ATTACHMENT "C"

H_2S ABATEMENT COST OVERVIEW AT THE GEYSERS

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Existing Systems: The latest generation of power plants at The Geysers KGRA that are now operating or are under construction rely primarily on Stretford systems to control H_2S emissions during normal operation. Non-condensible gases vented from surface condensers are ducted to their Stretford facilities where virtually all the entrained H_2S is converted to elemental sulphur. Depending on the gas composition which changes with time and location within the field, certain varying amounts of H_2S are dissolved in the condensate within the condensaers and therefore are not treated by the Stretford systems. To prevent release to the atmosphere, the plants are equipped with secondary abatement systems. These are relatively simple chemical feed systems which introduce a strong oxidizer and a catalyst to the condensate, oxidizing the H_2S to soluble thiosulphates. It has been demonstrated at PG&E's Unit 13 that the Stretford/secondary abatement systems will comply with the most stringent H_2S emission limitations during normal operations.

A typical 110 MW power plant uses about 2,000,000 lbs/hr of steam. The field wide average H_2S concentration is about 121 ppm. The incoming H_2S to such a "typical" power plant is therefore 240 lbs/hr. The most stringent emission limitation is 5 lbs/hr at PG&E's Unit 16; however, for the purpose of this illustration, 10 lbs/hr will be used which is roughly equivalent to the PG&E Unit 18 limitation. The abatement system processes the difference between the incoming (240 lbs/hr) and the emitted (10 lbs/hr) flow of H_2S, 230 lbs/hr. Of this roughly 85% (195 lbs/hr) is treated by the Stretford, 15% (35 lbs/hr) by the secondary abatement systems.

Stretford System Costs:

Total amount of H_2S treated annually at 85% capacity factor (8760 hrs/yr x 0.85 x 230 lbs/hr)	1,713,000 lbs
Treated by Stretford (85%)	1,456,000 lbs
Capital cost of Stretford System including overheads & indirects ($1982)	$6,800,000
Incremental capital cost of equipment (surface condenser vs. direct contact), including overheads & indirects	$3,100,000
Total capital cost of Stretford H_2S system	$9,900,000
Levelized annual cost at 18% fixed charge rate (FCR)	$1,782,000
Annual operation and maintenance cost (O & M - 5% of Stretford capital cost)	$ 340,000
Total annual cost to own and operate Stretford system	$2,122,000
Cost per lb of H_2S abated by the Stretford system $2,122,000/yr ÷ 1,456,000 lbs/yr	$ 1.46 /lb

Secondary Abatement System costs:

Total amount of H_2S treated (15% of total)	257,000 lbs.
Total capital cost of secondary abatement system ($1982) including overheads & indirects	$1,300,000
Levelized annual cost (18% FCR)	$ 234,000
Annual O & M cost (5%)	65,000
Annual Chemical Costs	291,000
Total annual cost to own and operate secondary system	$ 590,000
Cost per lb of H_2S abated by secondary system $590,000/yr ÷ 257,000 lbs/yr	$ 2.30/lb

Turbine by-pass system: Several of the more recent developers have proposed or are actually installing turbine steam bypass systems. During startups and immediately following shutdowns, steam is now vented ("stacked"), unabated, through mufflers from the steam supplier's relief station. The bypass system would condense the steam in the power plant's main condenser, separate the non-condensible gases, treat the gaseous H_2S in the Stretford plant, the dissolved H_2S by the injection of secondary abatement chemicals. Even though there is some question as to the overall effectiveness of this type of "stacking" H_2S abatement, the Lake County Air Pollution District (LCAPCD) de facto made this technology a licensing requirement. In its Determination of Compliance (DOC) for Geysers Unit 16, the LCAPCD required that although the design for this unit is complete (a carbon copy of Units 17 and 18) the use of a turbine bypass system will be specifically considered for "stacking" H_2S emissions control. The condition stated that the system should be capable of processing 50% of the turbine steam flow. If such a system should be constructed at Unit 16, it would rely on the plant's auxiliary equipment for its operation. For the 50% capacity, half of all the pumps, cooling tower fans compressors, etc., that are normally required to operate the plant at full load would have to run with a total electrical power demand of about 4000 kilo-watts (kw). Naturally if plant operation was interrupted due to a malfunction of any of these components, the bypass system would also be inoperative. PG&E's Engineering Department conducted a very thorough review of plant operations at Geysers 13, 14, and 15 since these units were started up. These units are equipped with surface condensers and Stretford/Secondary H_2S abatement systems. They are functionally very similar to what Unit 16 will be like. The study covered a total of almost 51,000 plant-hrs of operation and forced and scheduled outage periods. Adjustments were made to delete malfunctions from the outage record, which were clearly attributable to startup difficulties and were not indicative of long term plant operations. It was concluded that this type of a turbine bypass system can reasonably be expected to be available during 10 of 23 (43%) outages or 144 of 263 (55%) total outage hours excluding unit overhauls, annually.

Cost calculations: Using steam flow, H_2S content and emission limitation figures stated earlier, such a turbine bypass/Stretford/secondary system could process the following amount of H_2S:

Design steam flow (half of total steam flow)	1,000,000 lbs/hr
Total H_2S flow (120 ppm)	120 lbs/hr
Treated (all but 10 lb/hr)	110 lbs/hr
Total hours of operation	144 hr/yr
Total amount of H_2S treated annually	15,840 lbs
In Stretford (85%)	13,460 lbs
By secondary (15%)	2,380 lbs

Capital cost of turbine bypass system including overheads & indirects ($1982)	$1,690,000
Levelized annual cost (18% FCR)	$ 304,000
O & M costs (5% of capital cost)	85,000
Electric Power Cost ($1982)	63,000
Chemical cost ($1982)	3,000
Total annual cost to own and operate turbine bypass system	$ 455,000
Cost per lb of H_2S abated by the Turbine Bypass and Related Systems $455,000/yr ÷ 15,840 lbs/yr	$ 28.72/lb

Summary: The following table illustrates the relative costs of abating H_2S at the Geysers:

System	lb/yr H_2S Treated	% of Total	Cost - $/lb	Cost ratio
Stretford	1,456,000	84.2%	1.46	
Secondary	257,000	14.9%	2.30	1.6:1
Turbine Bypass	16,000	0.9%	28.72	20:1

Note of caution: The cost figures were calculated based on the following parameters:

Steam Flow	2,000,000 lbs/hr
H_2S content	120 ppm
H_2S partitioning	85%
Capacity factor	85%
Fixed Charge Rate	18%
O & M costs	5% of capital costs
Chemical costs	1982 level, not escalated
Power cost	1982 avg, replacement cost

Changing any one of the above figures will change the final cost per lb of H_2S abated. The cost of equipment does not vary with H_2S loading; therefore, units with lower H_2S contents would indicate higher abatement $/lb costs. The purpose of these calculations was to illustrate relative costs between existing and proposed H_2S abatement technologies rather than absolute values.