

INHIBITING DEPOSITION OF SILICEOUS SCALE*

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Lawrence Livermore Laboratory is developing the TOTAL FLOW process for efficient utilization of the thermal energy stored in high temperature-high salinity brines from the Salton Sea Geothermal Field (SSGF) for electric power production. Energy conversion is accomplished by flowing brine through mixed phase expanders and directing the high velocity exhaust jets onto the blades of an impulse turbine. Previous field experience, however, at the Sinclair No. 4 site in the SSGF indicated that deposition of siliceous scale (heavy metal sulfides and iron-rich amorphous silica) in nozzles and on turbine blades would be a serious problem when hypersaline brine is flash evaporated. An experimental program, therefore, was established to develop scale control techniques. Preliminary results indicate that scaling is a pH-dependent process that can be inhibited when brine is acidified with hydrochloric acid.

A mobile field test unit has been established at the ERDA-SDG&E test site in the southwestern part of the SSGF. Brine from the Magmamax No. 1 well was flowed through a steam separator that isolated vapor and liquid fractions formed as the brine moved from the geothermal reservoir, up the wellbore to the surface. Although the separated liquid phase was used for the initial brine modification experiments, subsequent work will involve remixing of liquid and vapor fractions prior to chemical additions. Average temperature and pressure of the brine were about 220°C and 265 psi, respectively. System through-put varied between 18,000 to 24,000 pounds of brine per hour. Flow through nozzles (8:1 expansion ratio, 1/4 inch diameter throat) was 1.25 pounds of brine per second. The nominal pH of unmodified brine flowing from the separator varied from 5.5 to 5.8. Dissolved solids content of the brine prior to and after expansion through nozzles was 18 weight percent to 22 weight percent, respectively. Nozzles and wearplates were fabricated from Ti-6Al-4V alloy. Three independent nozzles were operated simultaneously. During each acidification run, at least one nozzle was always operated as a control station flowing unmodified brine.

Thus far, four experiments, each of 20 hours duration, have been completed. Nominal scaling (copper sulfide, native silver, and iron-rich amorphous silica) from unmodified brine resulted in closure of up to 10% of the cross-sectional areas of nozzle throats. Thickness of scale formed on wearblades ranged between 0.019 mm to 0.04 mm. However, when brine was acidified to pH 1.5, 2.3, and 4.0, scaling in nozzles was eliminated and substantially reduced on wearblades. Acidified brine effluents remained clear several hours after collection. However, unmodified brine was slightly turbid when collected, with precipitates forming a few minutes after samples were taken.

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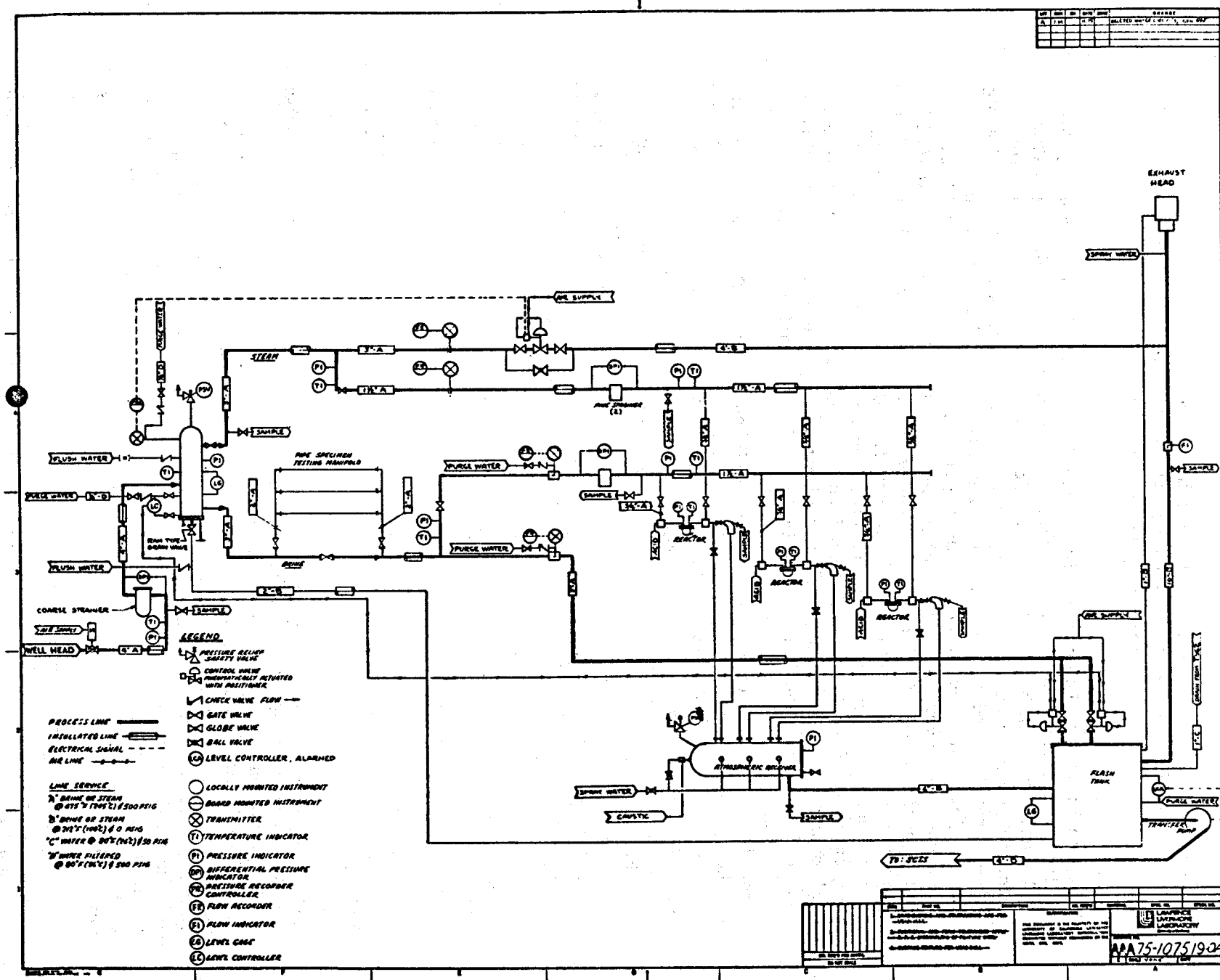


Figure 1. Schematic diagram of the Lawrence Livermore Laboratory Field Test Unit.

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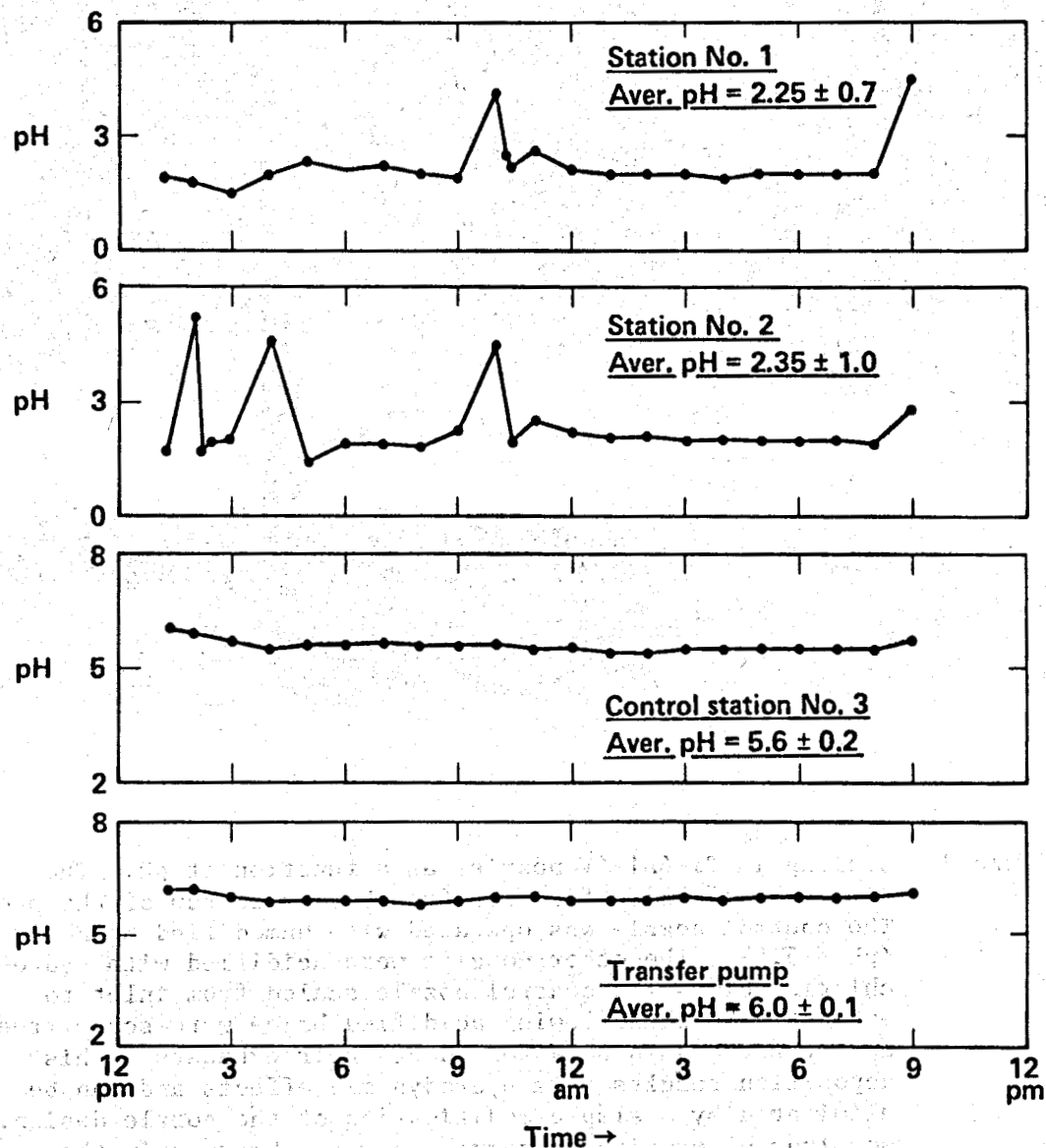


Figure 2. Results of a typical acidification run. Brine at stations No. 1 and 2 was acidified with hydrochloric acid prior to expansion through nozzles. Brine to station No. 3 was not chemically modified. The rise in pH at the transfer pump was a result of mixing expanded brine from the nozzles with unmodified brine by-passed around the experimental stations.

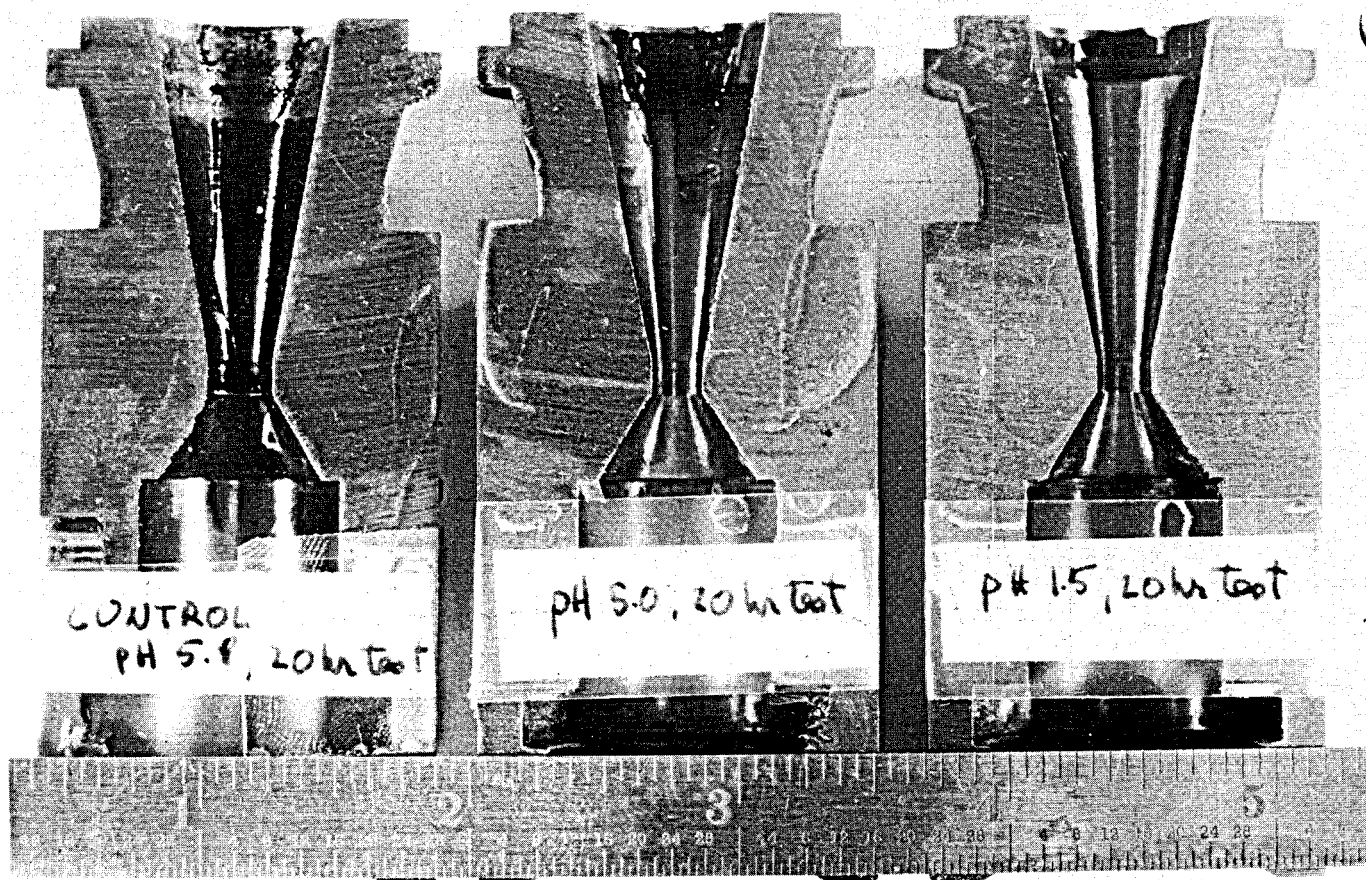
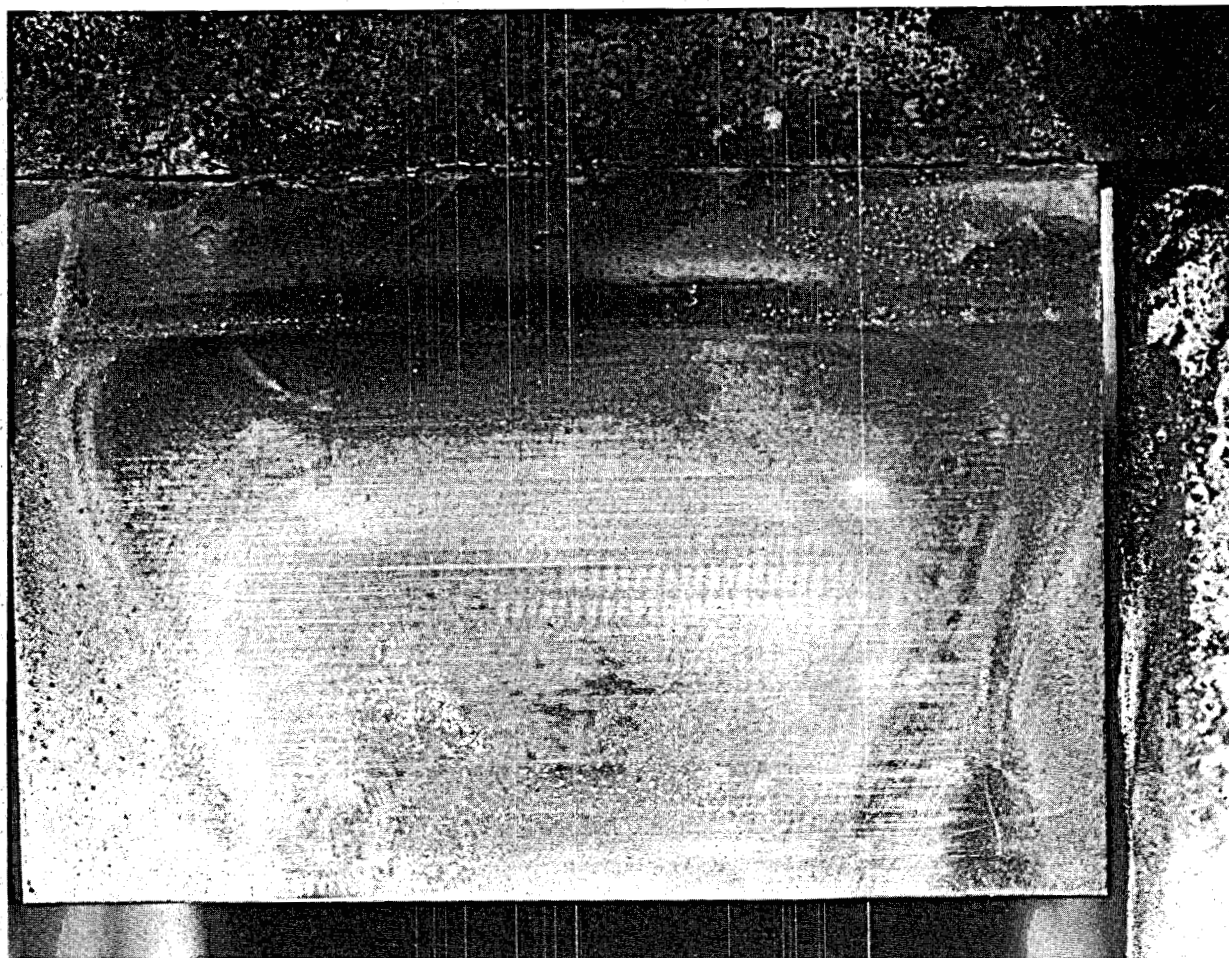


Figure 3. Scaling in Ti-6Al-4V nozzles as a function of pH. The direction of brine flow was from bottom to top of the photo. The control nozzle was operated with unmodified brine (pH = 5.8). The other nozzles were acidified with hydrochloric acid. The control nozzle scaled from inlet to exhaust. Nozzles flowing acidified brine were scale free except for a thin band formed at their exhausts. This deposition results from hydrodynamic effects and can be eliminated by a simple modification of the nozzle design. No signs of erosion or corrosion were observed in these nozzles. The rough edges shown in the photo were produced during sectioning.

Figure 4. Wearblade of Ti-6Al-4V alloy run at a pH of 2.3. No scale deposition occurred on central portion of blade exposed to direct nozzle exhaust. Original machining marks on blade are still clearly visible. Scale formed on blade edges is due to splash back and evaporation. No signs of corrosion or erosion were observed after 20 hours of exposure.

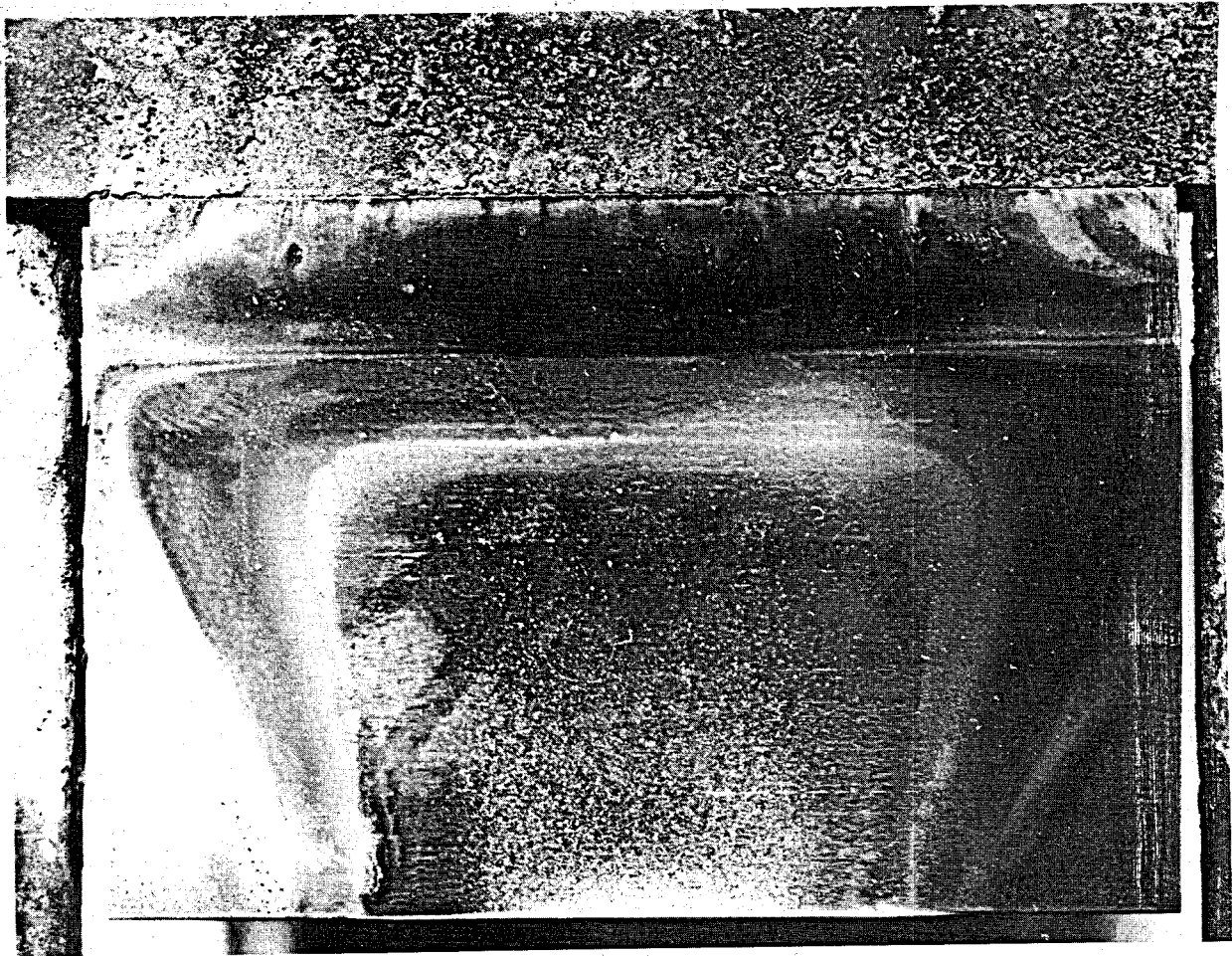


pH = 2.3



FLOW

Figure 5. Ti-6Al-4V wearblade exposed to brine for 20 hours. Machining marks and bare metal still are visible.

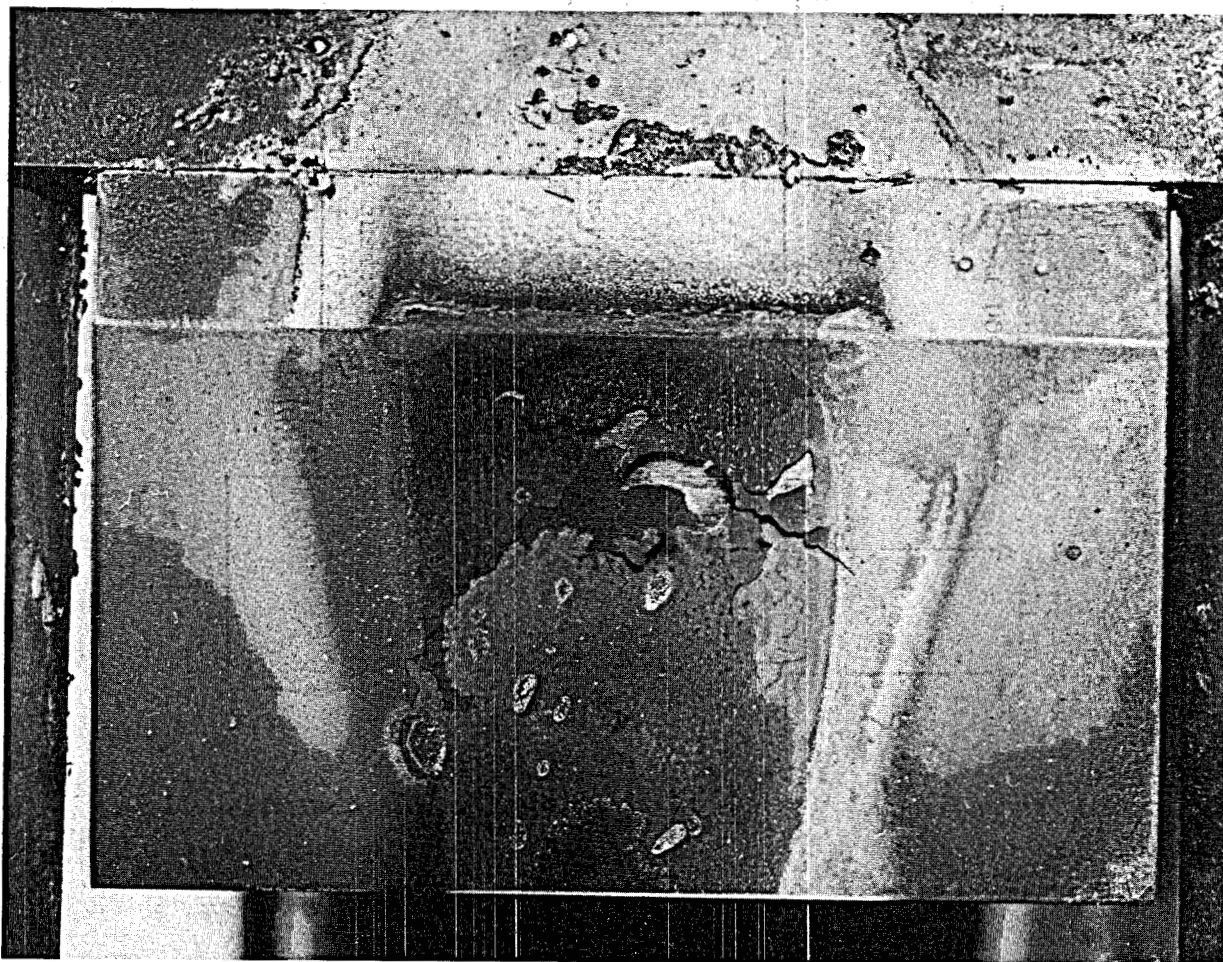


$pH = 4.2$



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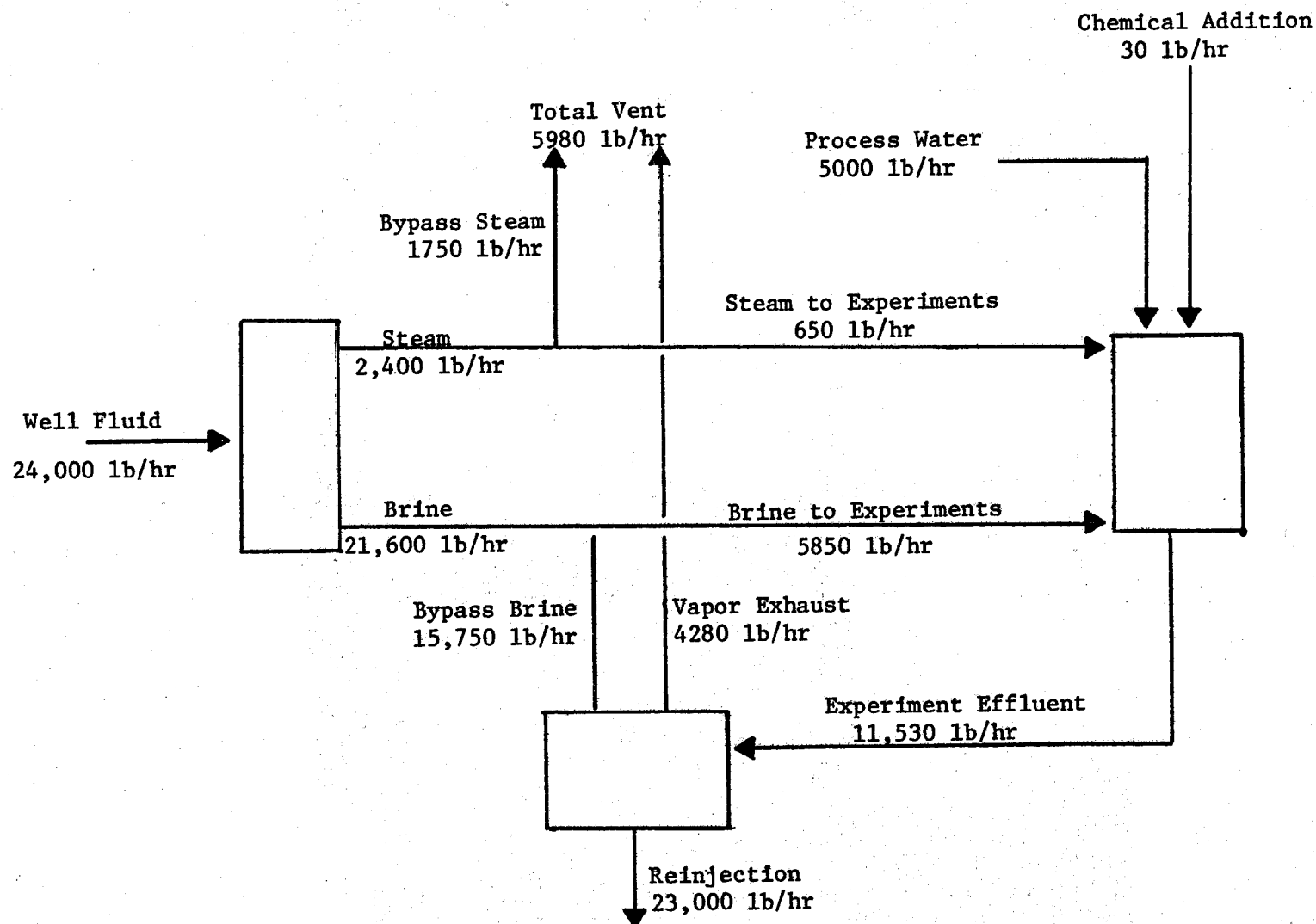
Figure 6. Ti-alloy wearblade exposed for 20 hours to unmodified brine. Scale thickness varied from $>40\mu$ at center to $\sim 20\mu$ at edges.



pH = 5.7



FLOW



Basis: 10% Quality at 300 psig, 20% TDS.

Figure 7. Mass balance for the LLL Field Test Unit.

WHAT WE DO NOT KNOW ABOUT SCALING

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The practical and field oriented aspects of the geothermal scale problem are outlined. Heavy emphasis is placed on actual field application of available theoretical and laboratory data. It will be shown that much more data, particularly from field experiments, is needed to come up with technically and economically sound solutions. Ideas and techniques offering possible solutions are discussed in detail.