CALIBRATED IMPRESSION PACKERS DEFINE PERFORATION SIZE, SHAPE AND CONNECTION TO PERMEABILITY IN SITU*

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INTRODUCTION

Inflatable impression packers are not new; they have been around for a number of years.[1,2,3] However, their use has been very limited, probably due to one or more of the following limitations:

1. High differential pressure was required to squeeze impressionable material into cracks or perforations, which necessitated an inflatable packer which was expensive to manufacture and difficult to make longer than about 10 feet.
2. The inflation pressure often had to be held for up to 10 hours in order to be able to retain an impression.
3. The inflatable packer had to be returned to its manufacturing plant to be repaired or redressed.

A new field-redressable, 30-ft long, low differential pressure inflatable impression packer system has been developed. Also, new impression materials which are oil resistant and which can make and retain in situ impressions in 10 minutes or less have been developed.[4]

During the development and field testing of this inflatable impression packer system, the minute detail and consistency of the impression retrieved on the new impression material suggested that, with careful calibration, accurate correlations could be made between impression size and actual in situ hole size.

Further investigation indicates that the amount of impression material extruded into a perforation under a head of noncompressible fluid is proportional to the formation permeability connected to the perforation.

This paper describes the eight critical parameters which must be known and/or controlled to calibrate impression size to actual size and extrusion height to effective connection to formation permeability in situ.

CRITICAL PARAMETERS

During the development and improvement of new impression materials, extensive laboratory tests were made with mini-impression packers in scaled-down tubes at various differential inflation pressures, temperatures, and inflation times which indicated that the following parameters were critical to impression packer calibration:

1. Circumference ratio - the ratio of the ID of the wellbore to the OD of the deflated impression packer
2. Type of impression material
3. Reactions of wellbore fluids and cleaning solvents on impression material
4. Thickness of the impression material
5. Inflatable tube characteristics
6. Temperature of the impression packer during inflation
7. Differential inflation pressure
8. Duration of inflation.

These critical parameters must be known and/or controlled to calibrate an impression packer to permit an accurate correlation of impression size to actual in situ hole size.

PERFORATION EFFECTIVENESS

Observed results from downhole impression

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packer runs and laboratory tests indicate that impression material cannot be extruded into a perforation which is filled with a noncompressible fluid and not connected to permeability.

Thus, this new calibrated impression material on an inflatable packer system becomes a tool which can be used to evaluate the effectiveness of perforations as defined by the following criteria:

1. Hole size adequate to allow viscous oil production and steam transmissibility while maintaining sand control
2. Effective penetration of the damage zone around the wellbore into permeable formation
3. Perforations in the desired interval
4. Proper distribution of perforations over the interval.

LABORATORY EQUIPMENT AND PROCEDURE

The definition of the eight critical parameters of calibration was made using inflatable mini-packers in the laboratory. These mini-packers consisted of a 12-in. length of 1-in. pipe to which was clamped a 10-in. section of 1-1/2 in. OD inflation tube. The inflation tube was covered with impression material and inserted into a section of steel tubing with appropriate slots, holes or ports for a particular test. The mini-packer and test tube were submerged in a water bath of the desired temperature. After allowing the system to come up to temperature, the packer was inflated with nitrogen to a specific pressure and the rate of extrusion into the perforations was measured. (Figure 1)

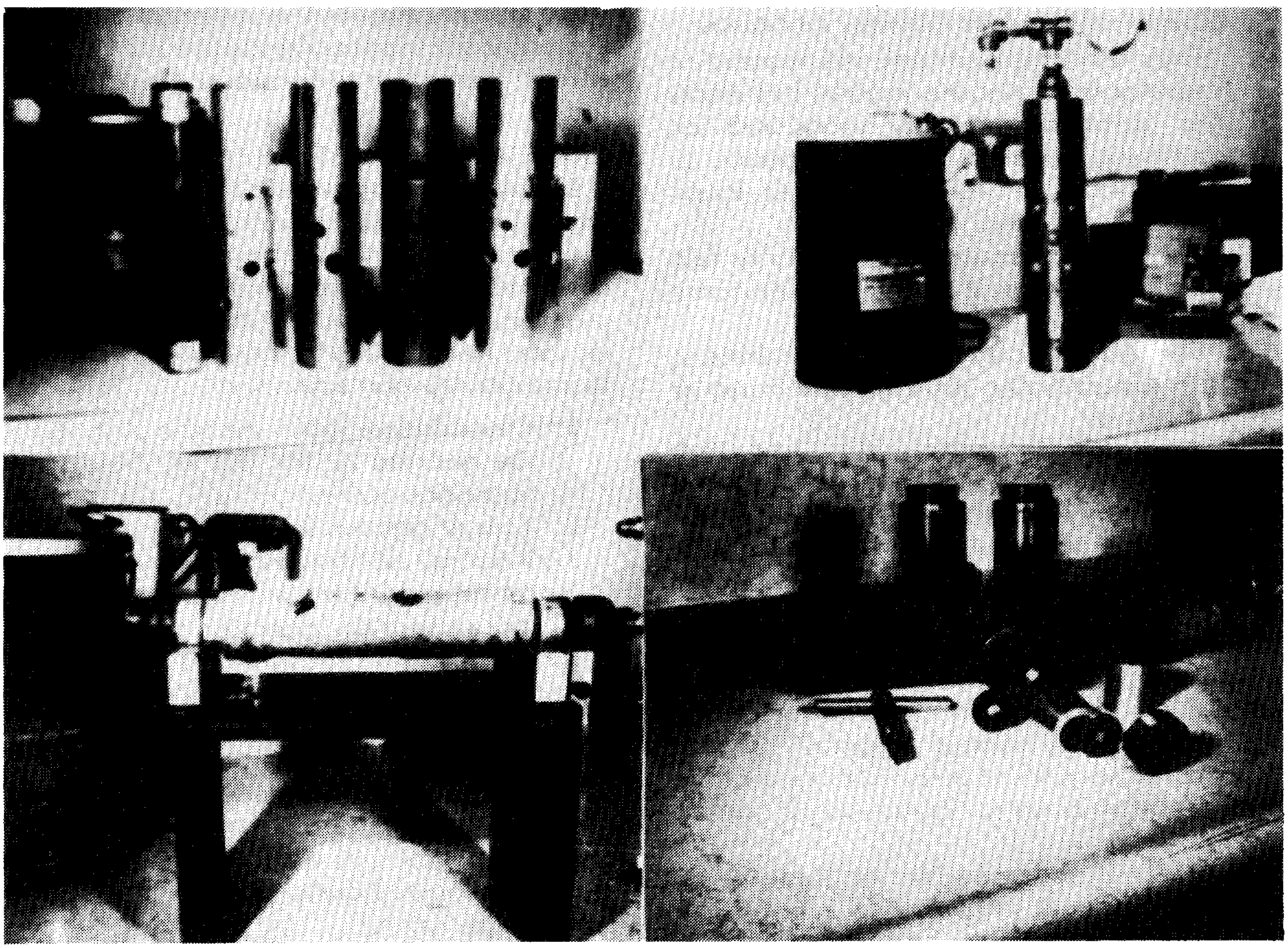


FIG. 1—CLOCKWISE: LABORATORY MINI-PACKER AND RELATED EQUIPMENT; EXTRUSIONS THROUGH PERFORATIONS WITH HOT BATH ON THE LEFT; EXCESSIVE EXTRUSIONS ON A DEFLATED MINI-PACKER; AND THE EXTRUSION HEIGHT VS CORE PERMEABILITY EQUIPMENT.

The effective perforation theory was first tested in a very crude manner. A section of 5-1/2 in. casing was perforated with 1/4-in., 3/8-in., 1/2-in., and 5/8-in. drilled holes over which 3/4-in. pipe collars were welded. The collars were sealed with pipe plugs and the ends of the casing were one-third dammed-up with welded plates so that the casing, perforations, and collars could be filled with water. A short inflatable impression packer was inserted into the casing and inflated. The impression packer showed no extrusions on the completely sealed perforations; however, one collar had a pinhole thread leak, and that perforation showed an extrusion, indicating that the impression material is very sensitive to the permeability which it "sees" in a perforation.

This sensitivity to permeability with the perforation was further tested in the laboratory with the mini-packer system. Three tube-mounted 1-in. by 1-1/2 in. oil well cores were mounted over 3/8-in. by 1-in. ports in a special steel tube. The cores were saturated with 90W gear oil to simulate low gravity crude oils and the port was carefully filled with 90W gear oil; then the mini-packer and core-mounted tube were placed in an oven until the desired temperature was reached, at which time the mini-packer was inflated opposite the cores of known permeability. After a specific inflation period, the mini-packer was deflated, removed and the extrusion height measured. Considerable difficulty was experienced during these tests in maintaining an adequate seal between the core and the mount and in finding core materials of similar permeabilities.

SIMULATED FIELD TESTS

To eliminate the problems of miniaturized testing and scale-ups, tests were conducted in a model well using full-size 30-ft long inflatable impression packers in nominal-size casings. The model well consisted of a 40-ft joint of 20-in. casing in the gound with piping to permit the circulation of water through a thermostatically controlled heater and a suitable mast with hoist for raising and lowering casing samples and inflatable impression packers into the well. Normal-size casings (5-1/2 in., 6-5/8 in., 7-in., 8-5/8 in. and 9-7/8 in.) were perforated with a series of three each drilled holes ranging in size from 1/4 in. through 3/4 in. by sixteenths. The full-sized 3-in. and 5-in. inflatable impression packers were then inflated in these perforated casing samples under known temperatures, inflation pressures and inflation time conditions with all other parameters held constant. From these full scale tests, calibration charts for specific conditions can be drafted to correlate impression size to actual hole size. (Figure 2)

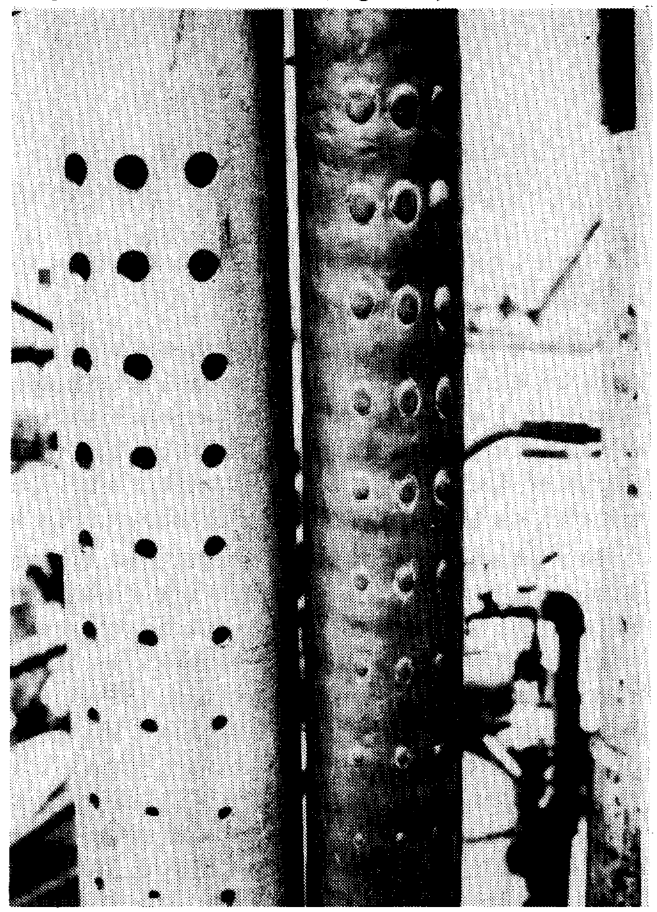


FIG. 2—FULL SCALE CALIBRATION EQUIPMENT FOR CORRELATING IMPRESSION SIZE TO ACTUAL HOLE SIZE. 5-1/2" CASING AND DEFLATED 3" IMPRESSION PACKER. NOTE: OVAL SHAPED EXTRUSIONS.

FULL SCALE EFFECTIVE PERFORATION TESTS

A synthetic filter material, Aloxite®, was selected to simulate the core material since this material is fairly uniform in porosity and permeability and is available in a variety of porosities. Aloxite can also be cut to any specific size and shape. Filter disks 1-1/2 in. in diameter and 1/2-in. thick were obtained in permeability grades 1, 2 and 5. The grade numbers correspond to the air permeability of 1 sq ft of material 1-in. thick in cu. ft of air per minute under a pressure of 2 in. of water at

70° F and a relative humidity of 10-25%. The water permeabilities of grades 1, 2 and 5 are 200, 500 and 1700 millidarcies, respectively. (Figure 3)

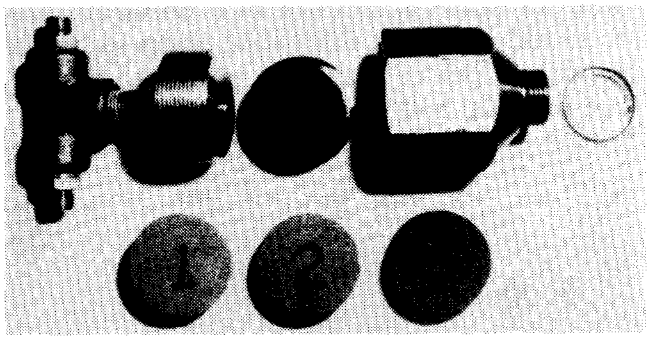


FIG. 3 ALOXITE FILTER DISCS WITH HOLDER FOR MOUNTING ON CASING. NOTE: THE NUMBERS INDICATE THE RELATIVE PERMEABILITY TO AIR.

These permeable discs were saturated with 90W gear oil and mounted in the special core holder shown in Fig. 3. Three sizes of perforations were simulated (5/16 in., 1/2 in. and 5/8 in. and three grades of discs (1, 2 and 5) for a total of nine were mounted on a joint of 7-in. casing as shown in Fig. 4.

The outside end of each vertical row of core holders was manifolded together and brought to the surface with 1/4-in. copper tubing to prevent water contamination of the gear oil in the casing and to permit back-flushing the cores. (Figure 4) After mounting and sealing all the cores, the inside of the 7-in. casing was filled with 90W gear oil to just cover all the cores. The 7-in. casing was lowered and secured into the test well full of water at a controlled temperature. A full-size 30-ft long inflatable impression packer was picked up and lowered into the 7-in. casing sample. After a sufficient time for equalization of temperatures, the packer was inflated to a specific inflation pressure with nitrogen and held for a prescribed time. After deflation, the packer was pulled and the impressions were calipered. This procedure was repeated numerous times at each specific temperature, pressure, and time station. After a significant lack of extrusions was evident, the casing sample was pulled and the cores were removed for study. Figure 4 shows a typical set of extrusions after an initial run opposite new cores.

To simulate the running of an impression packer opposite perforation in a wellbore above the fluid level, several runs were made *without* oil in the casing or oil in the 1/4-in. tubing manifold on the back side of the cores.

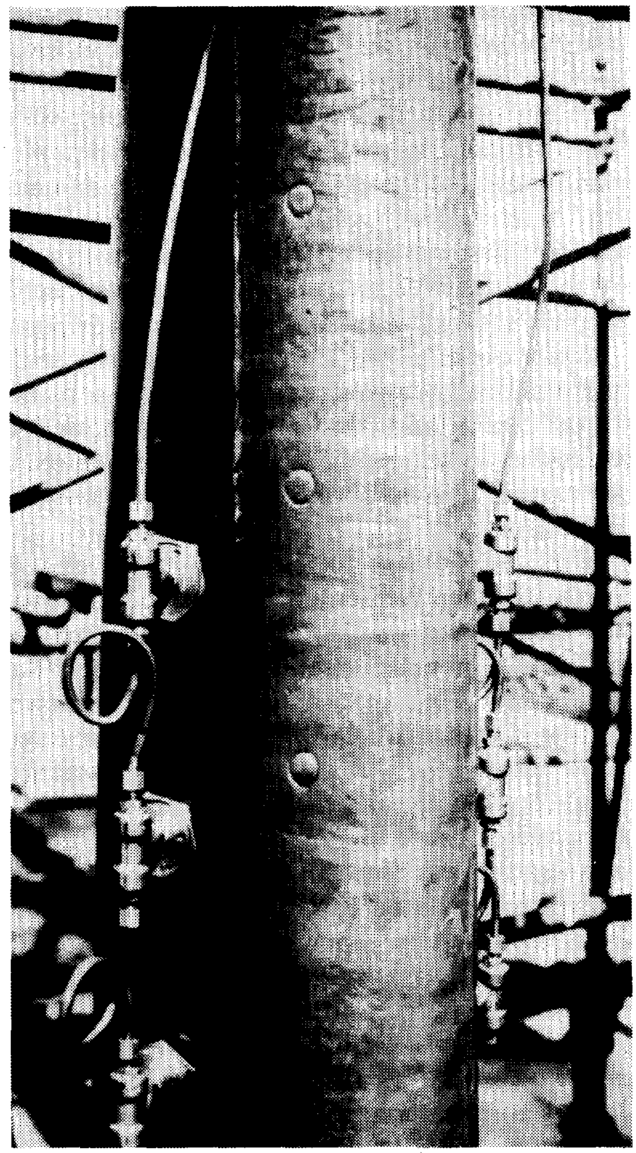


FIG. 4—ALOXITE DISC HOLDERS MOUNTED ON 7″ CASING WITH THE 1/4 INCH TUBING BACK PRESSURE MANIFOLDING SYSTEM. DEFLATED 5″ IMPRESSION PACKER WITH SIX (6) EXTRUSIONS AFTER A RUN OPPOSITE THE ALOXITE DISCS.

INTERRELATIONSHIP OF THE CRITICAL PARAMETERS

The measurable properties of an impression retrieved on an impression packer are the length, width and height of the extrusion. These properties are influenced to some degree by all eight of the following critical parameters.

Circumference Ratio

Since all measurements of extrusions are made on a deflated packer, it is important to know the circumferential relationship to the inflated state in which the impressions were made. Attempts to reinflate the packer to the same outside diameter as the wellbore on the surface for interpretation and calibration were unsuccessful, since the uncontained inflatable tube and impression materials react differently than when contained and compressed. Under constant conditions, extrusion height and size are inversely proportional to circumference ratio.

Type of Impression Material

The impression material is the heart of any inflatable impression packer system and must have the following properties:

1. A semipermanent set for good impression retention
2. Sufficient elasticity to return to normal size as the inflatable element deflates
3. Resistance to attack from crude oils, acids and oilfield chemicals for sufficient time to retrieve adequate impressions and to permit the removal of viscous crude oils with solvent washes for better interpretations
4. A smooth surface finish for good impression detail.

Three new impression materials have been developed meeting the criteria for specific applications. One type is excellent for water and gas wells; the second type is recommended for oil well use at temperatures up to 180° F while the third type is for use in oil wells up to 220°F. Well temperatures above 220° F must be cooled with fluids to 220° F or less because the rubber tube in the inflatable packer loses its strength and the impression material becomes excessively flowable.

Reactions of Wellbore Fluids and Cleaning Solvents on Impression Materials

The impression material used to cover an inflatable impression packer for recovery of downhole information from oil wells must have a certain resistance to attack from the oil environment. However, this resistance to oil attack should be only sufficient to permit recovery of the in situ information and to allow washing off the viscous crude oils with solvents. It is desirable that the impression material disintegrate when submerged in crude oil for an extended time since this would tend to dissolve or release any impression material left in the perforations of the wellbore.

Thickness of Impression Material

When impression material is extruded through an opening, the material is drawn from an area immediately around the opening. Therefore, the thickness of the extrudable material is an important consideration. The thickness must be sufficient to provide ample material for extrusion into casing perforations or liner slots. However, since the impression material is relatively soft and shearable, its thickness is limited to avoid extrusions greater than the pipe wall thickness.

Another factor to keep in mind is the thinning of the impression cover as it is stretched at high circumferential ratios.

Inflatable Tube Characteristics

The inflatable tube characteristics depend upon the type of reinforcing materials used in the outer structural element. The nylon reinforcing cord used in this inflatable packer system can be stretched both circumferentially and longitudinally simultaneously which permits using fixed clamps on both ends. This factor is especially important in the calibration of an inflatable impression packer system since the longitudinal stretch of the tube with both ends fixed is uniform and can be predicted accurately.

The high-strength metal reinforcing materials used in high differential pressure inflatable packers can only expand in one direction. Thus, as the tube expands circumferentially, it must contract in length and at least one of the clamps must be free to move on the support mandrel.

An inflatable packer with metal reinforcing as compared to a nylon reinforced packer is much stronger. However, this added strength requires more inflation pressure to expand the packer, which results in less pressure available for extrusion of impression material. This is particularly true at the higher circumference ratios.

Temperature of the Impression Packer System During Inflation

Temperature changes in rubber compounds can have marked effects on their physical properties. Most cured rubber compounds such as those used in the inflatable packer tubes tend to become more pliable at elevated temperatures and expand more easily, whereas the uncured or semicured compounds used in the impression materials become much more extrudable.

This tendency to overextrude at elevated temperatures can be counteracted to a degree by reducing the differential inflation pressure applied to the packer and/or the duration of the inflation period.

The temperature of the wellbore can be changed, in some instances, by dumping hot or cold fluids into the well immediately prior to running an impression packer. In all cases, it is very important to know the temperature of the wellbore fluid at the depth of interest immediately prior to running an impression packer so that the differential inflation pressure and/or the inflation time can be adjusted to stay within the optimum calibration range.

Differential Inflation Pressure

The pressure required to inflate a packer submerged in a fluid must exceed the hydrostatic pressure of the fluid column and expand the inflatable element. After the impression cover of the packer has contacted the wellbore, additional pressure must be applied to cause the impression material to extrude into an opening in the wellbore. This differential pressure between the inside of the packer and the hydrostatic pressure on the outside is an important parameter which must be carefully controlled.

Extrusion height is proportional to the differential inflation pressure under constant conditions.

Duration of Inflation

The elastomers used in the impression materials become increasingly flowable as the temperature increases. Therefore, the duration of the inflation period becomes a very important parameter for controlling extrusion height.

In all cases, the extrusion height increases with time under constant conditions; however, the maximum rate of extrusion occurs in the first five minutes. For this reason, very short inflation periods (one to two minutes) must be used in hot wells if accurate calibration of the impressions is desired.

INTERPRETATIONS OF IMPRESSIONS

The impressions retrieved on an inflatable impression packer fall into two categories - observable and measurable. When making an interpretation of the in situ wellbore conditions from the impression on a packer, three things must be kept in mind:

1. The impressions as seen on the packer are a reverse replica of the actual downhole conditions.
2. The circumference of the packer in a deflated state is much smaller than it is in the inflated state under which the impressions were made.
3. A certain amount of distortion results from contraction of the impression material.

The interpretation of the observable type of impressions was covered in a prior paper;[4] therefore, the discussion in this paper will be limited to the measurable impressions.

Extrusion Height

Extrusion height is a measurement of the extent of the extrusion of impression material into an opening in the wellbore and is seen on the packer as the distance from the cover near the base of the impression to the top of the extrusion.

Extrusion height increases with differential inflation pressure, temperature, inflation time, and decreases as circumferential ratio increases.

Tests indicate that the ideal extrusion height is between 0.100 and 0.200 in. for accurate calibration work. The length and width of the extrusions are difficult to measure if the extrusion height is less than 0.100 in. and extrusions beyond 0.300 in. tend to tear off or become distorted.

Perforation Size and Shape

The impression of a round hole will appear as an oval on the deflated packer due to the difference in longitudinal and circumferential stretch. Tests indicate that an average of the length and width of the oval impression $(L + W)/2$ gives an average diameter which closely approximates actual diameter at ambient temperatures.

Numerous full-scale tests were made in the test well including 10 different circumference ratios using two sizes each of two types of inflatable packers at three temperatures (100°F, 150°F, and 180°F) and three differential inflation pressures (100 psi, 125 psi, and 150 psi) with inflation time variations from 3 to 15 minutes.

A calibration chart similar to Fig. 5 was plotted for each run, and a study of this data indicated that accurate calibration of impression size to actual in situ hole size was most critical to temperature, circumferential ratio, differential inflation pressure and time of inflation. The circumferential ratio is controlled by the well configuration and the availability of a limited number of packer sizes. The downhole wellbore fluid temperature is controlled by the geothermal gradient in an area. Therefore, the two controllable parameters for accurate correlation of impression size to actual hole size are differential inflation pressure and duration of inflation.

Since it is impractical to develop a single calibration curve with four variable parameters, a series of optimum calibration curves were developed for specific conditions. Thus, by knowing the downhole temperature and the circumferential ratio before running the impression packer into the well, an appropriate differential inflation period can be selected to meet the specific conditions of a calibration chart and permit an accurate correlation of impression size to actual in situ hole size.

Figure 5 is an example of an optimum calibration chart for a circumferential ratio of 1.27 (5-in. packer in 7-in. casing) at 150°F. If these specifications correspond to the well conditions, then the run should be made using a differential inflation pressure of 100 psi and inflating for 6:50 min:sec. The criteria used for selecting optimum charts were that the extrusion height of the different sized holes be within the 0.100 to 0.200 in. range (dashed line) and that the correction factor be as small as possible.

To use this calibration chart, assuming that the run was made according to these specifications, the impressions on the packer would be calipered and the height, width and length recorded. The average diameters are calculated (L + W)/2 and entered from the left horizontally until the heavy line is intersected, then down vertically to read the actual in situ diameter.

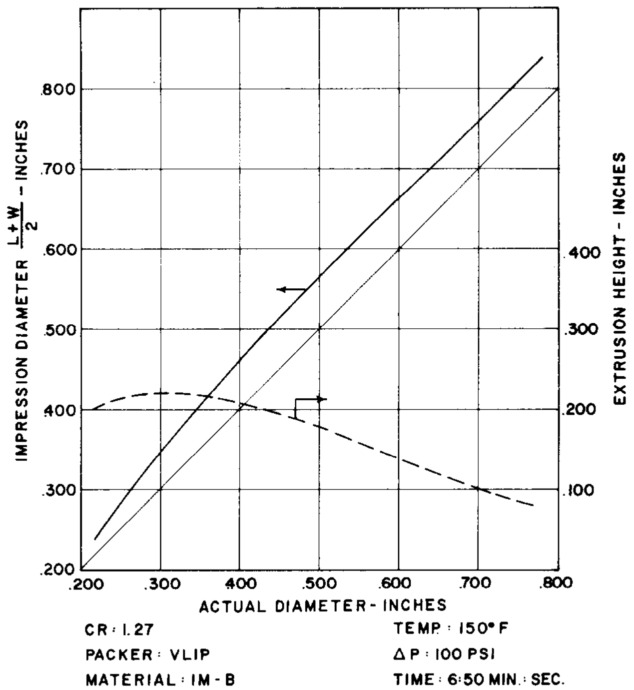


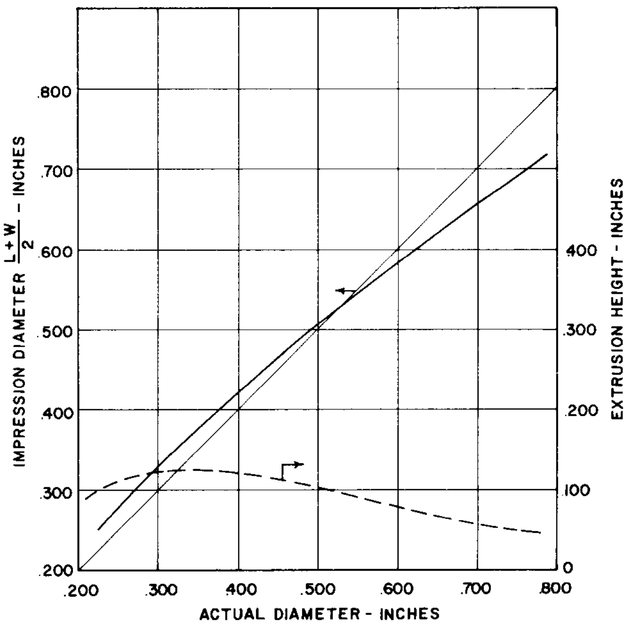
FIG. 5—AN OPTIMUM IMPRESSION PACKER CALIBRATION CURVE FOR CR 1.27 @ 150°F. DEVIATION FROM A 1 TO 1 RATIO IS MINIMAL AND THE EXTRUSION HEIGHT IS MOSTLY WITHIN THE 0.100 TO 0.200 INCH RANGE.

The extrusion height curve (dashed line) represents the values for open holes not backed by permeable formation and should be a maximum for these specific conditions.

Figure 6 is an illustration of a curve of less than optimum calibration due to the extreme stretch of the packer at a circumference ratio of 1.96. It is physically possible to run inflatable impression packers under those conditions and may be necessary to get below casing restrictions. However, it is not recommended going beyond a circumference ratio of 1.50 if accurate correlation of impression size to actual hole size is desired.

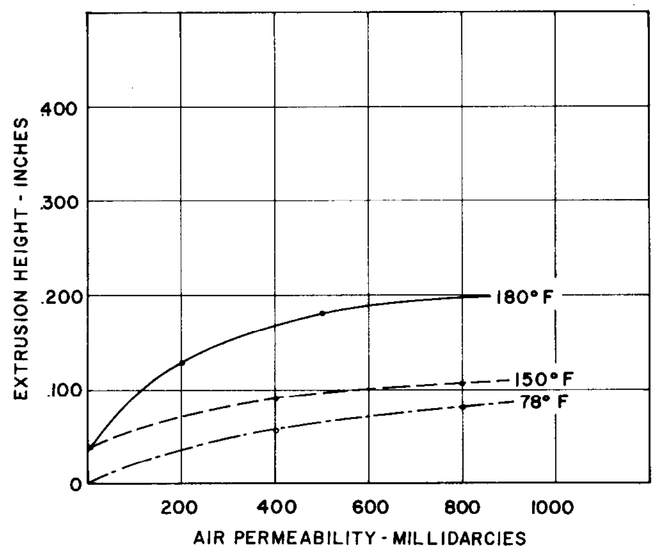
EFFECTIVE PERFORATIONS

Figure 7 is a plot of extrusion height vs the air permeability of oil well cores from data collected from mini-packer tests described above. These curves indicate that extrusion height of a perforation as seen on an inflatable impression packer is proportional to the permeability connected to the perforation and that only the magnitude of the extrusion height increases with temperature.



CR: 1.96 TEMP: 100°F
PACKER: VLIP ΔP: 125 PSI
MATERIAL: IM-B TIME: 10 MIN.

FIG. 6—A LESS THAN OPTIMUM IMPRESSION PACKER CALIBRATION CURVE FOR AN EXTREME CR OF 1.96. EXTRUSION HEIGHT IS BELOW THE MINIMUM FOR ACCURATE CALIBRATION AND CORRECTIONS GO FROM POSITIVE TO NEGATIVE AT LARGE DIAMETERS.



CR: 1.26 TEMP: VAR.
PACKER: MINI ΔP: 100 PSI
MATERIAL: IM-B TIME: 10 MIN.

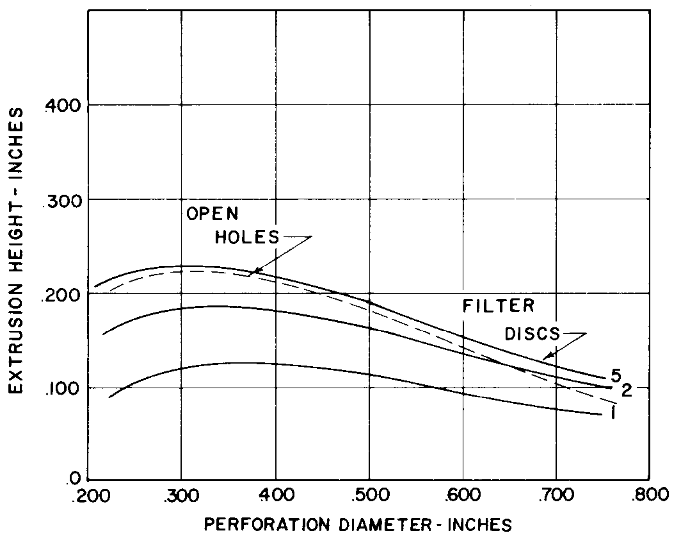
FIG. 7—EXTRUSION HEIGHT DATA FROM MINI-PACKER RUNS IN 90W GEAR OIL VS AIR PERMEABILITY OF OIL WELL CORES.

TABLE 1— EXTRUSION HEIGHT VS. ALOXITE DISC PERMEABILITY IN 90W GEAR OIL AT CR 1.27, 150°F WITH 100 PSI PRESSURE DIFFERENTIAL

Perforation Diameter	5/8"			1/2"			5/16"		
Aloxite- Air Permeability	1	2	5	1	2	5	1	2	5
Run #1 6 Minutes	.100"	.142"	* .135"	.096"	.156"	** .237"	.130"	.190"	.228"
Run #2 6 Minutes	.190"	M***	M	.155"	.130"	M	.270"	.200"	M
Run #3 6 Minutes	M	M	M	.218"	M	M	.165"	.210"	M
Appearance of Disc After 3 Runs	Dirty	Dirty	Dirty	Clean	Dirty	Dirty	Clean	Clean	Dirty

*Used Disc ***Missing
**On Bubble No Mark

Table 1 lists the results of three consecutive test runs made in the model well under constant conditions. Note that in Run 1 with new filter discs the extrusion heights are proportional to the permeability of the discs and that under these conditions more extrusion occurs in the smaller diameter perforations. Run 2 indicates that only half the cores had extrusions and Run 3 showed only three extrusions.



CR: 1.27 TEMP: 150° F
PACKER: VLIP ΔP: 100 PSI
MATERIAL: IM - B TIME: 6 MIN.

FIG. 8—A COMPARISON OF EXTRUSION HEIGHTS INTO VARIOUS SIZE OPEN HOLES VERSUS PERFORATIONS FILLED WITH 90W GEAR OIL AND BACKED UP BY ALOXITE FILTER MATERIAL OF THREE DIFFERENT PERMEABILITIES.

water and 90W gear oil. Note that the new discs have permeabilities to oil in the same ratios as their air and water values. The used disc runs confirm the packer extrusion and visual indications of core plugging.

The determination of the effectiveness of a perforation as stated above specifies that the perforation must be filled with a noncompressible fluid, the reason being that if the fluid is highly compressible such as a gas, then extrusion of impression material will occur regardless of the permeability within the perforation. Table 3 compares the results of tests with noncompressible and compressible fluids in the perforations. New Aloxite filter discs were run and rerun in 90W gear oil until the extrusions indicated severe plugging. Then all the oil was removed from the casing, and the tubing manifolds on the back side were drained. Run 14 shows the extrusion heights on a packer simulating a run above the fluid level in a well. Note that a complete set of open perforations is indicated where the previous Run 13 indicated that two-thirds

TABLE 2—RELATIVE PERMEABILITY OF ALOXITE DISCS

Permeability to Disc Number	Air SCFM/Sq Ft/Inch @ 70°F Under 2"H_2O	Water Millidarcies	90 Wt. Gear Oil 40 PSI @ 78° F CC/Sec	% Original Permeability
New 1½" Diam. x ½" Thick				
#1	1	200	0.39	100
#2	2	500	0.50	100
#5	5	1700	2.08	100
After 3 Runs (Table 1)				
#5 - 1/2" Perf. No extrusion	---	---	1.04	50
#2 - 5/8" Perf. No extrusion	---	---	Drip	Plugged
#1 - 5/8" Perf. No extrusion	---	---	Drip	Plugged
#1 - 1/2" Perf. Extrusion - .218"	---	---	0.413	106
#2 - 5/16" Perf. Extrusion .210"	---	---	0.439	88

Figure 8 is a plot of extrusion height vs hole size for the various diameter ports and the three different permeability cores. Note the proportionality of extrusion height to core permeability and that the extrusion height opposite the tighter cores (1 and 2) falls well below the openhole curve (dashed line).

Table 2 shows the results of relative permeability tests of the new and used Aloxite filter discs to air, of the discs were plugged to 90W gear oil.

FIELD EVALUATION OF JET PERFORATIONS

Table 4 shows the results of five inflatable impression packer runs over five different intervals in a new well immediately after perforation with four 1/2-in. jets per foot. The rows listed are vertical

TABLE 3— EXTRUSION HEIGHT VS ALOXITE DISC PERMEABILITY IN 90W GEAR OIL AND AIR AT CR 1.27, 100°F, WITH 150 PSI PRESSURE DIFFERENTIAL

Perforation Diameter	5/8"			1/2"			5/16"		
Aloxite - Air Permeability	1	2	5	1	2	5	1	2	5
Run 11 in Oil 10 Minutes	.070"	.128"	*	.125"	.147"	.160"	.170"	.178"	.200"
Run 12 in Oil 10 Minutes	.083"	.073"	M**	M	M	M	.220"	M	.230"
Run 13 in Oil 10 Minutes	.112"	.200"	.145"	M	M	M	M	M	M
Run 14 in Air 10 Minutes	.100"	.096"	.115"	.168"	.184"	.188"	.164"	.160"	.187"

*On Bubble **Missing No Mark

as seen on the packer. Perforation effectiveness in this case is strictly on an extrusion or not basis since mechanical movement of the packer during inflation caused distortion of the extrusion which precluded accurate size measurements. Note that Run 5 was above the fluid level and indicates 100% holes in the casing but that no definition can be made to connection to permeability.

Table 5 lists the results of five more inflatable impression packer runs in the same well over identical intervals after the perforations were washed with 10 gallons per foot of 12% HCl and 3% HF acid using a pushout washer with opposed cups two feet apart. After the acid wash, a suction washer with a 4-ft cup spacing was run and all acid was removed from the well. Note that the acid wash was extremely effective in that every interval shows 100% connection to permeability. The

TABLE 4 FIELD EVALUATION OF JET PERFORATIONS

Run Interval	Vertical Row 1	Vertical Row 2	Vertical Row 3	Interval % Effectiveness
Run #1 1104' - 1114' % Effective Perforations	4 Marks 8 Extrusions 8/12 = 67%	4 Extrusions 8 Missing 4/12 = 33%	4 Marks 8 Missing 0/12 - 0%	33%
Run #2 1064' - 1080' % Effective Perforations	7 Extrusions 13 Marks 7/20 - 35%	2 Extrusions 18 Marks 2/20 - 10%	8 Extrusions 12 Missing 8/20 = 40%	28%
Run #3 1045' - 1055'	12 Marks 2 Missing 0/14 = 0%	3 Extrusions 10 Marks 3/13 = 23%	13 Missing 0/13 = 0%	8%
Run #4 1020' - 1035'	18 Extrusions 3 Marks 18/21 = 86%	2 Extrusions 17 Marks 2/19 = 11%	6 Extrusions 14 Marks 6/20 = 30%	43%
Run #5 958' - 984' Above Fluid Level % Holes in Casing	36 Extrusions 0 Missing 100%	36 Extrusions 0 Missing 100%	36 Extrusions 0 Missing 100%	Not Determined

NOTE: Movement of the packer during inflation caused too much distortion of the extrusions to permit calibration. However, perforation effectiveness was clearly indicated.

TABLE 5 - FIELD EVALUATION OF JET PERFORATION AFTER ACID TREATMENT

Run Interval	Vertical Row 1	Vertical Row 2	Vertical Row 3	Interval % Diameter Variation
Run 1A 1104 - 1114'	13 Extrusions	14 Extrusions	13 Extrusions	
Average Diameter	0.366"	0.384"	0.484"	
% Effective Perforations	100%	100%	100%	24%
Run 2A 1064' - 1080'	22 Extrusions	21 Extrusions	20 Extrusions	
Average Diameter	0.345"	0.390"	0.479"	
5 Effective Perforations	100%	100%	100%	28%
Run 3A 1045' - 1055'	13 Extrusions	14 Extrusions	13 Extrusions	
Average Diameter	0.327"	0.394"	0.473"	
% Effective Perforations	100%	100%	100%	31%
Run 4A 1020' - 1035'	21 Extrusions	20 Extrusions	19 Extrusions	
Average Diameter	0.380"	0.383"	0.419"	
% Effective Perforations	100%	100%	100%	9%
Run 5A 973' - 995'	29 Extrusions	31 Extrusions	31 Extrusions	
Average Diameter	0.363"	0.393"	0.427"	
% Hole in Casing (Above Fluid Level)	100%	100%	100%	15%
% Deviation in Diameter by Vertical Rows	14%	3%	13%	

diameters listed are an average by vertical rows for each interval. The percent diameter variation by runs on the extreme right is an indication of the gun centralization effect; the top three being poor, and the last two, fair to good. The percentages at the bottom are the deviations from smallest to largest by vertical row over all intervals indicating fairly uniform hole sizes.

Figure 9 is a diagram after Suman[5] which emphasizes the problems created by decentralized casing and off-center perforation. The off-center perforation could explain the wide variation in hole size between rows on a particular run and could account for the failure to penetrate into permeability.

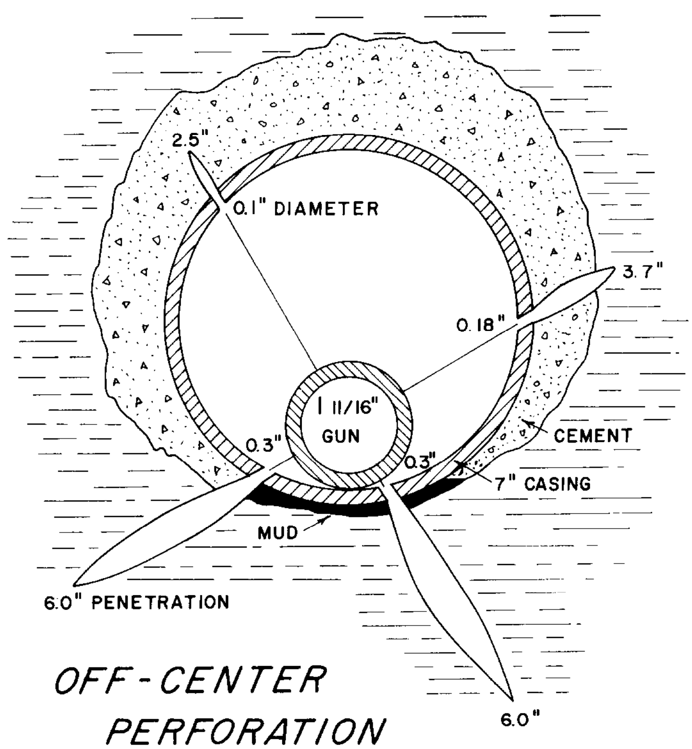


FIG. 9—THESE COMBINED EFFECTS OF UNCENTRALIZED CASING CEMENTING AND OFF-CENTER SMALL GUN JET PERFORATING MAY BE THE REASON FOR THE 40% INITIAL EFFECTIVENESS OF JET PERFORATION. (AFTER SUMAN[5])

CERTIFICATION OF IMPRESSION PACKER CALIBRATION

It can be seen from the previous discussion that the calibration of impression materials is a very sensitive process which is critically affected by many parameters. The ultimate process for assured accuracy would be a method of certifying the calibration of a specific inflatable impression packer system to the exact downhole conditions of the well under study. This would first require knowing as accurately as possible the well configuration, the type of wellbore fluids and the fluid level, as well as the temperature of the fluids in the well at the depth of interest. Then, an appropriate casing sample could be perforated with a variety of known-size holes and Aloxite core holders mounted on the opposite side which would be installed in the test well and heated to the same temperature as anticipated in the well under study. A freshly covered inflatable impression packer would be run into the test casing and inflated at the optimum differential inflation pressure and duration of inflation. After the run, the impressions on the packer would be calipered and a calibration curve would be plotted for those specific conditions. Then, the same packer would be run in the well under the same conditions and when the impressions were calipered, they could be accurately correlated through the certified calibration chart to actual in situ hole size.

CONCLUSIONS

1. A new inflatable impression packer system can be accurately calibrated by knowing and controlling the effects of eight critical parameters.
2. Through the use of calibration charts, the size and shape of impressions retrieved from a wellbore can be accurately correlated to actual in situ perforation size.
3. The height of the extrusions as seen on an impression packer indicates whether or not a perforation is effectively connected to permeability.
4. To be effective, a perforation must be:
   a. connected to permeability
   b. sized to permit fluid entry but hold back sand
   c. in the selected interval
   d. properly distributed over the interval.

   A calibrated inflatable impression packer can capture *all* this data in one run.
5. Field data indicates that less than 50% of new jet perforations are effective.

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