FLUSHING TECHNIQE USING LIQUID CO_2 FOR LOWER TEMPERATURE GEOTHERMAL WELLS

LIU, Jiangang, Yunchen Bureau of Water Conservancy, Shanxi, CHINA
ZHENG, Keyan, Beijing Corpn of Hydrogeol. & Eng. Geol., P.O.Box 100037,
Ba Li Zhuang, Hai Dian District, Beijing, CHINA

1. Introduction

The yield and life of lower temperature geothermal wells, and even its stability of water quality, depend on flushing technique mainly besides related to drilling quality. The goal of flushing is mainly to eliminate any natural and artificial unfavourable factors, which affected yield, as many as possible, in order to recover original permeability of the aquifer, reflect its water yield property accurately, and bring the utilization gaining of geothermal well into full play.

The traditional flushing methods using piston and air compressor usually be not very effective for lower permeability aquifer, for thicker mud wall or for oxidized corrosion of well screen. At recent years the flushing method using liquid CO_2 has been applying in China. It is characterized by saving on time, efficient and economization. Even some initial "died well" and waste well can also bring the dying back to life after the treament.

The main factors affected yield of geothermal wells include mud wall effect formed by drilling mud, fragments plug effect on well screen due to used for many years, chemical plug effect caused by corrosion of metal and scaling of water, and filling effect of cutting in pores or fractures of aquifer during drilling. All of these problems can be solved by using flushing technique of liquid CO_2.

2. Principal

In fact, flushing of CO_2 is a combined flushing of physical and chemical methods.

Liquid CO_2 can only be stored in special cylinders under high pressure. It boils and vapours at -78.5 ℃ in atmosphere. When the liquid CO_2 is injected into a lower temperature geothermal well at a certain position with the aid of drill pipe and high pressure pump system, the liquid CO_2 is immediately heated and strongly vapoured. It made its volume expanded rapidly. The steeply increased pressure acts to aquifer passing through casing pipe, and also mixes CO_2 gas and water to form two phase flow. Consequently, the strong air-lift pushes two phase floid rising and blowing out the wellhead. Meanwhile, the decreased water head in the well continues and intensifies vapouration of CO_2. Such futher decrease of density of two phase flow promotes air-lift further, and increases yield. Large number of release of CO_2 gas causes well blowing. After that the aquifer loses hydraulic balance because water losing from blowing. Thus, water from the aquifer recharges into the well rapidly under the action of large pressure difference. Such positive and negative "water shock" acted on well wall of an aquifer can efficaciously damage mud wall, burst plug and dredge filling. These are combined result of the vapourization action of CO_2 and the hydromechanics action of water flow.

Moreover, CO_2 reacts with numberous Ca^{2+} and Mg^{2+} from drilling mud to form precipitation of $CaCO_3$ and $MgCO_3$. It is favourable to weakenize the crystal lattice of colloid, and to increase hydrous diffusivity of mud wall.

3. Flushing Well Technique Using Liquid CO_2

Links up CO_2 cylinders with high pressure pipeline in well (e.g. drill pipe) and

high pressure pump using high pressure pipeline system formed by rubber tubes and steel pipes. When open the valves of CO_2 cylinders, the vapourized CO_2 pressure can push a certain quantity of liquid CO_2 to inject a well along the pipeline (Fig.1). It can be also injected deeper position of well with the aid of high pressure pump.

For deep well over thousant metres, the CO_2 can be injected respectively into several positions of different depthes. The quantity of injected CO_2 for each position can be calculated by the work need it doing.

For example there is a geothermal well with depth of 1459 m in Beijing. The upper part of the well is 800 m casing of diametre 168 mm, and the lower part is naked hole in diametre 130 mm. Temperature at the well bottom is 57 ℃. Its aquifer (fractured and ruptured reservoir formation) in 1300 m deep was selected as the first injected position. Total 17 cylinders of CO_2 (24 kg for each cylinder) were injected there. Then respective 29, 41 and 22 cylinders of liquid CO_2 were injected at 960 m, 580 m and 200 m (Fig.2). After that, the well blowing was produced first from fourth injected position. Then the third, the second and the first injected positions blew progressively. It reached flushing goal for whole well finally.

4. Flushing Well Technique Using CO_2-Polyphosphate

The polyphosphate includes sodium hexaphosphate ($(NaPO_3)6$), sodium superphosphate ($Na_4P_2O_7$) and sodium trithiophosphate ($Na_5P_3O_{10}$). They have three functions in flushing well,

(1) Complexing function

Polyphosphate complexes with calcium , magnesium and such metal cations from clay to form complicated dissolvable complex compounds. For example

$$Ca^{2+} + (NaPO_3)_6 \rightarrow Na_2(CaNa_2(PO_3)_6) + 2Na^+$$

$$Na_2(CaNa_2(PO_3)_6) \rightarrow 2Na^+ + (CaNa_2(PO_3)_6)^{2-}.$$

After these reactions, the concertrations of calcium and magnesium cations decrease sharply. Thus it eliminates viscidity of the clay and promotes diffusion of colloid.

(2) Decrease surface tension

Polyphosphates have active surface. It decreases the surface tension of clay. So it causes clay damp, mitkiness and increasing of permeability.

(3) Adsorption

A lot of sodium cations produced by dissolusion of polyphosphate displaces adsorption with calcium and magnesium cations of clay. It made calciferous clay become sodium clay which is easy for hydrolysis and diffusion.

There was an example in Yuncheng. The well is 301 m deep. Its aquifer is medium-fine sand and fine-silt sand of Quaternary. The well completed in 1978, but didn't use until 1982 because quite little yield. Combined flushing using CO_2 and polyphosphate was undertaken in september of the year. The original yield was 1 m^3/h before flushing. The flushing operation injected 700 kg sodium superphosphate first. Then 15 cylinders of CO_2 were injected after 8 hours. Blowing was 21 m high. Along with a lot of mud and sands blowing out, the yield of the well became 20 m^3/h.

5. Flushing Well by Injecting Acid with CO_2

Injected hydrochloric acid (usually with concertration of 10-15 %) can react with carbonated rock of aquifer and with rust of casing pipe chemically. So the injected acid would dissolve cuttings and fractures of carbonate and rust. Consequently, the yield of

well would increase because dredged permeability. During the operation some proper additives e. g. preservative, inhibitor, stabilizer and surface activator can be added.

No.3 geothermal well in somewhere of Hebei province was completed in July of 1977. The well is 1019 m deep. Its reservoir is Sinian dolomite. Pipe of diametre $4^1/_2$ enches casing to depth 976 m. Temperature is 71.5 ℃ at wellhead. Its artesion flow rate was 470 m^3 per day. Wellhead pressure was 1.8 kg/cm^2. Flushing this well by injected hydrochloric acid and CO_2 in 1985 due to the decrease of flow rate. After injection for 4 hours the well blew. Then liquid CO_2 was injected and well blew again at 20 minutes late. The flushing results show as follows,

	Temp.(℃)	WHP(atm.)	Flow rate(m^3/d)
July 1977 well completion	71.5	1.8	470
June 1985 before flughing	68.5	0.72	256.8
June 1985 after flushing	73.0	0.8	508.8

6. Conclusion

Flushing using liquid CO_2 for lower temperature geothermal wells achieved good results. It is suitable for various cases, basement or loose aquifer, steel or other material casing pipe, shallow well or deep well, new well or old well, and even waste well. It is able to save the time and to spend less money but get more yield. Underwent various tests for over 800 wells, the increased yield ranges from 20 % to 19 times, and the average is about 1-3 times usually. Its simple equipments and less investment are very convenient for application and population.

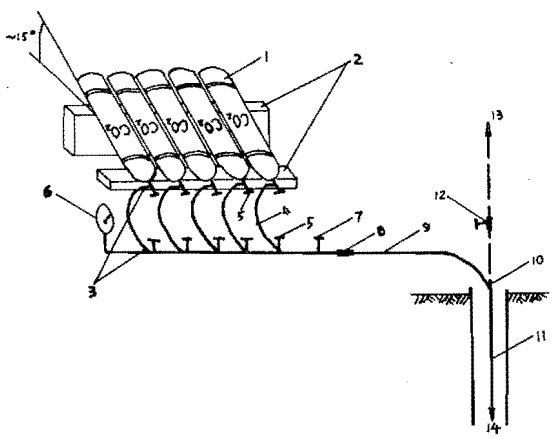

Fig.1 Sketch of Flushing Well Installation Using Liquid CO_2

1. CO_2 cylinders; 2. steeper; 3. high pressure joint; 4. high pressure rubber tube; 5. QF-2 valve; 6. pressuremeter; 7. general valve; 8. direct active joint; 9. surface high pressure pipeline; 10. toggle or tee joint; 11. downhole high pressure pipeline; 12. valve to pump or acid tank; 13. pump or acid tank; 14. to flushing position.

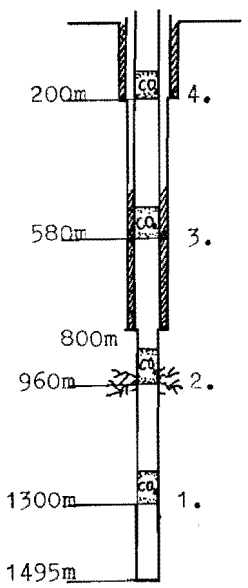

Fig.2 Sketch diagram showing injection position of liquid CO_2 in a deep well

★1, 2, 3 & 4 show the first, second, third & fourth injected positions of liquid CO_2.

References

HE, Q. and XU, J., 1979, A Test and Research on Flushing Well Using Liquid CO_2 Blowing. Hydrogeology and Engineering Geology, No.5. (in Chinese)

LIU, J., 1983, A Test and Its Application on Combined Flushing Well Using CO_2 and Injected Liquid. Technology on Water Conservancy and Hydropower, No.12. (in Chinese)