HIGH SALINITY GEOTHERMAL ENERGY CONVERSION BASED UPON THE OPERATING EXPERIENCE AT THE SAN DIEGO GAS & ELECTRIC-DOE GEOTHERMAL LOOP EXPERIMENTAL FACILITY LOCATED AT THE NILAND RESERVOIR, IMPERIAL VALLEY, CALIFORNIA, U.S.A.

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Research at the Geothermal Loop Experimental Facility (GLEF), co-funded by San Diego Gas & Electric (SDG&E) and the U.S. Department of Energy (DOE), was successfully concluded in September of 1979. In 13,000 hours of operation during a three and one-half year period, the nominal 10 megawatt electrical-equivalent GLEF provided engineers and researchers from SDG&E, national laboratories, government agencies and industry the opportunity to identify problems in working with highly saline geothermal fluids and to develop solutions that could be applied to a commercial geothermal power plant producing electricity.

Figure 1 shows the location of the site of the GLEF in relation to the other geothermal anomolies in the Imperial Valley. Figure 2 sets forth, in a concise fashion, the history of the GLEF.

The Niland Reservoir, which supplied fluid to the facility, has a high total dissolved solids (TDS) content of about two hundred fifty thousand (250,000) parts per million (ppm), but has a high downhole temperature between 500-600°F.

Figure 3 shows the constituents of the solids in the brine. Note that the silica content is approximately 200 ppm and that the chloride concentration is well over 100,000 ppm. Figure 4 shows a generalized range of non-condensable gas content of the brine that was used at the facility.

During the period 1976-1977, the facility was operated in a four-stage, flash binary cycle operation. The Final Report of the Geothermal Loop Experimental Facility discusses the operation of the facility in this manner. However, in 1978-1979, the facility was operated in a two-stage flash cycle configuration is shown in Figure 5. Figure 6 is an aerial photograph of the facility at the time the effluent brine clarifier filter was being constructed.

One of the largest obstacles to constructing a power plant at the Niland Reservoir is related to the reservoir brine. The solids that precipitate from the brine upon cooling not only form scale in the brine piping, but most of the solids are carried through the plant and are injected into the reservoir. This causes the reinjection capability of the wells to decline.

In February, 1978, Imperial Magma and Lawrence Livermore Laboratory began conducting a separate series of tests of equipment to remove suspended solids efficiently from the effluent brine prior to injection. One of the problems that had to be overcome was the relatively slow evolution rate of the silica in solution in the brine. This dissolved silica precipitated so slowly that quick removal of suspended solids from the effluent brine was not sufficient to preclude the brine from containing a degree of silica supersaturation. This silica tended to precipitate in the injection well or in the reservoir itself, causing potentially irreparable damage to the well or the reservoir.

The process that was decided upon and extensively tested by Imperial Magma (with the cooperation of the Envirotech Corporation) is similar to that used in water and sewage treatment industries. To verify the pilot test on a larger scale, the decision was made in mid-1978 to build a full-scale treatment facility at the GLEF, based on this process. The system consists of a reactor clarifier (Figure 7), media sand filter (Figure 8) and thickener (Figure 9). The period of operation of the clarifier/filter system was limited to less than 1000 hours, prior to project termination. Figures 10 and 11 are schematic representations of the operation of the clarifier filter system. Important conclusions derived from the GLEF Project are summarized as follows:

- Supersaturation of silica in the effluent brine can be quickly removed by a reactor/clarifier.
  - Most of the resulting suspended solids can be removed by settling/filtering.
  - Oxygen must be carefully excluded in order to prevent further reaction and generation of suspended solids.
  - Solid waste, predominantly silica, separated via the filter press, is readily transportable.

- The clarification process is relatively stable.
- Injection capability of the processed brine appears feasible if atmospheric oxygen can be excluded from the process.

- Reservoir injection capability and production evaluations were accomplished and the reservoir appears to be capable of supporting commercial power production.
- No induced subsidence was detected.
- Steam of acceptable quality, with further treatment, can be produced (See Figures 12 and 13).

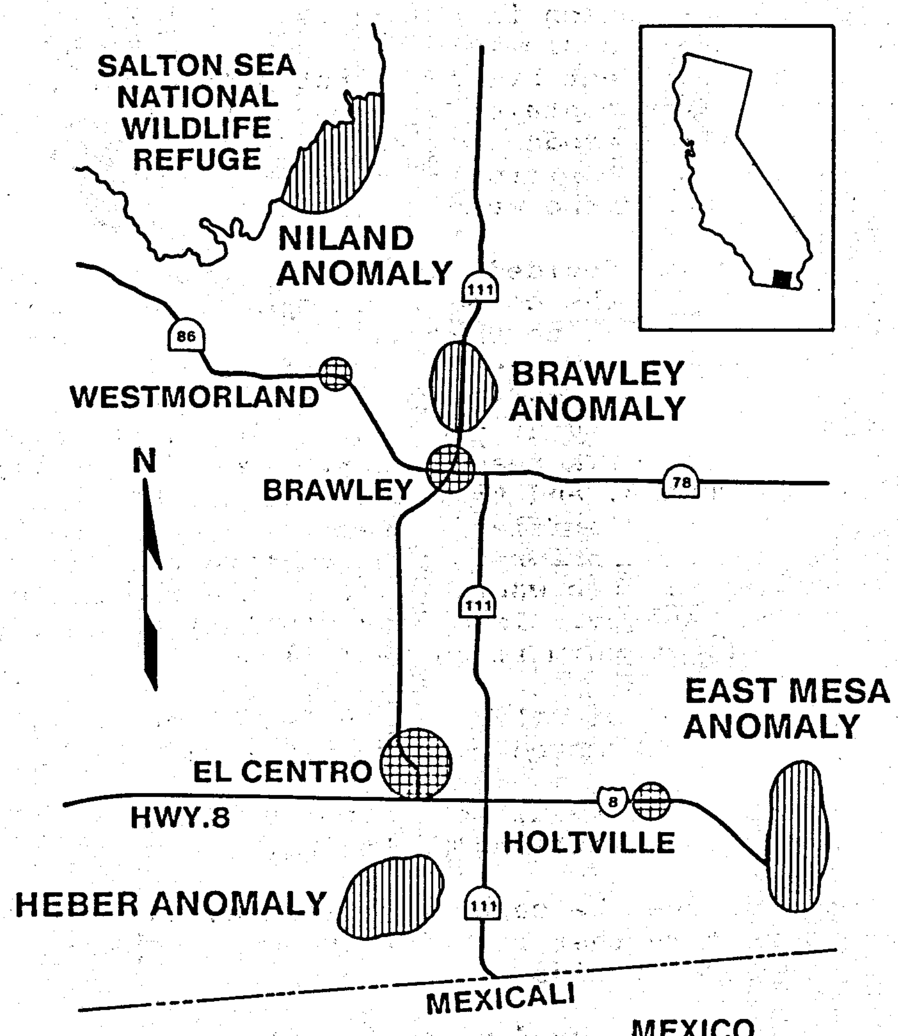

Fig. 1. Location of Imperial Valley geothermal reservoirs.

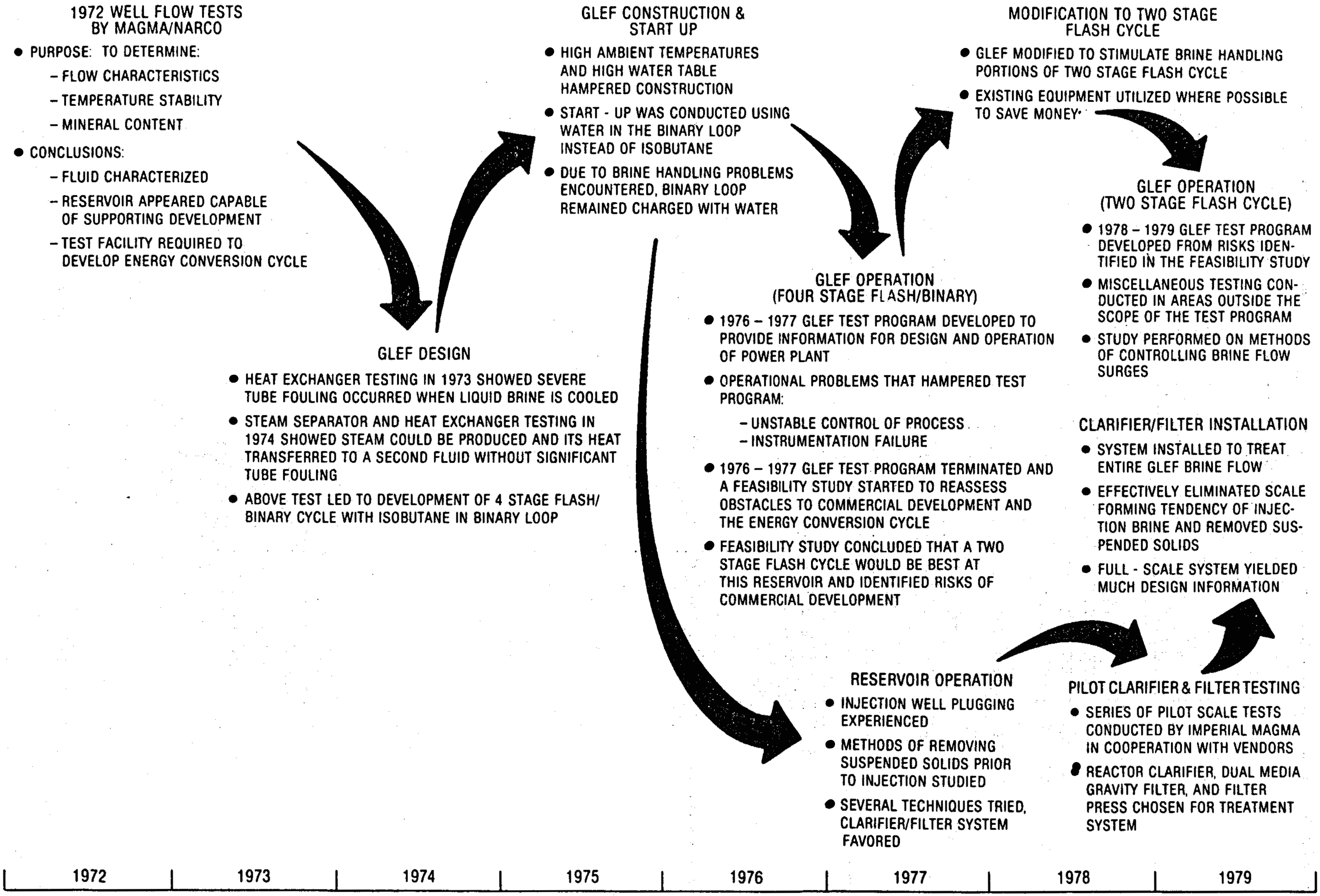

Fig. 2. GLEF history.

ELEMENT	HIGH	LOW	AVERAGE
Cl	146,000	94,000	121,000
Na	54,600	29,600	42,700
Ca	28,300	16,700	22,900
K	14,100	5,830	10,200
Mn	903	498	718
Sr	472	292	382
Zn	313	172	256
Si	236	152	204
Ba	195	79	142
Li	197	122	162
Fe	320	152	236
Mg	116	67	87
Pb	68	24	49

Note: All measurements are ppm

Fig. 3. Elemental range for generalized brine.

	DECEMBER 1976 % OF TOTAL GAS	AUGUST 1979 % OF TOTAL GAS
CO_2	98.14	98.92
CH_4	0.68	0.51
N_2	0.02	0.57
O_2	*ND	*ND
H_2	*ND	*ND

*ND implies none detected

Fig. 4. Generalized range of noncondensable gases in brine.

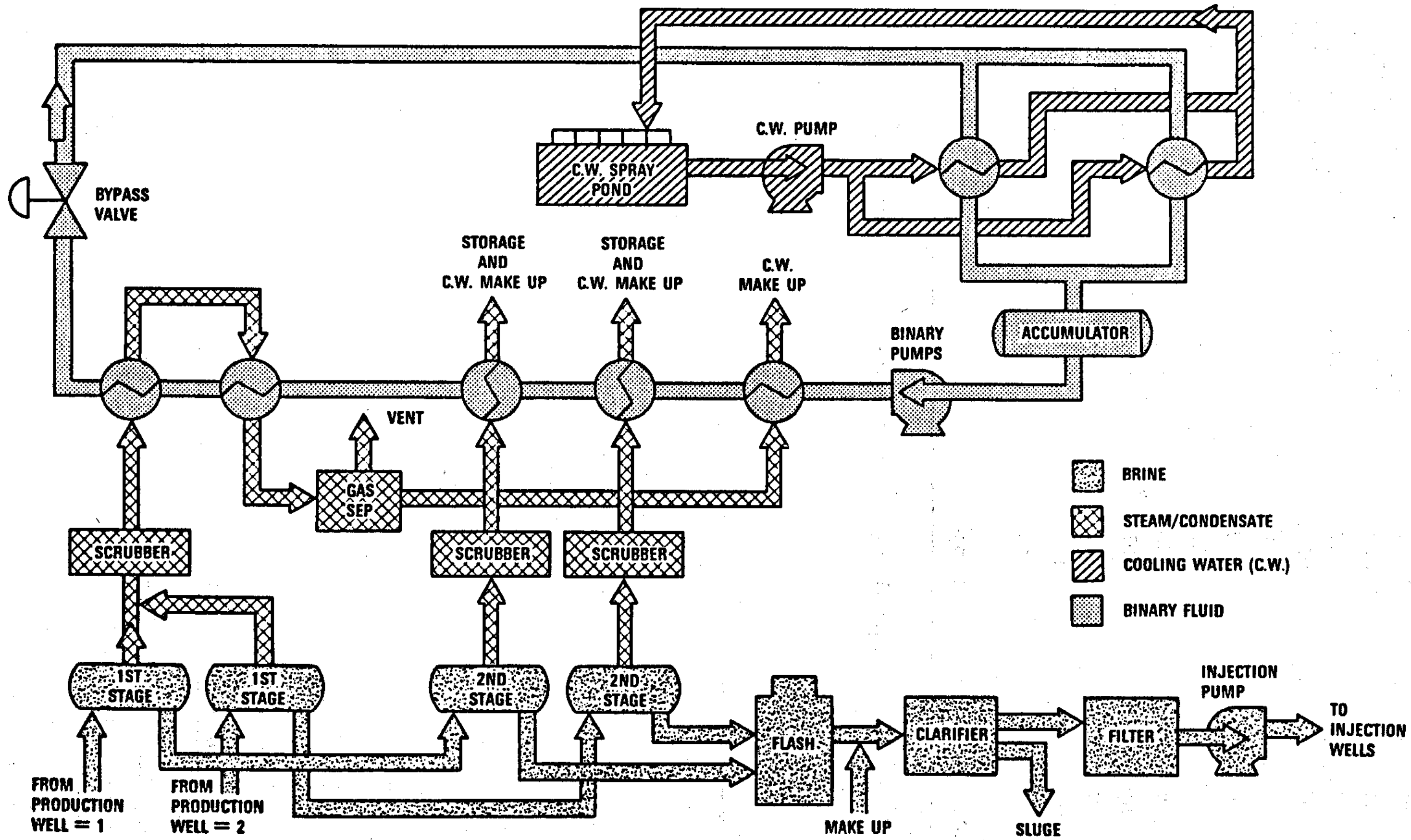

Fig. 5. GLEF process flow diagram.

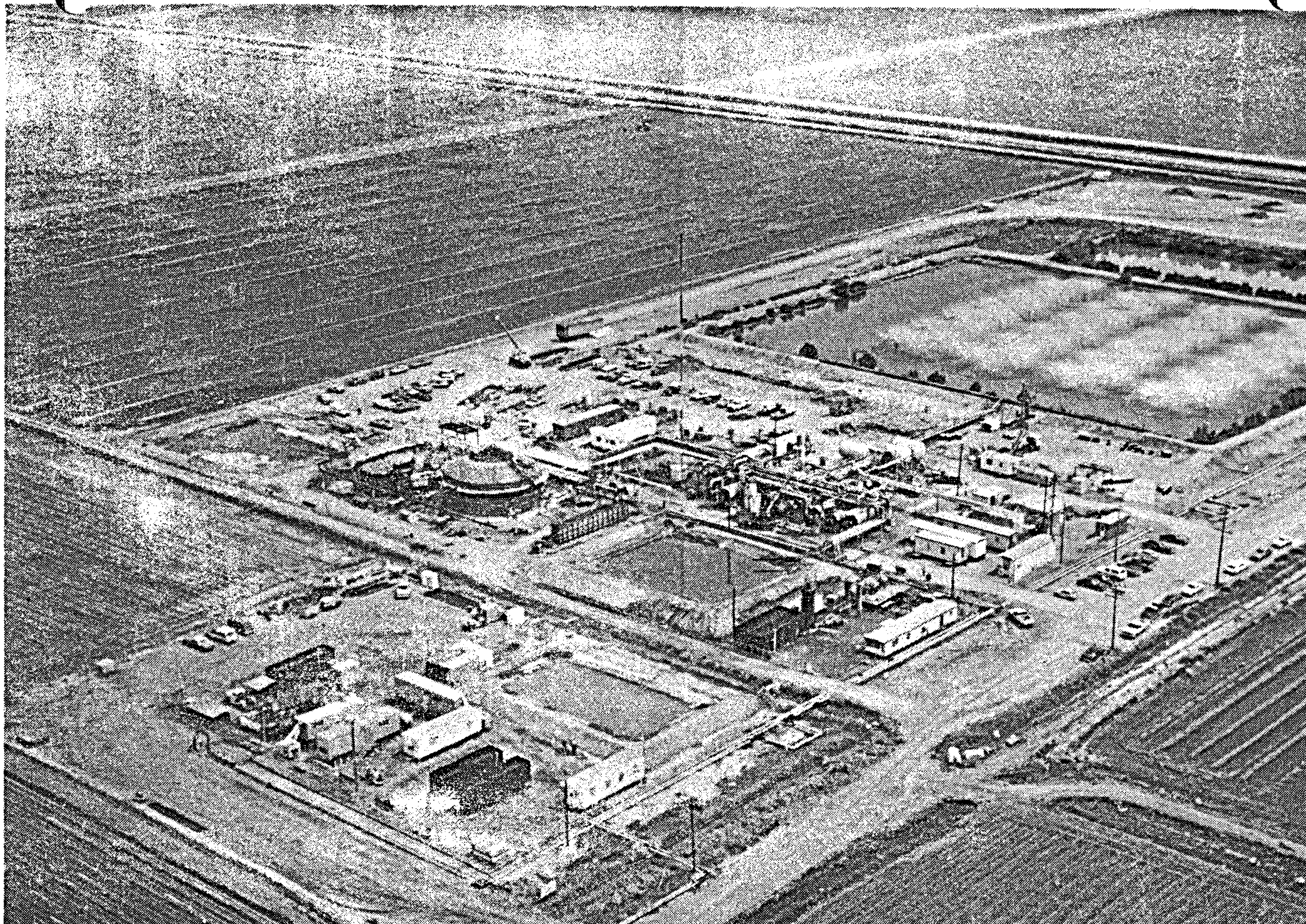

Fig. 6. Aerial photograph of Geothermal Loop Experimental Facility (GLEF).

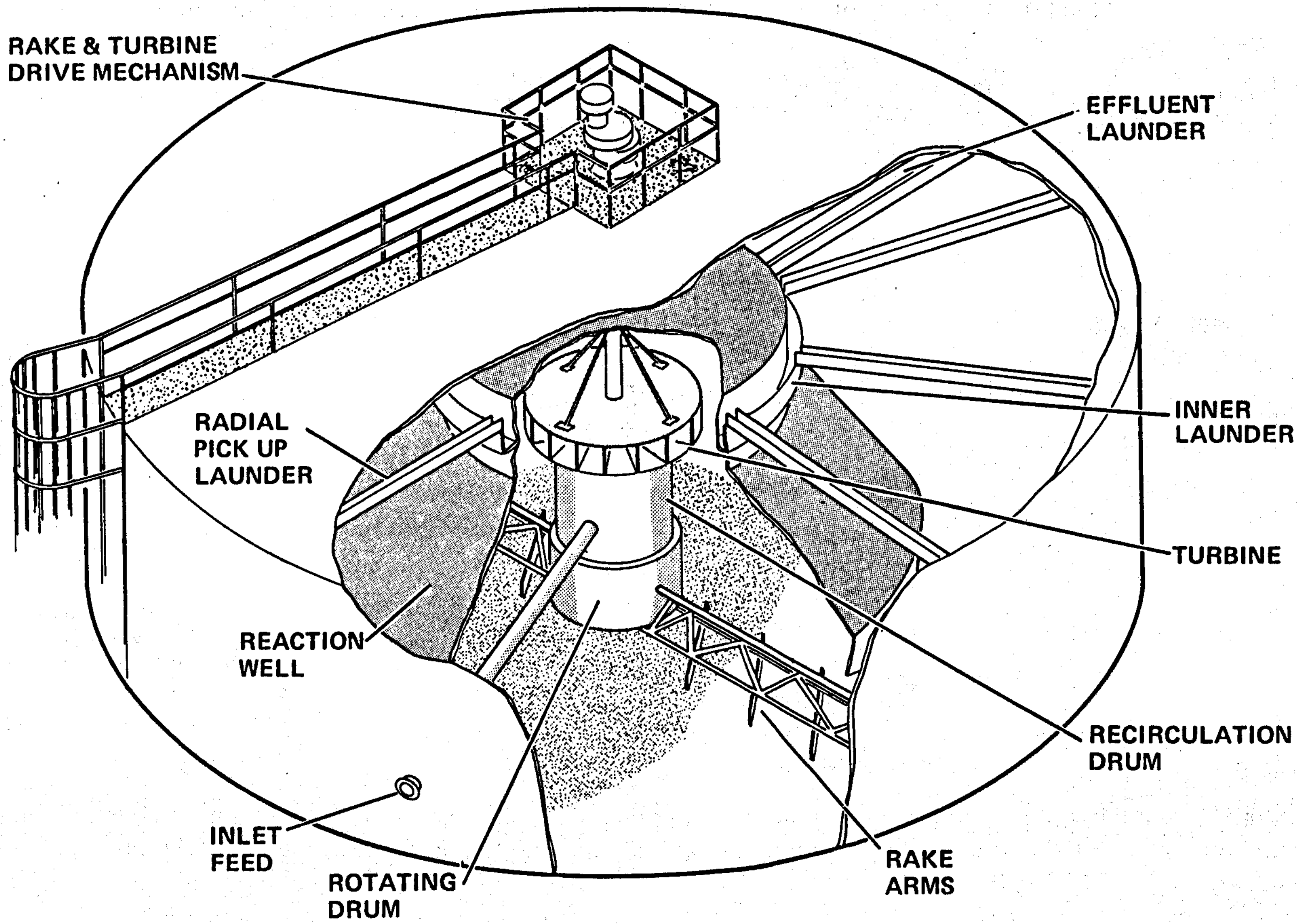

Fig. 7. V-17 Reactor/Clarifier.

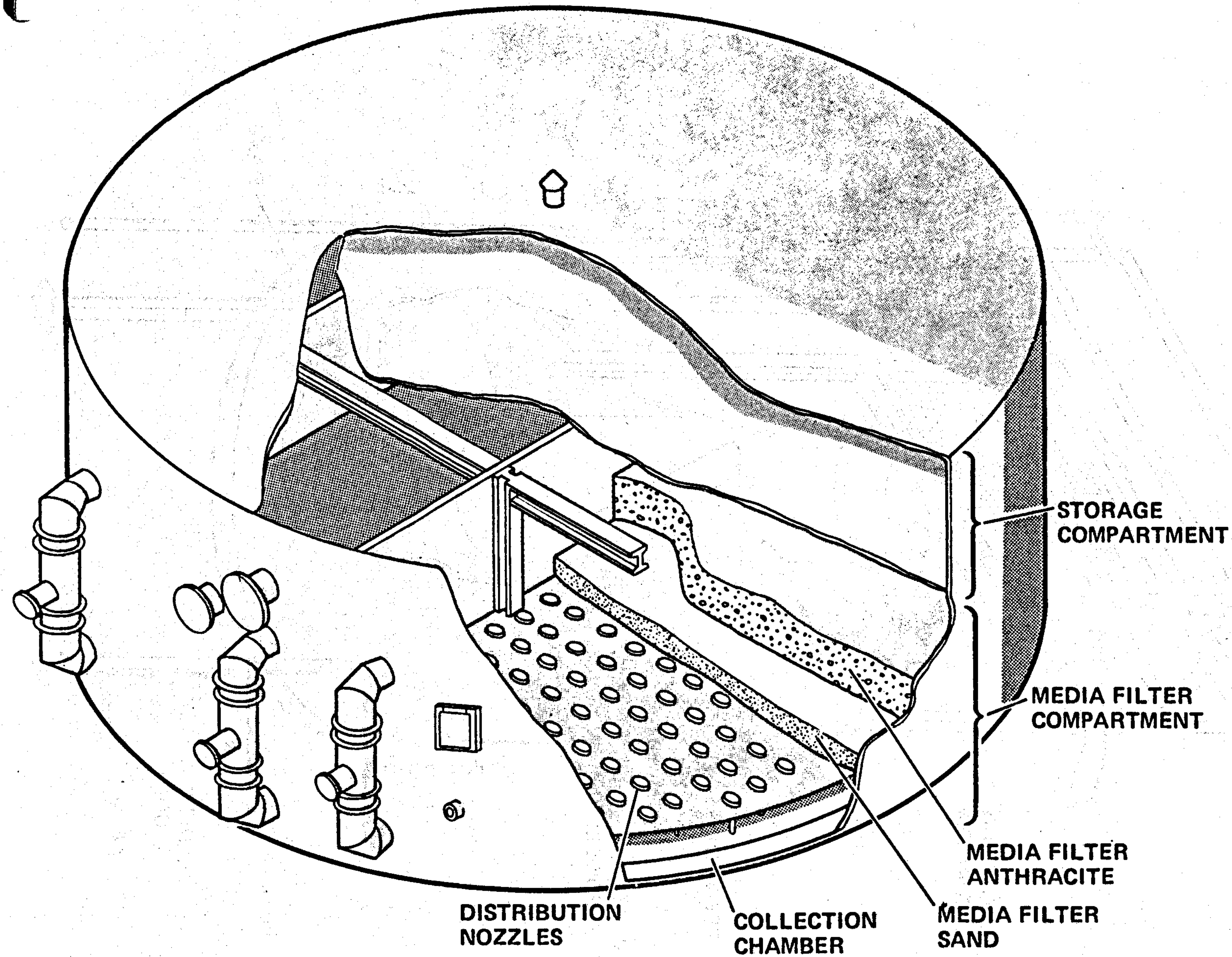

Fig. 8. V-18 SVG Sand filter.

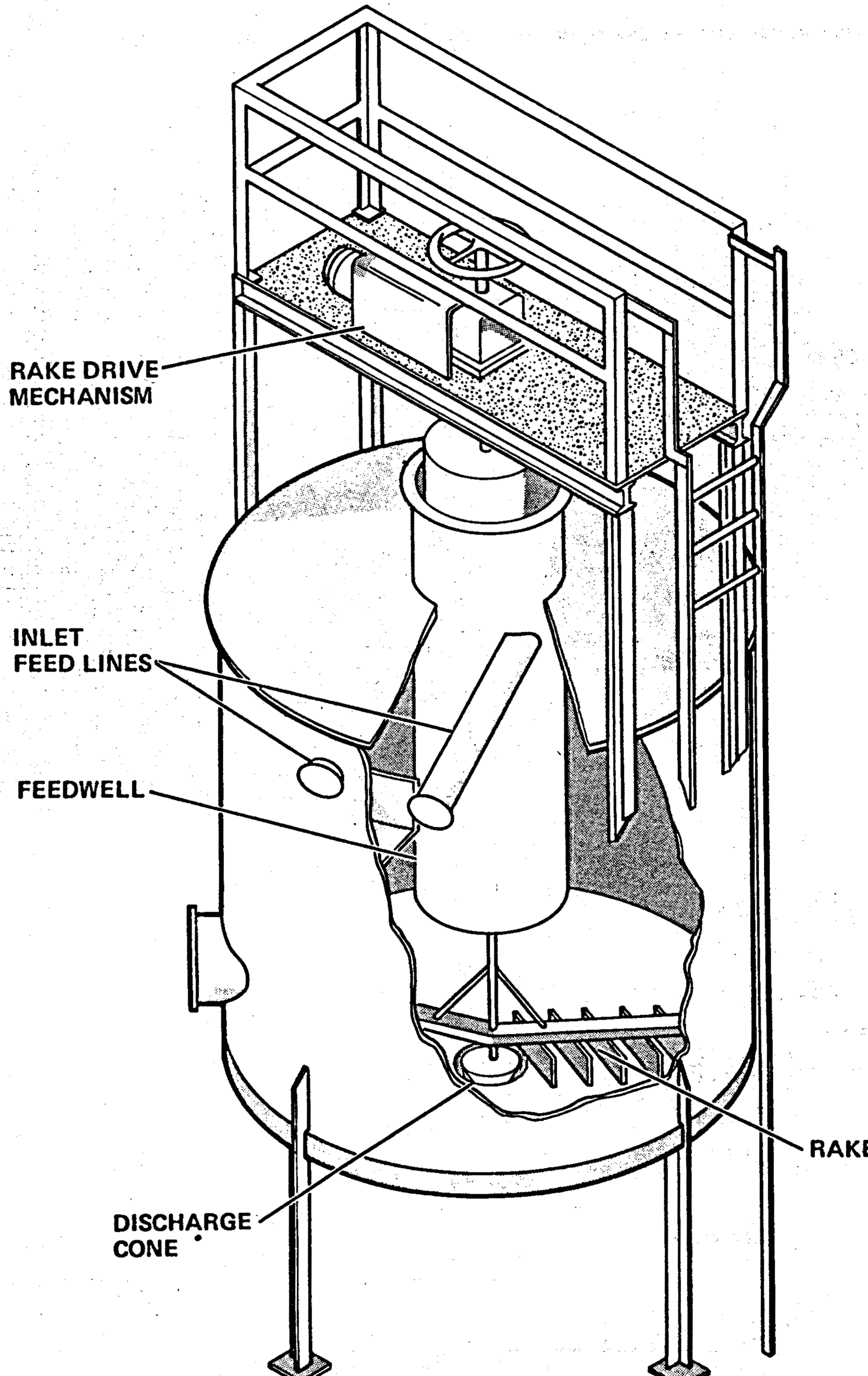

Fig. 9. V-22 Thickener.

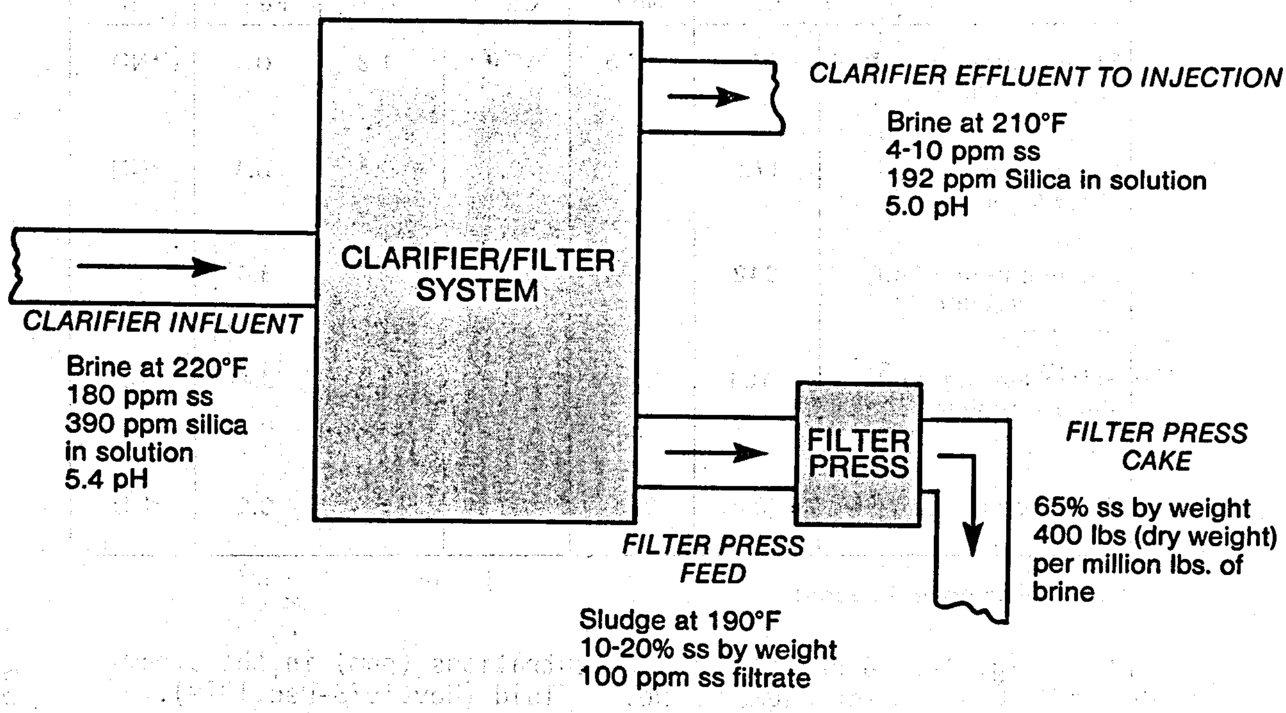

Fig. 10. Clarifier/filter system operation.

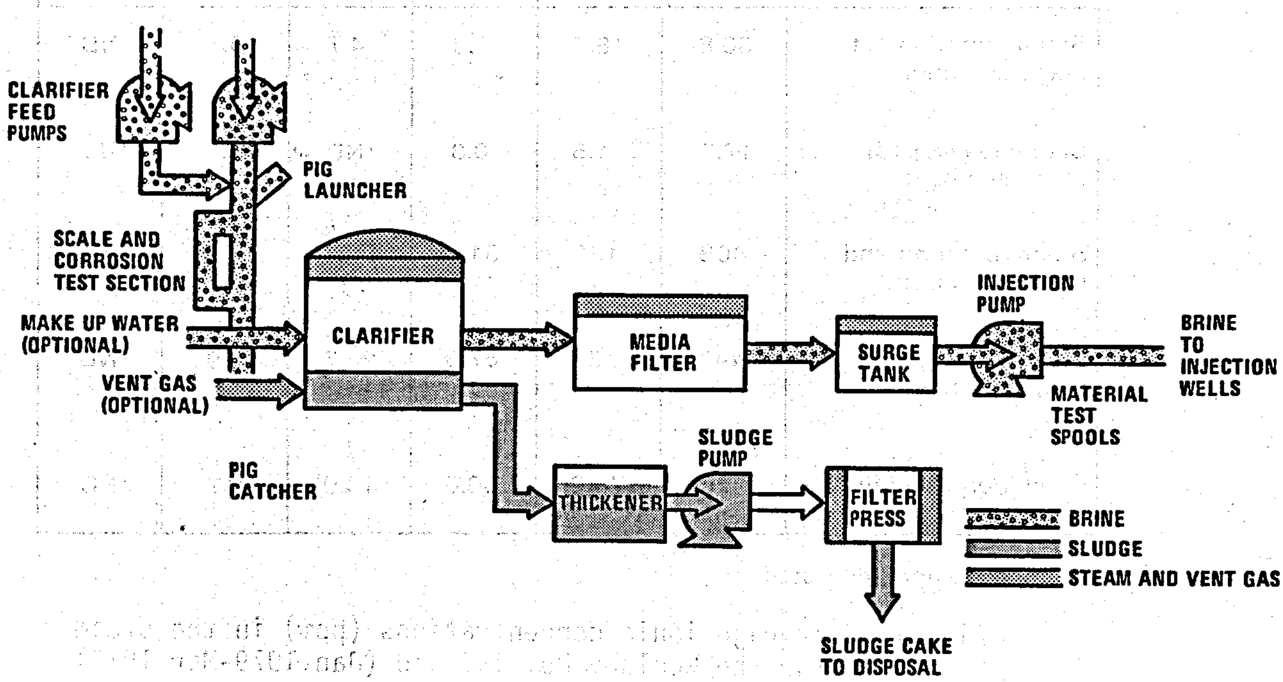

Fig. 11. GLEF process flow diagram.

	Cl^-	Na^+	Ca^{++}	K^+	Fe^{++}	Si
Steam entering 1st stage scrubber	37.1	7.5	3.4	1.3	0.1	*ND
Steam leaving 1st stage scrubber	17.2	1.8	0.6	0.4	0.1	*ND
Steam entering 2nd stage scrubber	342	171	63.6	32.7	3.4	1.5
Steam leaving 2nd stage scrubber	131	51.7	21.5	12.0	0.4	0.1
Combined Condensate	89.5	22.0	10.0	5.1	0.2	*ND

*ND implies none detected

Fig. 12. Average ionic concentrations (ppm) in the steam for Magmamax No. 1 fluid (Nov.1978-Dec.1978).

	Cl^-	Na^+	Ca^{++}	K^+	Fe^{++}	Si
Steam entering 1st stage scrubber	60.8	18.7	9.3	4.7	0.7	*ND
Steam leaving 1st stage scrubber	17.7	1.5	0.3	*ND	0.1	*ND
Steam entering 2nd stage scrubber	408	160	61.1	20.7	0.5	2.5
Steam leaving 2nd stage scrubber	447	136	67.3	25.7	0.9	*ND
Combined Condensate	225	78.2	30.0	14.0	0.7	*ND

*ND implies none detected

Fig. 13. Average ionic concentrations (ppm) in the steam for the Woolsey No. 1 fluid (Jan.1979-Mar.1979).