Backsurging perforations can increase production rates

Remarkable results from a high-rate Alaskan oil well prove the value of surging a formation. A wireline retrievable tool was used to subject existing perfs to a high pressure underbalance

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SUBJECTING FORMATIONS to a large pressure differential or underbalance is a common means of surging perforations to remove damage and increase flow from oil and gas wells. Underbalanced perforating, a standard industry completion technique, is normally used to obtain the pressure differentials intended to dislodge debris from perforations and flush the surrounding compacted zone. Gradually applied pressure underbalance can be achieved by swabbing or jetting to reduce hydrostatic head. Suddenly applied underbalance is achieved by evacuating the tubing in conjunction with a rupture disc, tubing-conveyed perforating systems or by using a new wireline-set, through-tubing backsurge tool.

These techniques, except for the through-tubing method, are often utilized only during initial completion and seldom during later workovers due to the expense and difficulty of achieving an adequate underbalance. Many operators prefer to perforate in balanced or overbalanced pressures conditions. This typically leaves perforations completely or partially plugged with gun debris, mud solids and shattered formation material that has been recompacted (see Fig. 1). Production logging shows that wells often produce from only 10 to 20% of the total interval apparently because of ineffective, plugged perforations.

BACKGROUND

Tubing-conveyed perforating (TCP) systems were specifically designed to create high pressure differentials during perforating. TCP methods are currently used only in special applications and cannot be repeated without round tripping production tubing.

Debate continues over the advantages of suddenly applied high pressure differentials across perforations versus the same pressure underbalance applied slowly.

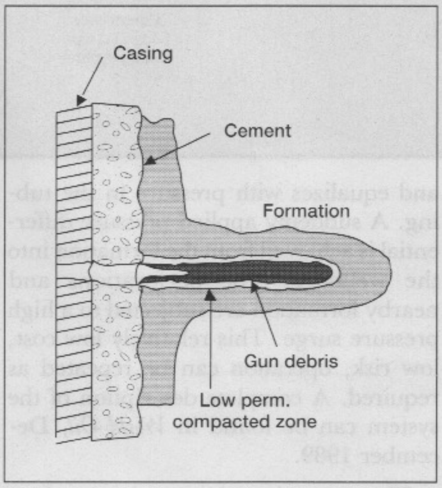


Fig. 1—Inefficient perforations can result from debris plugging and formation compaction.

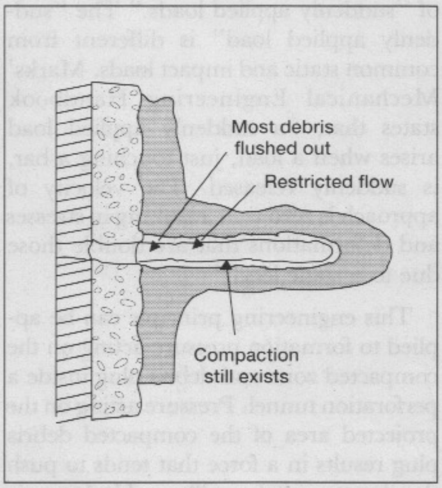


Fig. 2—Debris plugs and compacted zones can be flushed by underbalanced perforating or instantaneous surge techniques.

Swabbing or jetting fluid from production tubing creates a differential pressure from the formation into the wellbore. As the differential increases, perforations begin to partially or completely unplug (see Fig. 2) and the well starts to flow. The extent of unplugging depends on fluid velocities, formation consolidation, permeability and other reservoir characteristics. The merits of suddenly applied underbalance become apparent under these well conditions.

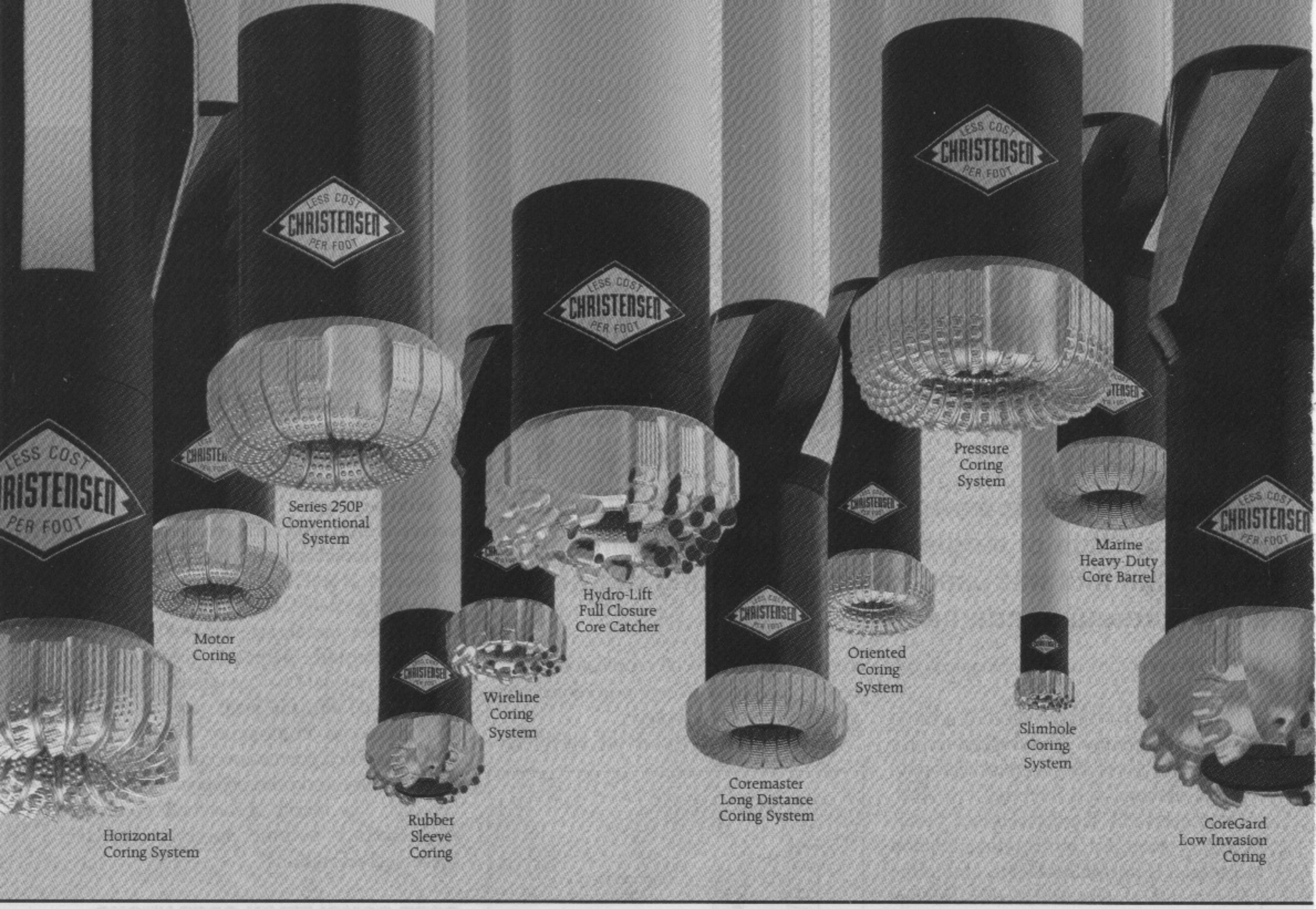
POST COMPLETION OPERATIONS

Instantaneous re-application of pressure underbalance, in wells with plugged perforations, is the only way to get a high differential across the entire interval for the purpose of dislodging additional plugging material. In a new completion, the well is often perforated (see Fig. 3), tubing is run and the packer is set before hydrostatic head is reduced by swabbing or jetting. If wellbore pressure below the packer is gradually reduced to zero and there is no flow because plugged perforations are holding back the full formation pore pressure, the question is, "would perforations be more likely to unplug if pressure is reduced to zero instantaneously?" The answer may be yes, and it appears that subjecting plugging material to higher pressure and ejecting force by instantaneous means is the explanation.

THEORY AND OPERATIONS

Suddenly applied differential pressure theory assumes that a shock load is more effective than the same static load and was first advanced by TCP developer Roy Vann. Until recently, direct field comparisons have not been available to prove this proposition.

In late 1990, a field test was made that



supported this theory. A perforated well would not flow when subjected to static underbalance, and fluid could not be pumped into the formation. After being "stimulated" with an equivalent suddenly applied pressure surge, the well flowed and fluid could be pumped into the formation. The through-tubing backsurge tool (see Fig. 4) was used.

This system basically consists of closing the tubing near bottom with a slickline-set, valve-type plug that will open at a pre-set pressure. Pressure above the plug is removed or reduced so that the valve can open at the appropriate differential across the plug. Pressure in the casing below the packer drops suddenly and equalizes with pressure in the tubing. A suddenly applied pressure differential is achieved from the formation into the wellbore. The perforations and nearby formation are subjected to a high pressure surge. This relatively low cost, low risk, operation can be repeated as required. A complete description of the system can be found in *World Oil,* December 1989.

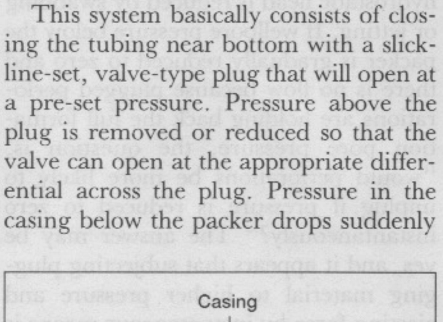


Fig. 3—Shaped charge perforators are used to penetrate casing and formation for production.

This discussion of instantaneous pressure differential is based on the principle of "suddenly applied loads." The "suddenly applied load" is different from common static and impact loads. Marks' Mechanical Engineering Handbook states that, "a suddenly applied load arises when a load, just touching a bar, is suddenly released. The velocity of approach is zero . . . resulting in stresses and deformations that are double those due to a static load."

This engineering principle can be applied to formation pressure acting on the compacted zone and debris plug inside a perforation tunnel. Pressure acting on the projected area of the compacted debris plug results in a force that tends to push the plug toward the wellbore. Under static conditions this ejecting force equals pressure differential times area. If the pressure

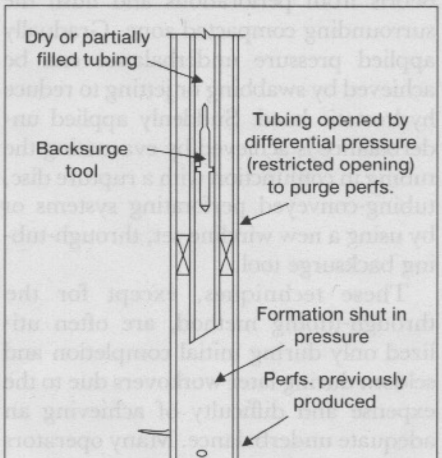


Fig. 4—The through-tubing backsurge tool can be set and retrieved from production tubing by wireline or slickline.

differential is applied instantaneously, conditions of a suddenly applied load are established, and the ejecting force approaches two times the product of differential pressure and area, or about double the equivalent static force.

The plug ejecting mechanism can also

be viewed as a stress within the debris plug and compacted zone. Under static conditions this stress is equal to the static pressure differential. An instantaneous pressure drop results in a suddenly applied stress phenomenon and stress on the plug increases to about twice that of static conditions.

Higher initial pressure forces and stress conditions may initiate flow through the plug permeability sufficient to begin eroding the plug. Continuing erosion results in higher flow velocities, which in turn cause increasing erosion.

APPLICATIONS AND RESULTS

Field results have confirmed that instantaneous underbalance stimulation can increase the production rate of existing wells. The most dramatic of these is an Alaskan well that was producing 2,300 bpd prior to a recent through-tubing backsurge operation. After surging, the well produced over 5,600 bpd, a 3,300 bpd increase and almost $2^1/2$ times the initial rate. This was beyond the expectations of even the most optimistic.

Production from low-rate wells was expected to double but, such gains seemed less likely from high rate wells. A probable explanation is that most of the perforation tunnels were indeed, fully or partially plugged. These plugged perforations did not fully contribute to well production until subjected to a suddenly applied, high-pressure differential. Equally remarkable are the results from the previously mentioned non-flowing well. These represent the first demonstrations of this technique as a possible alternative to acidizing.

Application of this technique in low pressure wells has interesting implications. A well with maximum available underbalance of 500 psi, for example, can momentarily achieve the equivalent of an imposed 1,000 psi pressure differential. Once flow has started, perforation plug removal may be aided by erosion and higher flow velocities.

> *Production from an Alaskan oil well was increased dramatically by application of an instantaneous pressure underbalance or surge.*

In pumping wells or other packerless completions, full pressure differentials cannot be achieved due to annulus fluid intrusion. Lower pressure differentials may be sufficient, when doubled by instantaneous application, to achieve effective cleanout under certain conditions. This can probably be predicted by calculation and definitely be determined by field measurements.

Simplicity, low cost and repeatability are advantages that make this technique feasible under many well conditions. The effects of repeating instantaneous pressure surges are unknown, but can easily be evaluated by further field evaluations.

These results appear to verify the apparent severity of shaped charge perforation plugging. Perforation plugging was previously documented in lab studies, which led to the development of high underbalance completion and workover techniques. The API subcommittee on perforating has addressed perforation plugging effects by including a radial flow test in the latest revision of API RP-43, the perforation evaluation specification.

Continued

OTHER CONSIDERATIONS

More desirable charges have a pressed metal-powder liner (see Fig. 3) that produces a slug consisting of particulate material. These slugs can be flushed out along with other debris.

A potential problem, however, exists in wells perforated using shaped charges made with solid-metal liners, such as sheet metal, that were drawn, rolled or mechanically formed. These charge types normally produce a solid metal nugget type slug, sometimes referred to as a "carrot." If a charge produces a large entry hole, the slug can flow back toward the casing with produced fluid and pass through the perf into wellbore. Deep penetrating charges, on the other hand, produce smaller entry holes and the slug may be too large to pass back through the perforation in the pipe.

The slug which trails the penetrating jet into the formation is normally located near the end of the perforation tunnel, close to the maximum depth of formation penetration. In consolidated formations, the slug could be held in that position by compacted debris and would cause no problem. Surging, however, may release debris and eventually cause the slug to move. Fluid flow can then carry the slug toward the casing where it may restrict flow if it lodges in or near the entry hole throat. This problem may also occur when using bullet perforators.

CONCLUSIONS

This technique is not a panacea and will not result in production improvements in all wells. Candidates must be carefully screened and properly selected. Sand flowback problems may be encountered in unconsolidated formations. Very tight reservoirs that require fracturing may show little or no improvement, and of course dry formations will remain unproductive.

The through-tubing, backsurge technique provides, for the first time, a means of direct before and after comparison of production results.

Wells in relatively permeable, well consolidated formations that were perforated using shaped charges with powdered-metal liners and without a large pressure underbalance are good candidates for through-tubing backsurge stimulation. Both gas and oil wells should be considered.

Low production rate wells and wells with no flow have been successfully stimulated using this technique. Available evidence and results from Alaska indicate that wells with high current production can also be improved. ■