HARD SCALE REMOVAL IN WEST TEXAS

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ABSTRACT

The first use of a through-tubing technique to selectively remove hard and inert scales in West Texas proved successful. The technique incorporates an abrasive jetting technology that uses two new coiled tubing tools and pumps specially manufactured particles through nozzles in a rotating head.

The goal was to remove an inert scale, predominantly barium sulfate, from the production tubing in an old gas well in order to deploy tubing cutters as close to the packer as possible. The engineering and actual execution of this project are examined here. The results are compared with the previous attempt to clean out the well and an offset well to show the economic value of the technique.

The subject well is located just south of Mentone, Texas, in a field that is notorious for barium sulfate scale production.

INTRODUCTION

As well production declines and water production increases, the potential of scale precipitation increases, provided that sufficient scaling constituents are in the produced water. The scale can plug off perforations and tubing jewelry and even scale up the tubulars, forming choke points or bridges in the tubing all the way to surface. As reservoir pressure declines, scale buildup and increased water production result in production losses and remedial treatments to remove the scale may be required.

The worst case is that the well's production tubing must be removed before other Formations can be perforated to increase production and extend well life. Scale removal may be necessary if the scale has either added weight that makes the production tubing too heavy to remove from the well, restricted the tubing enough to prevent a tubing cutter from reaching a reasonable depth or both.

To remove hardened scale from production tubing, the conventional means are using scale converters and dissolvers, mechanical methods, or a combination of both. Barium sulfate does not dissolve in acid unless it is converted into something acid soluble. The conversion process is very expensive and time consuming, and the converter works only on the scale surface area it contacts. Converter placement may be difficult in consideration of the volume of scale possible in the tubulars

Using mechanical methods (mills, bits, sonic hammers, impact hammers, reamers, etc.) is also very expensive and time consuming when dealing with extremely hard scales.

A new through-tubing technique based on abrasive jetting technology provides an effective solution for removing hard scale from tubulars without damaging the tubulars. The technique has been successfully field tested in most of North America, as well as the North Sea and parts of Africa, and has become widely used in the Gulf of Mexico for removing hard, insoluble scale from tubulars. This paper describes its first use in West Texas and outlines the steps taken to design, execute and evaluate this successful operation.

WELL BACKGROUND

A West Texas operator wanted to abandon one zone, pull the production tubing and perforate an upper interval that had production potential in a well just south of Mentone, Texas, in a field that is notorious for barium sulfate scale production. A workover rig was put on location and an attempt to pull the production tubing was made. The packer would not unseat when the tubing retrieval was attempted. The decision was made to cut the tubing above the packer and then pull the tubing from the well. The minimum inside diameter (ID) required by the cutter to reach the desired depth was 2.5 in. The operator used slickline with a 1 %-in. gauge to verify the ID of the tubing, and to determine the existence of bridges in the tubing. The gauge tagged up at 10,634 ft.

The field has a tendency for severe barium sulfate precipitation, which another operator had experienced a similar situation. In an offset well, the operator attempted to clean out the barium sulfate scale using a mill and motor on coiled tubing. Cleanout attempts were suspended after four mills, two motors and two different coiled tubing suppliers reached a depth of only 3000 ft. in six days. The operator decided to pull the tubing. This process required many weeks to complete and the total costs exceeded $1.5 million.

On the subject well, the decision was made to also utilize the mechanical means of mill and motor on coiled tubing, to clean out the barium sulfate scale as opposed to pulling the tubing, given the potential costs and time. After three days using a 2 3/8 in. mill, only 1600 ft. of scale had been removed. After the coiled tubing was pulled from the well, another l ½ in. gauge was run in the tubing and tagged a bridge at 2,636 ft. This bridge was believed to be fill from the previous motor runs.

At this point, it was decided to attempt to remove the scale using the new abrasive jetting technique conveyed via coiled tubing.

TECHNIQUE DESCRIPTION

The technique described by Johnson, Eslinger, and Larsen uses a new generation of bottoinhole assembly (BHA) to pump a specially engineered abrasive material to remove hard scale deposits. Job design and post treatment evaluation are accomplished using a software package engineered for this technique.

BHA DESIGN

The main components of the bottom hole assembly are the head module, the swivel, and downhole filter.

Head module

The head module consists of two primary components: a nozzle head and a drift ring. The nozzle head is attached to the rotating shaft of the swivel and contains selected nozzles. The offset radial nozzles in the head power the shaft rotation. The drift ring prevents tool penetration until the deposit has been removed to the outside diameter (OD) of the drift ring and it controls the size of the cuttings that pass the ring. The OD of the nozzle head and the drift ring are dependent on the well completion and the drift diameter of the deposit. The nozzle head configuration selected for the subject West Texas well has three carbide nozzles, two radial and one downward at 20 degrees.

Swivel

The swivel is the tool that provides reliable, controlled rotation of the nozzle head to efficiently remove wellbore deposits. The speed of the swivel is controlled to less than 200 rpm by a pressure-compensated viscous brake. The radial and thrust bearings operate in the brake fluid to resist setdown and pressure-induced loads.

Downhole filter

The downhole filter is assembled into the BHA to prevent pumping large debris (>0.040 in.) into the head module nozzles. If a surface filter is also used, the downhole filter primarily filters debris (rust, etc.) originating in the coiled tubing string. The filter is manufactured from Hastelloy* C276 sand screen and has a 0.040 in. screen gap. The assembly includes a bypass burst disk that ruptures if the filter clogs. Flow is from the outside to inside of the screen *to* facilitate easy cleaning and to prevent flushing filtered debris downhole if the bypass burst disk ruptures.

ABRASIVE MATERIAL

The abrasive material in combination with jetting is the key enabling feature for the removal of hard inert scales. Jetting with abrasive does not require ultra-high-pressure jetting to effectively remove hard deposits because the material removal mechanism is different from that of plain fluid jetting. High-velocity impacts of the abrasive on a brittle deposit develop a dense network of near-surface cracks. As the cracks propagate and connect after repeated impacts, small cuttings are dislodged and eventually the deposit is removed.

The abrasive material is a nontoxic substance, specially engineered and manufactured to exploit the different solid impact damage mechanisms between brittle (scale) and ductile (tubulars) materials. The size, density and fracture toughness of the abrasive are engineered to optimize scale cutting, whereas the shape and hardness of the abrasive are engineered to minimize tubular damage.

The design of the spherical particles for scale removal operations is a direct result of Johnson's theoretical and experimental study.

SOFTWARE PACKAGE

The software package is used to design the field treatments. It optimizes the scale removal technique by determining the nozzle head size and drift ring and the hydraulic horsepower at the tool. It predicts the most efficient abrasive particle concentration necessary for the maximum scale removal rate at the specified well parameters and conditions.

JOB PREPARATION

WELL DESCRIPTION AND OBJECTIVES

The well was a gas well that was plugged off. The production tubing was 3 ½-in. of two different weights: 12.95 lbm to 3,400 ft. and 10.3 lbm to 17,127 ft. The plugged-off zone did not produce enough gas to be economically feasible to clean out the scale and restimulate. However, a zone near 15,600 ft. had good production potential that made it economically viable to remove the scale from the well and the production string before to perforating and stimulating this new zone.

Because the packer could not be retrieved, the minimum depth necessary to employ a tubing cutter was 16,000 ft. The maximum OD of the cutter was 2 3/8 in., which requires at least a 2 ½-in. clearance hole.

LABORATORY TEST

Scale sample testing identified the scale as insoluble in hydrochloric acid, with a prevalent chemical composition predominantly of barium sulfate.

TECHNICAL DESIGN

Jetting performance

Using the software package, it was determined that two separate runs were required. The well most certainly contained a bridge consisting of barium sulfate at 10,600 ft. With the possibility of more bridges below 10,600 ft., a special motor that incorporated a positive displacement motor (PDM), drift ring and nozzle head was designed for the first run. A 1.625-in. OD polycrystalline diamond compact (PDC) bit was designed to make the pilot hole for the nozzle head, and the abrasive material would be used to remove the scale to a diameter greater than the drift ring. The drift ring size chosen for the first run was 2-in. OD. Once the first run had eliminated any bridges and cleared a 2-in. pilot hole to the desired depth, the second run would be made using the swivel with a IS-in. nozzle head and 2 %-in. drift ring. The abrasive material would be used in conjunction with both the PDM and the swivel runs to maximize scale removal.

A maximum rate of 1.0 bbl/min was allowed for the first run with the PDM. To get optimum nozzle pressure and reliable nozzle head rotation from the swivel, 1.1 to 1.3 bbl/min would be needed on the second run.

Wellbore cleanout

Because the well was plugged off, it could support a column of fluid. If there was not another bridge below the bridge at 10,600 ft., the contingency plan was to have nitrogen on standby and ready to pump once the tool got to 10,500 ft. Simulations showed that foaming the carrying fluid would slightly decrease the rate of penetration (ROP) but would retain sufficient velocity to carry solids up and out of the well under low bottomhole pressure (BHP) conditions.

EQUIPMENT

The well intervention operation was performed on land with a tractor/trailer coiled tubing unit. The coiled tubing size, mixing equipment and pump capabilities were an instrumental to the job design and execution.

Coiled tubing

A tapered 1 %-in. coiled tubing string with a burst pressure rating of 11,943 psi was selected because of its length of 17,500ft. Its pressure rating was also sufficient to achieve the required pump rates required for the job. The overpull limits for the string were between 15,000 and 22,000 lbf.

Mixing equipment

A batch-mixing unit was required to ensure the consistency of the carrying tluid and dispersion of the abrasive material. The unit chosen had two 50-bbl tanks, one of which could be pumped down hole while the other tank was being prepared. Each tank had paddle mixers. The capacity of each tank provided for enough time between batches to afford excellent slurry (carrier fluid and abrasive) homogeneity.

Pump capabilities

The treatment design specified that a minimum of 36 hours were required to complete the job. This substantial treatment time required a pump capable of achieving low rates for extended periods. Two pumps that met this requirement were sent to location, with one serving as a reserve unit.

Chemicals

The job design required 25,000 lbm of abrasive material and 800 bbl of carrier fluid.

Safety issues

Using abrasive jetting technology to remove hard scale had never been performed in the West Texas area or for this operator. A thorough prejob safety meeting was conducted before any equipment or chemicals were mobilized to the location, and another meeting was held before the actual operation began. All operational and safety concerns were discussed and resolved before the treatment, with the inclusion and involvement of the operator representative and all third-party personnel.

JOB EXECUTION

Although the job design predicted a 36-hour continuous job, preparations were made for a job that could take days if the wellbore conditions deviated from those anticipated. The job took eight days to complete: one day for rig-up, three days deploying the PDM and abrasive, a one-day break and three days using the swivel and abrasive.

EQUIPMENT RIG-UP AND SURFACE TESTING

Upon the crew arrival to location, a rig-up safety meeting was held with all personnel on location. The equipment was rigged-up to company and operator safety standards. An in-line filter (similar to the downhole filter) was placed in the 2-in. pumping line to prevent debris from frac tanks, pumps, mixers, etc., from reaching the BHA.

After rig-up, a preoperational safety briefing was held and involved all job personnel. The procedures for pressure testing and surface testing the equipment were outlined as well as the operation and all contingencies. A surface test of both the PDM and swivel was performed before each run to ensure normal operation of the tools, as well as to predict the surface pressures while pumping at the design rates.

RUN IN HOLE WITH PDM AND 1 5/8-IN. PDC BIT. 2-IN. DRIFT RING, AND ABRASIVE MATERIAL

The coiled tubing was run into the well cautiously to a depth 1600 ft. because the previous job had reached only that depth when using a 2 3/8-in. bit on a PDM. At this point, the weight indicator showed a loss of weight, which indicated that the tool was tagging scale. Next the carrier fluid and abrasive material were mixed and pumped to start removing scale. The flowback pit was outfitted with a screen to catch samples. All indications showed positive signs of scale removal. A significant volume of scale was found until the tool reached a depth of 2900 ft.

At this point, the weight indicator showed an increase in weight and the running speed of the coil was subsequently increased to 25 ft/min. The tool made a hard tag at 8853 ft., followed by an increase in ROP. The hard tag at 10,600 ft. was never found. Some restrictions were encountered, but the tool and abrasive material quickly cleaned through these areas. A maximum depth of 16,040 ft. was achieved, and a ball was dropped to open the circulation sub above the PDM. The well was circulated to remove the cuttings and abrasive material and then the coiled tubing and **BHA** were pulled out of the well. The PDM was removed and the swivel with a 2 %-in. drift ring was installed. Positive scale returns were recovered in samples for the duration of the treatment.

RUN IN HOLE WITH SWIVEL, 2 ½-IN. DRIFT RING AND ABRASIVE MATERIAL

With a drift ring larger than 2-in., scale was tagged at **7** ft. from surface. Large quantities of scale were coming back to surface and the ROP was much slower than the previous tool run with the smaller drift ring. The observed ROP was 200 ft/hr until a depth of 3515 ft. was achieved, after which the ROP increased to 25 ft/min. Past 8000 ft., the ROP slowed down owing to the increase in scale inside the tubing. Numerous restrictions were encountered; however, the tool and abrasive material removed the restrictions. Returns provided many scale samples and circulation was maintained for the duration of the operation. **A** maximum depth of 16,100 ft. was obtained with the swivel and 2 %-in. drift ring. The coiled tubing was then pulled out of the well after circulating the well clean, and a pre-rig-down safety meeting was held.

POST JOB EVALUATION

A slickline run was made with a 2 3/8-in. gauge ring to approximately 13,000 ft., where the gauge ring tagged an obstruction. Because of the minimal weight of the slickline, it was decided to run the tubing cutter. The tubing cutter reached a depth of 16,040 ft, where the tubing was then cut. It took three days to retrieve the tubing from the well. The workover crew noted a thin layer of scale coating the ID of the tubing. The layer was perfectly circular and had a diameter of approximately 2.6 in.

CONCLUSION

The new scale removal technique utilizing jetting techniques and abrasive material proved very successful in its first use in West Texas. The technique uses abrasive materials that remove scale from the wellbore without damaging the tubulars. The technique has performed well in removing hard insoluble scale from tubulars where conventional methods have failed or are very expensive.

The scale in the subject well was removed to enable tubing cutters to cut the tubing for workover retrieval with minimal time and cost in comparison with similar operations in an offset well. The operator could then reperforate and produce from a higher zone.

This technology provides an effective substitute for environmentally unfriendly chemicals and also huge time and cost savings over conventional methods of removing hard inert scales in West Texas wells.

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REFERENCES

Johnson, A., Eslinger, D. and Larsen, E.: "An Abrasive Jetting Scale Removal System," paper SPE 46026, presented at the 1998 SPE/ICoTA Coiled Tubing Roundtable, Houston, Texas, 15-16 April 1998.

*Hastelloy is a registered trademark of Haynes International, Inc.

Results at [illegible] (psi) circ pressure On bottom		
Job flow rate	0.98	bpm
Nozzle pressure	3503.28	psi
ROP	47.29	
Fluid consumption (hourly)	58.93	bbl/hr
Starting Beads used (hourly)	808.93	lbs/hr
Gel consumption (hourly)	117.86	lbs/hr
Nitrogen used (hourly)		Mscf/hr
Jetting temperature	123.63	F
Tubular 1 annulus flow velocity	151.00	ft/min
Critical stall time	3.87	min
Lag for detectable bit motion	0.23	min
Job fluid TVD	0.01	ft
(On - Off) bottom pressure, max	494.10	psi
Calc Static WHP (psi) = 1308		
Calc Circulating WHP (psi) = 1079		
Calc Circulating BHP (psi) = 7718		
Material concentrations		
Liquid gel added	0.50	gal/bbl
Liquid gel added per 50bbl	25.00	gal
Abrasives added	14.01	lb/bbl

Figure 1 - Performance for Motor Run

Results at [illegible] (psi) circ pressure		
Job flow rate	1.23	bpm
Nozzle pressure	3154.98	psi
ROP	44.78	
Fluid consumption (hourly)	23.60	bbl/hr
Starting Beads used (hourly)	1010.31	lbs/hr
Gel consumption (hourly)	147.19	lbs/hr
Nitrogen used (hourly)		Mscf/hr
Jetting temperature	123.63	F
Tubular 1 annulus flow velocity	108.56	ft/min
Critical stall time	3.59	min
Lag for detectable bit motion	0.24	min
Job fluid TVD	0.01	ft
Calc Static WHP (psi) = 457		
Calc Circulating WHP (psi) = 402		
Calc Circulating BHP (psi) = 7848		
Material concentrations		
Liquid gel added	0.50	gal/bbl
Liquid gel added per 50bbl	25.00	gal
Abrasives added	14.01	lb/bbl

Figure 2 - Performance for Swivel Run

ROP

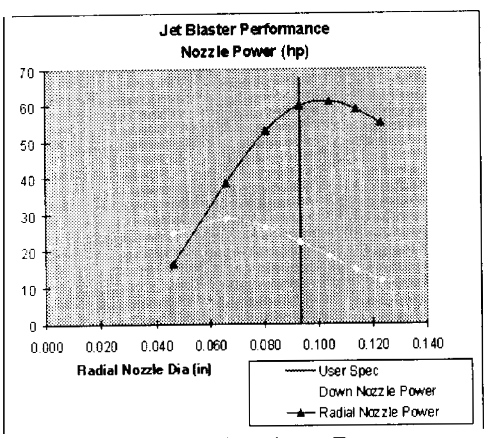

Figure 3 - ROP for Motor Run

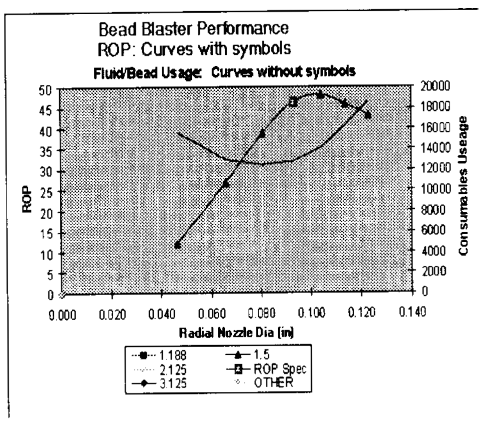

Figure 4 - HP for Swivel Run

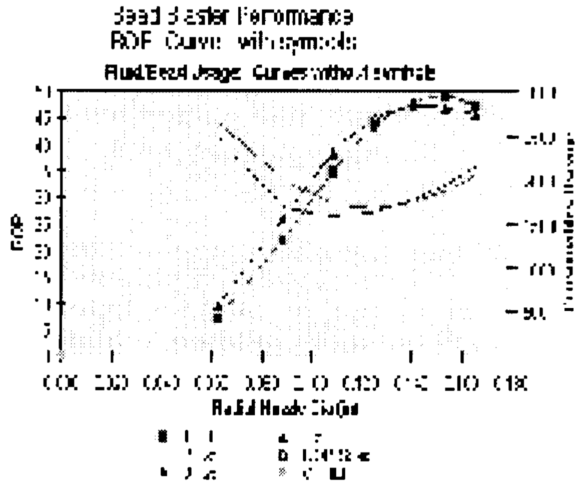

Figure 5 - ROP for Motor Run

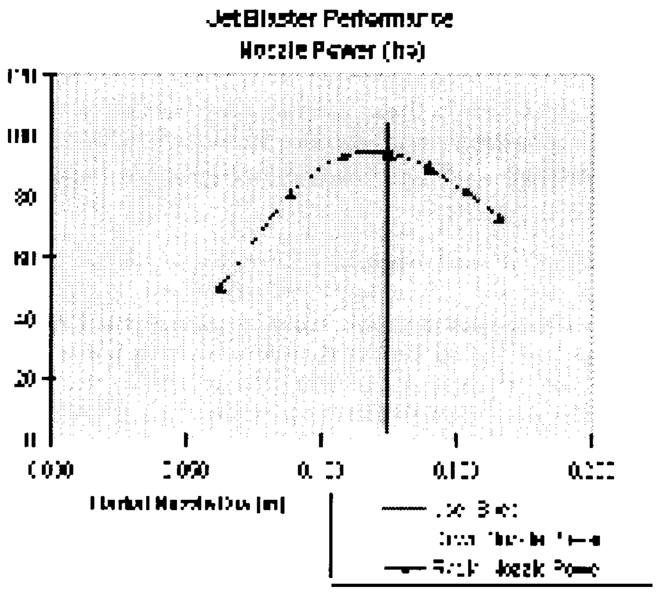

Figure 6 - HP for Swivel Run