DISCHARGE INITIATION BY GAS LIFTING:
PNOC-EDC EXPERIENCE IN PHILIPPINE GEOTHERMAL WELLS


PNOC Energy Development Corporation
Ft. Bonifacio, Makati City, Philippines
builing@edc.energy.com.ph
mikzprint@globe.com.ph

ABSTRACT

PNOC-EDC pioneered the use of gas lifting to initiate geothermal well discharges in the Philippines in 1992. Liquid nitrogen is gassified and pumped into the wellbore through a coiled tubing. The "lift" is achieved through the creation of a pressure drop between the reservoir and the wellbore at the injection point.

By October 1997, a total of 28 wells have been successfully discharged by gas lifting. This involved a total of 38 attempts, with 11 failures mostly caused by equipment breakdown during injection.

The paper also discusses considerations taken by PNOC-EDC in planning for and conducting a successful gas lifting operation.

INTRODUCTION

Most geothermal wells are capable of self-discharge, with flow initiation as simple as turning the valves open. This is characteristic of wells drilled into vapor-dominated systems and those within the naturally-two-phase regions of liquid-dominated reservoirs.

There are wells however which have cold water columns above the permeable zones which prevent the upflow of hot reservoir fluids from deeper sources. This is typical of some geothermal wells in the Philippines which were drilled into deep liquid-dominated geothermal systems.

Depending on several factors, discharge of these wells are initiated through one of several conventional means. Until the introduction of gas lifting into the PNOC-EDC operations in 1992, discharge initiation of a geothermal well was done through the use of any of the following techniques:

1) air compression;
2) boiler stimulation; or
3) two-phase injection.

Gas lifting therefore becomes the fourth well discharge initiation technique available to PNOC-EDC, although boiler stimulation had already been dropped from the company’s list of options.

MECHANICS

The earliest applications of gas lifting involved pumping of high-pressure compressed air into a tubing to depress the liquid level to the bottom of the tubing and then aerating it to flow. Figure 1 illustrates one such set-up.

Extensive use of gas lifting in the oil industry eventually led to its evolution into an engineering science involving two-phase flow and sophisticated equipment and instrumentation.

For a geothermal well, fluid flow can be initiated in two ways:
1. by increasing wellbore temperature to saturation; or
2. by reducing the wellbore pressure to saturation vis-a-vis the wellbore temperature.

From the steam tables, the saturated pressure $P_{sat}$, corresponding to the wellbore temperature can be known. The water column, $H$, to be gas lifted can then be approximated graphically as indicated in the figure to represent the equivalent pressure difference, $dp$, between the saturation and the measured pressures. “Lifting” of this column of cold liquid effectively creates the necessary pressure drop at the payzone, which in turn induces the flow of reservoir fluid into the wellbore and up the surface.

**PLANNING AND OPERATION**

**Well Selection**

The decision to put any well in the gas lifting program generally depends 1) on the inability of the well to discharge by itself or through cheaper stimulation techniques (air compression or two-phase fluid injection), and 2) on the urgency of discharging it. While the former is influenced by the relatively high cost of gas lifting, the latter becomes a factor only when operating necessities dictate the immediate discharge of a newly completed or worked-over well which could otherwise flow without gas lifting given sufficient time to heat up.

**Field Set-Up and Preparation**

Geothermal gas lifting is a job for a coiled tubing unit (CTU). This equipment is the medium which takes the lifting agent to the desired depths in the wellbore. It is rigged to the wellhead through its tubing injector assembly and connected to the source of the lifting agent through high-pressure lines. Figure 3 illustrates a typical set-up.

Liquid nitrogen is gassified before being pumped through the coiled tubing by means of a nitrogen pump/heater unit. With delivery pressures typically in the range of 1,000 to 1,500 psig and sometimes exceeding 2,000 psig, nitrogen gas can be injected through a 2” OD coiled tubing at about 300 to 1,500 scfm.

Preparation of a well for gas lifting requires a portable silencer for the testing stage. It has been PNOEC-EDC’s experience, however, that some wells would require extended injection of nitrogen to sustain the initial flow through the silencer, mainly because of the large pressure drops created at the wellhead tees in the early stages of discharge. This brought about the use of a “Y” spool which allows...
An average gas lifting operation would require a minimum of about 1,000 gallons of liquid nitrogen to as large as 3,000 gallons per well.

Since PNOC-EDC uses transported tanked liquid nitrogen instead of nitrogen generators at the worksite from where the source is several hundred kilometers away, it has been its practice to maintain at least two 2,000-gallon tanks for every planned operation. This practice has provided the operators more leeway and flexibility in achieving a successful job in the event of an equipment breakdown in the middle of an operation.

Actual injection of nitrogen up to the point of discharge can take as short as 30 minutes to as long as 3 hours. However, preparation of the well and equipment requires a minimum of one week mainly due to logistical arrangement for shipment and the need to prepare the site for the bulk of equipment to be used. For the present set-up used by PNOC-EDC, a full equipment complement, comprising of the CTU, nitrogen pump/heater unit, two 2,000 gallon liquid nitrogen tanks, a crane and ancillary equipment of the CTU, requires about 2,000 sq m around the well.

It is also common practice to ensure that the field set-up is ready before liquid nitrogen is delivered at site to minimize losses through natural evaporation.

Discharge and test equipment are prepared well ahead of the arrival of the gas lifting equipment. Preparations include installation of the silencer and discharge lines, reinjection facilities and downhole surveys of the well.

**Costs**

Gas lifting is not an inexpensive operation. This is the reason why PNOC-EDC considers it the last resort in well discharge stimulation. Generally speaking, a gas lifting job for a geothermal well is about two orders of magnitude more expensive than stimulation by air compression or two-phase injection. The average cost per job, which can be as high as US$90,000, is broken down as in Table 1. The relative figures reflect the cost to PNOC-EDC of a gas lifting job conducted by a service and equipment contractor - thus, the high service costs. Otherwise, much of the operating cost is expected to be on mobilization of the numerous pieces of equipment and materials.

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>% COST</th>
</tr>
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<tbody>
<tr>
<td>Nitrogen Services</td>
<td>30.0</td>
</tr>
<tr>
<td>Mobil/demob</td>
<td>25.0</td>
</tr>
<tr>
<td>Other Equipment</td>
<td>6.0</td>
</tr>
<tr>
<td>Liquid Nitrogen</td>
<td>4.0</td>
</tr>
</tbody>
</table>

*Table 1. Major cost components of gas lifting.*

**Lifting Agent**

Nitrogen has been the lifting agent used by PNOC-EDC. It is relatively cheap and safely transportable to locations. It is also chemically stable being inert, non-corrosive and non-toxic. However, its availability in large volumes, as required in gas lifting operations, has always been a problem for the
company. The company has thus invested on a high-volume high-pressure air compressor for the source of lifting agent in future gas lifting operations.

FIELD EXPERIENCES

PNOC-EDC has relied on gas lifting not only in discharging some of its exploration wells but also in production and development wells as well. The latter category in fact outnumbered the former by 4 to 3. The company largely gained maximum benefits from the technique in two ways, namely: 1) proving the discharge potential of the wells and subsequently the commercial viability of the exploration projects where all the wells did not have self-discharge capability; and 2) enabling discharge testing of the wells immediately after drilling or workover without the normal period given to the well for heat-up, thus beating contractual deadlines for steam availability in developed projects, as in the case of Malianagdong B in Leyte Geothermal Power Project (Yglopaz et al., 1998).

It is also PNOC-EDC’s experience that the success of a gas lifting attempt depends principally on hole condition and equipment condition. The word “success” here meaning the attainment of a sustained discharge.

Hole condition refers to the readiness of the well for discharge in terms of its permeability, downhole temperature and pressure. Whereas, equipment condition refers to the trouble-free operation of all necessary equipment.

PNOC-EDC also encountered several failures in its past gas lifting jobs primarily due to equipment troubles during operation. Such breakdowns would eventually lead to nitrogen wastage, and delays. On the other hand, there were also failures directly attributable to hole condition. The best examples, perhaps, are wells MG-27D and MG-29D (Yglopaz et al., 1998) which tended to cool down every time they would be discharged. The phenomenon was later analyzed as a direct effect of drilling fluids which were flooding the sector when two drilling rigs were active in the vicinity of the discharged wells.

Deep vs. Shallow Injection

The usual practice had always been deep injection of the nitrogen gas near the vicinity of the major permeable zone, averaging 2,000 to 2,500 m deep. A number of reasons justify this approach. To cite a few, deep “swabbing” injection enables clearing of the well of debris and drilling mud even before the start of the well discharge; or taking advantage of the reservoir pressure at this zone to reinforce the nitrogen gas action in initiating well flow. Deeper gas injection, however, increases the risk of the coiled tubing getting stuck in the wellbore as experienced by the company not a few times, aside from possibly requiring a larger volume of nitrogen for the same work to be done. The former, however, has mainly influenced PNOC-EDC’s recent attempts for shallow nitrogen injection as a stuck tubing in the hole not only jeopardizes the discharge tests but also entails considerable cost in the subsequent fishing and recovery operations.

Aquí (1997) attempted to establish an empirical correlation between submergence ratio and the required volume of nitrogen to sustain flow in a geothermal well. Submergence ratio is defined as the ratio of the submergence, H, over the total lift, L, in Figure 2. He also suggested that the ratio could aid in estimating the minimum depth of injection for a successful gas lift. Preliminary work on this potential application of the ratio has been done on two wells having similarities in relevant downhole characteristics (Table 2).

The wells are drilled in the same area and are about 1,000 m apart at their bottoms. Results suggest that shallow gas injection would pose additional difficulty in discharging the wells, taking into consideration the lower calculated submergence ratios at the production casing shoe for both wells. It is, however, striking that despite the relatively lower submergence ratios for PT-4D, calculated both at the casing shoe depth (1450 m) and at its major permeable zone (2020 m), the well still managed to discharge with only 400 gallons of liquid nitrogen to initiate flow. The volume is well below the average for most of the wells gas lifted by PNOC-EDC. The same is true for the other well, PT-2D, which only needed 252 gallons of liquid nitrogen to initiate discharge.
Table 2. Gas lifting data on two PNOC-EDC geothermal wells.

<table>
<thead>
<tr>
<th>Well</th>
<th>Depth, m</th>
<th>Temp., °C</th>
<th>Pres., MPag</th>
<th>Static Water Level, mVD</th>
<th>PCS mVD</th>
<th>Liq. Nitrogen Vol., gal. To Flow</th>
<th>To Sustain</th>
<th>Submergence Ratio @ PCS</th>
<th>@ MPZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT-2D</td>
<td>2065</td>
<td>238</td>
<td>13.8</td>
<td>500</td>
<td>1383</td>
<td>252</td>
<td>1122</td>
<td>0.66</td>
<td>0.72</td>
</tr>
<tr>
<td>PT-4D</td>
<td>2020</td>
<td>240</td>
<td>13.0</td>
<td>550</td>
<td>1450</td>
<td>416</td>
<td>1862</td>
<td>0.55</td>
<td>0.69</td>
</tr>
</tbody>
</table>

The major thrust of the study involves the determination of other empirical factors, aside from the submergence ratio, which can be used to estimate the minimum and optimum depths at which gas lifting can succeed, and the minimum volume of liquid nitrogen needed to achieve it. The authors hope to use the results of these studies in optimizing the application of the gas lifting technology in geothermal operations.

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REFERENCES


