Abrasive Jetting For Well Stimulation

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APPLICATIONS OF METHOD

Results from more than 700 wells indicate that this technique has proved versatile enough to permit many successful applications:

1. Perforating without the use of explosives.
2. Scale removal from perforations and open hole.
3. Use in place of bit to deepen holes or drill up magnesium plugs.
4. Enlarging well bore diameter of open hole sections.
5. Controlling direction of fracture.
6. Deep penetration for lower treating pressures.
7. Successful perforating where conventional means have failed.

In this service, an abrasive-laden fluid is pumped down the tubing and projected outward through small orifices, at a high velocity, thereby eroding away the surface being jetted. The carrier fluid can be water, oil, brine or acid, but the life of the tool is extended by using oil. The abrasive is normally sand, but could be a similar material.

Sometimes it is possible to remove scale in open hole sections by jetting with water or acid alone, but the addition of an abrasive will hasten the action. The optimum sand concentration has been determined to be one pound per gallon. Higher concentrations will do more work but also wear out the tools much faster.

Almost any type of tool can be made available, but those most frequently used are depicted in the attached pictures. In almost all cases, the guns are run on the end of the tubing string, but pump-down types are also used in 2 in. and 2-1/2 in. tubing. The nozzles are usually arranged in horizontal rows to permit the use of more than one set of orifices without having to trip the tubing.

For use in 5-1/2 in. or larger pipe, two, three, four, or six jet nozzles may be used at one time. In 4-1/2 in. pipe, either two or four may be used. Since friction loss is a principal factor, tools for use in small diameter casing, such as tubingless completions, are limited to one or two. Nozzles are evenly spaced around the tool so that a uniform standoff distance is maintained while jetting.

As illustrated in Fig. 1, the orifices in use have a coefficient of discharge near 1.0, which is the most efficient design. From field and laboratory tests, it has been determined that the optimum differential pressure across the orifices is between 2500 and 3000 psi for perforating pipe, but can be as low as 2000 psi for jetting open hole. Since commonly used nozzles have a 3/16 in. orifice, this results in velocities between 550 and 650 feet per second, or from 50 to 60 gallons per minute per jet. These velocities must be maintained to derive maximum benefit.

The body of the tool is subject to erosion from the deflected part of the jet stream and the return stream coming out of the perforation to start its trip up the annulus. This backwash action can be retarded by placing a hardened sleeve over the body of the tool, but the expense involved in the process has not yet allowed this approach to completely solve the problem. Since backwash is much more severe while cutting pipe than while working in open hole, it becomes necessary to use multistage tools, with more than one row of nozzles, when long pumping times are desired.

Changing from one row to another is accomplished by the use of an internal sliding sleeve, which is initially installed to block off the top row of nozzles in a two-stage tool. When jetting with the first row is completed, a ball is dropped into the tubing and seats itself in the sleeve. By applying pump pressure, the sleeve is moved down to block off the used nozzles, leaving the new row open. A third stage can be added, and actuated by dropping an additional ball at the proper time, but the size of this tool limits its use to 4-1/2 in. or larger pipe.

To properly apply this service, it is necessary to maintain circulation so that sand and cuttings can be continually returned to the surface. Therefore, the pump rate used (50 to 60 GPM per jet) must be adequate to keep the hole loaded. This requires the use of a stripper rubber-type wellhead to allow movement of the tubing. Directing the return stream into partitioned settling tank permits the recycling of fluid so that long jobs can be handled with a minimum of fluid. Most of the time, it is also possible to reuse the same abrasive, after screening out the cuttings. To reduce costs further, special tanks incorporating these features, plus a builtin sand proportioner, mixing compartment and pressurizing pump, have been constructed.

After jetting is completed, it is advisable to wash out any fillup by reverse circulating while slowly lowering the tubing. The bottom of every tool is equipped with a ball and seat arrangement which acts as a standing valve during jetting, but permits fluid movement for reverse circulating. This will allow the well to be produced

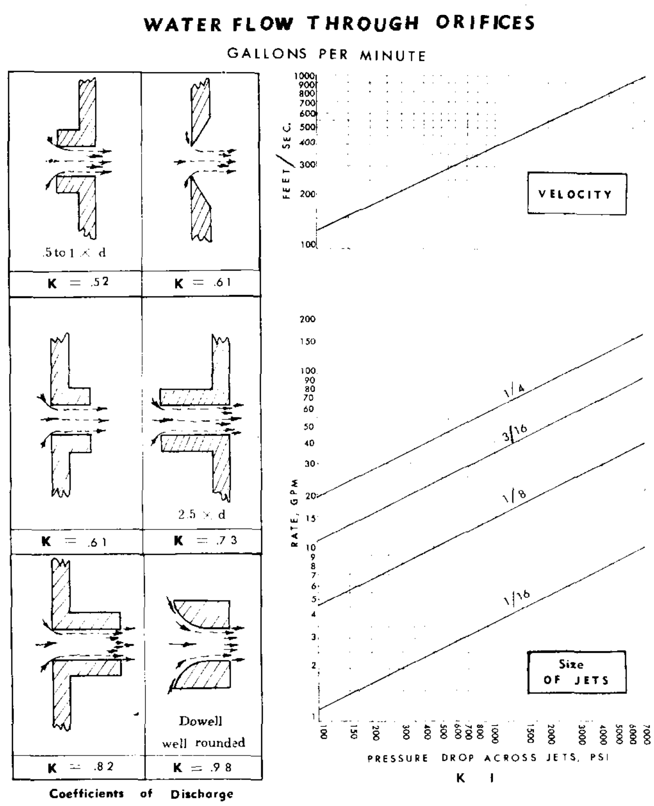
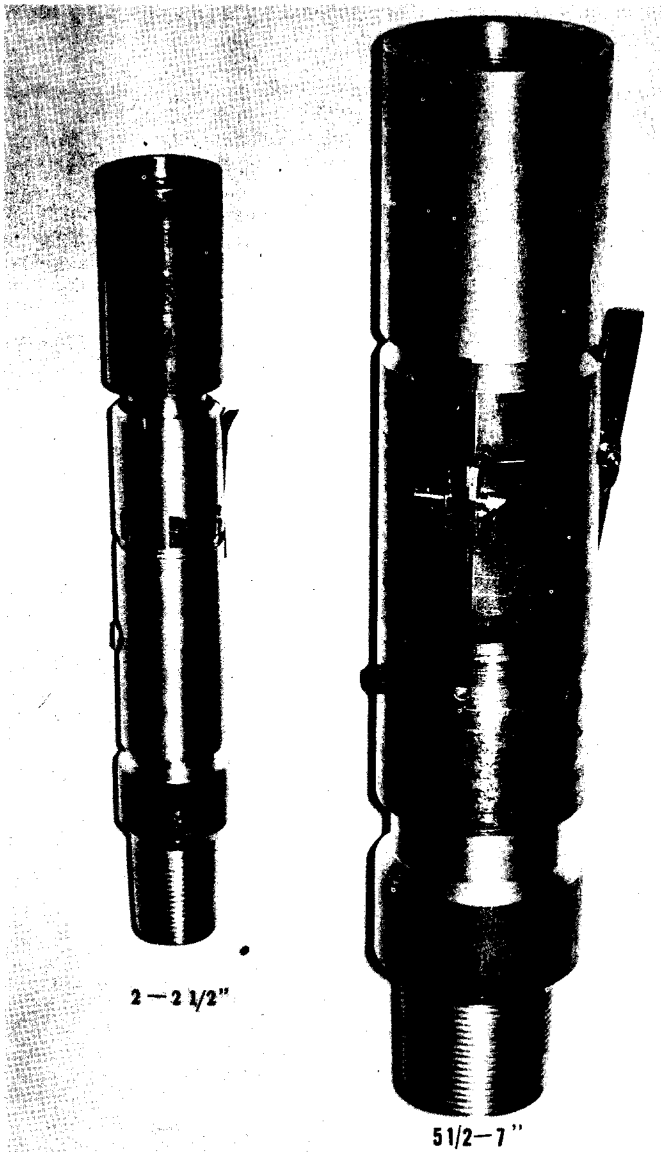


Fig. 1



COLLAR LOCATORS

through the tool if necessary. Often, a stimulation treatment is performed, down the annulus, immediately following jetting, without pulling the tubing.

Washing casing perforations with acid pumped through the jets is highly beneficial in limestone reservoirs, due to the turbulence created in the annulus. This keeps fresh acid in contact with the formation at all times by continually removing spent acid and dissolved material from the perforations.

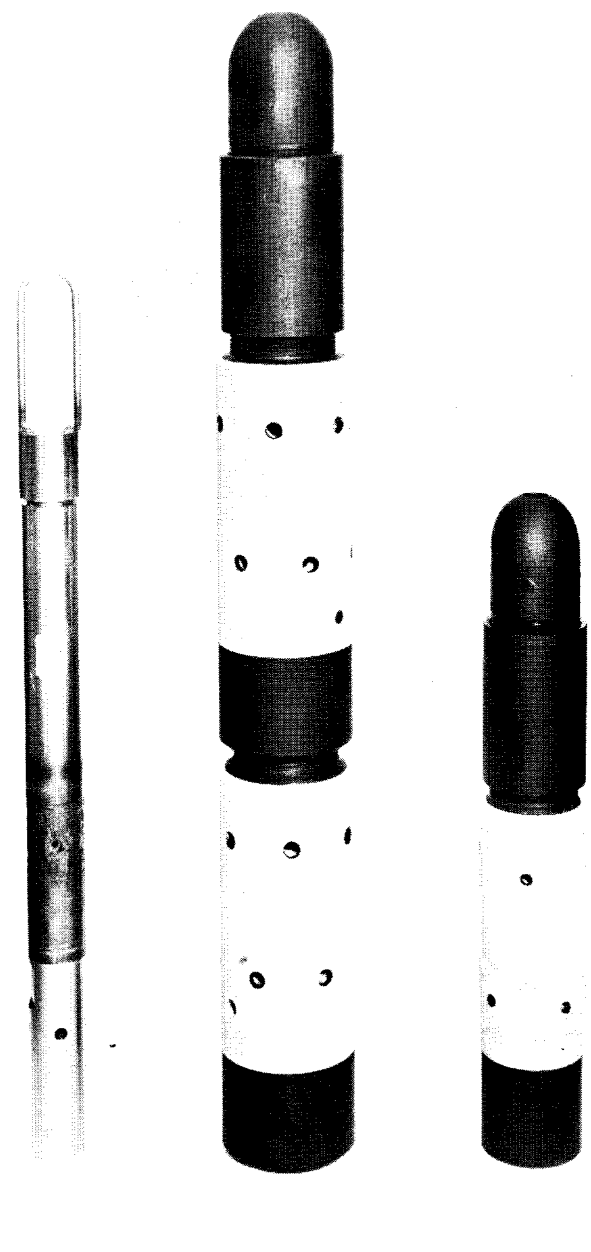
For Controlling Fractures

For the purpose of controlling fractures, it is sometimes desirable to make a disk-shaped cut, just as a string of pipe would be cut in two for salvage. In this process, the tubing carrying the jetting tool is continually rotated while jetting. This controlled point of entry, for fracturing fluid, will allow a larger volume stimlation treatment than would otherwise be possible, and still prevent production of unwanted water or gas. Since an annular cut offers smaller flow restriction it can take the place of many perforations, making possible the completion of a thick zone by a single horizontal cut when the reservoir tends to fracture vertically.

For those formations which tend to fracture horizontally, the tool is positioned so as to penetrate the streaks of greatest permeability. A circulating swivel must be used at the surface, and sometimes a rotating holddown should be used, just above the tool, to prevent vertical travel of the tubing. Results of surface tests to determine the time required to cut through the pipe by this method are given in Fig. 2.

Downhole orientation of the tool can be accomplished in several ways. If the exact bottom of the hole is known, and there is no debris, it would be practical to tag bottom and measure up to the desired position. Tubing tally and stretch calculations can be used, but this is probably the most unreliable method. To be positive, a collar locator can be used if a collar log of the well is available. Either of two types can be run in conjunction with the guns.

One type is mechanically operated to project feeler arms outward so that they catch in each collar when pulled up into it, giving a visible increase on the weight indicator. When using this type it is necessary to begin with a collar above the pay zone and then move down the



hole to each one in succession. A more recent development is the sonic collar locator which requires no mechanical actuation and indicates collars by a sound impulse that can be heard at the surface. It can, therefore, check any collar in any order.

Penetration tests have been run on the surface to give some idea of the effectiveness of abrasive jetting. Several of the tests were duplicated with very little difference in results, and by using a hold down, hole size in the pipe remained between 1/2 in. and 5/8 in., depending on the jetting time. However, experience in the field indicates that perforations have been as large as 1 in. when a hold down was not used. This was confirmed by perforating liners hung in a test well, after which observations disclosed that the gun was subject to vertical oscillation and therefore made irregular holes. This effect was more severe when tubing was suspended from a traveling block than when set in slips.

CONCLUSIONS

It is apparent that the advantages of abrasive jetting, over conventional perforating, are realized by:

1. Preventing the shattering of cement.
2. Obtaining deeper penetration for fracture initiation.
3. Eliminating the necessity for a large numer of holes.
4. Resulting perforations are smooth.

It has many special applications other than for perforating, as already mentioned.

ROTATING JET GUN DATA
(Cutting Slot in Pipe)

SIZE PIPE	NO. OF 3/16" JET NOZZLES	CUTTING TIME (MINUTES)
4-1/2" O.D., N-80, 16.6#	2	4
	3	3
	4	2-1/4
5-1/2 " O.D., N-80, 17#	2	5
	3	3-2/3
	4	2-3/4
7" O.D., N-80, 22#	2	6-1/3
	3	4-1/2
	4	3-1/2

Surface tests show slot width to be approximately 5/16".

Fig. 2