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"AIR QUALITY AS THE LIMITING FACTOR ON DEVELOPMENT OF THE GEYSERS GEOTHERMAL RESOURCES"

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Executive Summary

An air quality problem exists at the Geysers California as a result of hydrogen sulfide (H_2S) emissions from geothermal power generation. In this report the policy and legal issues engulfing the air quality problem and efforts to mitigate the problem are examined. Estimates are made of the air quality impacts of future generation capacity based on utility electricity supply plans as submitted to California Energy Commission (CEC). The status of current and developing H_2S abatement technologies is examined for availability and technical characteristics. Analysis is provided on the prospect and consequences of inadequate control of H_2S emissions H_2S control efficiencies of less than 95 percent may ultimately be ineffective if full field development is to be achieved at the Geysers.

Introduction

Geothermal energy, although not benign, is a desirable alternative to dependency upon other finite and relatively more environmentally harmful power generation cycles. It is the "preferred" source of the CEC for the generation of electric power but H_2S emissions have caused air quality problems.

The Geysers Known Geothermal Resource Area (KGRA) has been estimated by the Jet Propulsion Laboratories to have a full field potential electric generation capacity of approximately 6200 MW.[1] To date 502 MW (11 Units) of generation capacity has been installed by Pacific Gas and Electric Company (PG&E) and planned expansion has been slowed by H_2S problems.

Hydrogen sulfide is a noncondensible gas, usually associated with geothermal steam, which has a distinct, powerful odor affecting humans at levels of approximately .02 or .03 ppm (the latter figure being the California Ambient Air Quality Standard). Loss of the sense of smell can occur at about .06 ppm with eye irritation and fatigue resulting at H_2S levels of .06-.07 ppm.[2] Respiratory irritation from H_2S begins after one hour of exposure to levels of 100-200 ppm and death occurs at 600-900 ppm.

Emissions and Air Quality Impacts

Measurements of the net H_2S emission from the 11 units at the Geysers have been made by the North Sonoma County Air Pollution Control District (APCD). In September 1977, a total of 1174 lb/hr of H_2S was emitted by the power plants.[3] The use of H_2S abatement equipment, which had only been retrofit on three units at the time the measurements were taken, has proven undependable. These iron catalyst H_2S control systems have been only 40 to 70 percent effective at reducing H_2S emissions at full scale operation.

Calculations and estimates of H_2S emmissions from other geothermal developmental activities were also made and nonpower plant sources of H_2S (including well drilling, testing, well bleeds, a currently uncontrolled well, pipeline vents and natural fumerals) were estimated to emit 63 lbs/hr. Currently, about 1237 lb/hr H_2S is emitted to the atmosphere from geothermal development at the Geysers.

The meterological and topographical conditions of the Geysers region are such that it is extremely difficult to directly correlate H_2S emissions from the power plant and air quality impacts. The general pattern has been for H_2S

emissions released at the Geysers in Sonoma County to be transported to and affect the populated areas of Lake County a few miles downwind to the east.[4]

Prevailing meteorological conditions combined with the complexity of the local mountainous terrain result in violations of the California ambient air quality standard for H_2S (.03 ppm) in Lake County. During the one-year period from October 1976 to September 1977 hourly average hydrogen sulfide levels equal to or in excess of .03 ppm were measured 1092 times by the eight station air quality monitoring network maintained in the area by Stanford Research Institute.[5] The California Air Resources Board (ARB) estimates that it is necessary to reduce H_2S emissions by a factor of three (to about 391 lb/hr) for attainment of the air quality standard.

The Legal Framework

The Warren-Alquist Act of 1974 (AB 1575) placed the ultimate permitting responsibility for thermal power plants in California with the CEC. This means that future geothermal power plants (beginning with Unit #17) will go through the CEC Notice of Intent/Application for Certification (NOI/AFC) screening process.

The stated Commission policy is to consider geothermal as a "preferred" source for meeting electricity supply.[6] Policy and guidance, intended to maximize the use of geothermal resources, and to support the rapid expansion of geothermal power production was adopted by the Commission on March 22, 1978 in its Geothermal Policy Report, Recommendations for a Geothermal Resource Development and Power Plant Siting Program. The policy and procedures called for in this report are now being implemented in current regulatory cases. Through interagency action (CEC, ARB, North Sonoma County APCD and Lake County APCD) it is anticipated that existing and future H_2S air quality problems, as well as the

legal requirements and needs of each agency, can be satisfied in the Commission's common regulatory forum.

The ARB in response to the Federal Clean Air Act has drafted "model" New Source Review (NSR) regulations and requires that all APCD's in California adopt similar regulations.[7] These regulations ensure that a new stationary source for which an air quality permit is issued shall not prevent or interfere with the attainment or maintenance of any appliable air quality standard. Both national and state air quality standards are required to be considered by the ARB guidelines. Lake and North Sonoma County APCD's have adopted an NSR regulation in response to the guidelines established by ARB.

Both the ARB and the North Sonoma County APCD are presently proposing regulations to further restrict H_2S emissions from existing and future geothermal development. In proposed amendments the North Sonoma County APCD regulations would require that existing geothermal power plant units emit no more than 350 lb/hr or 290 lb/hr of hydrogen sulfide (to be determined by the district).[8] Also, any unit constructed after January 1, 1978, shall emit no more than: (a) three percent of the H_2S produced by that units steam; or (b) 0.1 lb. H_2S/hr/MW to the atmosphere; or (c) 10 lbs/hr to the atmosphere; or (d) a level which is feasible by the use of best available control technology (BACT). The proposed North Sonoma County APCD regulations will also place restrictions on non-power plant sources of H_2S.

ARB has held public workshops and has collected background information in order to draft model air pollution regulations for H_2S from geothermal operations.[9] The ARB staff report and recommendations are expected to be presented to the full board in April 1978. A summary of the ARB proposed model rules to control H_2S is presented in Table 1.

Table 1 ARB PROPOSED MODEL RULE ON H_2S*
CONTROL STRATEGY

YEAR		CONDITIONS TO BE MET	APPROXIMATE DEGREE OF CONTROL
1979	1.	Power plant units number 3, 4, 5, 6, 11, and 12 to emit no more than 200 gm H_2S/MWH (.44 lb/MWH).	90
	2.	Power plant units equipped with surface condensers to emit no more than 175 gm H_2S/MWH (.39 lb/MWH).	85
1980	1.	Power plant units equipped with surface condensers to emit no more than 100 gm H_2S/MWH (.22 lb. MWH).	90
	2.	All power plant units constructed or commencing construction during 1980 shall emit no more than 100 gm H_2S/MWH (.22 lb/MWH) when completed.	90
	3.	H_2S emissions resulting from "stacking" operations shall be reduced by 65 % (from levels associated with unabated steamflow) within 30 minutes.	65
	4.	H_2S emissions from drilling operations shall not exceed 5 kg/hr (11/lb hr) for every 1000 MW of electrical power generated.	60-90
1982	1.	The uncontrolled geothermal, well known as Thermal 4 (or the "Wild Well") will have its H_2S emissions reduced by 90% over its abated conditions.	90
1984	1.	All power plant units utilizing direct contact condensers will emit no more than 200 gm H_2S/MWH (.44 lb/MWH).	90
1986	1.	H_2S emisions resulting from "stacking" operations shall be reduced by 90% (from levels associated with unabated steam flow) within 30 minutes.	90
	2.	All power plant units completed after 1985 shall emit no more than 50 gm H_2S/MWH (.11 lb/MWH).	95
1990	1.	All power plant units equipped with surface condensers shall emit no more than 50 gm H_2S/MWH (.11 lb/MWH).	95
2000	1.	All power plant units equipped with direct contact condensers shall emit no more than 100 gm H_2S/MWH (.22 lb/MWH).	95

*Adopted by ARB April 26, 1978.

Projected Growth

In an effort to develop an integrated, statewide electricity supply strategy the Energy Commission has required that all California utilities' provide planning documents prescribing the manner in which each utility would meet future forecasted electricity demand for its service area. Table II lists all of the development currently being planned by electric utilities for the Geysers KGRA.[10] Three utilities, Pacific Gas and Electric Company (PG&E), Sacramento Municipal Utilities District (SMUD) and Northern California Power Association (NCPA) indicate that 2708 MW of electricity could be produced at the Geysers by 1990. The only other generation capacity now planned for the Geysers is 165 MW by the California Department of Water Resources.

It should be noted that H_2S control efficiencies were not indicated for iron catalyst control systems on units 1-11. These systems are not presently on all of PG&E's existing units, although it does appear as though PG&E expects to retrofit with iron catalyst and attain 90 percent abatement efficiency on these units.

The expected Geysers cumulative H_2S emissions utilizing various levels of control efficiency and assuming development proceeds as planned, are presented by year in the columns on the right in Table II. Expected cumulative emissions and the net relationship to current emissions levels at the Geysers is presented in Figure I. Although the utilities have indicated that up to 90 percent control of H_2S is expected, the ultimate degree to which H_2S must be controlled at the Geysers has not yet been established. Since ambient air quality standards are currently being violated, logic would indicate that net future emissions over 1174 lb/hr would cause continuing violations. Even 95% control of H_2S may not be sufficient if a reduction down to one third of current

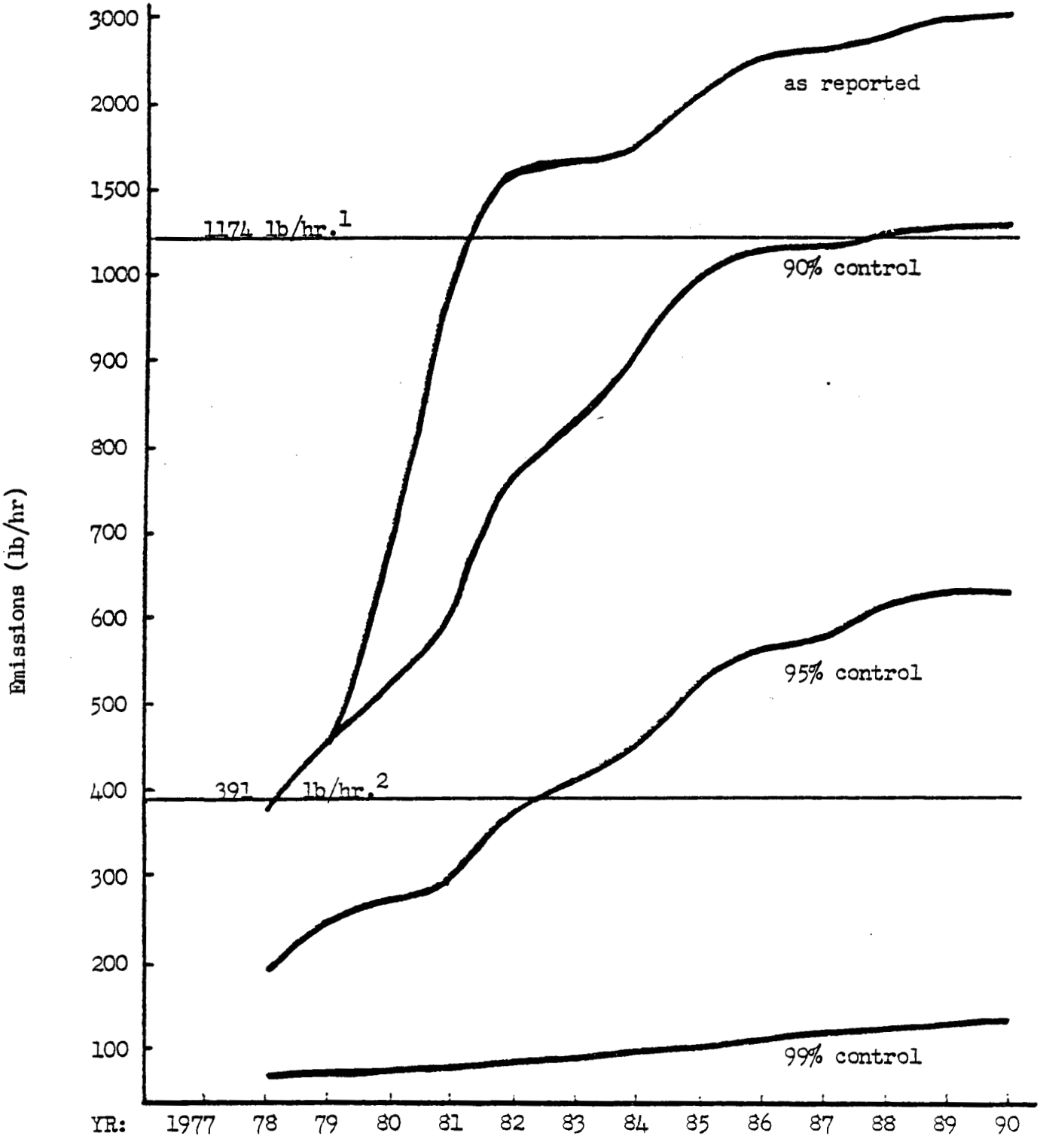
TABLE II

PROJECTED GEOTHERMAL POWER PRODUCTION AND H_2S EMISSIONS IN THE GEYSERS KCRA

	UNIT DATA							CUMULATIVE TOTAL CONTROLLED H_2S (lb/hr)			
UNIT #	YEAR ON LINE	SIZE (MW)	HEAT RATE (BTU/KWH)	H_2S EMMISSION FACTOR[6] (LBS/BTUx10^6)	CONTROL DEVICE[2]	CONTROL EFFICIENCY	H_2S EMISSION (LBS/HR)	TOTAL (MW)	As Reported	90% CONTROL	95% CONTROL	99% CONTROL
PG&E 1	1960	11	22,000	.076	IC	1	18.3					
PG&E 2	1963	13	22,000	.076	IC	1	21.7					
PG&E 3	1967	27	22,000	.076	IC	1	45.1					
PG&E 4	1968	27	22,000	.076	IC	1	45.1					
PG&E 5	1971	53	22,000	.027	IC	1	31.5					
PG&E 6	1971	53	22,000	.033	IC	1	38.5					
PG&E 7	1972	53	22,000	.016	IC	1	18.7					
PG&E 8	1972	53	22,000	.011	IC	1	12.8					
PG&E 9	1973	53	22,000	.005	IC	1	5.8					
PG&E 10	1973	53	22,000	.005	IC	1	5.8					
PG&E 11	1975	106	22,000	.028	IC	1	65.3	502				
PG&E 12	1978	106	21,376	.0138	IC	90%	31.3					
PG&E 15	1978	55	22,881	.0373	STRET	90%	46.9	663	386.8	386.8	193.4	38.7
PG&E 14	1979	110	22,000	.0142	STRET	90%	34.6					
PG&E 13	1979	135	22,000	.00885	STRET	90%	26.3	908	447.7	447.7	233.9	44.8
PG&E 16	1981	110	22,000	.00684	STRET	90%	16.6					
PG&E 17	1981	110	22,000	.0353	STRET	90%	85.4					
NCPA 1	1981	32	23,000	.22[3]	1	90%	161.9					
NCPA 1	1981	53	23,000	.22[3]	1	90%	268.2	1213	979.8	592.7	296.4	59.3
PG&E 18	1982	110	22,000	.0224	STRET	90%	54.2					
PG&E 19	1982	110	22,000	.0224	STRET	90%	54.2					
NCPA 1A	1982	32	23,000	.22[3]	1	90%	161.9					
NCPA 2A	1982	53	23,000	.22[3]	1	90%	268.2	1518	1518.3	744.2	372.1	74.4
PG&E 20	1983	110	22,000	.0224	STRET	90%	54.2					
PG&E 21	1983	110	22,000	.0224	STRET	90%	54.2	1738	1626.7	852.6	426.3	85.3
PG&E 22	1984	110	22,000	.0224	STRET	90%	54.2	1848	1680.9	906.8	453.4	90.7
PG&E 23	1985	110	22,000	.0224	STRET	90%	54.2					
SMUD 1	1985	100	24,000	.167	4	4	400.8	2058	2135.9	1001.1	500.6	100.1
PG&E 24	1986	110	22,000	.0224	STRET	90 %	54.2					
SMUD 2	1986	100	24,000	.167	4	4	400.8	2268	2590.9	1095.4	547.6	109.5
PG&E 25	1987	110	22,000	.0224	STRET	90%	54.2	2378	2645.1	1149.5	574.6	115.0
PG&E 26	1988	110	22,000	.0224	STRET	90%	54.2	2488	2699.3	1203.8	601.5	120.4
PG&E 27[5]	1989	110	22,000	.0224	STRET	90%	54.2	2598	2753.5	1258.0	629.0	125.8
PG&E 28[5]	1990	110	1	.0224	STRET	90%	54.2	2708	2807.7	1312.2	656.1	131.2

1. Information not provided by utilities.
2. Control Devices: IC= Iron Catalyst, STRET = Stretford Process.
3. The NCPA Emission Factor appears to be representative of an uncontrolled state.
4. SMUD did not indicate any control.
5. The location of Unit #28 was not given, it may or may not be in the Geysers KCRA.

FIGURE I: PROJECTED INCREASES IN H_2S EMISSIONS FROM PLANNED POWER PLANT UNITS AT THE GEYSERS



1 1977 Emission level.

2 ARB estimated roll back requirement

emission levels is required. Control efficiencies of 96-99 percent appear to be required if ultimate compliance with standards and full field development is desired.

The proposed ARB regulations (Table 1) call for 95 percent of all units completed after 1985. It is unclear at this time whether this degree of control can be technically achieved or is ultimately sufficient to prevent violations of the ambient air quality standard for H_2S.

H_2S Abatement Technologies

A substantial amount of money and time has been expended (primarily by PG&E) in efforts to control the releases of H_2S to the atmosphere by geothermal operations. Several different approaches to H_2S control have been investigated and the three most promising are: (1) Iron Catalyst; (2) Stretford; and (3) EIC Upstream. Information is provided in Table III regarding the H_2S abatement technologies currently being tested by PG&E. By mid-1979 more precise operational characteristics will be available on all these systems.

Of the systems under consideration, only the Iron Catalyst system has been in full-scale operation, with rather unsatisfactory results (40 to 70 percent efficiency). The Stretford system is expected to provide high control efficiencies on new units using surface condensers (as opposed to direct contact condensers on units 1-12). The Stretford system is presently unproven, however, because there is no operating experience to indicate the degree of H_2S partitioning which will occur in the surface condenser. The EIC Upstream system is in the very early stages of development but appears to be promising. If successful it would enable removal of H_2S from the geothermal steam resource before it enters the power plant.

TABLE III
Hydrogen Sulfide Abatement Technologies

	Iron Catalyst	Stretford	EIC Upstream
Abatement Efficiency	Actual 40-70% Potential 90%	80-98% 90+% from Condensate	90-97%
Expected Downtime	10%	5%	5%
Estimated Capital Cost	$3 million	$5.84-6.7 million	Similar to STRET
Estimated Annual cost	$995,000	$1,350,000 $2,275,000 with Condensate Treatment.	$1,245,00
Expected Availability	90% Abatement Full scale end of 1978	Fullscale on Unit 15 Early 1979.	Pilot July 1979 Mid-1982

Conclusion

The limit to which geothermal development can occur at the Geysers presently seems to be restricted by two factors: (1) the ultimate size of the resource, (which has yet to be definitively established); and (2) more immediately, by the failure to maintain the state ambient air quality standard for H_2S.

If it cannot be demonstrated that geothermal power plants can operate without causing violations of the .03 ppm hydrogen sulfide standard and comply with proposed hydrogen sulfide regulations of the ARB and local APCD's, it would be impudent to expect unrestricted development at the Geysers. No agency has yet established precisely what level of H_2S control (or emissions) will be required to allow full field development. Although most proposed regulation is presently in the range of 90-95 percent control, more stringent controls may be

necessary if thousands of megawatts of electricity are to be produced at the Geysers.

Achieving the goal of full field development remains hypothetical. Uncertainties presently associated with development of geothermal H_2S control technologies are numerous. It is possible that a level of H_2S control sufficient to eliminate H_2S as an environmental problem may not be available soon. Should adequate H_2S control prove unavailable planned geothermal development at the Geysers may be seriously hindered and eventually curtailed. Every effort should be made to ensure against such an eventuality. This analysis is intended to communicate the status of an eminent regulatory problem and encourage expanded research and planning to resolve the issue.

The views and conclusions contained in this report are those of the authors and should not be interpreted as necessarily representing the official policies of either the California Energy Commission or the State of California.

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