REDUCED TUBING FAILURES IN ROD-PUMPED WELLS UTILIZING DOWNHOLE CALIPER SURVEYS

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ABSTRACT

The downhole tubing caliper survey, as part of a preventative maintenance program, is an effective tool for reducing the number of future or repeat tubing failures that occur on rod-pumped wells. Preliminary field results of an investigation in the North McElroy Unit, Crane and Upton Counties, Texas indicate that downhole tubing caliper surveys may be the most economical and effective field method of eliminating worn or severely corroded tubing in a well and insuring against troublesome repeat tubing failures. Generally, common practice is to replace only the failed joint and any visually defective tubing until a certain frequency of failures occur, although hydrostatic testing is sometimes utilized as a means of detecting thin-walled joints.

This presentation compares common field practices to the downhole tubing caliper survey, from the standpoints of both economics and relative repeat failure frequency. The caliper survey's potential as a monitor of corrosion, wear, and downhole mechanical problems is also discussed.

INTRODUCTION

A preventative maintenance program for downhole equipment is necessary to keep failures and downtime at a minimum. A common problem with rod-pumped wells in severely corrosive environments is repeat tubing failures, which are expensive in terms of pulling unit costs and lost production. To determine how the occurrence of this type failure might be reduced, an investigation was made of tubing failures on rod-pumped wells in the North McElroy Unit, Crane and Upton Counties, Texas. The North McElroy Unit has been under waterflood since 1968, and includes 480 producing wells, with an average per well production of 24 BOPD and 176 BWPD. Many wells produce in excess of 750 BFPD with 95 percent water cut. Production is from the Grayburg Formation and the environment is one of severe corrosion in association with hydrogen sulfide.

FAILURE PRACTICES PRIOR TO MAY 1979

Standard well equipment is approximately 3000 ft. of 2-7/8 or 2-3/8 in., J-55 tubing with 3/4 and 7/8 in. "K" rods. Prior to May 1979, routine practice on every tubing failure was to locate and replace the failed joint and to visually inspect the tubing on the surface. Other preventative maintenance measures were utilized on some failures, but in many cases only the failed joint was replaced. Other measures included the use of downhole caliper surveys, hydrostatic testing to 4000 psig, testing with a pump truck to 500 psig, or upgrading the entire string with new, used, or electronically-inspected tubing. A brief description of these measures and utilization follows.

THE DOWNHOLE CALIPER SURVEY

An electro-mechanical caliper is a device run downhole on a wireline before the tubing is pulled. Depending upon the tubing size, a number of "feelers" continuously contact the tubing I.D., with the feeler indicating deepest penetration controlling potentiometer measurement (See Fig. 1). Feeler movement is thus converted to a voltage change which is amplified and recorded on a log at the surface. The utilization of centralizers above and below the feelers, and calibration before and after the logging run, insures that all feelers are properly aligned and recording correctly. After the log is obtained, the joints are graded by wall loss in 5 percent increments. Any joint with greater than 50 percent wall loss is culled and replaced with new, which is run on the bottom of the string. Joints indicating 0-25 percent wall loss are run next, and those graded 30-50 percent wall loss are run on top. In this manner, the tubing is arranged in the well where it is best suited to the conditions. Tubing with 55-75 percent wall loss is classified for use as surface line pipe.

A split detector is also run in conjunction with the caliper and operates similar to a magnetic collar locator. It is designed to pick up longitudinal splits that may not be penetrated by a feeler.

Additional considerations are:

(1) The well should be treated with corrosion inhibitor immediately after returning to production, since the feelers may remove inhibitor film in their path.

(2) The caliper survey does not provide any information about collars or threads, where approximately 12 percent of failures are estimated to occur.

(3) The caliper survey measures only internal wall loss and provides no information about external tubing condition. This is not considered to be a hindrance, since all tubing is visually inspected and externally-caused failures comprise a small percentage of total failures.

(4) Scale or paraffin buildup may prevent the caliper from obtaining an accurate log. In wells where these conditions are particularly severe, electronic inspection is desirable.

HYDROSTATIC TESTING

Internal hydrostatic testing generally utilizes a bar tool, which pressures up 1 or 2 joints at a time to 4000-5000 psig. This is performed just below the surface, as tubing is run back in the well. Ruptured joints or leaking collars are removed and replaced.

Additional considerations are:

(1) Tubing with severe defects such as deep tong marks or excessive internal metal loss might burst during testing, however, field experience has shown that tubing that has held 5000 psig may fail during

operation within a few days.

(2) Hydrostatic testing is an effective check of make-up practices and locating collar leaks, however, it does not detect <u>all</u> thin-walled and/or defective tubing.

TESTING WITH A PUMP TRUCK

While testing with a pump truck is actually hydrostatic testing, it is singled out so as not to be confused with the previously discussed test. It is performed by running approximately 10 joints at a time in the well, with either the pump or standing valve assembly at the bottom of the string, then pressuring up with water to 500 psig. All joints in the well are tested at each pressurization.

Additional considerations are:

(1) A 500 psig test is not a sufficient check for thin-walled and/or defective joints or leaking collars, since the tubing must withstand hydrostatic pressure as high as 1800 psi near the bottom of the well.

(2) Testing tubing by this method to any pressure is not recommended, since the combined effects of the test and hydrostatic pressure may cause a joint to fail after it is deeper in the well, necessitating pulling 1 or 2 joints at a time to determine which joint failed. This may prove time-consuming and expensive.

UPGRADING

Replacing the entire string of tubing is usually carried out after a well has experienced a series of repeat failures, or if the general appearance of the tubing is poor. Although most upgraded strings are replaced with new or electronically-inspected tubing, a used string that has been pulled from another well is sometimes utilized without inspection. The string that is pulled out of the well is then electronically inspected.

Additional considerations are:

(1) Although replacing all joints with new or electronically-inspected tubing assures a relatively long run-time before failure, it is very costly in terms of materials and inspection.

(2) Replacing a string with tubing from another well is not advisable, unless it has been calipered or electronically inspected. Since wells vary considerably in mechanical and/or corrosive conditions, tubing that has had few problems in one well, may fail immediately in another.

VISUAL INSPECTION

Tubing is visually inspected at every failure, regardless of additional testing or inspection. Joints with obvious defects such as deep tong or slip marks, bends, etc. are culled, and in addition, the film-forming ability of the inhibitor treatment is evaluated.

Additional considerations are:

(1) Experience has shown that a lack of external metal loss is not indicative of internal tubing condition. Therefore, visual inspection cannot assess overall tubing condition.

(2) Visual inspection is not a thorough external examination of every joint, collar, or thread and its limitations as an estimate of external condition should be realized.

INITIAL STUDY

To ascertain the effectiveness of field practices, the failure sequence for 115 wells was investigated for the 12 mo period from March 1978 to February 1979, with the results illustrated in Fig. 2. Preventative maintenance measures were categorized into:

(1) caliper surveys

(2) hydrostatic tests

(3) visual inspections, pump truck tests, or upgrades.

All wells had at least one failure during the 12 mo period. "Repeats", as depicted on the figure, were subsequent failures that occurred on the same 115 wells in the 12 mo period. The number of repeats totaled 76. Where one or more failures were attributed to improper makeup (IMU) or unscrewed joints (UNS), the number was so indicated in that block. (These type failures for the most part are not preventable by means of inspection.) By following through the failure sequence diagram, it appeared that failures which were calipered, a total of 24, stood less risk of failing again, and increased utilization of caliper surveys might be an effective means of reducing the number of tubing failures. Since the number of failures calipered was such a small percentage (12 percent) of the total number of failures, it was indeterminate at this time how many failures might be eliminated. Also, other factors influenced the failure data, including installation of continuous-feed chemical pumps and automatic pump-off controllers.

CALIPER SURVEY PROGRAM

As a result of the initial study, a program to caliper all tubing failures was initiated in May 1979, unless leaking collars were suspected or unusual circumstances dictated otherwise. It was anticipated that the program would be expensive in the initial months, as tubing would be replaced in many wells that had not been tested, inspected, or upgraded in some time, along with the additional caliper survey charges. With continual culling and rearrangement of tubing, it was projected that both the number of tubing failures and the amount of tubing replaced per failure would gradually be reduced, thus decreasing expenses.

The total number of tubing failures occurring each month from July 1978 to December 1979 and the "repeats within 90 days" (subsequent failures within 90 days of previous failure), are shown in Fig. 3. Total failures follow an erratic pattern up to March 1979, thereafter trending downward to December 1979 with a dramatic decrease in the last 6 mos. Repeat tubing failures within 90 days generally exhibit the same behavior as total failures, also decreasing dramatically in the last 6 mos.

Recent trends of both tubing and rod failures are summarized in Table 1. Total tubing failures during the caliper program from July thru December 1979 averaged 12.7 per month, in contrast to a 17.3 average the previous 12 mos, for a 27 percent reduction. Tubing "repeats within 180 days" averaged 4.7 per month from July to December 1979, compared to a 6.8 average the previous 12 mos, for a 31 percent decrease. Tubing "repeats within 90 days" went from 5.1 to 2.0 during the same time periods, resulting in a 61 percent failure reduction. Corresponding rod failures were reduced only 15-19 percent in the same periods. The downward trends of both tubing and rod failures indicates that increased utilization of continuous-feed chemical pumps, automatic pump-off controllers, etc. is responsible to some degree for the decline in failures. However, noting that tubing failures as compared to rod failures, were reduced by a greater percentage in every case, it can be concluded that the caliper survey program contributed significantly to the reduction of tubing failures. The largest percent reduction (61 percent) in tubing failures was in "repeats within 90 days", indicating the program sufficiently established that these type repeats can be reduced. Although total tubing failures and "repeats within 180 days" were also considerably reduced, it is conjectured that the program as of 1-1-80, was not sufficient in length to determine to what extent these longer-term failures might be decreased. These failures are expected to continue to decline, while "repeats within 90 days" may be approaching an irreducable minimum.

RUN-TIME COMPARISON

One measurable difference between the caliper survey and other practices is relative run-time before another failure occurs. Since wells vary considerably in conditions and rates of corrosion, the only plausible means to compare run-times is on a well-to-well basis. For this comparison, 19 wells were chosen on the basis of a large number of tubing failures in the 3 yr period 1-1-77 to 1-1-80, with at least one caliper survey during that time. It should be noted that these 19 wells are among the worst in the field in terms of failure frequency. As shown on Table 2, run-times have been tabulated and averaged following caliper surveys, upgrades, and "other" maintenance techniques which include hydrostatic testing, visual inspection, and pump truck testing. Eighteen of the 19 wells averaged a longer run-time following a caliper survey than "other". In addition, 18 of the 19 wells were calipered following the last failure and had not failed as of 1-1-80. A "+" following the number of days designates these cases, and indicates actual run-time will be somewhat longer.

Category averages for all 19 wells show that the caliper survey yielded more than 108 days additional run-time when compared to "other" practices. This more than doubled the average run-time on these wells with severe corrosion and/or mechanical problems. The average run-time following upgrades was the longest, as would be expected.

The data for actual failures following an operation was extracted (excludes figures with a "+") and is shown graphically by Fig. 4. Eighty-eight of 89 "other" actually failed in this period, in contrast to only 8 failures following 26 caliper surveys. The 18 caliper-surveyed wells which did not fail, had run an average of 222 days as of 1-1-80. Shown on the graph is the cumulative number of failures within a given number of days. As illustrated, a large number of "other" occurred within 30, 60, and 90 days, compared to only a few following caliper surveys. Since a relatively smaller number of failures were calipered, a corresponding smaller number of repeats would be expected. However, Fig. 5 expresses the failure data as a percentage of each respective category (e.g. 20 of 89 "other" failed within 30 days or 22.5 percent). Since the 18 caliper-surveyed wells that did not fail had run an average of 222 days, the data was not carried out beyond 210 days, as it might be erroneous. This data suggests that the caliper survey eliminates many short-term repeats.

SAMPLE LOGS

To investigate how the caliper survey eliminates these short-term repeats, several caliper logs were evaluated. Fig. 6 is a sample caliper survey run 12-15-79 in tubing that had not been pulled since 5-22-72, at which time 2 joints were replaced. Joint number 95 indicates 100 percent wall loss. If only this joint had been replaced, a series of repeats would probably have occurred, since substantial wall loss can be observed on several surrounding joints, and 90 percent of the string exhibited greater than 50 percent wall loss. It is significant that although this well did not have a history of tubing failures, the condition of the tubing was poor, and unless replaced, would have failed again in a short period of time. Production on this well is 80 BOPD and 40 BWPD, so downtime is expensive.

Another caliper survey, recorded 6-20-79, is shown in Fig. 7 for new tubing run in the well on 11-4-78. A hole was indicated by the caliper in joint number 116, and confirmed by the split detector. Note the repetitious intervals of considerable wall loss. When the interval length is measured, it is found to equal the stroke length of the pumping unit, and the distance between intervals is found to equal the rod length. It is reasonable to assume that each mark locates the area where the rod box wears on the tubing. Between each rod score mark a section of lesser wall loss is observed. This well was known to pound fluid for a time during this period, and one possible explanation for these marks is damage caused by rod and/or tubing buckling (tubing was not anchored). In addition, the overall rate of metal loss can be determined, since these were new joints as of 11-4-78 and experienced approximately 40-55 percent wall loss in 7 mos. By evaluating caliper surveys in this manner, mechanical and/or corrosion conditions can be diagnosed, monitored, and corrective measures can be taken.

ECONOMICS

All preventative maintenance programs ultimately prove their worth in terms of a decrease in expenses or increase in production. The benefits of the program should exceed its cost, if it is to be continued.

Expense per failure and total expenses for tubing failures are depicted quarterly for 1978 and 1979 in Fig. 8. Expenses include pulling unit costs, cost to replace failed equipment, and any routine maintenance service charges or equipment costs associated with tubing. Although expense per failure appeared to be trending slightly upward prior to initiation of the caliper program; as anticipated, a substantial increase from $1830 to $2245 was realized in the 2nd quarter 1979, with a corresponding increase from $86,000 to $128,000 in total expenses. Expense per failure continued to rise the following 2 quarters, reflecting the amount of tubing replaced. However, following the 2nd quarter, total expenses began a decline, and the increasing expense per failure was more than offset by a decrease in the number of failures. Moreover, the number of failures was reduced in the 4th quarter 1979, to the point that total expenses were actually less than before the caliper program was initiated.

The number of joints replaced per failure is expected to gradually diminish, as the overall quality of tubing in service is improved. The resulting decrease in expense per failure, coupled with an anticipated further reduction in the number of failures, should cause total expenses to continue to decline. In addition, for every failure eliminated, it is estimated at least 24 BO is realized, due to less downtime. Taking this into consideration, even if total expenses are not reduced beyond pre-caliper program levels, the benefits of increased production justify continuation of the caliper program.

CONCLUSIONS

Continuation of this program is necessary to realize the maximum extent to which tubing failures can be reduced by the caliper survey; although the economic justification for its continuation has been established. Economics are difficult to estimate prior to initiating a caliper survey program, and feasibility may differ in other fields, depending upon well depths, failure costs and frequency, etc.

Preliminary results of this program yield the following conclusions:

(1) The caliper survey is an effective and economical tool for reducing the number of repeat tubing failures that occur on rod-pumped wells.

(2) Grading, rearrangement, and segregation insures that tubing is utilized where it is best-suited, both downhole and on the surface.

(3) Diagnosis and monitoring of corrosion and/or mechanical problems, coupled with the removal of already-damaged tubing, allows improvements in chemical treatment and/or mechanical conditions to be effectively implemented.

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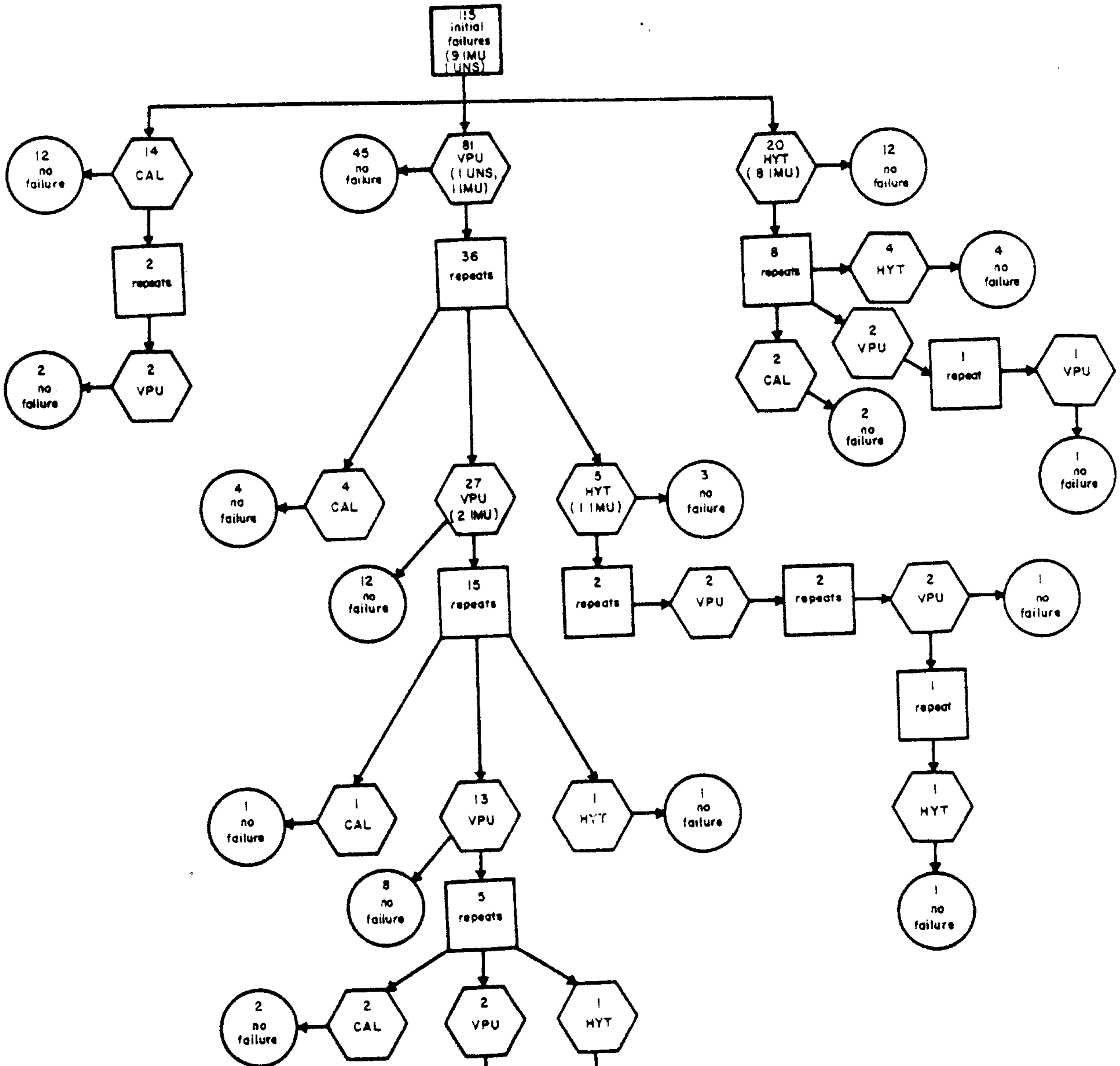
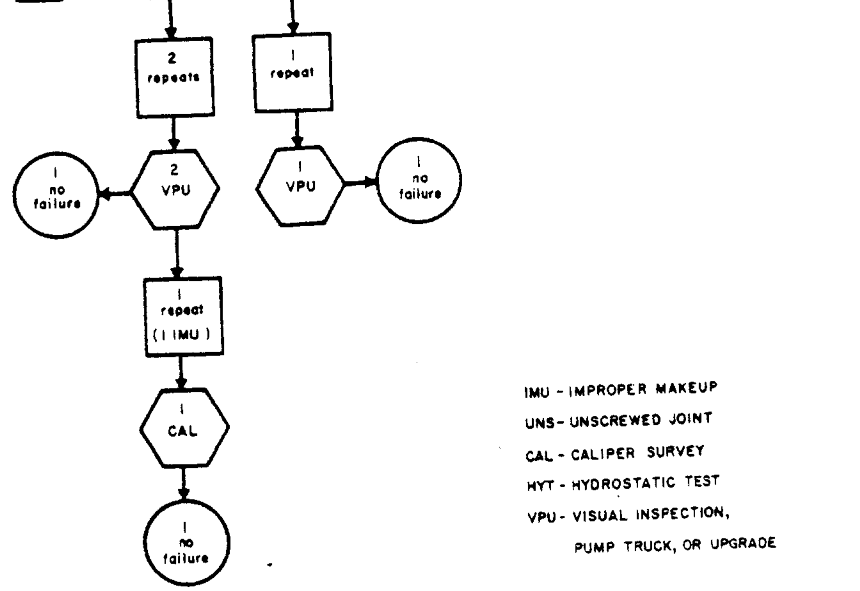

FIGURE 2—TUBING FAILURE SEQUENCE MARCH 1978 TO FEBRUARY 1979

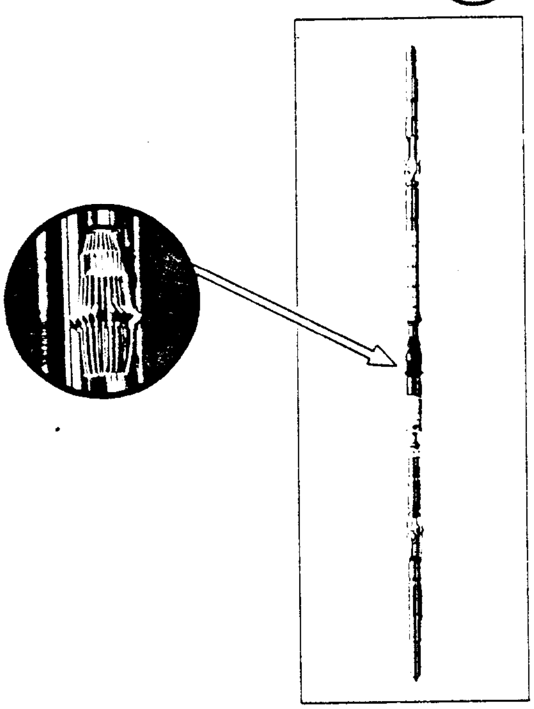

FIGURE 1—CALIPER TOOL

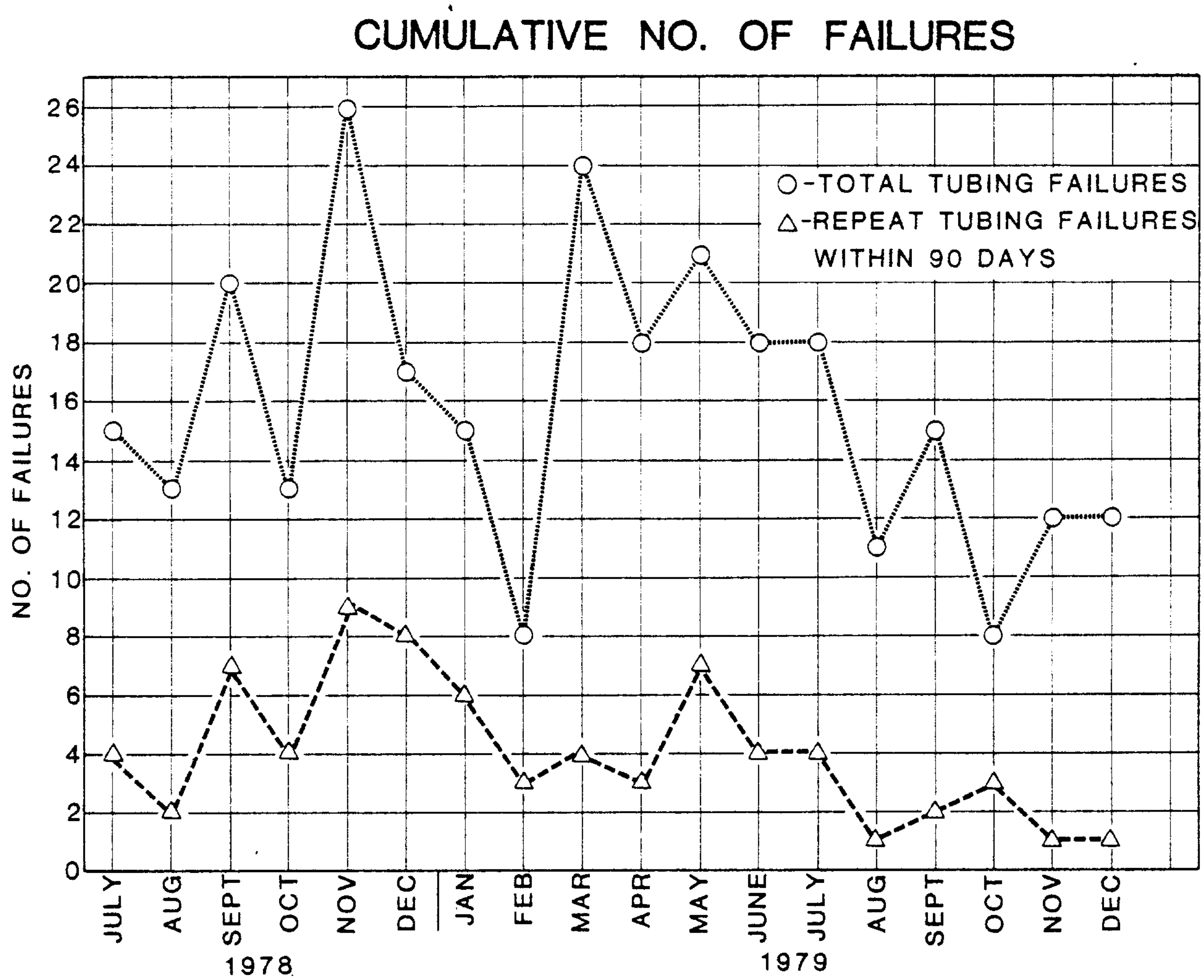

FIGURE 3—TUBING FAILURES

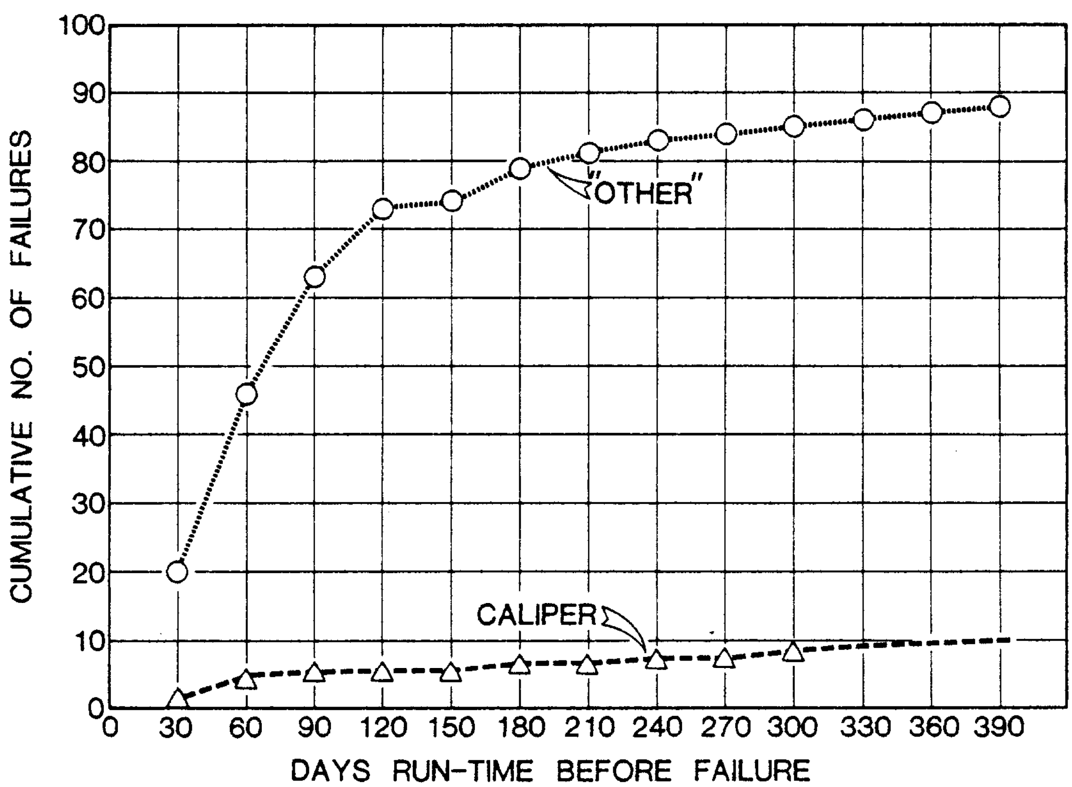

FIGURE 4—FAILURE RUN-TIME COMPARISON
19 WELL - 3 YEAR HISTORY
CALIPER VS. "OTHER"

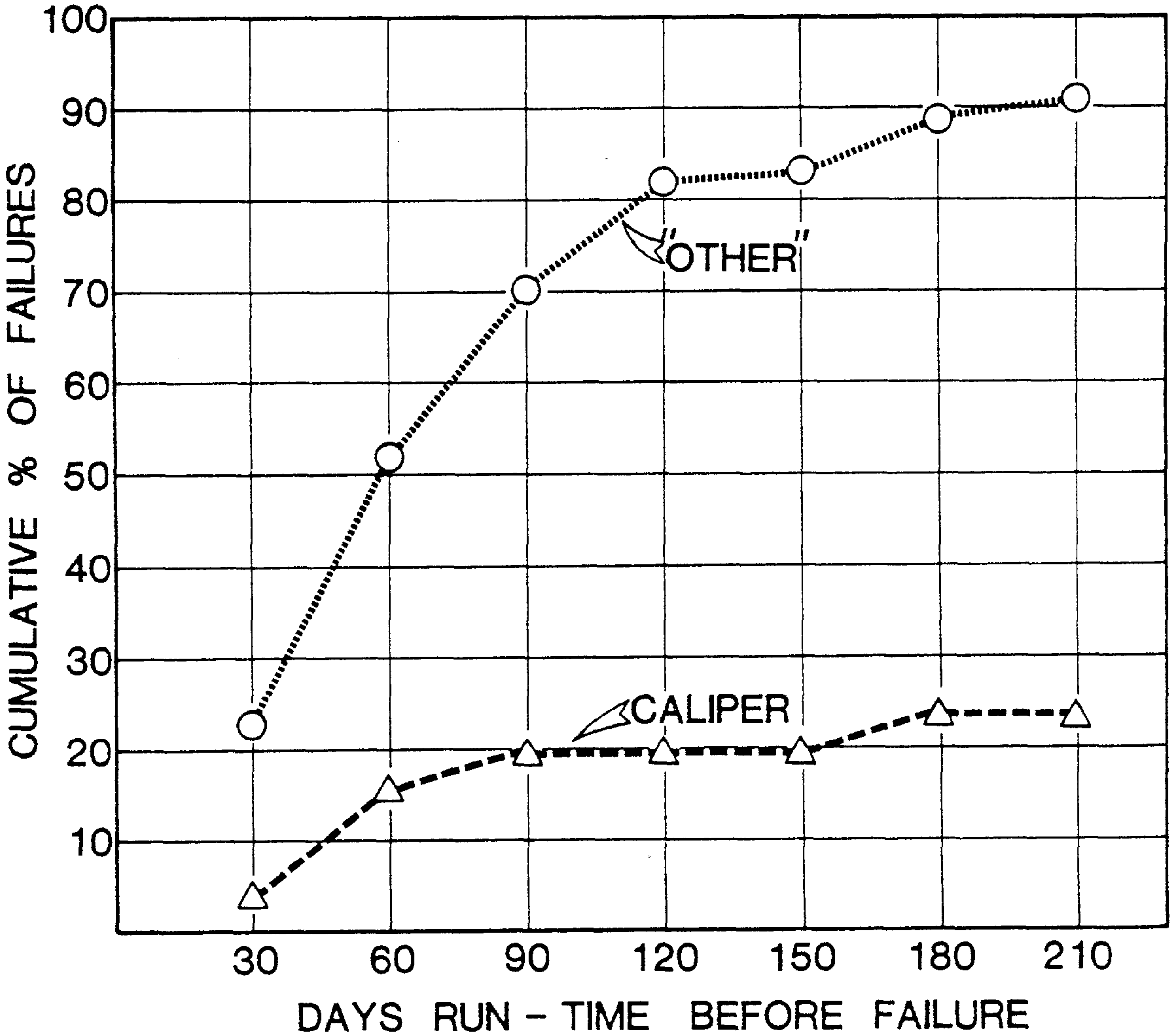

FIGURE 5—PERCENTAGE FAILURE RUN-TIME COMPARISON
19 WELL - 3 YEAR HISTORY
CALIPER VS. "OTHER"

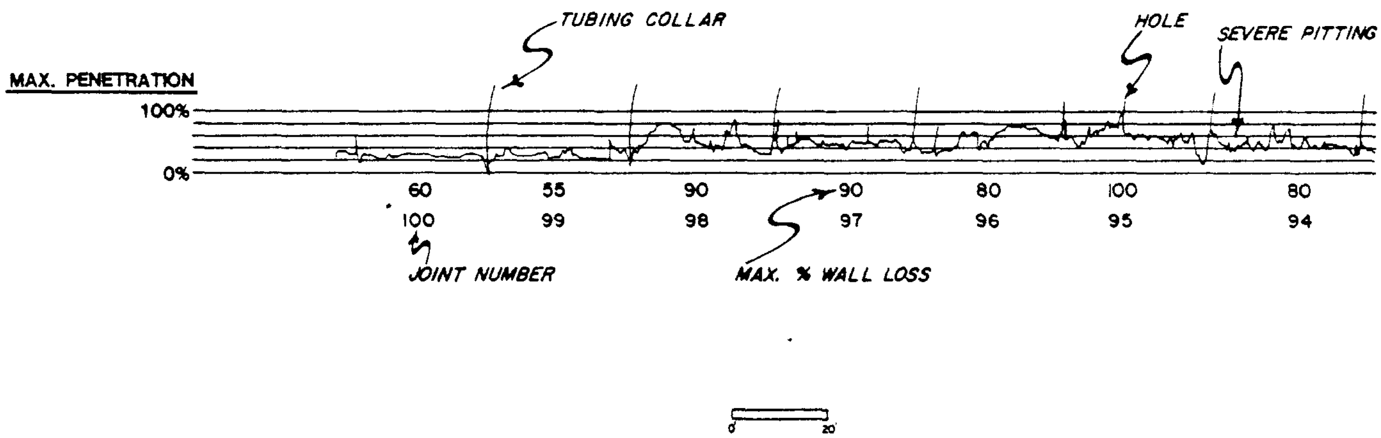

FIGURE 6—CALIPER SURVEY - EXAMPLE 1

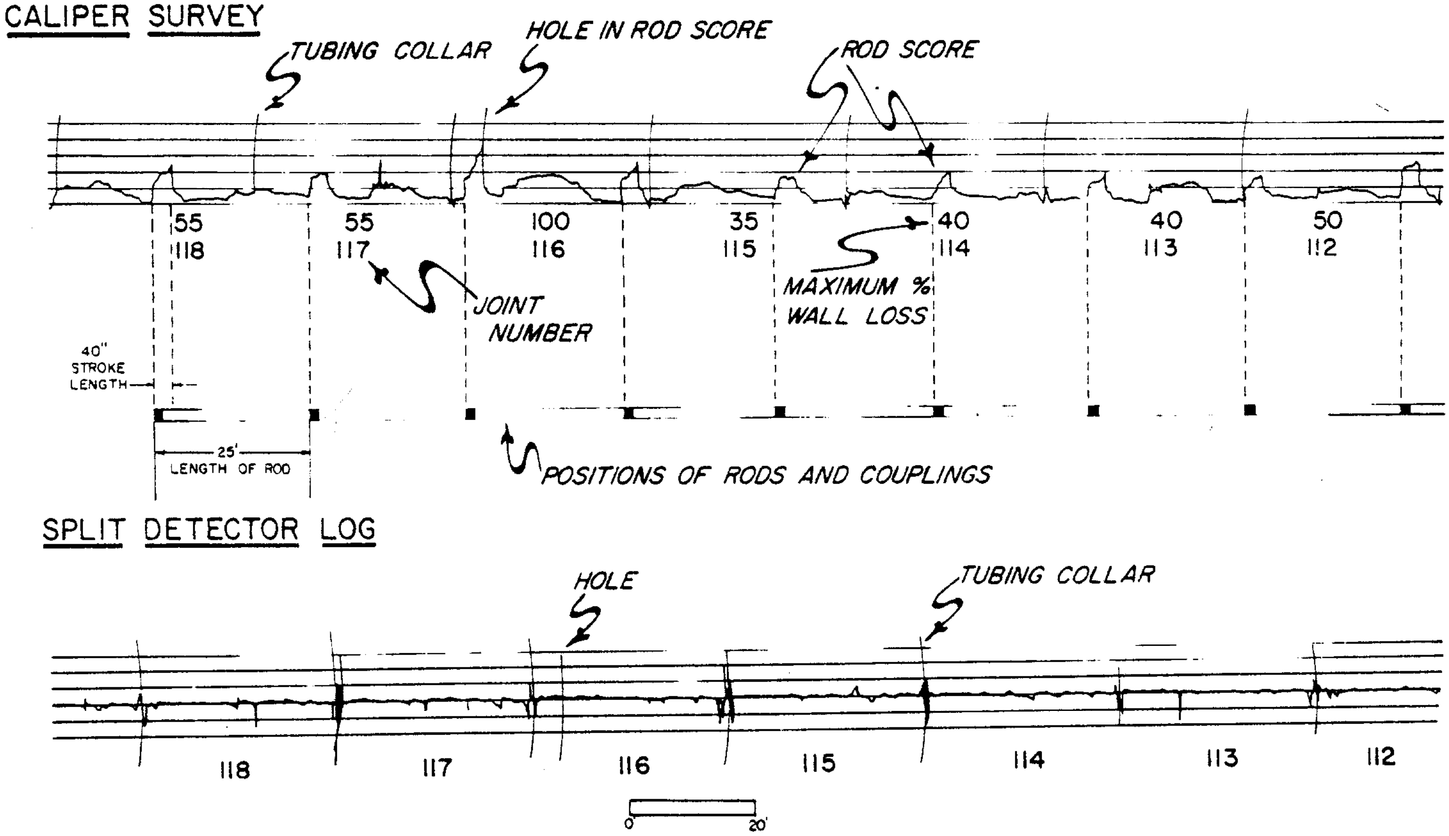

FIGURE 7—CALIPER SURVEY — EXAMPLE 2

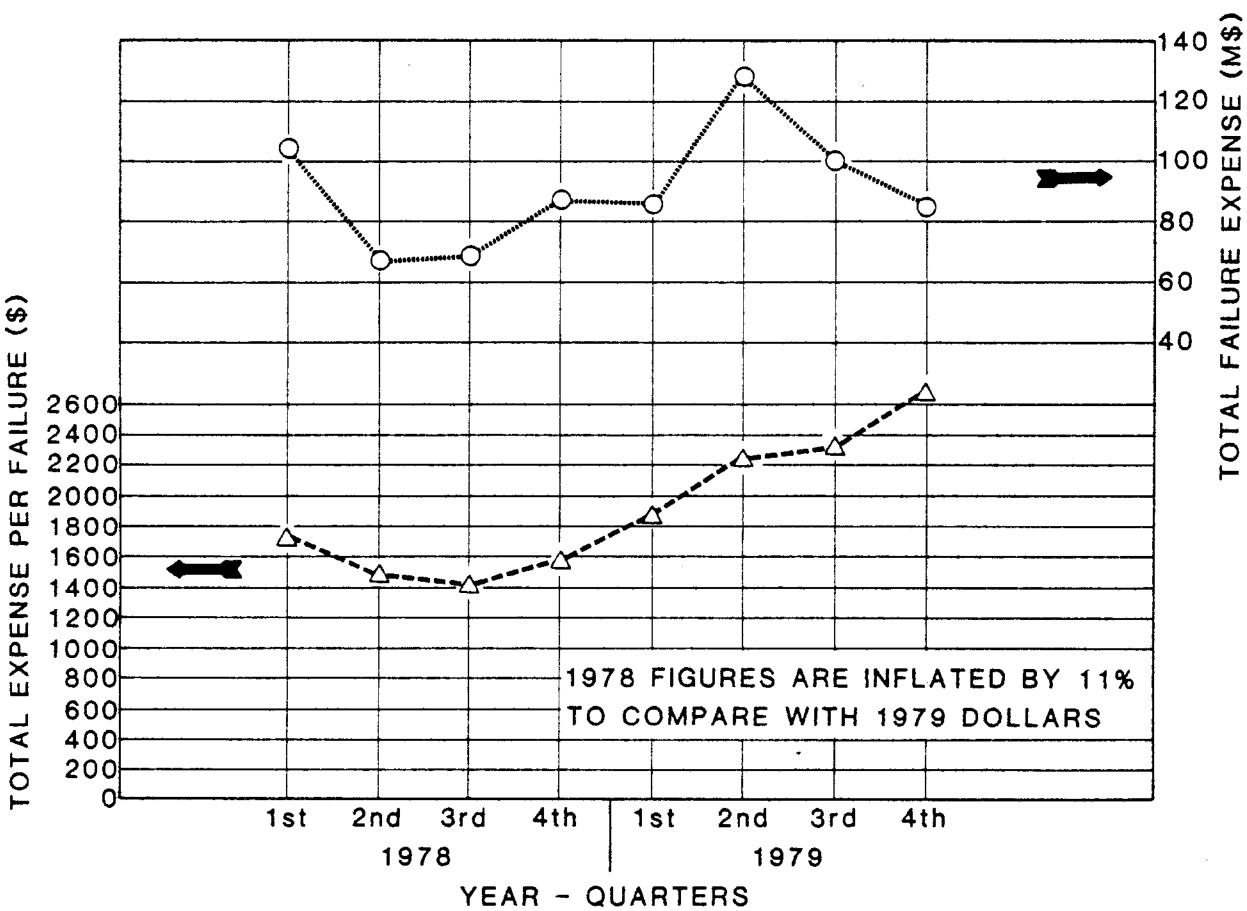

FIGURE 8—TUBING FAILURE EXPENSE

TABLE 1—SUMMARY OF TUBING AND ROD FAILURES

	TUBING	RODS
TOTAL FAILURES		
JULY '78 TO JUNE '79 (AVG. PER MO.)	17.3	16.6
JULY '79 TO DEC. '79 (AVG. PER MO.)	12.7	13.8
% REDUCTION	27%	17%
REPEATS WITHIN 180 DAYS		
JULY '78 TO JUNE '79 (AVG. PER MO.)	6.8	8.6
JULY '79 TO DEC. '79 (AVG. PER MO.)	4.7	7.0
% REDUCTION	31%	19%
REPEATS WITHIN 90 DAYS		
JULY '78 TO JUNE '79 (AVG. PER MO.)	5.1	6.8
JULY '79 TO DEC.'79 (AVG. PER MO.)	2.0	5.8
% REDUCTION	61%	15%

TABLE 2—TUBING RUN-TIME COMPARISON
19 WELL - 3 YEAR HISTORY

WELL NO.	DAYS RUN-TIME AFTER 'OTHER'	"OTHER" AVG.	DAYS RUN-TIME AFTER UPGRADE	UPG. AVG.	DAYS RUN-TIME AFTER CALIPER	CAL. AVG.
341	43, 97, 228	123	383	383	241+	241+
2164	11, 134*, 136*, 268, 31,45, 37	78	---	---	243+	243+
2864	90,87, 3,50, 8, 87	54	126,63	95	274, 191+	233+
3307	40, 64, 31, 49, 366, 101	109	117	117	196+	196+
3314	299,16, 43,62,68	98	---	---	237+	237+
3340	24, 104, 47	58	---	---	154*,272+	272+
3532	169	169	447	447	228, 194+	211+
3559	210,145,9,106,82	110+	---	---	61	61
3704	32, 39, 38	36	---	---	168, 227+	198+
3754	82, 36	59	---	---	30, 45, 196+	90+
3808	26, 37, 87, 25, 57, 16, 157, 59	58	169, 287	228	172+	172+
3811	7, 55, 5, 176, 301	109	322	322	178+	178+
4042	39, 34, 187	87	---	---	176+	176+
4642	28, 83, 217, 5, 16, 10, 26, 78, 176	71	---	---	55,374+	215+
4653	347, 35, 70	151	---	---	182+	182+
4709	54, 85, 8, 64, 6	43	---	---	404+	404+
4713	28,52*,114,91,97, 93, 22, 109	79	227	227	122+	122+
4751	54, 65, 15,166, 31	66	104*	104*	220+	220+
3438	83,83,64,104,38	74	---	---	33, 176+	105+
AVG. FOR ALL 19 WELLS		87		260		195+

* FAILURE WAS DUE TO IMPROPER MAKEUP OR UNSCREWING - NOT ENTERED IN AVERAGE OR FIGS. 4 & 5

\+ INDICATES WELL HAD RUN THIS NUMBER OF DAYS AS OF 1-1-80 AND HAD NOT FAILED