Existing Systems: The latest generation of power plants at The Geysers area that are now operating or are under construction rely primarily on Stretford systems to control H₂S emissions during normal operation. Non-condensible gases vented from surface condensers are ducted to their Stretford facilities where virtually all the entrained H₂S is converted to elemental sulphur. Depending on the gas composition which changes with time and location within the fields, certain varying amounts of H₂S are dissolved in the condensate within the condensers 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 H₂S to soluble thiosulphates. It has been demonstrated at PG&E’s Unit 13 that the Stretford/secondary

Stretford System Costs:

Total amount of H₂S treated annually at 95% capacity factor  
(8760 hrs/yr x 0.85 x 230 lbs/hr)  
1,713,000 lbs  
Treated by Stretford (85%)  
1,458,000 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  
$3,120,000  
Total capital cost of Stretford H₂S system  
$9,920,000  
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 H₂S abated by the Stretford system  
$2,122,000/yr ÷ 1,458,000 lbs/yr  
$ 1.46/lb

Abatement systems will comply with the most stringent H₂S emission limitations during normal operation.

A typical 110 MW power plant uses about 2,000,000 lbs/hr of steam. The field wide average H₂S concentration is about 12 ppm. The incoming H₂S 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 H₂S. 230 lbs/hr. Of this roughly 85% (195 lbs/hr) is treated by the Stretford, 15% (35 lbs/hr) by the secondary abatement system.
**Secondary Abatement System Costs:**

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total amount of H₂S treated (15% of total)</td>
<td>257,000 lbs.</td>
</tr>
<tr>
<td>Total capital cost of secondary abatement system ($1982) including overheads &amp; indirects</td>
<td>$1,200,000</td>
</tr>
<tr>
<td>Levelized annual cost (18% PCR)</td>
<td>$234,000</td>
</tr>
<tr>
<td>Annual O &amp; M cost ($)</td>
<td>65,000</td>
</tr>
<tr>
<td>Annual Chemical Costs</td>
<td>29,000</td>
</tr>
<tr>
<td>Total annual cost to own and operate secondary system</td>
<td>$90,000</td>
</tr>
<tr>
<td>Cost per lb of H₂S abated by secondary system</td>
<td>$2.36/lb</td>
</tr>
</tbody>
</table>

**Turbine by-pass system:** Several of the more recent developers have proposed or are actually installing turbine steam bypass systems. During startup 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-condensable gases, treat the gaseous H₂S in the Stretford plant, the dissolved H₂S by the injection of secondary abatement chemicals. Even though there is some question as to the overall effectiveness of this type of "stacking" H₂S 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" H₂S 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. PGE'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 H₂S abatement systems. They are functionally very similar to what Unit 16 will be like. The study covered a total of almost 51,000 plant-hours 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, H₂S content and emission limitation figures stated earlier, such a turbine bypass/Stretford/secondary system could process the following amount of H₂S:

Design steam flow (half of total steam flow) | 1,000,000 lbs/hr |
Total H₂S flow (120 ppm) | 130 lbs/hr |
Treated (all but 10 lb/hr) | 110 lbs/hr |
Total hours of operation | 144 hr/yr |
Total amount of H₂S treated annually | 15,840 lbs |
In Stretford (85%) | 13,460 lbs |
By secondary (15%) | 2,380 lbs |
Summary: The following table illustrates the relative costs of abating H\textsubscript{2}S at the Geysers:

<table>
<thead>
<tr>
<th>System</th>
<th>lb/yr H\textsubscript{2}S Treated</th>
<th>% of Total</th>
<th>Cost - $/lb</th>
<th>Cost Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stratford</td>
<td>1,456,000</td>
<td>84.7%</td>
<td>1.46</td>
<td>1.6:1</td>
</tr>
<tr>
<td>Secondary</td>
<td>257,000</td>
<td>14.9%</td>
<td>2.30</td>
<td>1.6:1</td>
</tr>
<tr>
<td>Turbine Bypass</td>
<td>16,000</td>
<td>0.9%</td>
<td>28.72</td>
<td>20:1</td>
</tr>
</tbody>
</table>

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

- Steam Flow: 2,000,000 lbs/hr
- H\textsubscript{2}S content: 120 ppm
- H\textsubscript{2}S partitioning: 95%
- Capacity factor: 85%
- Fixed Charge Rate: 10%
- 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\textsubscript{2}S abated. The cost of equipment does not vary with H\textsubscript{2}S loading; therefore, units with lower H\textsubscript{2}S contents would indicate higher abatement costs. The purpose of these calculations was to illustrate relative costs between existing and proposed H\textsubscript{2}S abatement technologies rather than absolute values.