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FAILURE ANALYSIS REPORT

WELL PRODUCTION CASING
BRADY NO. 5 WELL
GEOTHERMAL FOOD PROCESSORS, INC.
FERNLEY, NEVADA

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1.0 Introduction

Geothermal Food Processors, Inc., (GFP) located 65 miles east of Reno, Nevada, utilizes superheated water from the Brady Hot Springs Known Resource Area (Brady H.S. KGRA) in a cascaded vegetable drying plant. Geothermal water from a series of wells is pumped under pressure, without flashing, at temperatures up to 325°F (163°C) for process heat.

On 18 June 1979, Brady No. 5 well was stimulated after cleaning. The production casing failed at that time, causing a blowout. This report presents results of an investigation of that casing failure.

This report is a part of a continuing effort to gain insight into geothermal component materials used in the direct utilization of geothermal energy. The results of these analyses will provide materials data for use in the next issue of DOE's Materials Selection Guidelines for Geothermal Energy Systems.

2.0 Brady H.S. Resource

The Brady H.S. KGRA is liquid dominated and produces comestable grade water. Table 1 presents a recent analysis of water said to be typical of the resource. It should be noted that though surface manifestation (fumerole) discharges contain hydrogen sulfide, no hydrogen sulfide has been detected in the steam from producing wells.¹

Bottom-hole temperatures as high as 415°F (213°C) have been measured at Brady H.S. but ~ 338°F (170°C) is considered typical. The highest wellhead temperature reported is 325°F (163°C).

Serious carbonate scaling in the well bores occurs if bore-flashing is allowed. Normal practice at GFP is to use Peerless* line shaft pumps to maintain the fluid at a pressure 100 psi greater than the steam table vapor pressure indicated for the bottom hole temperature of the well. This practice is reported to prevent carbonate scaling. (The process is said to be covered by a Magma Patent).¹

3.0 Brady No. 5 Well

Brady No. 5 was the largest producer at the KGRA, yielding ~ 900,000 lb/hr total flow (steam fraction ~ 8 percent when discharged to atmosphere at 4160 ft altitude).¹

The well was completed about 20 years ago in the following manner. A surface conductor of 20 inch diameter casing was set to a depth of 20 ft and cemented in. Upper string

*Mention of a specific product, process or vendor is not intended to exclude other products, processes, or vendors which may give comparable results or render comparable services.

TABLE 1. COMPOSITION OF GEOTHERMAL WATER FROM
 GEOTHERMAL FOOD PROCESSORS PLANT

COMPONENT	CONCENTRATION (ppm)
pH	7.18
Cl ⁻	1100
SO ₄ ⁻²	301
HCO ₃ ⁻	98
CO ₃ ⁻²	0
NH ₄	NR ¹
H ₂ S	ND ²
TDS ³	2528
Na	827
Ca	43
Mg	1
K	42
As	0.13
Fe	0.08
Mn	0.01
NO ₃ ⁻	0
F ⁻	0.52

Recent analysis by Bureau of Laboratories & Research,
 Nevada Division of Health

¹Not reported

²Not detected by repeated USGS testing

³Total dissolved solids

casing of 16 inch diameter was set to 100 ft and cemented in. The production casing, 13-3/8 inch diameter was set to the bottom of the hole (~550 ft) and cemented. The cement is reported to probably have been a 10 sack mix of cement and sand such as was conventionally used for water well completion.¹

Prior to stimulation after cleaning (unspecified process) to remove a calcium carbonate plug, the interior of the production casing was inspected and appeared to be in good condition.¹ The well was stimulated, the production casing parted and blowout occurred.

4.0 On-Site Investigation

On-site investigation occurred on 13 November 1979, 148 days after the blowout.

Figure 1 shows the wellhead assembly. The arrow indicates ground level. Failure (parting of casing) occurred about 7 ft below ground level.

The exterior of the casing shows extensive corrosion of the steel (grade not reported) with continuous tuberculation or exfoliation of the entire buried portion. The attack appeared to become more severe with increasing depth (see Figures 1 and 2). Some very broad shallow pits were also observed. The remaining wall thickness at the point of failure was less than 0.125 inches with some perforations of more than one inch in diameter.

There were a few patches of cement clinging to the exterior of the production casing as indicated by the arrow in Figure 3. This cement was very fissured and easily broken with a pocket knife. Most of the exterior of the casing was devoid of cement.

Inspection showed no clear signs of internal corrosion. The interior, which had been exposed to weather since the blowout, showed a film of rust. No tuberculation or pitting from the inside was observed.

Early efforts to cap the well involved excavation of the stump of the casing. Figure 4 shows the excavated stump. No surface conductor or upper string casing, or its associated cement, were encountered during excavation.¹

5.0 Laboratory Investigations

No material was obtained for laboratory analysis for the following reasons:

- The casing had been exposed to weathering for 148 days. This exposure may have greatly altered the composition of corrosion products on the casing.
- The probable mechanism of failure is apparent from on-site investigations.

6.0 Conclusions

- Internal corrosion of the production casing does not appear to be a major factor in this failure. The produced geothermal fluid is oxygen free. On-site observations and other geothermal experience² indicates that corrosion by oxygen-free Brady Hot Springs geothermal fluid should not cause severe corrosion of carbon or low alloy steels.

- Failure of the casing of the Brady No. 5 resulted from severe external corrosion. This mode of failure of casing has also been reported at Wairakei, New Zealand and Cerro Prieto, Mexico.² The well is located in a mineral flat and it is proposed that during wet periods the exterior of the casing was exposed to aerated saturated chloride and/or sulfate salt solutions. These solutions appear to have completely destroyed the surface conductor and upper string casing and associated cements. The production casing then corroded until mechanical failure occurred.
- Liquid phase water is required for the proposed mechanism. Since production casing temperatures during fluid production are 310°-325°F (154-163°C) existence of liquid ground water in contact with the casing exterior is unlikely. Therefore it is suggested that most of the attack occurs during periods when the wells are killed.

7.0 Recommendations

Several means may be employed to promote longer life-time and greater reliability for existing and future geothermal wells at Brady H.S. KGRA. These recommendations are based on engineering alternatives without regard to the relative economics of the various choices. Further study is required to define the most cost effective choice. Such a study is beyond the scope of this analysis.

7.1 Inspection of Existing Wells

- The hazard and cost of a well blowout, and the serious deterioration of the casings of Brady No. 5 make adequate inspection of other wells at Brady H.S. imperative.
- In order to give reliable results, a well inspection method that detects external damage to the production casing must be used.
- A tool under the trade name Vertilog* is available from Dresser-Atlas* for this kind of inspection. The tool can be modified for 13-3/8 casing inspection. The tool has a temperature ceiling of 275°F (135°C) and a pressure limit of 15,000 psi. This tool could be used to inspect "killed" wells at Brady H.S. to a considerable depth. Tool operators should be cautious not to exceed temperature limit of the tool.

7.2 Reconditioning of Existing Wells

- If the production casings of other wells are found to be seriously damaged, the wells could be reconditioned by inserting and cementing (with suitable cement) a smaller diameter production casing. The new casing

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would need to extend sufficiently past the damaged area of the existing production casing to provide anchorage.

- Portland cement as such is not suitable in this application. At temperatures above 248°F (120°C) a very low strength phase is formed.³ Portland cements are subject to serious attack by sulfate and carbonate ions.³
- Type G cement with 80 percent silica flour has been shown to be satisfactory in saturated brines at temperatures up to 482°F (250°C).^{3,4} This material would be suitable for well cementing at Brady H.S. provided that soil conditions are alkaline (most probable case).
- Polyester or epoxy cements would provide maximum security in this application⁴ but would cost more.

The cements mentioned are state-of-the-art. Many well completion companies will be familiar with them.⁴

7.3 Cathodic Protection of Existing Wells

Cathodic protection is a standard process for water and gas or oil wells and in principle should work on geothermal wells.

- Cathodic protection of existing wells is questionable. Because of probable damage

damage to outer casings, the production casing must be protected. Cathodic protection from an external ground bed will protect only the outer-most electrical conductor. Therefore, significant shielding of the production casing by the residue of the outer casings may occur. Determination of the suitability of a cathodic protection system for existing wells requires a qualified cathodic protection engineer.

7.4

Future Wells

- Future wells should be completed using either Type G cement with 80 percent silica flour, an epoxy cement or polyester cement. Use of an epoxy or polyester cement for the surface conductor and less expensive Type G with 80 percent silica flour for other cementing might give the best results at least cost.
- Cathodic protection of new wells should be investigated. Current requirements during wet soil conditions with wells cooled down should indicate maximum current requirements. Services of a qualified cathodic protection engineer are required.

Figure 1. Wellhead Assembly from Brady No. 5. Arrow indicates apparent ground level. Casing diameter is 13-3/8 inches.

Figure 2. Brady No. 5 Wellhead Assembly. Note tuberculation of exterior and large perforation (arrow).

Figure 3 Another View of the Failed Production Casing. Arrow indicates a patch of cement.

Figure 4 Stump of Production Casing of Brady No. 5 After Excavation. No surface conductor or upper casing were encountered during excavation.

8.0 References

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3. Kalousek, G.L., Development of Cement for Geothermal Wells, Final Report, DOE Contract No. EY-76-C-02-0016 subcontract NO. 406003-S, Colorado School of Mines, Golden, CO, March 1, 1979.
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