source tests, and develop the ability to independently quantify H2S emissions during drilling, stacking and uncontrolled or controlled venting. Specifically, the following is also recommended for timely consideration.

- Measurement characterization of drift and trace toxics contained in particulate and gas phase must be performed during emission release events until such time as they are well documented and established.
- An emphasis should be placed on developing an accurate and comprehensive emissions inventory and geothermal resource chemical constituent database specific to the project and individual wells.
- Emissions limits and/or technology development and application to all known emission points based upon Best Available Control Technology (BACT) should be further developed, and tested for performance under good dispersion conditions before needed (start with the stacking control system).

• The possible need and advisability of air drilling should be investigated and the restriction removed from the ATC permit if necessary to provide safety in drilling.
• The need to factually determine whether a pressure surge (gas pressured) from the bottom of the hole in the reservoir, or water/mud hammer, caused the "explosions" is critical to potential risk, and DOH staff should seek an expert final opinion explained to their satisfaction.
• The maximum accidental exposure to those in close residency should be re-evaluated, and where concern exists, the individual resident be educated as to risks, made aware of any bad circumstances or risky operations as early as possible, and given whatever assurance possible about DOH resolve to protect their air quality.

3.0 INTRODUCTION

Element III is the third element of the Geothermal Action Plan by the State of Hawaii to investigate the unplanned venting incident on June 12 and 13, 1991 at the geothermal plant site of Puna Geothermal Venture (PVG) in Kapoha, Puna District, Island of Hawaii, involving the KS-8, a geothermal well. The lead agencies for this review are the State of Hawaii Department of Health (DOH), the Hawaii County Planning Department and the Mayor's office.

This Element III study was conducted at the request of the above agencies by an independent investigative team consisting of Robert L. Reynolds, Lake County Air Quality Management District, and Dr. Wilson B. Goddard, Goddard and Goddard Engineering, both of California. Work was initiated on 7/1/91, with the primary emphasis being an independent evaluation of the existing air and noise monitoring programs, monitoring the incident, and to develop recommendations for the appropriate changes in the monitoring program equipment and procedures. Secondary tasks included an evaluation of permits. Part II authored by Dr. Goddard includes a microscale meteorological evaluation of the project area and accident meteorology and an assessment of health complaints compiled with public member assistance. The accident can serve as a learning experience from which an improvement of the overall regulatory program can result. The investigators were assisted by Ross Kauper and John Thompson of the LCAQMD, whom performed review of data for consistency and aided in evaluating recommendations for station relocation.

3.1 Approach

The investigative approach was to collect and review the available documentation regarding monitoring station operation and the emissions event information. The team exchanged data and initial findings approximately every two days since July 9, 1991. Mr. Reynolds traveled to Hawaii and conducted meetings and interviews with DOH and County of Hawaii officials on July 1&2, 1991. Site inspection and meetings with public representatives in Hawaii were conducted on July 2, 3 & 4, 1991. Videotaping and phone interviews were performed to obtain additional understanding of actual operations and insight regarding measured area impacts. Meetings and conversations with the state health agencies, interested public and developer representatives occurred to refine the scope of the investigation and obtain additional insight regarding related aspects of the event.

The available information was gathered and analyzed for completeness and additional data requests and follow up were performed, not all are yet complete. Information analysis included evaluation of visual features, observations of site visits and video tape recordings of all equipment. Monitoring and quality assurance data was reviewed for completeness and internally checked for obvious errors or conflicts.

The event sequence and provided mud logs were reviewed for possible information regarding timing and source strength from which assumptions regarding emissions estimates were derived for use in impact assessment. This was performed without input from Element I.

Steam and or gas composition data was collected and reviewed to provide information regarding other possible monitoring concerns.

Included in the data requests were adequate area, monitoring and complaint location maps, that were plotted by Dr. Goddard, for the correlation of observed measurements and reported effects (See Part II). Also included were requested and reviewed copies of the ATC permit.

Information was largely reviewed as received, but substantial additional questions were asked of industry and vendors. When timely received, it has been incorporated into this report. Several questions remain. Individuals knowledgeable in geothermal development, services and regulation were relied upon and interviewed to obtain added insight in regard to specific questions to their area of expertise. Part I of this report is a compilation of the authors understanding and experience with the subject area and represent his best judgment. Part II of this report is authored by Dr. Goddard.

3.2 Approach Health Survey and Dispersion

-See Part II

4.0 Existing Aerometric Monitoring Program

4.1 Existing Aerometric Monitoring Stations

At the time of the site visit seven H_2S air monitoring stations were operational. The Hawaii Department of Health (DOH) operates four of the stations. Each of two stations report to two different Deputy Directors. The Clean Air Branch (CAB) is part of Environmental Health and the Air Surveillance and Analysis Branch (ASAB) is part of Health Resources. The developer, OESI or Puna Geothermal Venture (PGV) utilizes a contractor "Science Applications International Corporation" (SAIC) to operate three additional stations. These stations are listed below with an indication of the H_2S monitor type, presence of meteorological and noise monitoring instruments and operating entity. Considerable additional documentation on configuration is available but is not included in this report. Each station's location is shown on the attached Map A.

Station Summary

Name	Location	Type	H2S	Met	SO2
Alvarez Station (CAB)	Kaupili Street	C	X	X	X
Wade Station (CAB)	Leilani Avenue	C	X	X	X
Leilani Station(ASAB)	Kahukai Street	C	X		
Nanawale Station (ASAB)	Flower Road	B	X		
Ormat (PGV) SW	Adjacent to HGP-A Site	F,P	X	X	
Ormat (PGV) SE	1800 ft. SE of Well KS-8	F,P	X		
Woods Station (PGV)	NE of Project Kapaho Rd.	B	X		
Irvine (SAIC)	Kahukai Street	C			
Mobile (CAB)	Between KS-8 and E Pad	P			

Key: C = Community, B = Background, F = Fenceline, P = Permit
PGV = Puna Geothermal Venture, ASAB =Air Surveillance and Analysis Branch, SAIC = Science Applications International Corporation, and CAB = Clean Air Branch

4.2 Site Visits

Each of the air monitoring sites were visited and videotaped for reference on July 2&3, 1991, and the equipment and records maintained on site were briefly reviewed. Quality assurance and quality audit data was requested prior to site inspection and again during the site visit if it had not yet been provided. The sampling lines/manifolds, water traps, calibration and Quality Assurance (QA) equipment were inspected for obvious leaks, bad connections, and maintenance practices. The station operators were interviewed to determine their extent of knowledge regarding the station equipment and manner in which it was utilized and serviced to demonstrate a reasonable level of understanding. The frequency of maintenance activities, span checks, precision checks and quality audits were discussed with station operators. An opportunity to explain any equipment problems that existed was provided. The manner in which collected data was handled was discussed and the appropriate data and station check forms were requested. Where available, the information was utilized in this review. Information available from the station logs, forms or note books including calibrations, span checks, and audits were reviewed.

4.3 Observations, Discussion and Problems

All existing stations produce reasonably reliable data, with the possible exception of: 1) the CAB stations when they experience water deposition and condensation problems in the sample acquisition system; and 2) the PGV-SE station being artificially low if H2S is scrubbed by material in the manifold. The operators appeared intelligent, familiar with the instruments, and capable of calibrating and maintaining the stations operative. Unfortunately, there is a need for an improved quality assurance and audit program, and some additional equipment and training at the DOH operated stations.

Quality assurance and auditing problems are minimal for SAIC, greater for ASAB stations and serious for the CAB stations. Quality assurance audits have not been performed at the CAB sites. The SAIC program could be used as a model for the other stations operational procedure, if desired. A quality assurance program requirement as developed and utilized in the Geysers is also provided in Reference 1 for consideration. The ATC permit required EPA guidelines do not exist for H2S monitoring but may be successfully adapted from existing EPA SO_2 monitoring procedures. Attention must be paid to some of the parameters if a 1-3 ppbv sensitivity is sought.

At a minimum, the SAIC and both state programs should be audited semi-annually by independent DOH personnel and equipment and preferably on a quarterly basis. ASAB staff would appear to be in the best position and qualified to accomplish this task. Audits should be performed by using equipment independent from that used for station calibration and precision checks, otherwise true independent audit requirements are missing. If possible, it would be most desirable to audit from the intake probe on at least an annual basis. DOH personnel should inspect SAIC stations on a regular basis and consider being the primary contract manager of SAIC instead of PGV, though PGV would pay costs of the contract.

Three different operational entities, operating three small monitoring programs of similar purpose is difficult to endorse. All could benefit from a sharing of resources to improve spare parts availability, audit frequency, staff time and operator resource without an increase in costs. Additionally, it was noted that the DOH stations operate without the extreme security measures that were implemented with the SAIC sites (cyclone fences and razor wire). DOH stations were in easily accessible areas and apparently better accepted by the public.

The two separate state programs and PGV's sponsored SAIC program should be modified to carefully complement each other, and preferably combined into one effort governed by a committee that includes significant public environmental representation and influence in decisions.

There is a need to assure the public that the monitoring results are valid and that the stations are there at a considerable cost to serve the purpose of protecting the public interest. It may be appropriate to form a consortium under the auspices of the state to perform the monitoring program and specifically identify the stations to indicate their public importance. Removing the razor wire from the PGV funded stations would reduce the negative public perception of the monitoring program function. It should be emphasized that monitoring station operations are one of the most visible manifestations of commitment to the protection of public concerns.

Each participant should play a role that enhances the other in performing the monitoring, quality assurance, quality audits and data verification which adds credibility even with recalcitrant detractors. The data should thus be credible and reported as accurately measured numbers which is made widely available. Problems with past efforts to monitor should be acknowledged, since it is likely some skepticism results from a failure of that system to report events that some public members clearly believe they experienced on a semi-continuous basis during the HGPA project.

Similar circumstances were experienced in the Geysers Geothermal Area development prior to the formation of a consortium Geysers Air Monitoring Program (GAMP). This program includes active environmentalists and industry and air regulatory agencies who share the decision making power for the Geysers Air Monitoring Program (GAMP). This unification of mutual interest provided for public input, helped establish the program objectives and reviewed and unified all available monitoring data. The purpose of the effort was to generate technical aerometric information everyone would accept. We are presently in the third renewal of the program. The costs are paid by the industry and a contractor operates the stations. The method of operations were determined and are audited by air agency staff. New industrial members have joined and the program can be adjusted to accommodate any new monitoring needs. This model would seem appropriate for the Pahoa area. At a minimum, DOH should audit the SAIC operated stations on a regular unannounced basis, and possibly serve the role of contract administrator by having PGV pay costs through the state whom would contract with SAIC. This would increase the credibility of the data in the public's view and assist PGV/SAIC in establishing credibility of the air monitoring program that is well deserved.

4.4 Access to Data and Modernization

Modem access to the SAIC stations is possible at present, but apparently is not utilized by DOH. It was not used during this event. To add this feature to the CAB stations would require minimal effort. The ASAB stations reportedly have new data loggers planned and could incorporate modem access. This attribute of data availability should be incorporated promptly into the information tools available to DOH, both for operational and QA functions, and to assist in emergency or other air management decisions.

The ASAB stations were in the apparent process of equipment changes and the CAB stations were only recently established in February of this year. The H2S monitors (not sampling) system equipment at all sites can be considered modern and near state of the art. The data logging and permeation tube calibration equipment at the ASAB stations is outdated and in need of replacement. Permeation tubes are more problematic than gas bottle dilution systems. All stations had proper shelters and temperature controls. The data loggers were nonfunctional at the ASAB stations, but plans are reported to exist for the upgrade of this equipment. Each entity performing ambient monitoring utilizes a different sample line and manifold system.

4.5 Intake Manifold and Sampling Line Problems

There is a serious problem of water condensation within the sample acquisition system and a potential for significant analyzer interference at the DOH•CAB stations. This appears to result primarily from the stainless steel heated intake probe and manifold not performing in the desired manner. Condensation was so severe in the sampling line at the "Wade Station" as to cause water pooling in the sample line prior to the sampling line particulate filter. A potentially more serious sample line problem exists because of observed corrosion on the exterior of the stainless steel probes. Similar corrosion is presumed to be occurring in the internal surfaces of the probe which may scrub or oxidize H2S and therefore reduce instrument response. The extreme amount of condensation observed in the sample system will also affect the operation of the SO2 scrubber, and potentially cause H2S to be scrubbed. A verbal recommendation to promptly first audit all DOH stations and rectify the condensation problem at CAB stations was given during the site visit. The ambient sample is drawn from the heat traced manifold horizontally which may also contribute to the condensation problem. These factors could be expected to cause ambient H2S readings to be reported considerably lower than are actually occurring. Attempts to dry and purge the line were immediately made, but the condensation problem was again present the next day.

The SAIC and ASAB stations use a combination of Pyrex and Teflon for manifold and sample line. The probes and water drop or insect traps are set up in a typical manner to ensure a short residence time and maximize the removal of dirt or water droplets. The sample line is withdrawn vertically from the top of the manifold. They appear to perform well with no condensation noted but may retain a considerable number of trapped insects. In all observed sites more frequent cleaning of the sampling manifold appears to be necessary. This is especially a problem at the SAIC - Southeast Station where spider webs and a light (oil) film was observed in the manifold. The station operator explained that the agricultural location of the station was an especially serious problem for spray exposure(s). The general degraded state of intake probes/manifolds cleanliness needs to be corrected by regular maintenance at all stations, and can be suspect of causing artificially low level H2S values. This is especially important since no audit or check has ever been performed using the entire probe/sample system, and that also measures the contamination effect which may reduce the H2S levels prior to analysis. A weekly check, and cleaning, if necessary, would seem appropriate, and maybe relocation if the problem is not controllable. It is advised that the external intake probes be directed downward (even though positioned under an inverted funnel). Consideration of a coarse insect screen to reduce insects entering the sample manifold might also be appropriate, but should be further investigated and tested before implementing. The SAIC stations use a large diameter intake pointed upward and are therefore especially susceptible to the insect and agricultural spray problems.

Consideration should be given to using a uniform sample probe configuration that can be as short as possible, incorporates an effective water droplet and insect trap, having inlets directed downward, and which avoids the water carryover/condensation problem. The assembly should be easily leak checked and cleaned, or replaced on a regular basis at all sites. The manifold should be positioned or balanced to best track ambient temperatures in an attempt to avoid condensation.

4.6 Quality Assurance and Data Reduction

Written quality assurance procedures, with appropriate work sheets and forms are customarily utilized at air monitoring stations. CAB stations in particular were remiss in this regard, with only a notebook (which is taken off site) used to record QA activities and instrument adjustments. Only the SAIC stations had posted procedures, adequate work sheets and the customary bound station log. The station log allows a proper record of station problems, activities and status that is not removed from the site (duplicate sheets are created). The ASAB stations, as a result of the initiative of the operator, had a draft operating procedure for the TECO instruments, diagrams and clear procedures.

ASAB stations are audited by a semi-independent party quarterly. Unfortunately, the ASAB equipment utilized is not totally independent, and is typically used to check the permeation tubes at both ASAB operated stations. Data loggers were not functional at ASAB stations. The technician that performs the audits also services the station and as such, a proper independent audit does not result. The Irvine station had apparent slow response problem(s) and required two hours for the daily span and zero check. This response is indicative of equipment problems which should be resolved. The ASAB stations are considered the poorest equipped because of the use of permeation tubes, absence of data loggers and meteorological monitoring.

Data reduction procedures at the ASAB stations were largely by hand reading of the strip chart, and by data logger dump to a personal computer at the CAB stations. Monthly data tabulations could not be provided. In both cases the results had historically been that only zeros were measured and therefore the formal data reporting had been placed on a low priority.

SAIC has an extensive QA and data handling program that is well documented and formalized. Still SAIC data tabs show a 1 ppb at 01:00 hours frequently, which is likely an artifact of the automated span check. These types of instruments are actually only accurate to plus or minus 2 ppb, or maybe worse, for zero baseline measurement reporting. Data should be corrected as presently reported. The stated zero drift tolerance of .025 ppm in the quality assurance plan fortunately is not used, but again provides good reason to utilize a 10% chart zero offset to determine the extent of the zero drift.

4.7 Background Data Stations

A review of available measured H2S background data has apparently shown little or no existing H2S in the vicinity of the project. Actually, all sites show zero H2S except when attributed to a source event, or as in the case of SAIC data a suspected artifact of the span check. Background station operation is at considerable expense and the continuing effort is difficult to rationalize as necessary, as incorporated into the ATC permits in the present manner. A natural emissions inventory could be carried out in the general area, and if sources are not identified that are likely to contribute, a years worth of no detectable amounts of H2S for background should be considered acceptable as establishing background as near and indiscernible from zero. Additional meteorological monitoring is likely to be more helpful in discerning any influence of VOG or future volcanic activity, should it occur, and procedure worked out by the EPA and California Air Resources Board for such events could and probably should be followed.

It is suggested to use zero H2S as the background value and simplify the enforceability of permits. The resource saved could be redirected to provide better meteorological monitoring, remote data access, source testing and other pollutant monitoring that would address public concerns.

4.8 Strip Charts or Hard Copy of Data

Strip charts can be invaluable for use in an area that experiences power failures or when instrument problems begin to happen. Strip chart recordings were offset by 10% only at the ASAB stations; however, data loggers at the other sites can report negative numbers as well as over range numbers and are useful in determining instrument operation. Nevertheless, it is suggested that dual trace charts be utilized that operate in two ranges such as 0-100 ppbv and 0- 500 ppbv, and that a 10% zero offset be utilized to better track and document instrument drift for the operator. A ten inch chart is also markedly easier to use when attempting to read in the 5 ppb range. The span and zero drift limits are tolerable, given the apparent measurement objectives, but need to be clearly delineated (especially SAIC's QA) as to when adjustments are to be made. All operators appeared to be aware of this problem.

4.9 Meteorological Monitoring at Stations

There were only three met stations operating as part of the system at the time of the site inspections. These were located on 10 meter towers at the CAB Wade & Alvarez and SAIC-SW stations. QA procedures were adequate at SAIC, but were not documented at CAB. The method of alignment at SAIC was customary and easily confirmed from the ground. CAB needs to adopt the procedure of aligning the vane and monitoring arm with true north to easily verify direction by site inspection and independently audit at least once after establishing a station. The Irvine site, with its elevated geographical location, is suitable for additional meteorological monitoring and should include such immediately if concern over additional venting exists.

5.0 Existing Noise Monitoring Program

5.1 Monitoring Program Description

An extensive effort is put forward to monitor noise by SAIC under contract to PGV. A PGV staff person charged with permit(s) compliance on site has also begun to play a more active role in the noise complaint handling and monitoring effort.

The extent of noise monitors exceeds permit (GRP #21) requirements for monitoring but may not be recording and utilizing the necessary data. PGV has three permanent and one mobile continuous noise monitoring stations, one hand held unit used by PGV staff for complaint evaluation and one that is reportedly loaned to the public. The Hawaii County and DOH each have a hand held B&K monitor which is apparently utilized intermittently. All PGV equipment is modern Quest Model 2700 or 2800, B&K, etc., yet it is not clear that the necessary L_{10} can be measured while under automated operation.

An open ended pipe microphone housing is utilized and intended to be somewhat directional (pointed at the project area). The housing also provides protection from the elements; however, they can also be expected to exaggerate the effect of the rain, wind and insects if they enter or fall on the steel chamber. The microphones are 1/2 inch Type I, but do not incorporate a dehumidifier. The calibrators are certified by the manufacturer on the recommended schedule.

Hourly averages are logged and included with aerometric data at the SE and SW sites. They are downloaded daily and reviewed by SAIC in San Diego. Additional data loggers are maintained with the stationary monitors and downloaded into a personal computer for further reduction. A five inch strip chart recorder is maintained of output data. An SAIC descriptor is available providing more detail on equipment and procedure. The data at the SE and SW sites is remotely accessible. The stations are summarized in the table below.

Noise Monitoring Resources

Name	Location	Make	Model Number	L_{10}	L_{Max}
Leilani Station (Irvine)	Kahukai Street	Quest	2800	M	M
Ormat SW, F	Adjacent to HGP-A Site	Quest	2700	?	?
Ormat SE, F	1800 ft. SE of Well KS-8	Quest	2800	M	M
Mobile (PGV), P	Between KS-8 and E Pad	Quest	2800	M	M
DOH	Hand Held	B&K	2231	X	X
County of Hawaii	Hand Held	B&K	2225	X	X
PGV	Hand Held	Quest	2800	M	M
PGV	Hand Held - Public Use	Quest	2800	M	M

Note: L_{10} and L_{Max} are not available commonly on all instruments.

5.2 Geothermal Resource Permit (GRP) Requirements

From a simple reading of Condition #24 of the GRP, the following is offered as the applicable two components of the GRP noise limit. The first limit is an L_{10} of 55 dBA day and an L_{10} of 45 dBA night (slow A scale) for 20 minute reporting intervals. The second limit is a 65 dBA day and 55 dBA night maximum (slow A scale). Authorized exceptions, and procedures for defining them are given in part C. Monitoring is not presently configured to determine compliance with these limits. Monitoring is not presently performed at the nearest residence, and it should be made clear that the SW and SE sites are acceptable alternatives to the nearest residence requirements for enforcement. A L_{10} value for 20 minutes would customarily require more than minute samples to determine.

It is obvious that part "a" intends to apply a limit that is modified by part "b" and the time interval set for this modification is 20 minutes. It might also be argued that from the reading of part "b" that unless the noise is impact in nature then limits of "a" apply. It is also clear that BACT is required for exceptions provided in part "c", and would be determined on an individual exception basis. It was not possible to evaluate if BACT is being applied for exceptions.

The actual noise limit applicable as practiced and adequacy of reporting is not clear to this investigator. Does the 10% time allowance of a 10 dBA increase apply to an L_{10} measurement for 20 minute intervals or a maximum of two, one minute intervals out of a concurrent running 20 minute period of time? Can you exceed the general limit by more than plus 10 dBA?

It would appear from PGV's present practices that they compute the hourly averages at monitoring sites, and determine if they exceed the limit. They also compute and report the twelve hour averages, but it is not clear why. If they do exceed they see if three or more one minute plus periods of the 20 minute intervals were also exceeded. If not, then an exceed doesn't occur. If an exceed occurs, they then determine what caused it with the assistance of the near source monitor. If it isn't the project (i.e. crickets, rain, etc.), then the incident is not acted upon. The slow dBA maximums and a determination whether they go over the 65 and 55 dBA levels are apparently not reported.

5.3 Regulatory Noise Needs

DOH or Hawaii County should have at least one monitor with shelter and modem access that can be used at a persons home when there appears to be a conflict with the developer. Sound activated tape recorders can also be very useful in some circumstances. Spot checks performed by an agency would add credibility. Site inspections of PGV's effort and periodic comparison of calibrators could also add to the credibility and acceptance of PGV's noise program.

The present noise standards are not likely to be completely acceptable to the community as levels are allowed to exceed those required for sleep and quiet outdoor activity. Open windows are apparently customary in Hawaii and worsen this situation. As the complaint response requirements are intimidating and may not be appropriate for a friendly resolution of the noise complaint(s), especially if in compliance and impossible to mitigate, it may place PGV in a difficult circumstance to resolve. The standards might even be construed as deceitful given the obvious fact that the wording allows a level 10 dBA higher 10% of the time than the 55 and 45 dBA stated as a general noise limitation.

Typically, noise assessments for BACT are not easy. The LCAQMD has completed a study and finalized a report that has been made available to Hawaii agencies. This might serve as a start. If necessary, the Planning Director should seek advise from an independent consultant. This is one area where an ounce of prevention (especially prior to constructing) is worth a ton of control after the fact.

As an example, steamline pressure release valves were observed during the site inspection to be without mufflers and not directed away from residents. They should be muffled and possibly directed to an abatement system to be considered to qualify as BACT. They are designed to respond to emergencies and will sound like a large explosion when ruptured because of an over pressure. This would appear even more important if wellhead shut-in valving must be manually operated to correct this condition.

As a general comment, except for the requirement of BACT, the GRP and monitoring program fails to acknowledge that dBA's determine the level of sound, not noise. Some sounds are extremely irritating, such as brake squeal, and even at low dBA levels mitigation should be applied. While this fact will be essential to incorporate into any successful program, it is not achieved without substantial and careful evaluation of complaints genuinely and sincerely given. Clearly a preventive technology based and not reactive complaint based regulatory program is preferred.

Footnote: People don't complain about noise until they are already angry!

6.0 Uncontrolled Venting of KS-8

6.1 Accident Scenario

The accident or uncontrolled release scenario involves several phases, and while these are not certain, assumptions must be made if the dispersion and ambient measurements are to be evaluated with meaningful hindsight. The Element III Team was to be provided the Element I report but as of 7/17/91 had not received the report. The following is therefore offered as a plausible sequence of events as reconstructed from reports and interviews. Video was provided by the public, but video considered confidential was not viewed nor was evidence taken that should be treated as confidential. The confidence in the scenario is thus lessened and may warrant correction.

The initial release of gas and H2S occurred on 6/12/91,18:49 hrs.; while circulating the bottoms up (drilled material settled on the bottom) after a long period of stationary inactivity. The drilling mud apparently released H2S as a distinct and sharply defined value on the mud measurement equipment (186 ppmv peak). Carbon dioxide emissions also increased and were likely mixed with the H2S. This gas release plume was probably cool, contained heavy gases and would be anticipated to be poorly or non buoyant, and may have been transported intact in light winds. There were several odor complaints from neighbors shortly after, which were probably caused by this release; however, it is unlikely that this release contributed to the high ambient H2S measurements observed later that night. After the initial momentary release, the mud showed only normal levels of CO2, and no H2S release is apparent until the major uncontrolled venting incident.

The more serious incident began at approximately 23:16 hrs. and involved two or possibly three quick initial releases of gases and/or steam that caused considerable damage to the drilling equipment and shook windows of nearby residence. The shock waves have generally been described as explosive and may have been the result of water or mud "hammers" built up in the well bore as gases or vapors evolved. The fluids gained velocity as they were driven to the surface, and compressed the vapor as they encounter a mechanical blockage. They are a common problem dealt with in handling high temperature geothermal fluids.

It is uncertain as to the exact nature of the initial release, but it would appear that a large fracture was encountered capable of producing high temperature flashed steam. Entrance to a void area may account for the observed weight on the drilling hook significantly increasing, and within the next few minutes a recorded 14 foot drop of the Kelly. Drilling mud temperatures and pumping pressures increased then significantly dropped. The gas/vapor release or explosion necessitated the temporary abandonment of the rig. This initial phase, including the described "explosions", are assumed to have contributed little in the way of significant H2S emissions, since the rig deck personnel were reported to have not been acutely exposed to H2S or steam burns. It is not clear any personnel or occupational exposure alarms were activated. The alarms may have been deactivated by the explosion, but even that is not certain. The mud monitoring equipment was believed to have been made nonfunctional after the first "explosion".

This initial "explosive" phase was followed by a continuous release of a plume of saturated steam and water which passed through various points of the rig floor, through the rig structure siding, out the dog house windows and any open or ruptured line communicating with the well bore. The plume rise was estimated at approximately 65 feet. Portions of the plume were redirected downward as it exited the rig deck skirting. The estimated steam flow was 150,000-200,000 lbs/hr. The H2S concentration was not measured, but judging from KS-3 and other nearby well test for flashed steam, 700-900 ppmw is considered a good approximation. Given the concentration and estimated flow rate, an emissions rate of 105 to 180 pounds an hour of H_2S results. PGV estimated 30% of the water content remained in the flashed steam and reported observing a characteristic popping noise likely resulting in evaporative cooling. The release continued without apparent change until approximately 06:00 hrs on 6/13/91.

At approximately 06:00 hrs on 6/13/91 a line relieving pressure from the casing was opened, directing the steam horizontally to the west northwest in a 254° direction with considerable momentum towards the residential areas. The internal diameter of the choke line is 3" (assumed double strength 4" pipe). The choke release height is 66" above pad level. Emissions continued as described previously, though assumed at a reduced rate from the choke or "HCR" line providing a pressure relief. The total well steam emissions are presumed to have increased given the two separate release points with the majority of emissions exiting the choke line. Assuming an approximate 35 foot, 4" double strong pipe (3.1" ID), and a 3" gate valve fully open, the flows were estimated at 370,000 lbs/hr with 1500 PSI well head pressure 119,000 lbs/hr, at 500 PSI. Since flashing and carry over occurred, the flow utilized is 200,000 lbs/hr, though obviously variable. The total steam release is estimated to have increased to 200-250,000 lbs/hr following the inclusion of the choke line. The plume from the choke line was reported to have mixed to the ground as it passed over the pond and under the canopy of nearby papaya trees.

Water was pumped down the drill string reaching the bottom of the hole beginning at 10:30 hrs. on 6/13/91. Venting continued until 04:00 hrs. on 6/14/91 at which time the choke line was closed and water was pumped down the annulus (well casing minus drill string) causing a pressure drop from a reported 1,700 to 900 psi, and significantly reducing emissions. LCM (plugging material) was introduced to the annulus and successfully plugged the escaping steam from around the steel rams and emissions from the well were reported as controlled by 10:00 hrs on 6/14/91. Most emissions ceased as evident from the noise data by 0600-0700 hrs on 6/14/91. Odor complaints continued and were confirmed by DOH•CAB staff. PGV is uncertain as to the occasional small steam releases continuing, or the possibility of a gas cap forming and slowly leaking as gas of possibly high concentration. The last verified odor complaint apparently occurred at 22:15 hrs. on 6/15/91, and can perhaps be explained in Part II of this report as return flow. If not, one must assume emissions from from KS-8 occurred and caused the complaint.

6.2 Field Air Sampling and Noise Monitoring During the Event.

The electrochemical cell alarms and Houston Atlas H_2S analyzer on the drilling site apparently were rendered nonfunctional by the accident and apparently did not sound an alarm. Instantaneous or short term measurements were made by a number of different individuals and compiled by PGV and DOH staff for consideration. They are incorporated by reference and constitute a substantial information base.

The H2S monitoring equipment used included a Color Tech Rotating Head Sampler (DOH), Gas-Tech and Draegar Tubes (DOH & PGV), and a Jerome (PGV) field portable hand held monitor. Of these methods the Jerome 631x, followed by the Draegar and Gas Tech tube methods are most reliable. A degree of darkening determination must be made for the Color Tech's Rotorods after a specified interval of rotation and are judged more difficult to accomplish, especially at night. DOH should plan to convert to a Jerome or similar equipment.

A considerable number of measurements were made in the immediate area by DOH staff. These numbers validate the fact that the stationary air monitoring instruments were not necessarily measuring a worse case at any given time. Unfortunately, the high value measurements recorded on the property and off the project that initiated the evacuation, were not compiled as part of those data sheets.

Questioning of PGV and drilling staff disclosed that several values in the ppmv range were measured. The first values reported, consistent with the Emergency Plan requirement, were directly downwind of the uncontrolled vent off the project site and were the highest reported at 29 & 22 ppmv (29,000 & 22,000 ppbv). These values, reported by a PGV staff member, either resulted in, or confirmed the early decision to evacuate the Lanipuna Estates. Questions were posed as to whether the value was in error, and if it could have possibly been a misread of the display. The PGV staff member who made the measurements stated the second reading was to make sure he had not misread the instrument, and that he had not misplaced the decimal. He appeared to be competent, knowledgeable and capable of properly operating the instrument. He had previously used the instrument. Generally three distinct samples are taken, but the first sample should, if not representative, be lower than the actual number.

On 6/14/91 the instrument was compared to an H2S excursion measured at the Irvine Air Monitoring Station and agreed within 10%. At the time of the site inspection on 7/3/91 it was suggested that a span check be performed, but the instrument had apparently suffered a malfunction, and was to be returned to the manufacturer. No reason to disqualify or discard the numbers generated by the instrument are apparent.

The PGV staff member deserves compliment for acting in a responsible and timely manner consistent with the Emergency Plan in reporting the values. The middle of a potential emergency is the wrong time to doubt an instrument purchased for and used in the manner designated. Subsequent numbers taken by Draeger and Gas Tech methods make the initial high numbers even more plausible. A reading of 20 ppmv was reported adjacent but immediately upwind of the rig, a 5 ppmv value was reported approximately 500 ft downwind measured at 10 am on 6/13/91, and a 2.9 ppmv value was reported as measured at 600 feet downwind at about 11 am on 6/13/91. All occurred after the 29 ppmv measurement taken immediately after the accident. This information would indicate a validity of the higher number based on the lesser dispersion likely to have occurred with the initial release under nighttime conditions.

The use of this Jerome 631x owned by PGV was extensive. From conversations with PGV and DOH staff, and in our experience, it is more likely to produce useful, timely, extensive and accurate data than the other methods utilized. The survey mode is especially appropriate for use in cases of accident investigation to warn the user as well as make measurements. The H2S values collected by the Draegar or Gas-Tech method, can be considered reliable if in the ppm range. They are more characteristically used in the work environment. The Color Tech Rotorod is not advised simply because superior alternatives exist. The sample is an integrated 10 minute or longer sampling and the degree of shading must be judged from a comparison chart subject to operator interpretation.

6.3 Field Noise Monitoring During the Event

The noise monitoring effort was significant and continued throughout the event. There is little disagreement that the legal limits were exceeded by a substantial and continuing amount at all permanent monitoring stations. The reader is referred to the "Puna Geothermal Venture, Noise Monitoring Program, Well Blow Out Data Report, June 1991". The uncontrolled venting noise levels clearly exceeded GRP permit limits by 25 to 35 dBA. Numerous spot measurements were made by a consultant and PGV staff whom surveyed the area and reported similar results demonstrating the widespread noise exceeds. Compliance was re-established after controlling the vent.

6.4 Drift and Emissions Estimates

Results of an analyses of drift reported to be deposited on the windshield of a visitor to the site using EPA method 601 was submitted by a public member and is presented below. Catchment analyses was performed on four homes. Apparently, these are the only samples taken during the event for constituents other than H2S. It should be noted that such sample collection, while of interest, does not establish the deposition rate which is critical to understanding any effects. It may, however, establish the need to consider decontamination cleaning of equipment with significant drift deposits and indicate a need for additional source and ambient testing. Sample collection three weeks later is not viewed as rational, and such was not suggested. The components of the windshield deposit is as follows:

Component	Reported value	Units
Lead	678	ppmw
Nickel	90	ppmw
Chromium	72	ppmw
Manganese	118	ppmw
copper	16.3	ppmw
Zinc	19.2	ppmw
Arsenic	less than	10 ppmw
Iron	6.53	percent
Aluminum	1.56	percent

The catchment samples were taken on the afternoon of 6/13/91 and show no exceeds of drinking water standards, though some components of concern were shown to be present at the Alvarez residence. The data should be compared to future, or if available past, analysis. If the effort was properly designed, and consideration of water volumes, rain, evaporation, etc., were incorporated, these sites might serve as long term recording sites. At the present time it is inappropriate to conclude anything other than the catchment waters met suggested standards on 6/13/91.

6.5 Monitoring And Actions That Should Have Been Considered

No abatement was in place and no apparent or reported attempt to barrier the noise, sample the plume, or redirect the plume was made. Plans for the future should bring these issues forward for consideration promptly once personnel safety issues are addressed. A system should be prepared and valved into place during any future high risk drilling to control noise and air emissions. A cyclone and H2S abatement system as used during air drilling might be appropriate.

There was apparently no drift samples collected by DOH or PGV. This task could have been easily accomplished at established intervals downwind, and would have aided greatly in assessing the potential impact on water catchments and particulate release. No sample of downwind TPSP or PM-10 measurements were made.

The permits require quantification and characterizations of emissions by the permit holder after a malfunction resulting in a 100 ppb exceed. These are apparently not available (see ATC Condition #23) and as of 7/15/91 they have not been provided and are assumed to not exist. The closest located characterized well is KS-3. Test data from it and other nearby wells were obtained from Thermochem which is contracted to PGV for chemical analyses. These analysis are utilized to produce the emissions plume descriptors. There is no assurances that the characteristics of KS-7 or KS-8 is similar, and in fact given the reported 30 ppmv values for H2S on the rig deck during the KS-7 "gas kick", they may be significantly different. The evaluation of drift deposited on the windshield from the plume of KS-8 would indicate such is the case.

6.6 Emissions Estimates of Trace Components

The following concentrations were utilized as estimators for potential impacts and are based largely on well KS-3 and KS-1A simply because that was the only data provided for close proximity wells. Additional data may be available but has not been provided. A steam condensate analysis for well KS-3 was performed by Utah Research Institute on 3/30/91 and provided on 7/15/91. Sampling methods did not detail if a complete steam analysis was accomplished but a verbal check and review of the results indicate a simple analysis of condensate. Ion closure was not apparent. Values were reported as non detectable except for salt components. It appears that the analysis required by ATC Condition #20 have not been completed and significant portions of constituents largely ignored from an analytical chemistry perspective. The possibility of using HGP-A data was suggested, but judged inappropriate as the resource is somewhat removed. The issue of brine occlusion and drift carry through in the absence of flashed steam passing through a sèparator is difficult to ascertain (it is estimated a 30% carry through occurred). The constituent contaminants entering the flashed steam depends significantly on the dynamics of the flash and water droplet removal process, especially if down hole flashing is occurring. A conservative approach would be to use the brine numbers directly, or at 30% although emissions level estimates would be biased high.

Component	Lower	Upper	Units
hydrogen sulfide	493	1200	ppmw
ammonia	0.168	1.49	ppmw
arsenic	unreported	unreported	
lead	unreported	unreported	
cadmium	unreported	unreported	
chlorides	unreported	unreported	
boron	unreported	unreported	
mercury	unreported	unreported	
ph	unreported	unreported	
Total Dissolved Solids	unreported	unreported	
Total Suspended Solids	unreported	unreported	
nickel (not required)	unreported	unreported	
chrome (not required)	unreported	unreported	
	unreported	unreported	

The only data that appeared relevant and could possibly be used to determine components of flashed steam were for KS-1A total brine and post flash brine. Mass balancing using the reported 0.7989 flash fraction is shown below. The data does not appear to be useful since the computed values are likely within the analysis error.

Component	Post Flash	Total Brine	Steam, ppmw
Arsenic	0.49	0.1	0.00182876
Mercury	0.0017	0.0003	-5.241E-05
Boron	8.43	1.7	0.00591689
Silica	1170	235.27	-0.0212793
Aluminum	<2.50	<.50	na
Barium	32.3	6.5	0.00559519
Manganese	8.13	1.63	-0.0061873
Chloride	18500	3720.06	-0.3629991
Fluoride	0.91	0.18	-0.0037564
Sulfate	14.2	2.86	0.00548254
Total Dissolved Solids	33100	6655.89	-0.650895

After some dicussion and analysis, it was determined a valid characterization could not be provided, but is dependent upon the nature of volatilization and carry through. Therefore in Part II of this report emissions are assumed to be 100% of those of brine provided in the ATC application.

The reader is refered to Part II of this report for an estimation of brine content based upon the PGV application provided information, and estimates of possible impact.

6.7 Event Evaluation & Recommendations; an Air Quality Perspective

The accident was not anticipated nor acknowledged until underway. Abatement technology to control emissions was not in place. Management and analytical characterization of emissions was not available. This limited the assessment of impact potential. Field measurements were not correlated to emissions or the configuration characteristics of the release as the accident continued. Estimation of emissions did not occur though venting continued for a substantial period of time. The accident happened during a least desirable time of the day to handle an emergency.

In forecasting and detecting the event, it is apparent the failure of down hole temperature probes, the earlier gas release of H2S resulting in complaints, and the lost circulation should help warn operators of risk in the future. It may be practical to improve the mud logging gas detector(s) response time by adding a second but less sensitive detector or Jerome type sensor with a quicker response time to the mud monitoring operation. Presently, the configuration and instrument have a delay of several minutes. Relocating the mud sampling device (versus sample transport through a sample line) is an alternative. A second readout device could also be displayed on the rig deck. Drilling slower and circulating more mud when near suspect depth, paying attention to bottoms-up characteristic and carefully monitoring the heat load and volume changes of the mud (this is done at present) are obviously appropriate, given hindsight. The issue would be how slow to drill, and to take steps that maximize the response speed. It may be appropriate to look for mud components (i.e. high chloride) characteristic of geothermal brines, or other gases that might be occluded into the mud and not necessarily be released or detected. If a high pressure entry appears likely, appropriate parties should be notified and placed on alert and continued drilling delayed to reasonable daylight hours.

If an accident or pressure release occurs, it would be desirable to be prepared to characterize the emissions as soon as practical. The on site Ex-Log (Tectonic) staff are generally capable of doing this for H2S and should be assigned the task with possible assistance of other staff. A direct in-steam sample probe might be necessary and should be prepared ahead of time. Samples should also be collected for other components such as drift and particulate. Analysis should be repeated as frequently as practical and necessary to track the venting steam characteristics. An estimate of emissions release point height and total release would be necessary, and could be made from visual inspection, well head pressure (if necessary it can be estimated from the temperature using steam tables) and the size of vent(s). This information should be provided to the emergency or event managers whom can with this information and existing real time meteorological data, utilize mathematical models to anticipate the worse case plume path and probable concentrations. Field staff can be directed to these areas to establish the validity of predictions through monitoring and to visually observe downwind locations and areas generating public complaint.

Air pollution control technology to treat an uncontrolled or forced-release should be required to be in place and operational prior to drilling in areas at depths suspect of behaving like KS-8. This could include valved in large capacity pressure relieve valves, H2S abatement capability, wet cyclones for particulate removal and noise mitigation, and possibly even a large capacity muffler or stack. A typical system is shown in Figure 2, which also utilizes hydrogen peroxide to oxidize and stabilize H2S. These need to have the capability of being promptly or automatically activated. The system should have an overcapacity, be directed in the best direction and sampling ports built in at appropriate locations to allow determination of emissions. Consideration of removing the ATC limitation on air drilling should also be evaluated if the developer believes that method to be safer, and perhaps more capable of controlled drilling. The practice of allowing short term uncontrolled venting (7 minutes, per ATC) needs to be evaluated as to possibility of appropriate concern for loosing control of such venting and rather abatement is in place to mitigate.

During the site inspection, a review of the records and interviews with staff, the quantifying and considering of the above factors was always a secondary objective. This is really the only way to protect the public. No amount of monitoring, after the fact analysis, or good intention will improve the air quality without the preventive steps to avoid, control as necessary and manage temporary emissions.

6.8 Interaction with Emergency Response

PGV staff and agency staff did act responsibly in implementing the Emergency Response Plan, which is the subject of Element II. PGV and their staff member whom acted promptly and reported the first high values displayed a commitment to the protection of the public. This was apparent from the joint committee on Element II meeting attended.

It is clear that you can not put enough permanent air monitoring stations in the community or deploy sufficient field monitoring equipment to measure pollutants at the time of a large air emissions release to represent "worse case" which will tell you, with certainty under all possible conditions, when to evacuate without the considerable risk of being too late, in error, or without an adequate safety margin. It is for this reason that emergency responders also need to consider personal H2S safety alarm needs.

Monitors such as the Jerome, which can measure over a wide range and also act as a personal warning system (in survey mode), are best suited for field measurements in suspected high and low value areas. The use of mathematical models as noted above, can be automated with modern meteorological systems, but this type of system must be in place prior to any accident. If an accident and event continues for an extended period of time, as the subject one did, such tools can prove invaluable. The compliance and community air monitoring system can greatly assist in making and confirming decisions and impacts, but only if emissions data is also available or they happen to be in the worse case location.

When developing a new resource and technology there simply are no guarantees, and to offer such is to raise skepticism in a careful person. A good healthy dose of such skepticism for DOH staff would be appropriate for this project at this point. The drilling safety, blow out prevention and well integrity issues should properly be the responsibility of agencies which specialize in the area, or a third party (with adequate bonding and insurance) should be utilized to assess developer procedures and plans.

7.0 DOH Authority to Construct Permit No. A-833

It was agreed prior to the initiation of this independent investigative effort that a permit review could not be accomplished in more than a precursory manner, and would need substantial more time than available at present to complete. The summary below is mostly relevant only to the specific uncontrolled venting accident of 6/12/91/ to 6/14/91 and should not be considered complete or relevant to the many required performance criteria, plans, notifications, etc. The site was visited on the afternoon of 7/2/91 with DOH staff and again on 7/4/91.

The most relevant permit conditions are as follows. Condition #23 was implemented when the stations measured H2S above 100 ppbv for an hour average. Similarly if the uncontrolled venting is considered a blowout, Condition #26 applies regardless of impact. Both conditions require a report within five days that is to include "the estimated project emissions". Condition #13 has a similar requirement for well equipment failure. Condition #17 has a similar requirement for "each steam release incident" or "inadvertent release". To date this estimate has not been provided the investigative team, and was not available for the emergency planning. The level of contamination and net emissions from the source would have greatly assisted the emergency response, and should have been available in a competent manner as soon as possible. Emission estimates were also requested by this investigation for the KS-7 gas kick, but have not been provided. This lack of apparent source testing and emissions characterization makes it difficult to manage and greatly lessens the ability to learn from such accidents. The limitations placed on the emissions sources must ensure the ambient goals under worst case. Figure 1 utilized to explain the LCAQMD program explains in a simplistic manner the necessary components of a regulatory system. The permit at several points is confused by differing ambient goals under different operational or breakdown scenarios (i.e., the standard of performance is 5 ppb, a 25 ppb increment, or 100 ppb). There is an obvious attempt to make the permit BACT driven, but goals appear to be set to accommodate potential problems the developer may encounter, and not to achieve defined ambient air goals.

Per Condition #23 the drilling is to proceed only "after the permittee has demonstrated to the Department of Health that contributions from the well ... will not result in or contribute to the exceed hydrogen sulfide ambient concentration of 100 ppbv". This latter requirement is a substantial obligation and one that is unlikely to be made with great certainty. Clearly it calls for mitigation to control or avoid repeats of the subject uncontrolled venting. Condition #23 goes on to state notifications can not constitute a defense to violations.

Condition #13 requires "During well equipment failure or malfunction which result in hydrogen sulfide emissions, the permittee shall apply best available control technology, etc. It is not clear that the well equipment for Condition #13 purposes, also means during drilling. The electrochemical cell referenced for flow testing results were not available and it is not clear it has been or is practical to be utilized. If in fact they were available and deemed accurate, they should have been used to help quantify the uncontrolled venting emissions. The LCAQMD experiences with such devices has been negative in nature, and would warn that such results may be unreliable.

Condition #17 has several other requirements such as increasing the weight of mud, shutting in the well, limiting emissions to five (5.0) pounds per hour, no more than seven (7) minutes of venting, and "In no case shall air drilling be used". The 5 lb/hr emissions rate needs to be clarified as to whether it is an instantaneous rate or the two combined allow a "42 lb/hr instantaneous rate" or greater provided it does not continue for more than 7 minutes. The air drilling restriction may be counterproductive in the event the resource is different than expected. The removal of this restriction should be considered. Though it makes for more expense and difficult management, it may be the safest manner in which to proceed.

Condition #5 requires an ambient monitoring program that has been implement-ed, and is the focus of this report.

Condition #20 requires the very kind of information needed for power plant and well field environmental design considerations and to help estimate emissions as was desired in this case. Unfortunately, there is no specified time to perform or submit the data from the tests, and tests apparently have not been performed to date. The condition should be modified to be accomplished during initial well venting (clean out with no separator) and again during separation and flash testing. Given the high chloride content in the resource, tests should include gas phase HCL and possibly HF. Other constituents of concern should be considered as information develops on the character of the resource. Tests should be carefully thought out and performed using geothermal resource sampling techniques and analysis (not wastewater). Chemical characterization of the resource is critical at the earliest possible time to assist in ensuring that plant and emissions control equipment reliability is not going to be adversely effected by any unexpected constituent(s), and that unexpected emissions of concern not go unquantified. A very high temperature versus low temperature flash resource should initiate such careful review.

DOH staff should review circumstances and decisions as information is made available to assist in anticipating problems and in determining appropriate permit to operate conditions. Frequent and or long term stacking, if necessary because of reliability problems, will create air quality and project cost problems. The claimed BACT efficiency of the present stacking control for H2S and particulate removal (including injected NaOH) needs to be substantiated prior to need, by testing under good dispersion. It is likely the sunken location will present some unique plume characteristics. The effects of allowing direct infiltration of alkaline scrub solution laden with dissolved H2S needs to be evaluated. Especially given the fact that acidification of the waste stream will release H2S and such might be confused with background or geogenic H2S in the future. It appears that little need for the facility is anticipated, but only experience will determine this need and a careful update is appropriate.

The peak values of H2S are commonly five times the hourly average during the uncontrolled venting. People smell and commonly respond to peak or short term values. The closer the proximity the greater the maximum exposures are likely to be, and the worse the already intolerable AAQS of 100 ppbv will be considered by those exposed. This issue is especially relevant to Condition #17. More careful consideration in light of the complaints received should be given to lowering this limit, determining what technology to mitigate is available and possibly establishing a shorter term standard.

The number of reports and notices required per well is quite large and may serve to further enlighten as to compliance. They are listed below for further reference and should be evaluated as to whether they have been filed and contain useful information. It was beyond the scope of this effort to accomplish such a task.

Special Condition 2
- notification prior to construction

Special Condition 5
- siting plan for required air quality and met station(s)

- in the event of a one hour average H2S concentration greater than 25 ppb (above background) and 100 ppb (including background) Hilo Dist. Health Office also notified
- monthly air quality and met summaries
- annual electronic file (2 copies) for air quality and met data

Condition 7

- 2 days prior to aerated mud drilling
- 2 days prior to aerated water drilling
- 2 days prior to well venting
- 2 days prior to flow testing operations, and
- 2 days after completion of aerated mud drilling
- 2 days after completion of aerated water drilling
- 2 days after completion of well venting
- 2 days after completion of flow testing operations

Special Condition 9

- request to flare excess gas
- post event flaring report

Special Condition 13

- notification if abated H2S rate is 5 lbs/hr or more (flow testing)
- notification (immediate) of equipment malfunction/failure
- post event report within 5 days

Condition 15

- Daily reports on H2S upstream, NaOH injection rates, and H2S concentration and emission rates downstream during flow testing

Special Condition 17

- in the event of inadvertent steam releases during well drilling of more than 7 min/hr or H2S emissions of 5 lbs/hr or more

Condition 18

- chemical abatement plan prior to flow testing

Condition 19

- upon release of any toxic emissions into the ambient air (as mitigation)

Special Condition 21

- diesel usage (by engine and well) at completion of well
- certification of fuel injection timing adjustment (retard) for three diesel engines used for rig no. 2, prior to startup

Special Condition 22

- 2 day written in advance of unabated well venting
- Public notification (newspaper notice) 24 hrs in advance
- Residents within 3500 ft. notified 24 hrs in advance

Special Condition 23

- upon exceeding 100 ppb (one hour average) H2S ambient level
- post event report within 5 days

Condition 26
- upon well blowout
- post event report within 5 days
- weekly report - if a continued blowout

Special Condition 28
- H2S hourly average for monitoring data >25 ppb (above background) Hilo Dist. Health Office also notified

Attachment I-7
- upon completion of construction or installation of any equipment covered by the A/C

Normal operations for implementation of the 5 ppb increment needs to be defined with certainty. Does this include stacking emissions should the plant have long term operational problems? As presently worded, it may encourage venting just to keep the limitation from being enforceable.

Review of the plant and well field components reliability in view of any significant changes in resource temperature, chemical characteristic, etc., and the likelihood that reliability will be affected should be carried out.

Drift and trace materials are measured in Lake County even now that they are largely controlled and very low, just to alleviate public concern and verify emission assumptions and measurements. Such a program should be considered for inclusion in Hawaii. Drift needs to be characterized for accidental and controlled vents. This includes clean outs, and future stacking relative to possible effects on catchments and vegetation. This monitoring would compliment the existing H2S program and might also utilize PIXE or Dicot/XRF analysis of repairable particulate.

Meaningful source tests need to be performed and comparative results established for BACT decisions as published for stacking mufflers, and other components. These appear to be inconsistent with LCAQMD experience and the anticipated abatement needs to be tested as soon as practical by properly conducting source tests. The gas reinjection system is nearly identical to that used at Coso Hot Springs, which did not operate as hoped, and is now on a variance allowing two hundred and fifty (250) pounds per hour emissions.

8.0 Public Members, Comments and Questions Offered

The most common statement was that this (the accident) must not happen again. Clearly the public feels threatened by the event and the potential for reoccurrence. The belief that they have been ignored was common near the project area, and across the board all felt that the health effects issue was being ignored. Conversations with DOH and the Pahoa Homeowners association members lead to the recognized need to investigate and correlate complaints with technical dispersion information. This is addressed in Part II of this report. An attempt has been initiated that should be carried on. The data is unique and can add much to our knowledge about air pollution and H2S exposure.

It was also noted that reported effects sometimes given in response to a complaint and even the effects table for H2S indicates a less severe effect and mortal danger at higher levels than is more commonly accepted. For example, compare the PGV application with the DOH news release of 6/13/91. A fireman compared the numbers with a nationally distributed database, and asked if some people were more sensitive and what the effects were on infants. Obviously, these are real concerns that are only worsened when information conflicts. In reality, it is clear no one should be exposed to levels even approaching the higher levels generally quoted, and the fact that they will not be needs to be made completely believable.

The following questions and comments were also commonly expressed. How would this matter have faired if it had been on the E or HGPA pad sites? How close is too close. At times it is simply easier to just buy property or replace systems than mitigate against expected accidents! Nuisance easement or purchase of homes should be a possibility! Why aren't other toxic components measured? The state is just doing what the developer proposes in writing permits! It is obvious that public questions and emotions still need to be addressed.

Working on a common need can help turn the public into a resource instead of an adversary, by including them in reacting in a positive manner to an adverse situation. The need for community involvement, assurance and empowerment will be greater than ever if they are to accept the project as a neighbor. Obvious concern exists over future development, and if this could be better quantified it might lessen anxiety. The people are a real resource and their energy and concern must be directed to positive change.

Emergency Plan: The stationary air monitoring network can and should be used to assist emergency management decision making, but not as the primary criteria in the absence of reasonable worse case/location information.

Some people are convinced that there is a master plan and they have no possibility of influencing decisions unless they act irrational.

Conclusions Air

1. The plume release characteristics and quantity of H2S were more severe than assumed plausible in the existing worst case blowout scenario incorporated

into the facility permitting. Impacts were worsened by the nature of the uncontrolled release and the directing of the high velocity release plume through a pipe and valve setup in a horizontal direction toward the nearby residential area. Monitoring of noise and air was extensive.

2. A high of 29,000 ppbv (29 ppmv) was measured off the development property and reported. Additional measurements on the drill pad and approximately 500-600 ft downwind of the plume confirm the likelihood of this high value which initiated evacuation. Ambient stations recorded several excursions above the 100 ppbv level. Some air monitoring stations did not completely respond to H2S excursions.

3. A variety of methods were used to take measurements by several different parties. Not all of this data appears to have been compiled to date into one report. The higher values were not included in the data provided by DOH.

4. The existing stationary air monitoring network in place at the time of the accident was extensive for H2S. A total of seven (7) Pulse Fluorescence Detector (TECO and Monitor Lab) instruments were operational for the detection of H2S within a few miles (see map A). Only three meteorological monitoring stations were in place. A meteorological monitoring station established by PGV's predecessor was operated adjacent to the drill site until 6/12/91. However, the data was not audited or reported. This is really quite a wealth of exposure effects and monitoring information for air agency review. The health survey information provided by the public needs to be evaluated extensively, and the permit standards considered.

5. Minor maintenance and quality assurance problems exist at all of the air monitoring stations. These problems are more severe for DOH operated stations. With the exception of sample line condensation problems at the DOH•CAB stations, it is unlikely that the reported values are markedly different or lower than actual ambient H2S levels that occurred. The SE station manifold is dirty enough and has an oil film that could reduce reported values. The need for zero stability and calibration for H2S at low concentrations is great for the desired accuracy referenced in ATC permits.

6. No measurements of ambient drift, trace metal particulate, total particulate or gases other than H2S have been made by DOH or PGV.

7. No source tests to characterize the incident vented steam content of H2S, salts, particulate or trace toxics were made.

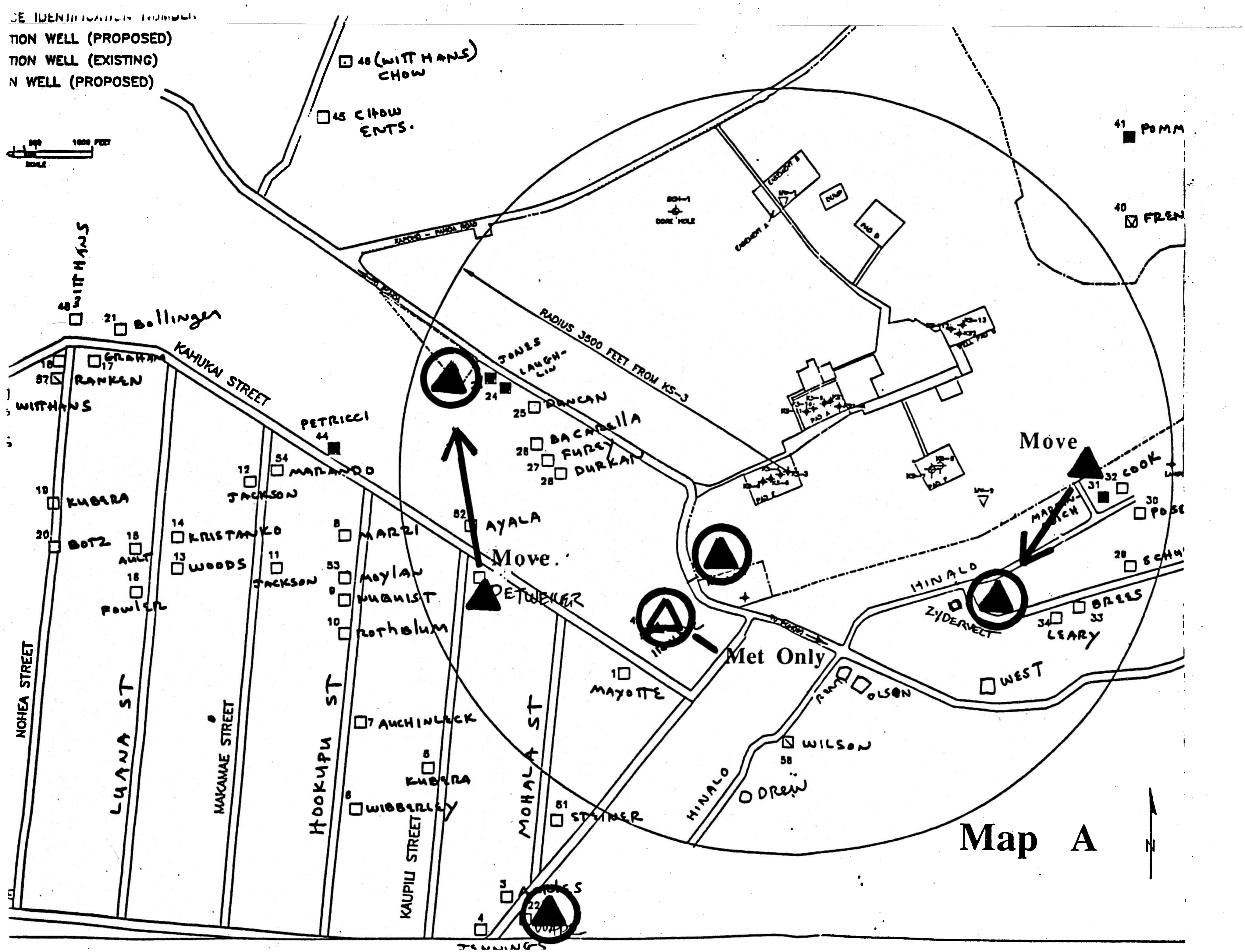
8. No attempt to abate air emissions or mitigate noise were made during the uncontrolled venting, other than to regain control and stop the venting. A high pH mud and water was reported to be used when trying to control the well that adds some abatement potential.

9. Health and nuisance complaints were made at a variety of locations to several agencies/parties. These have not yet been compiled into one report or the validity of the complaints completely investigated.

10. Resource characterizations required by the ATC permit for tested wells do not appear to have been completed to date or the data could not be provided this investigative team. The actual level and quantity of H2S and other emissions can only be estimated.
11. No quality audits of the SAIC stations by DOH have been performed or are planned. SAIC is under contract to PGV/OEIS not DOH.
12. No formal sharing of quality assurance or audit functions by the three entities performing air monitoring occurs.
13. A distrust exists between the various effected parties and government. The term at "war" was used. All parties need to get together to facilitate good management when an undesirable circumstance occurs. No one wanted, or should be willing to accept this accident as a continuing type of occurance, or desire to avoid remedying. This circumstance, in this investigators opinion, is a result of a lack or perceived lack of any major role played by DOH in resolving complaints, ensuring abatement and performing verification of permit compliance. The perception is not equitable to DOH and needs to be corrected. The permits also are in need of improvement. PGV operates and responds to most complaints in a process that would generally be considered somewhat intimidating. In short, some of the public doubt DOH is looking after their best interest when issuing or enforcing permits, and are concerned about bad politics, the unknown and additional perceived problems at the facility. The uncontrolled venting has heightened this concern and anxiety.
14. Any distrust of the public and policy makers will increase as the public learns the one hour 100 ppbv limit is unacceptable and that their complaints have commonly resulted at levels far below the value.
15. The close proximity of many residents heightens the potential for a high exposure occurring and going unmeasured. It is unlikely a warning can be provided for a massive and sudden release unless they are incorporated into the drilling program warning system directly.
16. Peak levels of H2S were commonly four to eight fold that of hourly averages measured (reported on clock hours).
17. Telephone modem access exist at SAIC operated stations, but is not utilized by DOH. Modem access to DOH stations is not in place, but could reasonably be added. DOH stations should use the CAB data logger with modem.
18. Source tests and characterization need to be completed promptly, including for such items as HCL and other corrosive materials.
19. The cellars are dangerous to the workers, and could add difficulty to any repair necessary. The need for them for volcanic lava flows should be carefully considered against risks. Someone is going to get hurt if an H2S head gas leaks through a valve, or they are in the cellar when an unintentional steam release occurs.

Conclusions Noise

1. During the uncontrolled venting, noise levels clearly exceeded GRP permit limits by 25 to 35 dBA. Numerous spot measurements were made by a consultant and demonstrated the widespread noise exceeds. Similarly PGV staff surveyed the area and reported similar results. Compliance was quickly re-established after controlling the vent.
2. PGV has three permanent and one mobile continuous noise monitoring station, one hand held unit used by PGV staff for complaint evaluation and one that is reportedly loaned to the public. The equipment is modern (Quest Model 2700 or 2800), and reasonably deployable to determine compliance with the GRP condition #21. The single ended open pipe microphone housing utilized is intended to be somewhat directional and provide protection from the elements; however, it can also be expected to exaggerate the effect of the rain, wind, and insects if they enter or fall on the steel chamber. It also excludes to some degree non project noise.
3. The limit incorporated into the GRP is cumbersome and could even be considered misleading. The levels allowed at night are known to interfere with sleep and daytime levels can interfere with speech. The permit condition uses uncustomary verbiage, and it would be difficult to establish compliance or violations with presently reported data.
4. The project noise is often the dominant noise in the area, though rain, wind, insects, and residential neighborhood noises dominate and/or contribute significantly to the noise levels measured at times.
5. Considerable SAIC/PGV staff effort is expended on the noise monitoring program, which is designed to isolate project contribution at times of complaints or exceeds. A complaint line and protocol of operation exists that would be intimidating to anyone whom is not an aggressive person or pushed to the point of being angry. It appears SAIC/PGV procedures do not measure L_{10}'s as required by the permit, and if automated measurement of such is not possible with the Quests monitors needs to be resolved.
6. DOH and Hawaii County has available a hand held B&K, but their involvement in evaluations of compliance or responding to complaints appears to be inconsistent. DOH's involvement is limited since the state ordinance applies only on the island of Oahu. Hawaii County responds to the complaints as required in the issued GRP.
7. Hand held monitors are unlikely to be able to easily determine compliance or a lack of such unless the maximums are exceeded, or part A of GRP Condition #24 is applicable in the absence of impact noises.
8. The direct drive drilling rigs are not normally considered BACT in Lake County, however the extent of noise mitigation is impressive to the point of perhaps qualifying as BACT. Unfortunately, the extent the rig must be enclosed to achieve noise goals must be evaluated from a drilling staff safety perspective.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41 POMM
40 FREN
21 Bollinger
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KUBARA
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AULT
FOWLER
KRISTANKO
WOODS
JACKSON
MARANDO
PETRICCI
JONES
LAUGHLIN
DUNCAN
BACARELLA
FUREY
DURKAI
AYALA
MARZI
MOYLAN
NUQUIST
ROTHBLUM
DETWEILER
AUCHINLECK
KUBARA
WIBBERLEY
STEINER
MAYOTTE
COOK
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SCHM
BREES
LEARY
ZYDERVELT
WEST
OLSON
WILSON
DREW

Map A

FIGURE 1

FUNCTIONS OF AN AIR QUALITY MANAGEMENT DISTRICT

The Lake County Air Quality Management District and other air districts in the state are charged with maintaining an effective air pollution control program to protect public health and welfare and thus ensure the enjoyment of the physical environment in which we live. Such a program must incorporate a method to attain and maintain air quality standards, abate public nuisance and health hazards present in the ambient air, and be responsive to nuisance complaints from citizenry. Minimum ambient air quality standards are set by the federal and state governments, and implementation plans have been enacted in all districts (generally consisting of rules and regulations) to attain and maintain air quality within these standards.

For even the most simplistic air quality control program there are several essential components. These include:

1. Establish a goal (ambient air quality standard);
2. Monitoring of the air (decide if the goal has been reached);
3. Determine the source of air pollutants (emission inventory);
4. Develop a control strategy (adopt rules and regulations);
5. Enforce control strategy (ensure compliance with adopted rules and regulations).

These activities are not independant of each other but are links in a chain; when one is nonexistant an effective control program will not exist. The ambient air quality standard is the most crucial parameter and determines the need for the other components. These components are presented graphically below.

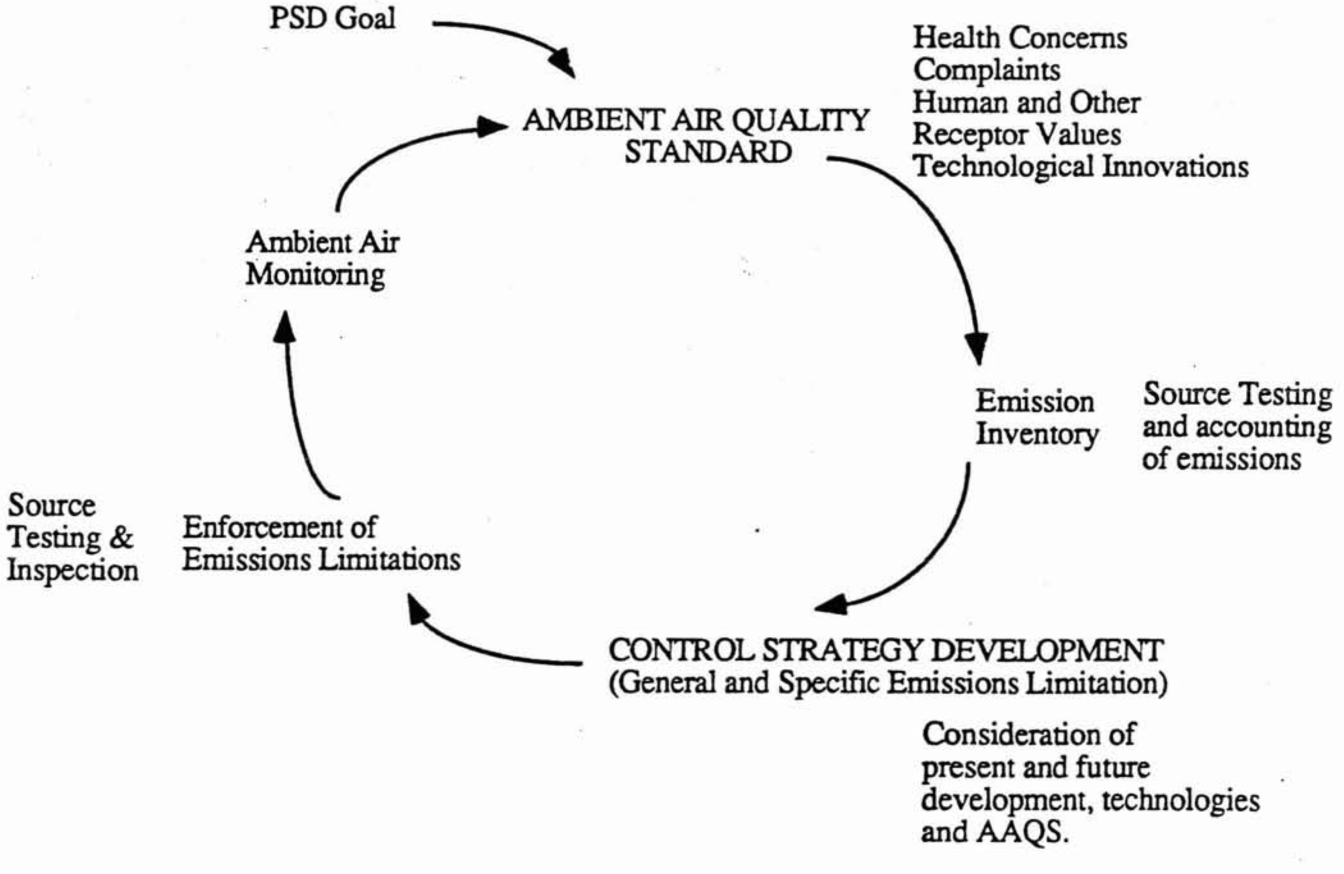
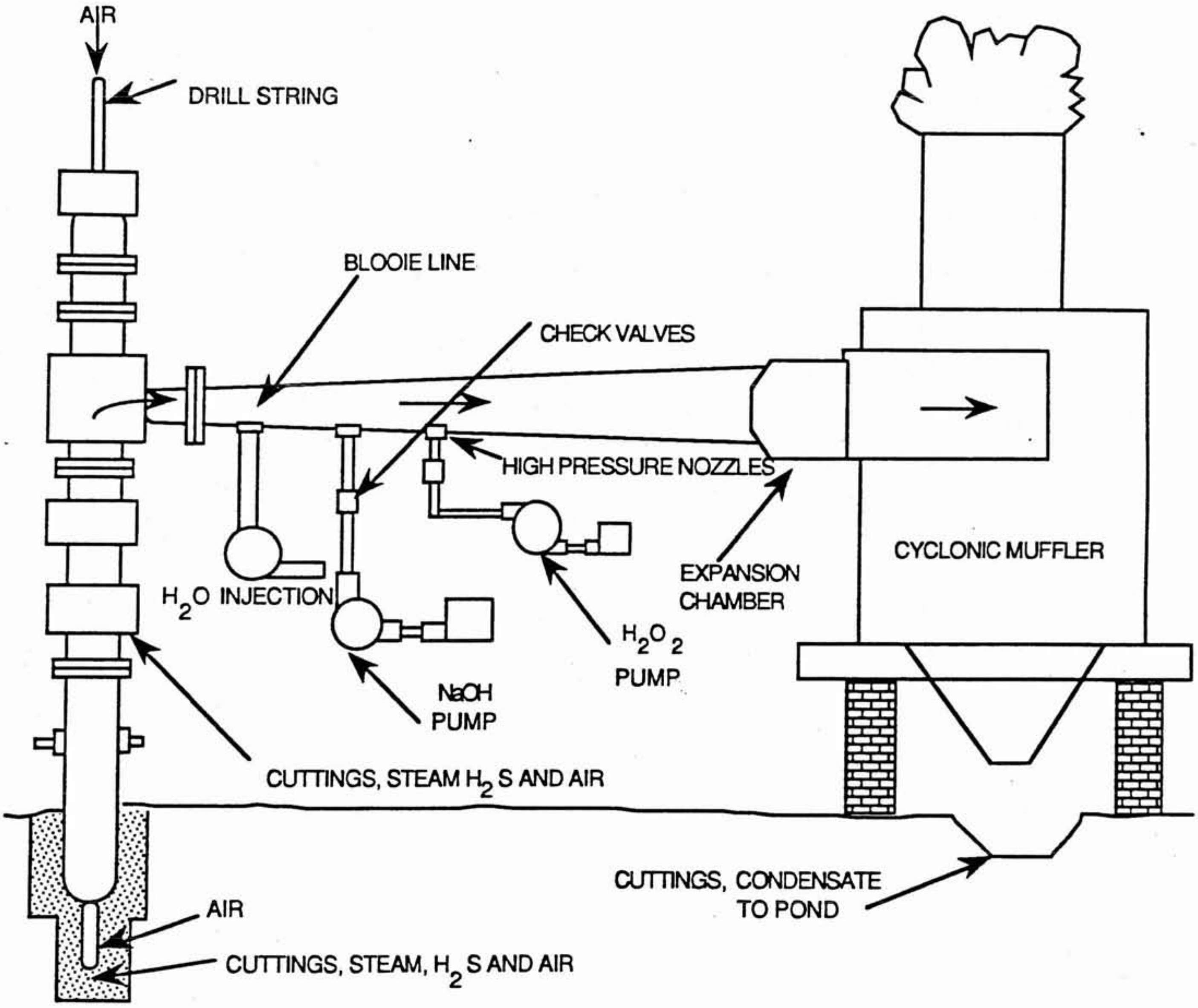


FIGURE 2



A TYPICAL GEOTHERMAL DRILLNG/MUFFLER SET-UP

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