

## Casing Inspection Caliper Surveys: Results and Implications to Operations in Leyte Geothermal Production Field

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**Keywords:** Caliper logs, casing inspection caliper, solids carry-over in steam, casing wall erosion, casing wall thinning

### ABSTRACT

14 production wells in Leyte Geothermal Production Field (LGPF), Philippines, manifested potentials for casing wall thinning in mid-2001. These wells were suspected to have flowed steam with solids carry-over, which were subsequently collected in solids traps, pipeline and separators during the preventive maintenance schedule of the power plants. Four of them were prioritized for observation and were subsequently subjected to casing inspection caliper (CIC) logs.

Two of the surveyed wells, 209A and 401, have been assessed to have serious potential problems due to their relatively thinned production casing from about 100m depth to near-surface. The degree of erosion is believed related to the duration of use of the wells and the length of time they have been on steam production (as compared to two-phase or liquid-dominated discharge).

CIC surveys are recommended for the other steam-producing wells. A series of repeat annual CIC surveys is also proposed for representative wells that have recently turned to steam discharge for monitoring the thinning rate of the production casing walls.

### 1. INTRODUCTION

Solids carry-over in steam began to affect operation of the Tongonan 1, Upper Mahiao and Sambaloran fluid collection and recycling systems (FCRS) as a result of massive fluid extraction from the reservoir between 1996 and 2000 when additional power plants in LGPF with a combined installed capacity of 595.25 MWe began commercial operation. Whereas in wells producing wet steam, erosion of surface pipelines was not severe, in dry steam wells severe erosion of branch lines and rapid thinning of compensator liners and separator vessels were observed (Villa and Salonga, 2001). Samples collected from solids traps, pipelines and separator vessels consisted mainly of sand-sized silica scales and corrosion products. Measures implemented in the field, involving the use of solids traps, steam washing using brine and cold spring water (Villa et al., 2005), prevented further damage to surface equipment. Such measures, however, were not able to address the possible damage inflicted by the high-velocity solids on the casing and liner strings, assuming they originated downhole.

The reported presence of formation cuttings in the collected samples pointed to several on-line production wells as the source of the solids carry-over. Accumulation of corrosion products in the carry-over solids also suggested that erosion

of the inner walls of pipeworks, and probably the production casings of the wellbores, was taking place.

The magnitude of the problem was highlighted by the damage caused by the suspended solids in the sacrificial valve of well 413D (Figure 1). Holes as large as 1"x 2" diameter upstream of the valve gate were carved out by the abrasive nature of the solids in the fluid coming out of the wellbore.

This observed severity of damage in surface equipment led to a more serious concern – that the production casings of the wells might have been similarly affected, putting them at great risk. Considerable thinning and eventual breaching of the casing wall could lead to shallow steam leakage within the pad vicinity, causing environmental and safety problems. Mitigating measures were therefore put in place, part of which involved the inspection of production casings of some of the affected wells.



**Figure 1. Well 413D sacrificial valve damaged by solids carry-over in steam.**

### 2. CANDIDATE SELECTION

Downhole casing inspection caliper surveys (CIC) were subsequently scheduled on four priority wells experiencing the solids phenomenon. The wells were selected from 14 suspected and confirmed sources of the solids carry-over based on relative age (older wells had higher priority), on blockage history (tool access to at least 100 to 200 meters below surface), and on type of discharge (wells with dry discharges had higher concentration of solids carry-over).

Older wells were believed to be most prone to entries of solids into the wellbore due to wear and tear of their casings and liners. It was also expected that the abrasive effects of the high-velocity particles in the upflowing steam would be most pronounced in the uppermost section of the wellbore where fluid velocity tends to increase. Thus, the logs in the upper 100 to 200 meters of the casing would have been sufficient to determine the general condition of the

production casing with respect to the effect of the solids in the produced steam.

Three of the “oldest” wells in the project were listed as priority wells for inspection, namely, 209A, 301 and 401. The first was the biggest well in the Tongonan 1 field prior to start of production in the early 80’s, with about 20 MWe at the wellhead. Wells 301 and 401 are the discovery wells in the South Sambaloran and Upper Mahiao sectors of the field, respectively. All these wells produce nearly pure steam. Inspection results of the FCRS equipment connecting these wells also suggested that they were likely sources of solids.

A relatively newer well, 413D, was also included in the list in the light of the solids-induced damage it had on its sacrificial master valve (Figure 1).

Prior to the CIC surveys, 8” go-devil (gauge ring) runs were performed on the wells to determine the maximum depth that the caliper tool could reach in the 9 5/8”OD production casing. Table 1 summarizes the results of the runs. Included in the table is the resulting maximum CIC logged depth in each well.

**Table 1. Summary of 8” GD runs. All depths are in meters (measured depth) referred to CHF.**

Well	Top of Liner	MCD on 8” GD	Max. CIC Logged Depth	Remarks
413D	654	650	630	CIC tagged obstruction at 635m during run-in.
209A	654	633	620	CIC felt obstruction at 628m
301D	817	417	400	
401	464	464	300	

### 3. EQUIPMENT INFORMATION

The equipment used for the surveys is a 60-finger CIC run on a mono-conductor electric wireline (Buñing, 2003).

The tool is about 12 feet in length and 5” in diameter. It has an 8” base plate near the tool bottom – thus the need for a pre-log 8” Go-Devil survey to determine the maximum depth that the tool could pass through.

The tool is rated 300°C, enabling surveys without the need for quenching. The well must however be shut or flowed at the lowest possible bleed condition.

Sixty (60) simultaneous ID measurements are taken by the tool at a minimum sampling rate of one data set per 3 inches of tool movement, which can vary depending on consistency of the logging speed. Logging can only proceed upward from the maximum cleared depth. Wall thickness measurement is accurate to  $\pm 0.02$  inch. This log accuracy, coupled with the 60 simultaneous circumferential measurements, provides a high degree of repeatability and reliability of the over-all log.

Repeat sections are conducted over selected depths of investigation to ensure that accuracy of measurement is attained in all surveys.

The system only records the minimum and maximum ID at every measurement depth. This ID measurement is then converted to wall thickness based on calibration data for specific casing weights in the well. Calibration is done before tool rig-up and after rig-down. The processed log, as

presented in this report, displays the measured thickness of the casing superimposed on the nominal thickness of a fresh casing. An important assumption here is that the external casing wall is unchanged as the tool measures only the internal diameter of the casing. A different type of downhole equipment is required for a combined internal/external measurement.

### 4. SURVEY RESULTS

The results of the CIC logs on the four wells are summarized in Table 2.

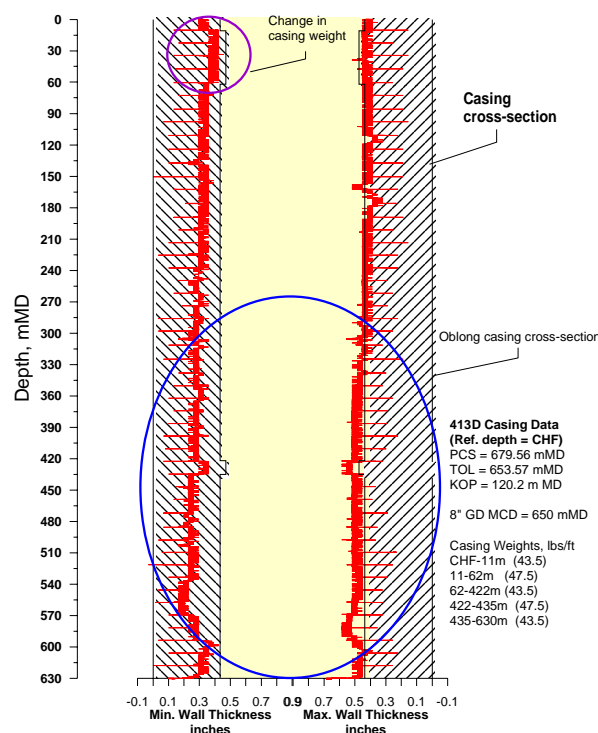
Discussions on the survey results for each well follow.

**Table 2. Summary of CIC logs. Measured wall thickness and thinning are accurate to  $\pm 0.02$  inch.**

Well	Nominal Casing Weight	Nominal Casing Thickness	Measured Average Wall Thickness	Average Casing Wall Thinning	
	ppf	inch	inch	inch	% Nom.
413D	43.5	0.435	0.33 - 0.41	0.03 - 0.11	6.1 - 24.1
	47.0	0.472	0.39 - 0.43	0.04 - 0.08	9.8 - 17.0
209A	54.0	0.540	0.36 - 0.38	0.16 - 0.18	42.1 - 33.3
301D	43.5	0.435	0.4 - 0.42	0.02 - 0.03	3.6 - 6.9
401	43.5	0.435	0.31 - 0.37	0.07 - 0.13	17.6 - 29.9

#### 4.1 Well 413D

Logging was limited to 630m (Figure 2) after the CIC tool tagged an obstruction at 635m during run-in.



**Figure 2. CIC log of Well 413D showing negligible physical changes in the casing wall.**

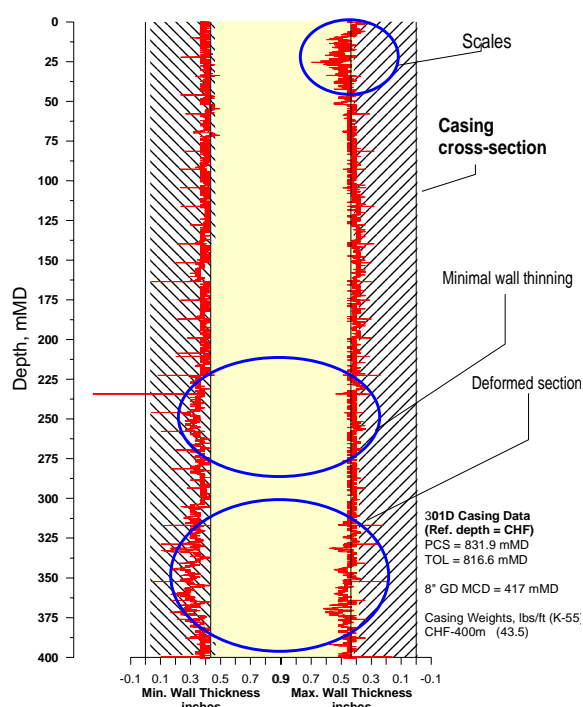
The log shows a long section of the casing with a less-than-circular cross-section, which was likely caused by doglegs past the kick-off-point in the hole. Other than this, there is no significant anomaly in the log that would suggest thinning of the inner casing wall attributable to the abrasive action of solids in steam.

The 6.1-24.1% thinning estimated from the logs (Table 2) are localized in nature may have not been necessarily caused by the solids carry-over.

The log also detected the placement of a heavier casing, 47.5 lbs/ft, which was not reported in the official casing tally. These are logged in sections 11-62m and 422-435m (Figure 2). The standard casing weight of 43.5 lbs/ft is listed in the casing tally. Any other casing weight detected in the log by virtue of a measured uniform ID throughout a casing joint is interpretive.

#### 4.2 Well 301D

The log (Figure 3) does not show any significant thinning in the internal casing wall, although the section from 330 to 380m shows slight casing deformities (oblong or dented to maximum of about  $\pm 0.2$  inch). Average wall loss is insignificant in the range of 0.02 to 0.03 inch, mostly in the 225-325m section.



**Figure 3. CIC log of Well 301D showing negligible physical changes in the casing wall.**

Wall gain (ID reduction) of as much as 0.25 inch is measured from about 10 to 55m. This is the same depth range where the 8"GD survey tagged partial obstructions in the casing, and is interpreted to be possible scales deposit.

Overall, the logged section of the 9 5/8" production casing of well 301D does not show any casing problem that could require repairs. Except for the possible pittings throughout most of the logged interval, no evidence of thinning due to abrasion by solids carry-over in steam is found in the upper sections of the casing. It is therefore presumed that no casing wall thinning deeper than the logged depth may be attributable to the abrasive solids carry-over in steam.

#### 4.3 Well 401

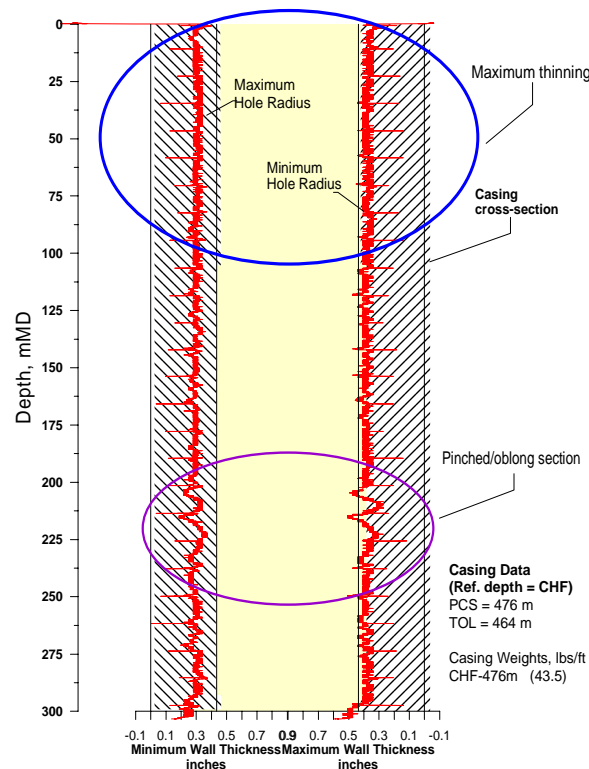
The 9 5/8" casing of well 401 appears to have thinned throughout the logged section (Figure 4). In general, about

0.31-0.37 inch of wall remains of the 0.435-inch wall thickness (43.5 lbs/ft K-55 9 5/8" casing).

Thinning appears to be uniform throughout the logged section, with the possibility of having one side of the casing to be least physically affected.

Oblong or slightly pinched sections within the 200-240m section have also been noted.

A repeat section log between 150-250m confirms accuracy of the above measurements.



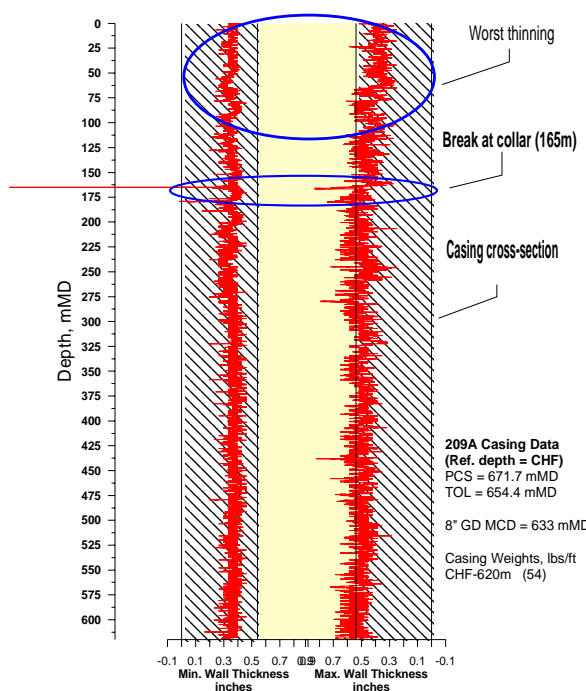
**Figure 4. CIC log of Well 401 showing relative thinning of the production casing wall.**

#### 4.4 Well 209A

Logging was limited to 620m (Figure 5) after the CIC tool tagged an obstruction at 628 both during run-in and pull-out of the tool in the first attempt to log the well.

Survey failure on the first attempt was caused by physical damage on several caliper fingers of the tool. The damage was most likely caused by the obstruction tagged at 628m.

Of the four wells logged, this well appears to have the worst casing condition. The log shows a very rough casing wall, indicative of possible scales and/or corrosion. Casing "deformities" are tagged at 165 and 179m. The 165m deformity is a 0.5m opening or break in the casing coinciding with a collar. Immediately below this break, from 165 to 167m, is an oblong section with a minimum measured ID of 8.24 inches against a nominal fresh casing ID of 8.545 inch.



**Figure 5. CIC log of Well 209A showing relative thinning of the production casing wall.**

The worst thinning is observed at the intervals listed in Table 3 below. Overall, an average of 0.16 - 0.18 inch of wall thickness has been lost from the 54 lbs/ft casing string.

**Table 3. Casing intervals in Well 209A where wall thickness is 0.30 inch or less.**

Depth Interval (meter)	Nominal Casing Weight (ppf)	Fresh Casing Nominal Wall Thickness (inch)	Measured Maximum Wall Thickness (inch)	Remarks
6.5	54.0	0.540	<0.30	
54-63	54.0	0.540	0.30	
72.5-73	54.0	0.540	0.30	
91.5	54.0	0.540	0.30	
103.5	54.0	0.540	<0.30	
165	54.0	0.540	0.00	Blowout at collar

## 5. IMPLICATIONS ON OPERATION

The logs may be used to roughly group the production wells in Leyte. Well 209A represents those wells that have been supplying steam to the 112.5 MWe Tongonan 1 Geothermal Power Plant since 1983. These are the oldest producing wells in Leyte that have initial discharge enthalpies in the order of 2000 kJ/kg. Their enthalpies climbed up to above 2700 kJ/kg shortly after the commissioning of the new power plants in the field beginning 1996, and have since produced pure steam.

Another group of wells is represented by well 401. Similar to the group represented by well 209A, these wells are originally highly two-phase wells (with discharge enthalpies above 2000 kJ/kg prior to commissioning), but were utilized only for the newer plants beginning 1996-1997. Production from these wells eventually turned to steam as well with total discharge enthalpies of 2700-2800 kJ/kg.

As evidenced from the CIC logs of wells 209A and 401, these two groups of relatively older production wells are

believed to have the highest potential for thinned casing walls due to longer exposures to the solids carry-over in steam. The logs, thus, underscore the need for further downhole evaluation of the other suspect wells in this group.

Another group of wells may be represented by wells 301D and 413D. These are the wells that initially discharged two-phase fluids in 1996-1997, but later turned highly two-phase to steam with continuous production. These are therefore relatively younger production wells with shorter periods of exposure to suspended solids in steam. Presumably still at the early stages of wall erosion, these wells are worthy candidates for a series of regular, probably annual, repeat CIC surveys for the determination of the rate of thinning of the production casings. The production casings of wells 301D and 413D appear to be in relatively good shape, despite the positive indications of thinning at some intervals. While it is not known at what stage the thinning of the casing wall commenced, it would certainly pay to have a second CIC log of these wells in one to two years time after the first to determine the rate of thinning and subsequently enable the placement of appropriate preventive measures for the wells.

Early detection of progressive casing wall thinning may be able to minimize the cost of a subsequent workover and prevent the potential loss in production due to casing failures. Wells 110D and 111D, which are two of the other candidate wells for CIC surveys, underwent workover operations in 2003 to recover declining production capacities. Mechanical failures in the liners and production casings during the workover, however, prevented the rigs from totally achieving the workover objectives.

Similarly, well 209A was unsuccessfully worked over a few months after the survey, with the job terminated without clearing the whole wellbore due to metallic obstructions in the hole that could cause the drill pipes to get stuck. Consequently, the expected gain in steam production from these wells was not realized.

Well BL-1D, a steam well in Palinpinon 2 Geothermal Production Field, also underwent a series of CIC logs, which was done at about one year interval (Aqui, 2003). The logs were able to measure a rate of thinning which corresponded with ultrasonic thickness measurements at the wellhead and branchline over the same period of observation. Based on these information and other attending factors, eventually it was decided that the well should be cut from production. Such a decision might have saved the company from employing potential damage control costlier than the revenue loss from the decommissioned well. Measures such as this example are believed to be applicable also in the case of the LGPF wells producing steam with solids carry-over.

## 6. CONCLUSION

The results of the CIC surveys conducted on representative wells reinforced the idea that the production casing strings of a number of production wells in the Leyte Geothermal Production Field are being eroded by suspended solids in the produced steam. Older wells with a longer history of steam production are more likely to be affected adversely by the solids erosion.

In the light of these observations, the authors believe that most, if not all, production wells in the field that have long ago turned to steam discharge should be subjected to similar CIC surveys. Repeat CIC measurement for the

wells that have just recently turned to steam from two-phase is especially recommended for the determination of the rate of thinning of the casing walls. Knowledge of the thinning rate will be a useful guide in employing timely mitigating measures and in programming downhole preventive maintenance works for the affected wells.

## 7. ACKNOWLEDGMENT

The authors wish to thank PNOC-EDC Management for the permission to publish this paper.

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