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

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ABSTRACT

PNOC-EDC pioneered tlie use of gas lifting to initiate geothermal well discharges in the Philippines in **1992.** Liquid nitrogen is gassified and pumped into tlie wellbore through a coiled tubing. Tlie "lift" is achieved through tlie creation of a pressure drop between the reservoir and tlie wellbore at tlie 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 tlie upflow of liot reservoir fluids **from** deeper sources. Tliis is typical of some geothermal wells in tlie 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 tlie use of any of the following techniques:

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

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

MECHANICS

Tlie 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 wcllbore temperature to saturation; or
2. by reducing the wellbore pressure to saturation vis-a-vis tlie wellbore temperature.

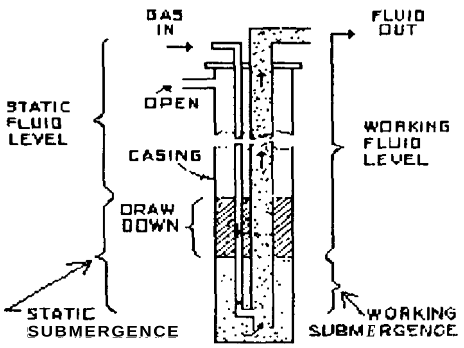

Figure 1. Early gas lifting set-up for an oil well (after Brown, 1973).

Gas lifting aims to satisfy the latter in initiating geothermal well discharges. Figure 2 illustrates this graphically.

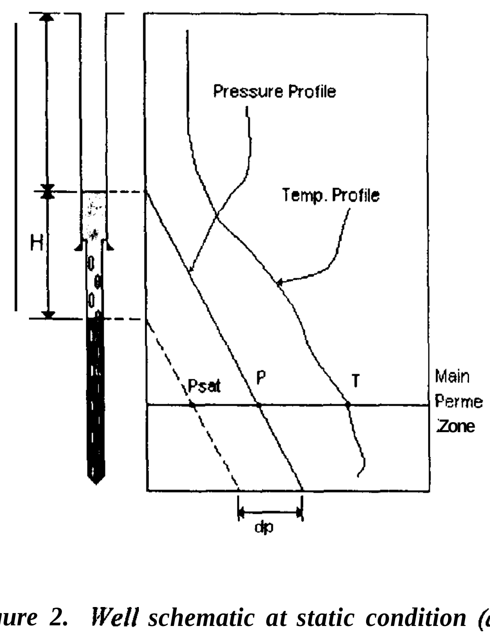

Figure 2. Well schematic at static condition (after Aqui, 1997).

From tlie steam tables, tlie saturated pressure P_{sat}, corresponding to tlie 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 tlie saturation and tlie measured pressures. "Lifting" of this column of cold liquid effectively creates that necessary pressure drop at the payzone, which in turn induces tlie flow of reservoir fluid into tlie 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 tlie inability of the well to discharge by itself or through cheaper stimulation techniques (air compression or two-pliasc fluid injection), and 2) on tlie urgency of discharging it. Wliile tlie former is influenced by tlie relatively high cost of gas lifting, the latter become$ a factor only when operating necessities dictate tlie immediate discharge of a newly coinpleted 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 tlie desired depths in the wellbore. It is rigged to tlie wellliead through its tubing injector assembly and connected to the source of tlie lifting agent through high-pressure lines. Figure *3* illustrates a typical set-up.

Liquid nitrogen is gassified before being pumped through tlie coiled tubing by means of a nitrogen pump/heater unit. With delivery pressures typically in tlie 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 tlie testing stage. It has been PNOC-EDC's experience, however, that some wells would require extended injection of nitrogen to sustain the initial **flow** through the silencer, mainly because of tlie large pressure drops created at tlie wellliead tees in the early stages of discharge. This brought about tlie use of a "Y" spool which allows

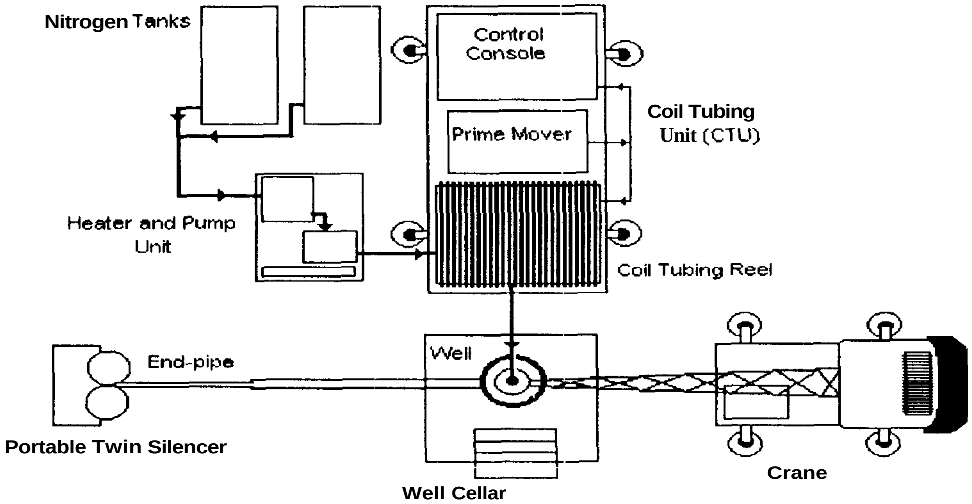

Figure 3. Nitrogen gas lifting set-up. 1

near-vertical discharge of the well even when the tubing is still stubbed in the hole.

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 geothernial 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.

COMPONENT	% COST
Nitrogen Services	30.0
Mob/demob	25.0
Other Equipment	6.0
Liquid Nitrogen	4.0

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 lias 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 lias relied on gas lifting not only in discharging some of its exploration wells but also its production and development wells as well. Tlie latter category in fact outnumbers tlie former by **4** to **3.** Tlie company largely gained maximum benefits from the technique in two ways, namely: 1) proving tlie discharge potential of the wells and subsequently tlie commercial viability of tlie exploration projects where all tlie wells did not have self-discharge capability; and 2) enabling discharge testing of the wells immediately after drilling or workover without tlie normal period given to tlie 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. tlie word "success" here meaning tlie attainment of a sustained discharge.

Hole condition refers to tlie readiness of tlie well for discharge in terms of its pernieability, downhole temperature and pressure. Whereas, equipment condition refers to tlie 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 tlie other hand, there were also failures directly attributable to hole condition. Tlie best examples. perhaps, are wells MG-27D and MG-29D (Yglopaz **et** al., 1998) which tended to cool down everytime they would be discharged. The phenomenon was later analyzed as a direct effect of drilling fluids which were flooding tlie sector when two drilling rigs were active in tlie vicinity of the discharged wells.

Deep vs. Shallow Injection

Tlie usual practice had always been deep injection of the nitrogen gas near tlie vicinity of tlie 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 tlie well of debris and drilling mud even before the start of tlie well discharge; or taking advantage of tlie reservoir pressure at this zone to reinforce tlie nitrogen gas action in initiating well flow. Deeper gas injection, however, increases tlie risk of the coiled tubing getting stuck in tlie wellbore as experienced by tlie company not a few times, aside from possibly requiring a larger volume of nitrogen for tlie same work to be done. Tlie former, however, lias mainly influenced PNOC-EDC's recent attempts for shallow nitrogen injection as a stuck tubing in tlie hole not only jeopardizes tlie discharge tests but also entails considerable cost in tlie subsequent fishing and recovery operations.

Aqui (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 tlie submergence, H, over tlie total lift, L, in Figure 2. He also suggested that tlie ratio could aid in estimating tlie minimum depth of injection for a successful gas lift. Preliminary work on this potential application of the ratio lias been done on two wells having similarities in relevant downhole cliaracteristics (Table 2).

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

Well	Major Permeable Zone (MPZ)			Static Water Level, mVD	PCS mVD	Liq. Nitrogen Vol., gal.		Submergence Ratio	
	Depth, in	Temp., °C	Pres., MPag			To Flow	To Sustain	@ PCS	@ MPZ
PT-2D	2065	238	13.8	500	1383	252	1122	0.66	0.72
PT-4D	2020	240	13.0	550	1450	416	1862	0.55	0.69

Table 2. *Gas* ***lifting data on*** *two PNOC-EDC* ***geothermal wells.***

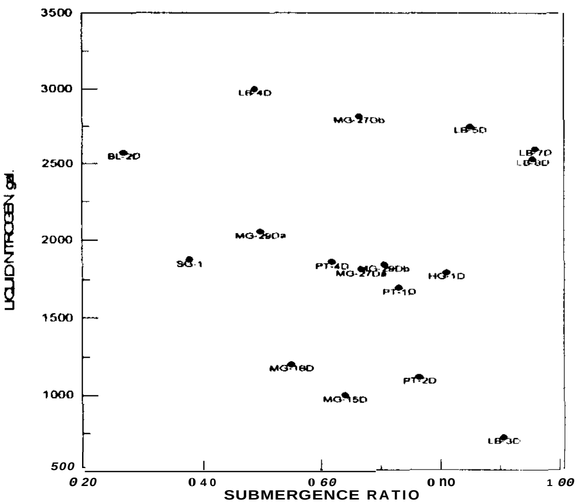

Figure 4. Plot *of* ***submergence ratio*** *vs. actual* ***volume*** *of liquid* ***nitrogen needed to sustain discharge of some PNOC-EDC wells.***

Prediction of the required voluine of nitrogen to gas lift a well using the submergence ratio has also been attempted with encouraging initial findings. Figure 4 suggests at least three possible trends or groupings of data points in the plot of submergence ratio vs. liquid nitrogen volume for some of the wells gas lifted by PNOC-EDC. Despite the expected general trend of lower nitrogen volume to higher submergence ratio, the authors can only surmise at this point that there are several more properties, wellbore and reservoir-wise, which need to be factored in the correlation in order to understand the apparent grouping of certain data points.

ON-GOING STUDIES

The preceding experiment following Aqui (1997) has therefore initiated a detailed study of the possible factors which produce the data trends in Figure 3.

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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