Summary Report on HGP-A Well Flow and Environmental Tests (1980)

Black, perception, Bottom, Reservoir
Hall 500

SUMMARY REPORT
ON
HGP-A WELL FLOW AND ENVIRONMENTAL TESTS

For

THE RESEARCH CORPORATION OF THE UNIVERSITY OF HAWAII
HONOLULU, HAWAII

APRIL 1980

S-78020-80

ROGERS
Engineering • San Francisco

Rogers

SUMMARY REPORT
ON
HGP-A WELL FLOW AND ENVIRONMENTAL TESTS

For

THE RESEARCH CORPORATION OF THE UNIVERSITY OF HAWAII
HONOLULU, HAWAII

Prepared by

ROGERS ENGINEERING CO., INC.
Engineers and Architects
111 Pine Street
San Francisco, California 94111

APRIL 1980

S-78020-80

Rogers

SUMMARY REPORT

HGP-A WELL FLOW AND ENVIRONMENTAL CONTROL TESTS

A flash steam separator, equipped with steam pressure and liquid level controllers and venturi meters for measuring the separated steam and hot brine flows, was installed at the HGP-A Well Site in the Puna District on the Big Island (Hawaii).

These facilities, depicted in Dwgs. E-03-111 and E-03-113, were installed in order to accurately measure production rates of steam and hot brine from the well, and more particularly to determine the amount and composition of noncondensable gases produced by the well in conjunction with the steam.

A well test was deemed appropriate in order to make one final determination of well flow characteristics before committing the power plant condensing and gas removal equipment for purchase.

The HGP-A Wellhead had undergone a substantial workover program during the summer. The well workover was necessiated by apparent deterioration of the casing cement bond, as evidenced by rapid increase in static wellhead pressure corresponding to an observed increase in the temperature profile in the wellbore. Cement bond logs were run, and they too confirmed the loss in integrity of the cement bond.

In order to restore the mechanical integrity of the well, a casing perforation and cement squeeze job was performed in the 9-5/8" casing. In addition, a portion of the 7" slotted production liner was cut and removed from a depth of 2,200 to 3,000 feet. This zone was cemented off because it was an undesirable zone of production of lower temperature brine. A 7" casing tie-back string was cemented to surface to complete the well workover. These modifications to the well added further impetus to the desirability of retesting the well.

Since the power plant would require a steam separator with its controllers and associated flow meters for steam and brine flow, it was a matter of buying and erecting these facilities early so they could be used for the well flow test facility as well. The well test separator permitted a comparison to be made of the results with those obtained previously by the Lip Pressure Method. Other important benefits accrued by the test were: (1) training of the operating personnel and debugging the test facility, so this activity would not have to be done concurrently and thereby complicate the startup of the power plants itself; (2) assuage the concerns of the community by early demonstration of the fact that facilities could be designed to operate in an environmentally acceptable manner in a geothermal well production operation.

There was a commitment made to the HGP/Development group that the well flow tests would be designed and conducted in a manner that would comply with the requirements for noise and H_2S abatement. These requirements were that the noise intensity would be no greater than 65 dB_A at a distance of one-half mile from the well site and the H_2S gaseous discharge would not exceed the equivalent of 400 grams per MW hour (44 ppm).

Because this was to be a short term test (two weeks maximum), the desire was to minimize capital costs for the noise and H_2S abatement equipment. After reviewing various alternatives, the rock muffler and the caustic/hydrogen peroxide process were selected to provide the required abatement of noise and H_2S.

Discussions with control valve manufacturers indicated the steam pressure control valve (letdown valve) would exceed 110 dB_A so this valve and associated piping were buried in a concrete valve box. The steam discharged to atmosphere through a diffuser pipe installed in the plenum of the rock muffler.

The rock muffler was constructed of a concrete box which contained a plenum chamber created by a framework of steel pipe over which were placed steel grating and a five-foot layer of 1" to 1 1/2" crushed rock. The cross-sectional area of the rock muffler was sized for a superficial steam velocity of 2,400 lbs/hour-ft^2. The rock muffler proved so effective that a normal conversation could be conducted beside the muffler. The noise level measured on the road fronting the well site was only 44 dB_A.

The caustic and hydrogen peroxide system for H_2S abatement, which was first tried successfully at The Geyers during air drilling operations, was selected as the method of H_2S abatement for the short term well flow test.

FMC furnished data developed at The Geysers on the requirements for caustic and peroxide as a function of the percentage H_2S abatement. (See Figure 1.) Based on this data, the caustic and peroxide injection systems were designed to provide 7 moles of caustic per mole of H_2S and 4.5 moles of hydrogen peroxide per mole of H_2S in order to achieve 92% abatement. Static in-line mixers made out of steel baffles were installed immediately downstream of both the caustic injection nozzles and the hydrogen peroxide injection nozzles in order to increase the efficiency of contact between the chemicals and the H_2S in the steam. By use of the static mixers, it was hoped to achieve a marked decrease in chemical consumption, approaching the stoichiometric mole ratios for caustic and hydrogren peroxide of two and four respectively.

The caustic determines the effectiveness of the H_2S abatement because it reacts with the H_2S and removes it from the steam. The hydrogen peroxide merely serves to oxidize the hydrosulfide to a sulfate so that it cannot revert back to H_2S as it would if the hydrosulfide stream became acidified. Therefore, the effective use of caustic is extremely important to the success of the abatement program.

The caustic was received at the well site as a 50% solution. This was reduced in strength to 10% for use in abatement. Because of the extreme purity required in handling hydrogen peroxide, it was used directly as received, as a 50% solution. FMC furnished the injection pump and high purity aluminum piping for the hydrogen peroxide injection system. FMC (Mr. Castrantas) also provided instructions on the safe handling of hydrogen peroxide and was very helpful in discussions relating to the process chemistry and test results.

The well flow tests were performed over the period December 29, 1979 through January 17, 1980. Well flow was initiated by opening the master valve and the 10" wing valve to the vent silencer. The initial flow rate was very high and the ratio of flash steam to brine indicated that flashing was occurring in the wellbore. As flow continued, the total flow decreased while the steam fraction increased to about a 50/50 ratio, indicating that the flash point had progagated down into the reservoir. This flow behavior was similiar to that evidenced during earlier tests, in the ratio of about 65/35%, although the steam fractions in the earlier tests were somewhat higher.

Figure 2 is a plot of well flow as a function of separator pressure, which was varied from 60 psig to 170 psig. It is of interest to note that, unlike wells in which flashing occurs in the wellbore and where the wellflow follows a curve when plotted against wellhead pressure, the wellflow in HGP-A is nearly constant over the range of wellhead pressures tested. This is because flashing occurs in the formation (reservoir) and flow is limited by the formation permeability.

There was an agreement with the local community that steam flow to the vent silencer would cease by sundown so as not to disturb the community with the high intensity noise and H_2S odors which eminate from the vent silencer. For this reason the 10" wing valve to the steam separator was opened to heat up the system after only about five hours of flowing to the vent silencer. This amount of time was not sufficient to clean out the well, so cuttings and rock debris were introduced into the separator test facility. The debris caused some difficulties with plugging and wear of the seats in the brine bypass block valves, which were opened to avoid damage to the liquid level control valve.

The 10" wing valve to the vent silencer was closed, and all the well flow was directed to the steam separator by sundown, as prescribed. When well flow was reasonably stable, the caustic injection pump was started and 10% caustic was sprayed into the steam through the nozzles located in the steam line downstream of the pressure control valve.

For the first test point, because of difficulties with the caustic injection pump the rate of caustic addition of 10% solution was limited to a mole ratio of 3.2. This rate was less than half the design rate of 7 moles caustic per mole H_2S, but analysis of the H_2S (by Drager tube) in the steam discharged from the rock muffler indicated the H_2S level to be less than 6 ppm. The liquid drained from the rock muffler was very black in appearance (sulfides) and the pH was in excess of 11.

Analysis showed 16 ppm of H_2S in the untreated brine from the bottom of the separator, all of which essentially would be flashed off with the steam when the separator liquid was vented to atmosphere through the vent silencer.

Analysis of the incoming steam showed 774 ppm of H_2S to be present. Therefore, the overall abatement was 97%. This extremely effective performance was attributed to the static inliner mixers that were installed. The rock muffler also contributed to the effectiveness because the rock surfaces provided an extremely large amount of wetted interfacial area of contact for the H_2S and caustic.

A sample of the steam plume from the rock muffler was analyzed for caustic carryover, and there was no evidence of caustic entrainment in the steam. The rock muffler not only proved effective as a silencer, but it also served as an effective coalescer to prevent caustic mist carryover with the steam plume vented to atmosphere.

For the second test point the caustic injection rate was reduced to an equivalent of 2 moles caustic per mole H_2S. At this rate of injection the H_2S in the steam plume from the rock muffler increased to 20 ppm for an overall abatement of 95%. The liquid drain from the rock muffler was very black and the pH = 11.

When the caustic rate was reduced further to 1.5 moles caustic per mole H_2S equivalent (third test point), the H_2S in the steam plume from the rock muffler rose to 91 ppm (86% abatement), and the liquid drain from the rock muffler registered pH = 7.

The test points were repeated in a second series in which hydrogen peroxide was injected at the equivalent rate of 4.1 mole/mole H_2S. The injections of the peroxide made a dramatic change in the color of the liquor drained from the rock muffler. The color changed from the black sulfide to water white (soluble sulfate). There was a fine suspension of reddish material, iron oxide, which settled out in the percolation basin.

The H_2S results were reproduced in the second series of tests but with one exception: at the 1.5 mole caustic per mole H_2S equivalent rate of injection, there was a noticeable odor of SO_2. Analysis of the steam plume from the rock muffler indicated the presence of 120 ppm of SO_2.

The presence of SO_2 raised the question as to whether SO_2 had been present in the first series of tests in which only H_2S had been analyzed. A third series of tests were performed duplicating the same conditions but analyzing for SO_2 at each test point. After some difficulty in obtaining reliable SO_2 analysis at the beginning it was determined that SO_2 would not be released into the vented steam providing the pH of the liquor from the rock muffler was maintained above 11.

A 20% caustic solution was made up and additional tests were made at caustic mole ratios up to 8 and peroxide mole ratios to 6. There was less than 1 ppm of H_2S or SO_2 released in the steam plume from the rock muffler at these high injection rates.

Conclusions

1. The steam flow rate at plant design conditions, 160 psig separator, are adequate for the power plant design capacity of 3 MW.

2. The quantities of noncondensable gases in the steam are no greater than those specified in the condenser and gas removal equipment specifications.

3. More than 92% H_2S abatement can be achieved in the test facility at near stoichiometric quantities of caustic and hydrogen peroxide injection because of the high contact efficiency provided by the static mixers and the rock muffler.

4. The rock muffler satisfies the requirements for noise attenuation and serves as an effective coalescer to prevent chemical mist entrainment in the vented steam.

Recommendations

1. The condenser and gas removal equipment be released for purchase as specified.

2. The rock muffler be kept as an integral part of the plant installation, so it can be used for steam venting purposes whenever the power plant is shutdown.

3. The caustic and hydrogen peroxide system be retained but only caustic be used in the treatment (H_2S abatement) because the liquor from the rock muffler immediately percolates into the ground through lava tubes and there is little opportunity for the liquor to become acidified and release H_2S.

FIGURE # 1

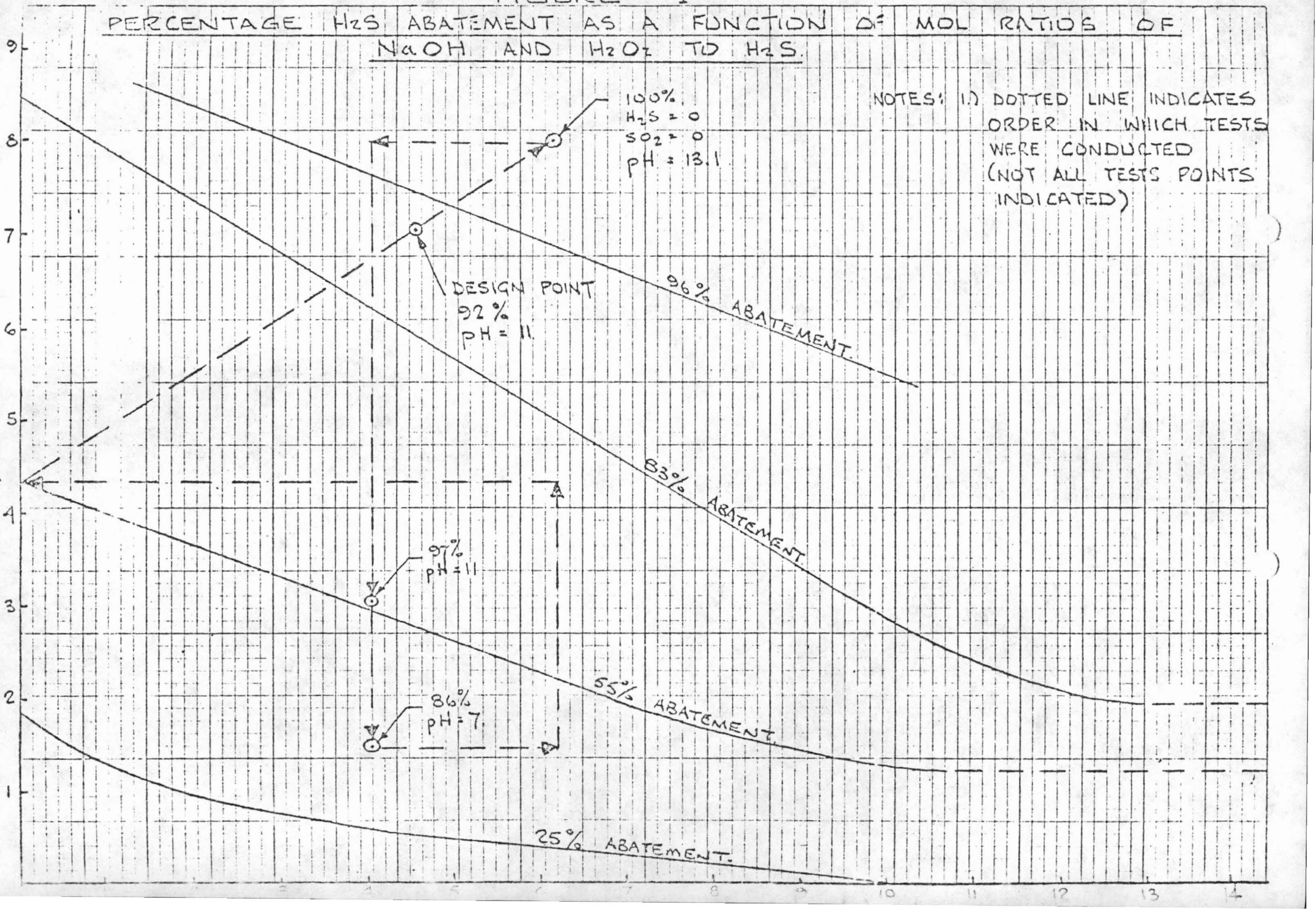
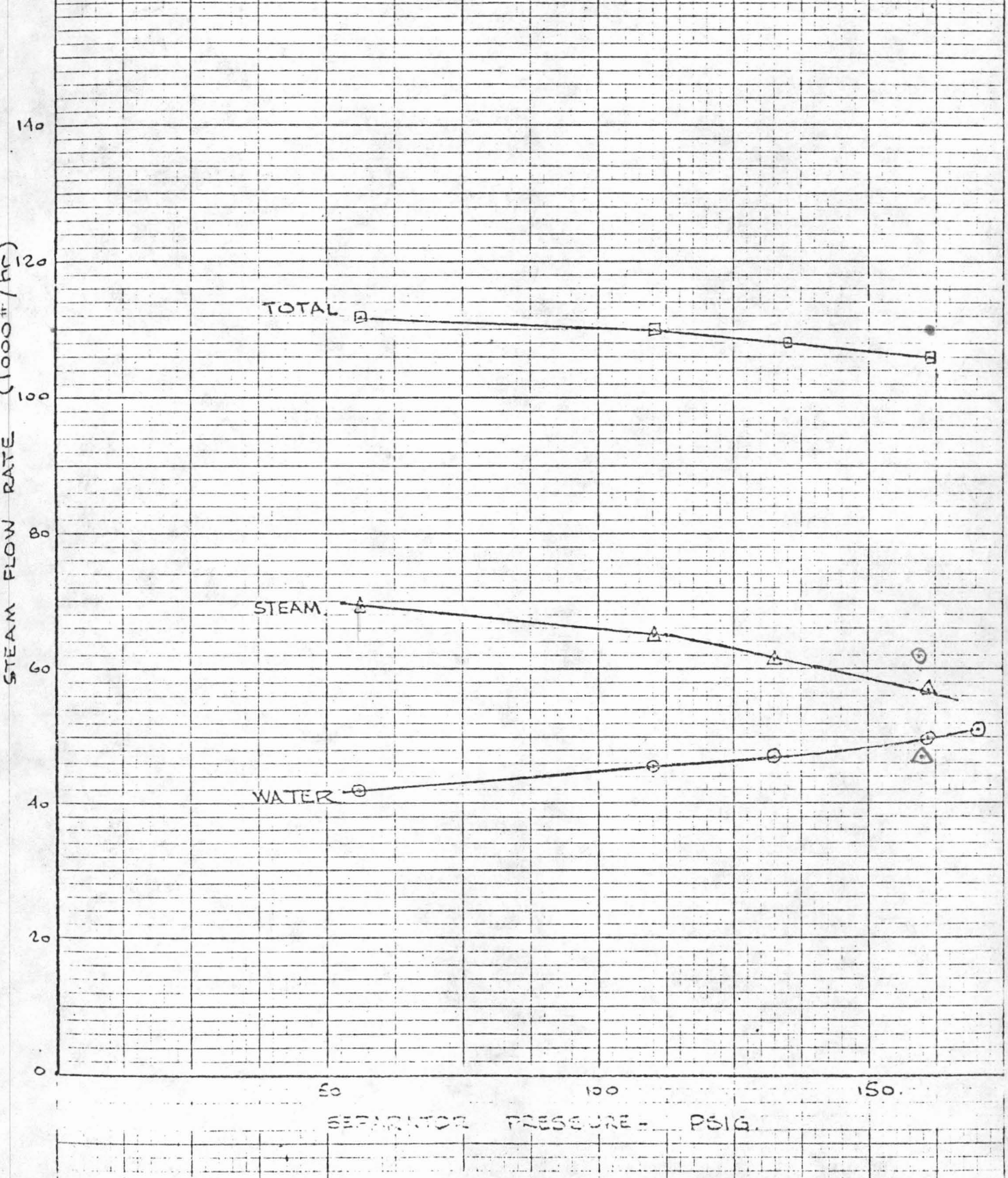
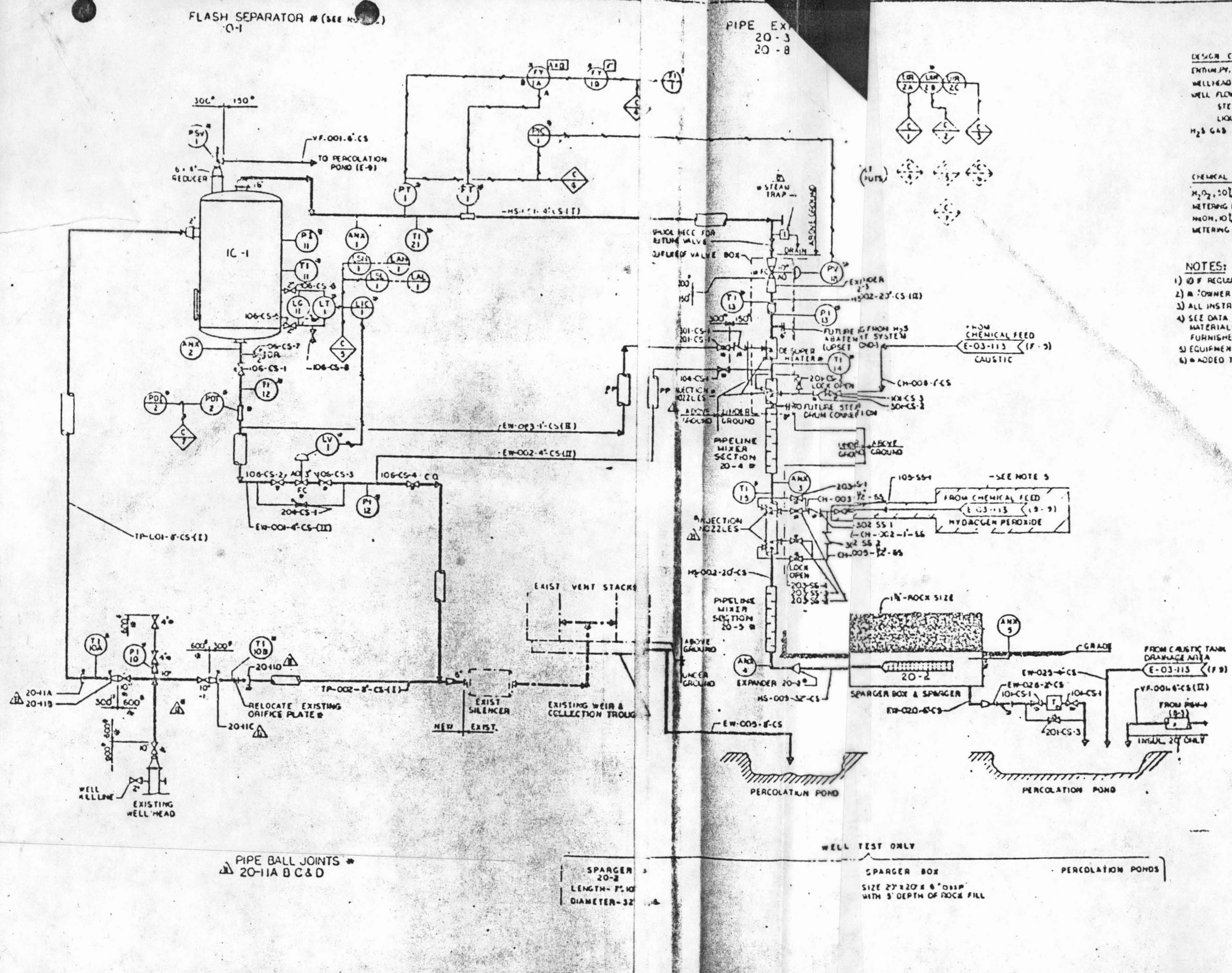

PERCENTAGE H2S ABATEMENT AS A FUNCTION OF MOL RATIOS OF
NaOH AND H2O2 TO H2S
NOTES: 1.) DOTTED LINE INDICATES ORDER IN WHICH TESTS WERE CONDUCTED (NOT ALL TESTS POINTS INDICATED)
100%
H2S = 0
SO2 = 0
pH = 13.1
DESIGN POINT
92%
pH = 11
97%
pH = 11
86%
pH = 7
96% ABATEMENT
83% ABATEMENT
55% ABATEMENT
25% ABATEMENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14

FIGURE # 6

GRAPH SHOWING STEAM WATER AND TOTAL FLOW AGAINST FLASH SEPARATOR PRESSURE.





DESIGN CONDITIONS		FLOW RATES MIN	TO	MAX
ENTHALPY, TOTAL	BTU/LB		500	
WELLHEAD PRESSURE	PSIG	375		50
WELL FLOW, TOTAL	LB/HR	131,000		150,000
STEAM	LB/HR	79,900		104,000
LIQUID	LB/HR	51,100		46,000
H_2S GAS	LB/HR	59.8		68.5

CHEMICAL TREATMENT				
H_2O_2, 50% WT LIQUID	GAL/HR	54		62
METERING PUMP MAX.	GAL/HR		124	
NaOH, 10% WT LIQUID	GAL/HR	538		618
METERING PUMP MAX.	GAL/HR		(1)620	

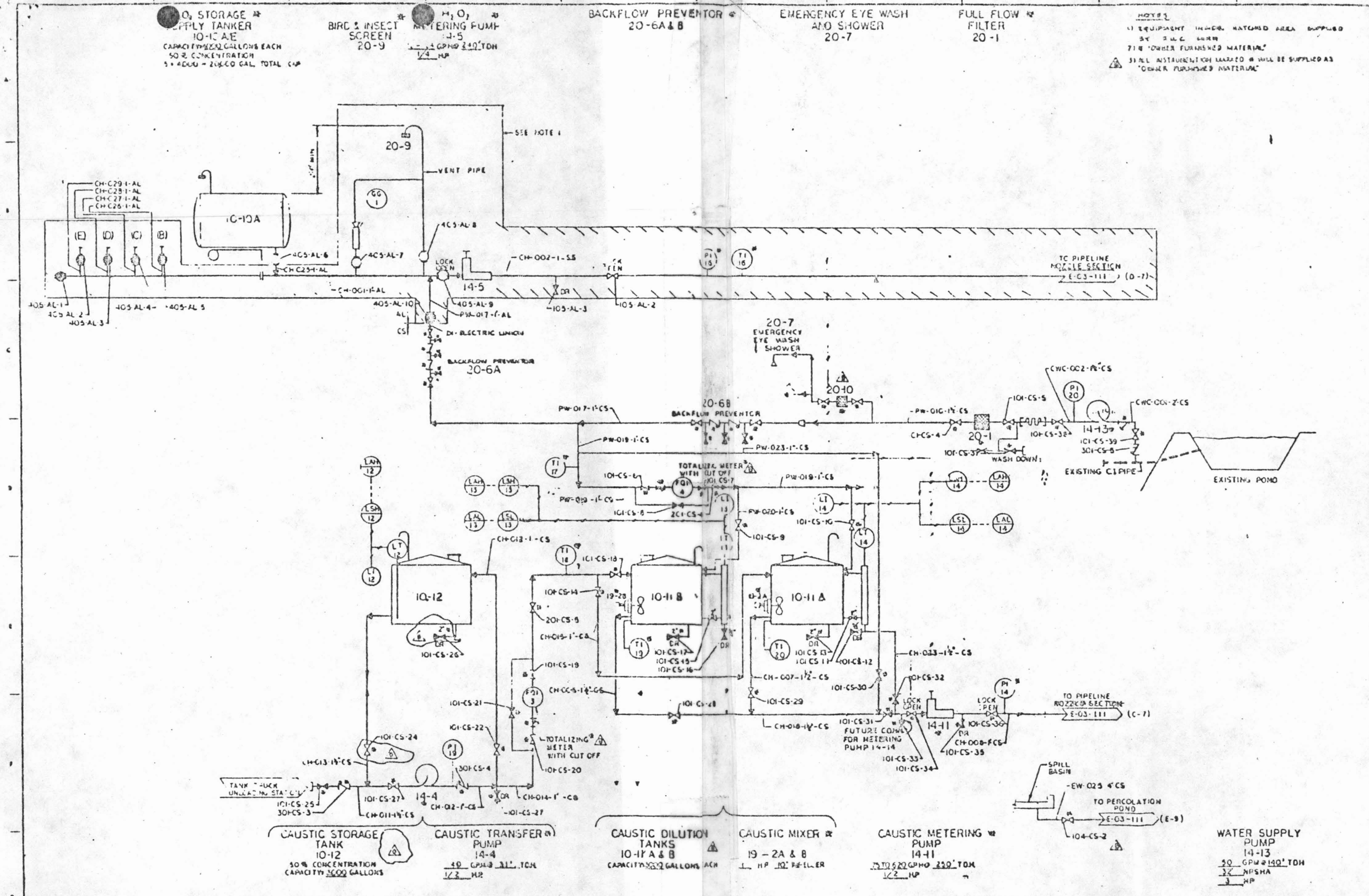
NOTES:

1) (1) IF REQUIRED NaOH IS INCREASED BY HIGHER CONCENTRATION.
2) * "OWNER FURNISHED MATERIALS"
3) ALL INSTRUMENTATION IS "OWNER FURNISHED MATERIALS"
4) SEE DATA SHEET DS-15-008 OF SPECIFICATION 15C-PIPING MATERIALS FOR PIPING MATERIAL SUPPLIED AS "OWNER FURNISHED MATERIALS"
5) EQUIPMENT INSIDE HATCHED AREA SUPPLIED BY FMC CORP.
6) * ADDED TO OWNER FURNISHED INSTRUMENTION

RESEARCH CORPORATION
of
UNIVERSITY OF HAWAII
APPROVALS

HGP-A WELL HEAD GENERATOR
PROOF OF FEASIBILITY PROJECT
PIPING & INSTRUMENTATION DIAGRAM
WELL HEAD TEST SYSTEM

E-03-[illegible] 0



RESEARCH CORPORATION OF THE UNIVERSITY OF HAWAII

APPROVALS

HGP-A WELLHEAD GENERATOR
PROOF OF FEASIBILITY PROJECT
PIPING & INSTRUMENTATION DIAGRAM
TEST CHEMICAL FEED SYSTEM

JOB NO. 578030

E-03-113

ISSUED FOR CONSTRUCTION

ISSUED FOR BID

REVISION

REFERENCE DRAWINGS