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Air-Mud Drilling Separator Modification

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ABSTRACT

Geothermal air-mud drilling separators are used to remove air from drilling fluids and formation cuttings to allow recycling of the reconditioned drilling fluid. Surges and slugs of air and liquid expanding up the casing string into separators not only create structural instability but can result in severe carry-over and pit volume loss. This paper is a simple case study on modifications made to a conventional drilling separator to address performance, safety, and environmental issues. Modeling of these simple cyclone separators was performed to identify problem areas. By applying fluid mechanics techniques, modifications were developed to enhance the performance of these air-mud drilling separators ten-fold and eliminate the problems of unit instability and drilling mud spray covering the location.

Introduction

Geothermal wells are often drilled from 3,000 to 5,000 feet using mud and then are converted to air drilling to total depth. Once the 9-5/8 inch casing is set, the mud in the annulus is displaced using pressurized air. It is from this point forward that an air-mud separator is employed to remove the vapor from the entrained liquid and solids. Without this tool, hot fluid and debris would be blown out of the blowie line and across the location, thereby creating noise and spreading waste products as shown in the typical image of Figure 1.

Conventional drilling cyclones are typically “can-type” tanks with a tangential entry as shown by the photograph in Figure 2. As the flow exits the blowie line and enters tangentially into the circular tank, a spin is induced forcing the denser material to the vessel wall for gravity drainage. The air is often deflected downward, reverses direction in the vortex tube, and is ejected out the stack. The fluid and debris exit the bottom and is circulated onto a shaker table to remove the solid fines whereupon the cleaned mud is recycled.

These drilling cyclones are not optimally designed and tend to have rather low separating efficiencies. Its performance can be adequate during some other phases of drilling operation but not acceptable during mud displacement or when production zones are encountered. It is during these occasions that hot mud or formation fluids can be blown throughout the location or the cyclone itself is blown from its supports and off the location. These episodes may be entertaining from an anecdotal point of view, but are clearly undesirable to all parties involved.

Environmental and safety awareness and concerns are becoming increasingly important. Although no casualties have been reported from these transients, the event does occur with regularity and may cause a disastrous incident in the future. These vessels are from six to sixteen feet in diameter and made with massive amounts of steel in and around them. To tip one over, blow holes through one, or blast one off a location requires considerable energy. Ejecting drilling fluid and debris over the location or sending particulates upward to cover the hillsides are rather undesirable events.

Even if these ecology and safety issues were corrected, the separation efficiencies from these devices would still be far less than acceptable. Some units are too big to capture the small particles, while others are too small to handle large volumes. Mod-

Figure 1. Typical blowie line steam discharge without muffler.
Figure 2. Conventional drilling cyclone separator with tangential entry.

Modeling has shown that conventional drilling separator efficiency is less than 15 percent of an optimum design. The old configuration was unacceptable so it was revamped to achieve the best performance using as much of the existing constituents as feasible.

Old Configuration

The drilling separator in this study was from Medco Rig Number 2 that was operating in the Wyang Windu Geothermal Project, Indonesia. There are up to a dozen of these near identi-
cal drilling separators in use or on stand-by. Figure 3 shows a basic layout of the drilling separator. The drilling flow exits the casing string, into the blooie line, transitions upward in a 10 inch line, is diverted by an elbow and enters the separator. The flow enters the unit through a short tangential inlet into the seven foot diameter container. The main flow spins downward to a flat bottom with the vapor component transitioning upward and out through a partially perforated, 36 inch pipe (Figure 4) and exit elbow and the liquid and entrained solids drain toward the center of the container, out the drain pipe, and down to the mud-pit or shaker table where the cuttings are separated and removed.

In this design, the tangential inlet protrudes into the seven foot diameter container and discharges against a drill pipe lined erosion wall. The 36 inch vortex tube is perforated with two-inch diameter holes and has deflection plates installed in the vortex finder. Since the separator has a flat can bottom with a central drain, the mud and other entrained debris must move from the container wall and migrate to the 12 inch drain at the center for removal.

Modeling and Analysis

Modeling the old drilling separator configuration suggested that the following types of problems could occur. The associated separator component that may be responsible for the problem is indicated in italic face text.

The small inlet piping creates high velocities producing high centrifugal forces but that benefit is often more than off-set by high particulate shearing and small particle generation. Smaller particles are harder to capture and remove than larger particles. Furthermore, higher velocities generate high impulse forces that can cause separators to be ejected into the surrounding jungle. The force is roughly a function of the velocity squared which greatly affects the stability of the equipment.

The erosion lining of 3-1/2 inch drill pipe, although a conventional way to protect blooie mufflers for the past 25 years, creates a substantial amount of turbulence. The liquid and solid to vapor boundary layer is disrupted and deflected which creates substantial re-entrainment and carry-over. Erosion control may also be better maintained by judicious material and inlet design.

The perforated vortex tube (discharge stack pipe) has 2 inch holes that act as short circuit pathways allowing incomplete separation components to exit the vessel at moderated rates. During higher rates, these holes cause additional carry-over.

The flat bottom drain plate is not conducive to good drainage. This condition becomes increasingly worse as the flow rate increases. The spinning fluid concentrates against the canister wall with a concave slope toward the center drain. Furthermore, the vortex finder tube creates a low pressure gradient directly above the drain reducing the available head for the drainage piping. This reduction in available head is further compounded by vortex formation down the discharge drain. All these conditions limit the amount of drainage and can cause a high liquid level in the vessel until the vapor fraction re-
entrains the mud and cuttings out through the stack scattering
the discharge onto the drilling location and surrounding envi-
ronment.

The *elbow after the flat plate discharge* limits the available
head for drainage. This compounds the negative effects of the
flat bottom drain plate cited above.

The *deflection plates in the vortex finder tube* ay distort the
vortex formed on the bottom plate and increase the pressure
drop through the exit stack piping.

### Revamped Design

Although a new generation of portable separators could
have been designed for multipurpose drilling service, there was
inadequate time to implement such an undertaking. A fast-track
approach was commissioned to modify the existing separator
based on the above technical findings. The following list of
modifications and retrofits was implemented to the existing
drilling separator:

1. A 20 inch "surge tee" was installed to dampen the flow into
   the inlet. This would also act as a flow conditioner to en-
   hance separation.
2. The tangential inlet run length was extended for improved
   flow profile development.
3. The protruding inlet was eliminated to equalize the flow
   more quickly and to reduce erosion.
4. The 3-1/2 inch drill pipe segments were removed to improve
   boundary layer conditioning.
5. The 2 inch diameter holes were plugged in the vortex finder
tube to prevent short-circuiting of mud and cuttings into the
exit flow.

6. The baffle plates in the vortex finder tube were removed to re-
duce pressure drop up the exhaust stack and increase separa-
tion efficiency.
7. The flat bottom plate was removed and replaced with a 5 foot
long cone to increase the vapor disengagement length and to
enhance liquid drainage out the exit piping by establishing a
higher hydrostatic head.

Figure 5 shows the modified design of the drilling separator.

### Results

These modifications were implemented during drilling
stand-by time and did not effect any rig down-time. Perform-
ance modeling indicated that the revamped separator could in-
crease the surge and drainage capacity by ten-fold over the
prior system. Since its conversion, field performance has been
excellent. No excess carry-over or pit volume loss has been ex-
perienced and the new location and surrounding area are clean
of drilling mud and formation debris. Flow stability has im-
proved and everything is functioning as expected. It should,
however, be noted that this unit is modified for air-mud drilling
and is not designed to handle large amounts of steam and brine.

### Conclusions

1. Medco Rig Number 2 was experiencing substantial mud loss
during air purging of the 9-5/8 inch casing. Large volumes
of air and entrained mud would exit the stack blowing mud
across the location.
2. Rig down-time limitations required that the existing unit be
modified cost-effectively and quickly. Modeling of the sepa-
rator showed that a ten-fold increase in performance could
be achieved.
3. To date, the performance of the modified drilling separator
is performing very well. There is no observable carry-over
during air-mud drilling operations, the system is stable, and the location is clean of drilling mud and formation debris.

4. Although, a ten-fold increase in performance has been achieved with these modifications, the modified system is still incapable of handing large amounts of steam and brine production.

5. Conventional air-mud drilling separators can incur serious dysfunction resulting in high carry-over rates and, if the conditions were bad enough, the catastrophic launching of the vessel off the location.

6. Conventional drilling separators are inefficient devices that can not only be inherently unstable during upset conditions but are only 15% as efficient at catching and removing particulates as high efficiency designs.

7. Clearly a new generation of multipurpose drilling separators are needed to handle various geothermal resources under drilling; testing, and flowing conditions. No existing geothermal drilling separators can effectively support all activities.

**Recommendations**

Develop a safer and environmentally compatible drilling separator that can meet the following criteria.

1. It can be used for air-mud drilling operations and well testing with up to 100 times reduction in carry-over emissions.

2. It must be stable and resistant to upsets that may blow the unit off of the location.

3. It should handle a 25 megawatt equivalent well without creating an environmental or safety hazard.

4. It should be capable of accurately flow testing a well while performing drilling operations to reduce down time and drilling cost.

5. It should be easily transportable without torch cutting the unit into excessive number of sub-components and re-welding them back together on the new site.

6. It must be cost-effective to build, to maintain, and to operate.

A proposal has been submitted to the Geothermal Drilling Organization (GDO) and the California Energy Commission (CEC) to develop an improved drilling separator.

**Acknowledgments**

Many sincere thanks to W.T. Howard and R.E. Engebretsen of Mandala Nusantara for the opportunity to assist on the revamp project and to present this paper.

**References**
