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WELLHEAD CASING THICKNESS MEASUREMENT AND REPAIRS

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ABSTRACT

Isolated instances of wellhead casing thinning at the surface due to kelly whip, drill pipe wear, and/or corrosion at the Geysers has prompted Calpine Operating Plant Services (COPS) to monitor casing thicknesses. A systematic program has been developed to measure casing thicknesses once per year utilizing an ultrasonic thickness measurement tool. A maximum allowable pressure is calculated for the minimum casing thickness measured and repairs are initiated if necessary. Several Geysers wells have had excessively thin casing and have been repaired using innovative techniques developed by COPS. The wellhead thickness measurement program and the repairs to excessively thinned casing have ensured reliable operation of the COPS' Geysers steam fields.

INTRODUCTION

As the Geysers steam field has matured, there has been an increase in noncondensible gases sometimes accompanied by increases in chloride in the steam produced by the wells. Consequently there has been an increase in corrosion rates for both surface and downhole equipment. As a result of increased corrosion (in isolated instances) combined with the phenomena of "kelly whip", during drilling, wellhead casing thicknesses have been eroded. In order to ensure the integrity of wellhead casings, Calpine Operating Plant Services (COPS) has developed a method for monitoring the thickness and integrity of wellhead casings. Several operators have developed systems to perform this monitoring. However, this paper will discuss only the techniques that COPS has incorporated to monitor casing thickness and repair thinned casing at the surface.

BACKGROUND OF WELLHEAD CASING THINNING

Since 1986, several operators have been testing well casing thicknesses because of observations indicating increased casing corrosion rates. In order to maintain safe and reliable operation of their geothermal wells, COPS implemented a wellhead thickness testing and casing repair program.

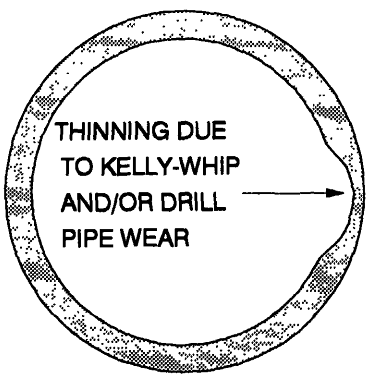
CAUSES OF CASING THICKNESS REDUCTION

Corrosion, one cause of casing thickness reduction, can lead to general wall loss, localized wall loss from localized condensation, and/or pitting wall loss. Internal corrosion in geothermal wells is initiated by condensation of the steam on the inside of the casing, particularly during shut-in conditions when the casing is cooler. This thin layer of condensate absorbs constituents from the steam such as hydrogen sulfide, carbon dioxide, and chlorides to form sulfuric, carbonic, and hydrochloric acids. External corrosion can also occur but is not a typical problem at the Geysers since the high wellhead temperatures prevent condensate from forming on the outside of the wellhead. External corrosion can become a problem, however, if the production casing is partially buried. The buried section can be an area of cooling and moisture held by the surrounding soil can form condensate on the casing and begin the corrosion process.

Drill pipe wear is another source of casing thickness reduction. This is caused by rotation of the drill pipe and tripping in and out of the hole while drilling. Another drilling related problem is "kelly whip", caused by the rotation of the kelly while drilling (Figure 1). These drilling related casing wear problems are especially pronounced when the rig is off center from the hole. The wear will vary according to the degree which the rig is off center and the length of drilling time.

FIGURE 1

TOP VIEW OF CASING WITH KELLY WHIP AND DRILL PIPE WEAR

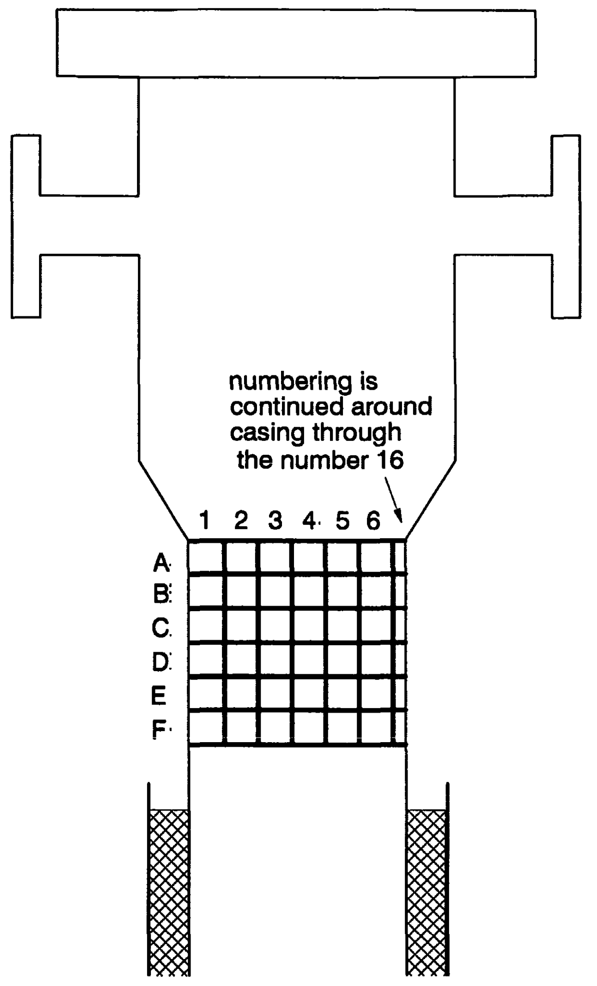


WELLHEAD CASING THICKNESS MEASUREMENT

In order to accurately monitor casing wall thickness in all of COPS' geothermal wells, a methodical technique was developed for consistent measurements. A grid pattern has been painted on each well casing to mark the points on the casing for annual thickness testing. The grid begins at the bottom of the casing head and extends downward. The points for measurement are in rows and columns and the points are approximately 2" apart around the circumference of the casing (Figure 2).

FIGURE 2

CASING THICKNESS MEASUREMENT GRID



Wellhead thickness measurements are taken using a hand-held ultrasonic thickness (UT) tester. Calibration of the UT measurement tool is extremely important and is performed on a known thickness calibration block which is heated to wellhead temperature by placing it on the 3" wellhead wing valve. Calibration of the tool is verified: 1) before well casing thickness measurements on each well; 2) at the half way point of each well's casing thickness measurements; 3) after the completion of each well's casing thickness measurements; and 4) at any time a large change in casing thickness is measured.

The transducer is placed on the pipe with a high temperature gel (1000°F rated) that provides a good full surface contact for the ultrasonic measurement. The transducer is rated to measure up to 1000°F with no required transducer temperature compensation, however, if the transducer is exposed to high temperatures for too long, then the transducer must be cooled. If the hand-held measurement tool begins to display unusual thicknesses, the transducer may have become too hot and is cooled by dipping it in cool water.

The key to accurate results is the use of a uniformly consistent procedure that is repeated for all wells. In order to ensure consistency and accuracy, COPS utilizes, to the extent possible, the same personnel to perform the measurements on all wellhead casings. To reduce recording error, a UT tester is utilized that automatically records on-the-spot measurements to an electronic database for subsequent downloading to a computer. An on-the-spot written record is also taken as hard copy back-up.

If excessively thin sections of casing are measured, these sections are remeasured in order to verify the reduction of wall thickness. Bad measurements will occur when: 1) the transducer becomes too hot; 2) a gap between the transducer and the casing occurs due to inadequate gel; 3) the transducer is not held in good contact with the casing; 4) the UT tester is out of calibration. The transducer must be placed on the casing in the correct and consistent transmit/feedback orientation in order to obtain consistent results. Pitting corrosion can give varying results due to the typically varied sizes of pits and could be confused with a bad reading.

With most wells, the casing thickness is measured on an annual basis. If a well with an overall wall loss of 20% is detected, the thickness is checked at least every 3 months.

THICKNESS MEASUREMENT DATA EVALUATION

In order to determine the safe minimum casing thickness, a calculation of pipe stresses must be performed based on shut-in wellhead pressure. According to ANSI B31.1, the maximum allowab549le pressure in a pipe is:

$$P = \frac{2SE(t_m - A)}{d - 2y(t_m - A) + 2t_m}$$

Where:

- SE = Maximum allowable stress from ANSI B31.1 Appendix A (psi)
- t_m = Pipe wall thickness (inches)
- A = Additional thickness for mechanical tolerances
- d = Pipe inside diameter (inches)
- y = coefficient from ANSI B31.1 Table 104.1.2(A)

For example, a 9-5/8" K55 36lb/ft string of casing has a maximum allowable stress (SE) of 13,800 psi, measured wall thickness of 0.109", an inside diameter of 9.407", no allowance for mechanical tolerances, and a "y" coefficient of 0.4. The maximum allowable pressure is:

$$P = \frac{2*13{,}800psi*(0.109''-0)}{9.407'' - 2*0.40*(0.109''-0) + 2*0.109}$$

$$= 315\ psig$$

This is the allowable pressure by code under ideal conditions. However, the following is a list of intangible conditions that make the geothermal conditions less than ideal and should be considered when evaluating action to be taken:

1) It is possible there are localized points where casing is thinner than the minimum measurement.

2) Surface imperfections can cause unaccounted-for stress concentrations.

3) Additional stresses can be acting on the wellhead from the wellpad piping, thermal cycling movements, and stress transmitted throughout the surrounding rock formations (e.g., tectonic or subsidence related stresses).

4) Additional stress and metal hardening is caused at the heat affected zone adjacent to welded flanges (i.e. - casing heads). This occurs particularly when the casing is improperly heat-treated during welding.

At the Geysers, COPS has developed the following action guidelines for wellhead casing thickness measurements:

13-3/8" casing

thickness over 0.25"	Acceptable and no action required
thickness 0.15"-0.25"	Take additional readings around thin area. Field Superintendent and Engineering evaluate if further action needs to be taken.
thickness under 0.15"	Leave location immediately and restrict the area. Minimize wellhead pressure. Evaluate corrective action that is required.

9-5/8" casing

thickness over 0.20"	Acceptable and no action required
thickness 0.10"-0.20"	Take additional readings around thin area. Field Superintendent and Engineering evaluate if further action needs to be taken.
thickness under 0.10"	Leave location immediately and restrict the area. Minimize wellhead pressure. Evaluate corrective action that is required.

WELLHEAD CASING REPAIRS

When it is determined that wellhead casing thickness reduction has become unacceptable on a particular well, then corrective action is taken to ensure the safety and operational integrity of the field. In cases where the casing wall thickness is reduced beyond repair the well is plugged and abandoned. Otherwise, the section of thinned casing is repaired. COPS has developed a technique to repair some cases of thinned well casing in place. This procedure has been performed successfully on 3 Geysers wells that had excessively thinned casing near the surface. The procedure is as follows:

1) Steam flow is quenched and pressure reduced to zero by pumping water down the well. A well casing plugging tool is rigged up over the well with a lubricator. The plugging tool has slips that catch in either the up or down direction in order to prevent the tool from being blown out of or slipping down into the hole. The casing plug will ensure no pressure is present while work is being performed on a potentially dangerous area of thinned casing.

2) The casing plug tool is then run into the hole making sure the tool is set at least 2' below the level at which any welding will take place.

3) The running tool is removed from the hole with the plug remaining at set depth. The running tool and related equipment are moved back away from the well to allow the repair work to be accomplished more easily.

4) The casing head 3" wing valve is kept open to bleed off any unexpected steam leaks.

5) A piece of casing to be utilized as a "patch" is obtained. This consists of a piece of spare casing that is one size larger and an inside diameter nearly matching the outside diameter of the casing to be repaired. The spare piece of casing is cut longitudinally in half. The cut edges and the ends are ground smooth and beveled in preparation for welding. The length of this casing corresponds to the length of excessively thinned casing plus 2".

6) The two halves of the piece of casing (casing patch) are slipped over the outside of the well casing (Figure 3).

7) First, A certified welder longitudinally welds the patch. The top of the patch should butt up to the bottom of the existing casing head.

8) Next, the top of the patch is welded, making sure that the weld penetrates into both the original casing head weld and the casing head itself.

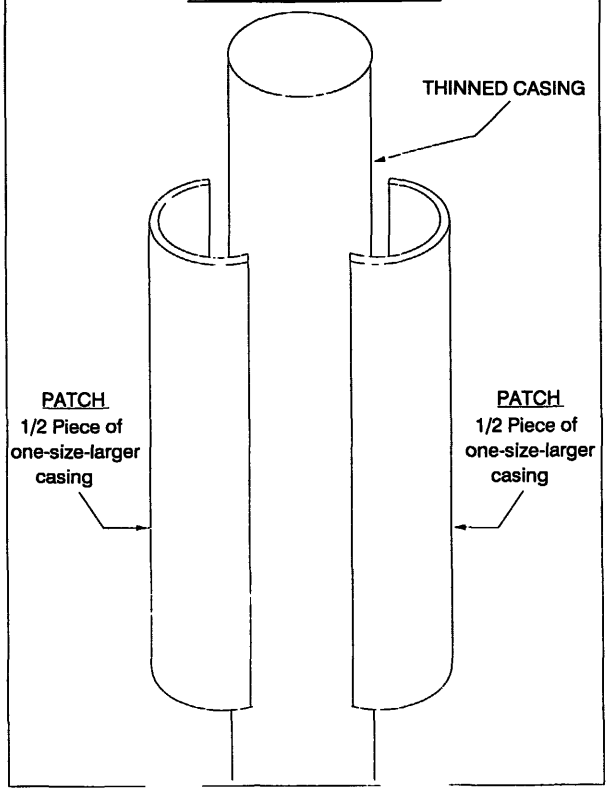
9) The final weld is done on the bottom of the patch joining it to the existing casing.

10) The casing plug running tool is rigged up and the plug removed from the well.

11) The well is then returned to service.

Another technique was required on one particular well in which the casing wall thickness reduction was so deep that it was not practically possible to repair it using the technique described above. The following is the description of this second technique of which the final result is illustrated on Figure 4:

FIGURE 3
CASING PATCH DIAGRAM



Steps 1) through 3): Same as technique described above.

4) The 9-5/8" production casing and 13-3/8" surface casing were cut off to just above the top of the 20" conductor casing.

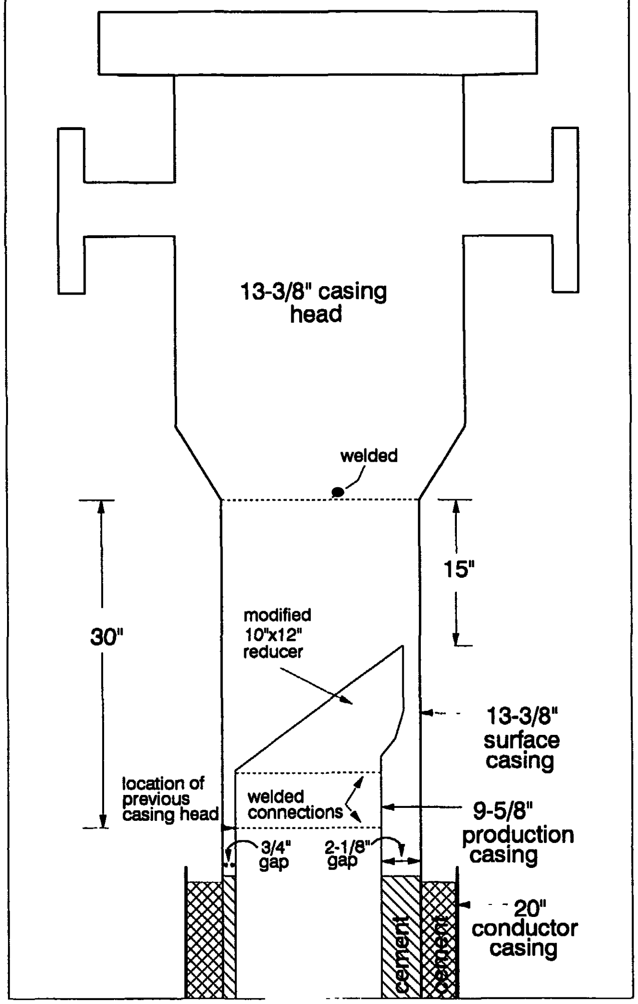
5) A modified 10"x12" reducer was butt welded to a short piece of 9-5/8" casing and the assembly butt welded to the existing 9-5/8" casing stub (Figure 4). The purpose of the modified eccentric reducer was to guide any downhole tools into the 9-5/8" casing which otherwise would have hung up on the lip of the casing due to the misalignment of the 9-5/8" casing (3/4" gap on one side and 2-1/8" on the other side).

6) Then a piece of 13-3/8" casing was welded to the 13-3/8" well casing stub, making sure there was about 15" from the top of the 9-5/8" modified eccentric reducer to the bottom of where the new 13-3/8" casing head would be welded (Figure 4).

7) A new 13-3/8" casing head was welded onto the 13-3/8" well casing.

8) The wellhead valves were then reinstalled. The casing plug was removed and the well returned to service as in steps 10 and 11 of the previously described procedure.

FIGURE 4
AS REPAIRED CASING USING TECHNIQUE 2



SUMMARY

Because of concern over the thinning of wellhead casing at the Geysers due to corrosion and kelly whip, COPS has developed a program to systematically monitor and track the thickness of wellhead casings. COPS has also developed methods for repairing near-surface, thinned wellhead casings. These methods and programs will maintain the continued safe and economical operation of the COPS' Geysers steam wells.

ACKNOWLEDGEMENTS

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REFERENCES

The American Society of Mechanical Engineers, 1989 (with addendums up through 1991); ASME Code for Pressure Piping B31.1 an American National Standard, Power Piping; Sections 102-104.