# DEVELOPMENT OF A PROTECTIVE SHROUD FOR DOWNHOLE INJECTION TUBING

Michael Rock[1]
[1]Century Drilling and Energy Services, 166 Karetoto Road, Wairakei, Box 341, Taupo New Zealand

**Key Words**; geothermal, antiscalant tubing

**ABSTRACT**

Downhole injection of antiscalant fluid is used to limit run down in two phase well output due to calcite scaling. The use of this process in the Kawerau geothermal field had been failing due to breakage of the injection tubing at the wellhead. A shroud was constructed to protect tubing from forces generated as the flow turns at the wellhead tee. This shroud failed after a short time in service. Analysis was carried out which suggested the failure was due to fatigue caused by two phase slug flow in the well bore and wellhead piping. A new shroud was designed to withstand the fatigue loading. Field measurements of wellhead vibrations where taken to determine the frequency spectrum of the wellhead and compared to the fundamental frequency of the failed shroud. The new shroud design incorporated features to raise its fundamental frequency above the wellhead vibration frequencies. The new shroud design has been installed on several wells in different geothermal fields, one of which has been in operation since April 1998. The operational history of the new shroud demonstrates the success of the design.

## 1 INTRODUCTION

Downhole injection of chemicals in two phase wells to control calcite deposition within the well liner or casing has been used successfully in the Kawerau field (New Zealand) since April 1989. The components within the well consisted of tubing which is suspended from a glanded flange bolted on the measurements valve flange. The tubing is kept taut by a sinker bar attached to the lower end. A schematic of downhole antiscalant equipment is shown in figure 1. Although the original system worked reasonably well the tubing would break off immediately below the gland flange on a regular basis. Failure of the tubing was put down to fatigue caused by slugs of water deflecting the tubing towards the branch of the wellhead tee. The solution to this was to shield the tubing from the flow near the wellhead tee. A shroud was constructed from a single piece of pipe and welded to the underside of a sandwich flange. This shroud failed within two weeks of installation. The shroud broke off near the gland flange. Examination of the surface suggested fatigue had caused the shroud to fail. The fracture surface was in poor condition as the shroud had been hammering against the gland flange. Alternative shroud designs were then investigated.

## 2 DESIGN

Design of an alternative shroud considered two options. The options were a free ended shroud similar to the one originally built or one with its lower end guided. The restrained end shroud has the advantage of minimizing the effect that the turning flow has on the shroud but requires internal modification to the wellhead to enable the shroud to be supported. This type of shroud has been used successfully by other operators, for example Contact Energy Ltd at Ohaaki, New Zealand. The free ended type requires no modification to the wellhead but instead requires more design input. The free ended design was explored because of the potential manufacturing cost savings, ease of installation and reduced well outage time during installation.

Side entry designs for antiscalant tubing access into wellheads is a further option. However with higher output wells (>300 t/h mass) a large sinker bar is required which must be passed through the measurements and master valve. Hence this design is not practical for Kawerau or similar fields.

After the original shroud failed the following information was obtained that was relevant to the investigation.

1. Flows and wellhead pressures over the time period the shroud was in service, about two weeks. (Well output was approximately 340 t/h with a wellhead pressure of 17 barg)
2. Length of time shroud was in service (approximately two weeks)
3. Geometry of failed shroud.
4. Slug rate of fluid coming out of well (a period of 3 to 7 seconds – obtained after shroud failed)
5. Predominant frequencies of wellhead vibrations. (5, 30.5 & 61 HZ – obtained after shroud failed)
6. Shroud material (SA106 grade B)

Vibration frequencies of the wellhead were obtained by vibrational analysis of wellhead deflections.

Two areas were considered that may have caused the shroud failure. These were vibration at the fundamental frequency of shroud (harmonic vibration) and cyclic deflection caused by slugging flow (slug load).

The fundamental frequency of the original shroud was determined to be about 20 Hz by using AutoPIPE pipe stress analysis program. The fundamental frequency was in the range of the measured wellhead vibrations. From the vibration report the wellhead accelerations were small and were considered not large enough to cause significant stress to the shroud. Hence loading caused by harmonic vibration was not considered the cause of the failure.

The approximate number of cycles to failure for the original shroud was calculated using the total number of slugs (and hence cycles) over a period of two weeks. The fatigue stress limit for the pipe material was calculated and an appropriate stress intensification factor chosen for the weld detail between the gland flange and shroud. This enabled the moment which caused the shroud to fail to be calculated.

A shroud was then designed which would not be stressed beyond its fatigue limit when subjected to the same moment. A schematic of the shroud is shown in figure 2. Where possible standard pipe and fittings were used as they are readily available and cost efficient. The attachment of the shroud to the sandwich flange had to be such that the effect of the weld on the shroud due to the bending moment was minimized. It also had to fit inside the wellhead pipework. The detail chosen resembled a welding neck flange. The shroud length was minimized by removing the measurements valve and fitting the sandwich flange directly to the wellhead flange.

Because of its resistance to fatigue compared with higher strength steels, low carbon steel was chosen for all components. SA106 grade B was used for the pipe & fittings while the spigot was to be machined from engineering round.

As an additional safeguard against failure the shroud was designed so that its natural frequency did not coincide with the vibration frequencies of the well. This was done by dividing the shroud into several sections of different stiffness. This raised the natural frequency above the well vibration frequencies. The reducing pipe sections has the benefit of reducing the sectional area of the shroud exposed to the flow. This should have the benefit of reducing the moment at the base of the shroud.

A PTFE bush was installed in the free end of the shroud to stop the antiscalant tubing from deflecting sideways and rubbing on the shroud.

## 3 RESULTS

The new design of shroud was not installed in well KA19 Kawerau Geothermal Field until March 11 1999 because the well had calcited up and required a work over. A slightly modified design was fitted in KA35, a higher output well but with less slugging (approximately 500 t/h at 14 barg). KA35 has larger flange on top of the wellhead tee than KA19, the well which the original design was for. It was installed on March 5 1998. Since then both wells have been operating without either the shroud or the tubing failing.

Material for the spigot proved difficult to obtain as mild steel in the size required was not stocked. The spigot blank was cut from plate.

Modifications to the original design (similar to those detailed above for KA35) have been installed in wells in a different geothermal field within New Zealand. These are performing as expected apart from corrosion of the tubing armour within the shroud immediately above the PTFE bush. The corroded tubing was investigated by a materials engineer. It was observed that the corrosion had occurred when the glanded flange had been leaking. Once this leak had been stopped no further corrosion was observed.

During maintenance of KA35 well on April 13 1999 it was observed that the PTFE bush had been eroded to about half its original depth. The bush was replaced. Alternative materials for PTFE were considered but it was found that they were both expensive and not commonly available.

## 4 DISCUSSION

As the correct materials for construction of the spigot proved difficult to obtain, plate had been substituted for bar. This is not recommended as there is a potential for the plate to delaminate along its rolling axis. An alternative is to remove the neck from a welding neck flange and use this as the spigot or obtain a special forging.

Alternative materials for the PTFE bush could be considered. A harder plastic or soft metal may be used. This could however cause accelerated wear to the tubing. Currently at Kawerau the tubing is withdrawn approximately 150mm at regular intervals to limit wear of the tubing at any particular position. For the Kawerau geothermal field it has been chosen to make the bush longer to make allowance for erosion. The bush is to be replaced every time the down hole equipment is inspected.

The corrosion of the antiscalant tubing armour is possibly caused by geothermal water and condensate within the shroud. A leaking gland could mean that chemicals within the water and condensate would be concentrated when the steam flash exits the gland. The small flow upwards through the bush would not allow water to drain out. This could be avoided by making a hole or holes in the free end immediately above the PTFE bush.

Further improvements to the design could be made to allow the shroud and sinker to be withdrawn without requiring the well to be quenched. This would make inspection and maintenance of the downhole antiscalant equipment easier. This would be an advantage in geothermal fields where water supply to wells for quenching is difficult.

## 5 CONCLUSIONS

The free ended shroud design for protecting antiscalant tubing at Kawerau has proved to be effective and has been in service for 16 months. A minor problem occurred, namely erosion of the bush at the end of the shroud. This problem should not be difficult to overcome.

Corrosion of the tubing armour occurred when the same shroud design was used in a different geothermal field within New Zealand. A leaking gland appeared to have triggered corrosion of the armor within the shroud. Once the leak was stopped corrosion ceased. A small modification to the shroud should mean that the problem is avoided.

Further improvements to the design to enable easier withdrawal of the antiscalant system for maintenance could be investigated.

## 6 ACKNOWLEDGEMENTS

The author is indebted to the input and feed back on the design from the Kawerau steamfield operations staff : Mike Wharry and Ken Scott.

## 7 REFERENCES

Robson, Q. and Stevens, L. (1989). *Antiscalant Trial at Kawerau Geothermal Field*: Proceeding of The 11th New Zealand Geothermal Workshop 1989.

Robson, Q., Blair, A. and Perales, K. (1990). *Antiscalant Injection Trial at Kawerau Geothermal Field*. New Zealand:

GRC Transactions 1990 International Symposium on Geothermal Energy.

Burgess, P (1997). *Vibration analysis survey of wells KA19 and KA35 on 28 September 1997*. Report for Downer Energy Services Limited, Wairakei. (Unpublished report)

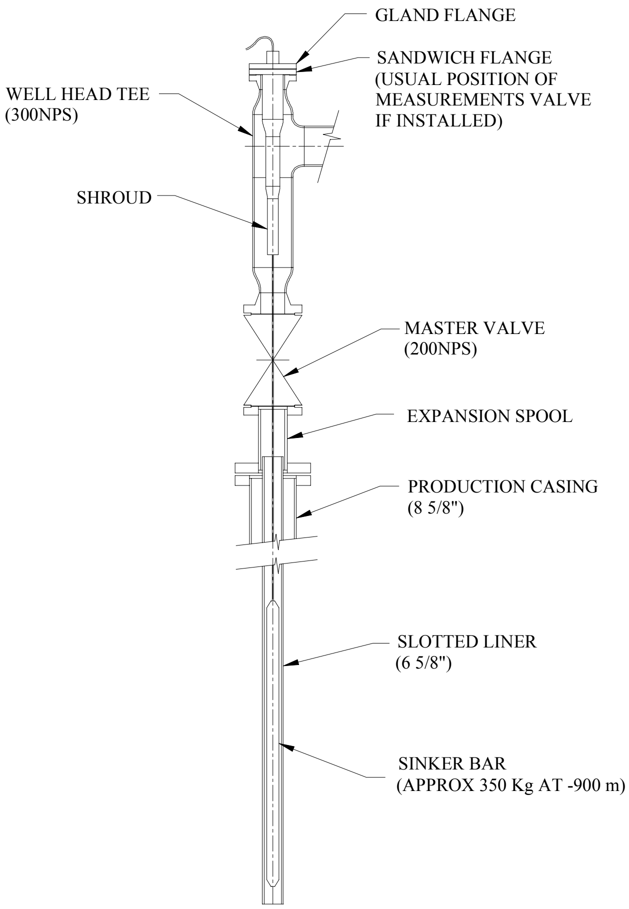


Figure 1
Antiscalant downhole equipment

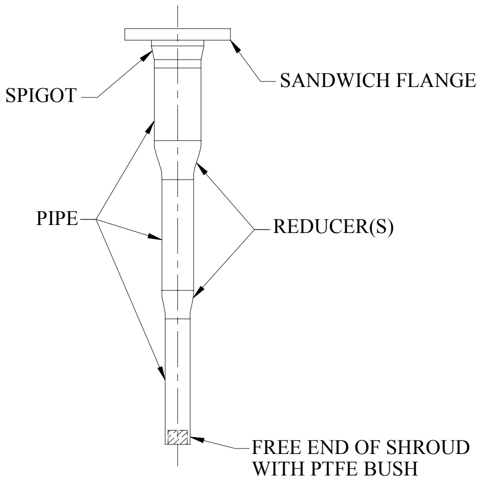


Figure 2
Antiscalant tubing shroud