Attachment B

RELATIONSHIP OF RESOURCE UNCERTAINTIES TO ABATEMENT COSTS

Geothermal resources around the world have characteristics that vary widely. With respect to H_2S, the quantity of H_2S in the vapor phase (steam) can vary from a few parts per million to a few percent. This wide variation in chemical composition is even found over relatively small geographic areas. In The Geysers resource area of California, for example, the H_2S concentrations for individual wells are from 40 ppm to over 1500 ppm and the average concentrations in the steam entering plants varies from approximately 45 ppm to over 400 ppm (almost 10 to 1) as shown in Table-1 is based upon information contained in the Dames and Moore report. In fact, PG&E Units 3 and 1 are located less than one mile from each other and have H_2S concentrations that vary by a factor of more than 2.4 to 1 (445 ppm vs. 185 ppm). Units 3 and 14 are located less than 2-1/2 miles apart and the concentrations vary by a factor of 6.6 to 1 (445 ppm vs. 70 ppm). The ammonia in the steam, which is a major factor in the amount of partitioning that will occur, can vary just as significantly as the H_2S.

Thus, it is likely that H_2S and ammonia concentrations at different locations in the Island of Hawaii will vary significantly from the values found at the HGP-A well. Even greater differences can be expected at locations on other islands within the State of Hawaii.

Further, as shown in Table 6.1-2 of the Dames and Moore report, the H_2S concentrations for a given group of wells can increase and decrease significantly over the life of the wells.

The variations in expected H_2S and ammonia concentrations which occur with differences in geographic location and those which occur over the life of the

Table 1

H_2S CONCENTRATIONS AND
PARTITIONING FOR POWER PLANTS
AT THE GEYSERS(1)

Generating Unit		H_2S in Inlet Steam ppmw	Partitioning %
PG&E Unit	1	185	(2)
	3	445	(2)
	4	370	(2)
	5	280	(2)
	6	355	(2)
	7	220	(2)
	11	330	(2)
	13	45	90
	14	70	90
	15	320	80-90
	16	70	(3)
	17	350	95
	18	65	(3)
NCPA	2	70	94
SMUD Geo	1	80	(3)

(1) The values in this table as taken from Dames & Moore, EPA 68-02-3508, 1984.

(2) These units utilize a direct contact condenser rather than a surface condenser. Therefore, partitioning data for them is not relevent.

(3) No partitioning data was provided for these plants in the Dames & Moore report.

wells can have significant impact upon the performance and cost of abatement systems. The cost impact is illustrated by the following examples which are based totally upon the Dames & Moore estimates.

Example 1 (Base)

The Dames and Moore report assumes: 544,000 lb/hr of incoming steam
1,000 ppmw H_2S in incoming steam

- o 90% partitioning
- o 99% abatement of H_2S in off-gas stream using Stretford
- o 95% abatement of H_2S in condensate stream using H_2O_2 secondary abatement

This results in an emission rate of 7.6 lb/hr of H_2S or approximately 98.6% abatement.

The cost for this level of abatement is estimated by Dames and Moore to be 4.6 mills/kWh for secondary abatement and 9.6 mills/kWh for the Stetford in 1983 dollars. This is a total of 14.2 mills/kWh for abatement to a 7.6 lb/hr emission level.

Example 2

It would be reasonable to expect, based upon experience at other geothermal locations, that a power plant located in the Puna District of Hawaii might actually end up having steam with 50% to 100% more or less H_2S than the concentration in the HGP-A well. If an H_2S concentration of 1200 ppm were the case and only 90% partitioning occured, the amount of H_2S in the off-gas would increase by 7%, and the amount in the condensate would increase by 140%.

With 98% abatement required, the cost of the Stretford system would be about the same as Example 1 (9.6 mills/kWh) while the cost of secondary abatement would increase to approximately 11 mills/kWh (118 lb/hr H_2S removed from condensate vs. 49 lb/hr). This is a total cost of abatement of over 20.6

mills/kWh or a doubling of abatement costs for a 20% change in total incoming H_2S and a change in partitioning from 90% to 80%. This emission rate would be 11.7 lb/hr vs. the 7.6 lb/hr for Case 1.

Example 3

It is also possible that the H_2S concentration might be lower and the partitioning higher than Example 1. If the H_2S concentration were 750 ppm and the partitioning 95%, the amount of H_2S in the off-gas would decrease by 20% and the amount in the condensate would decrease by over 60%.

With 98% abatement required, the cost of the Stretford would decrease slightly from Example 1 (say 9.0 mills/KWh) and the cost of secondary abatement would reduce by approximately 70% to about 1.4 mills/KWh for a total cost of abatement of less than 11 mills/KWh. This is a reduction of approximately 23% in cost for a 25% reduction in incoming H_2S and a 5% increase in partitioning. The emission rate would be approximately the same as Case 1, 8 lb/hr.

These three examples are summarized in Table 2. It is obvious from these three examples that the variations in geothermal resource chemistry that can reasonably be expected for resources in Hawaii will have a very significant impact on the cost of abatement of H_2S, the cost of electricity produced by the power plant, and the overall economics of power generation projects.

The variation in cost of abatement shown in these three examples is over 10 mills/kWh. Depending upon the overall characteristics of the project, increases in costs of 10 mills/kWh could easily be enough to make a project uneconomic, while the increases in plant emissions might have insignificant impact upon the environment depending upon the specific geographic location, meteorology, and other factors associated with the site. Thus, it appears that the 98% abatement requirement for all plants in Hawaii might not provide for adequate balance between environmental and economic considerations for scenarios that have a reasonable probability of occurence. A regulation that requires a review of the ambient air quality impacts, cost of abatement, and

availability of technology rather than a fixed percentage abatement appears to be a reasonable approach to ensuring protection of the environment without arbitrarily placing overly expensive requirements on projects.