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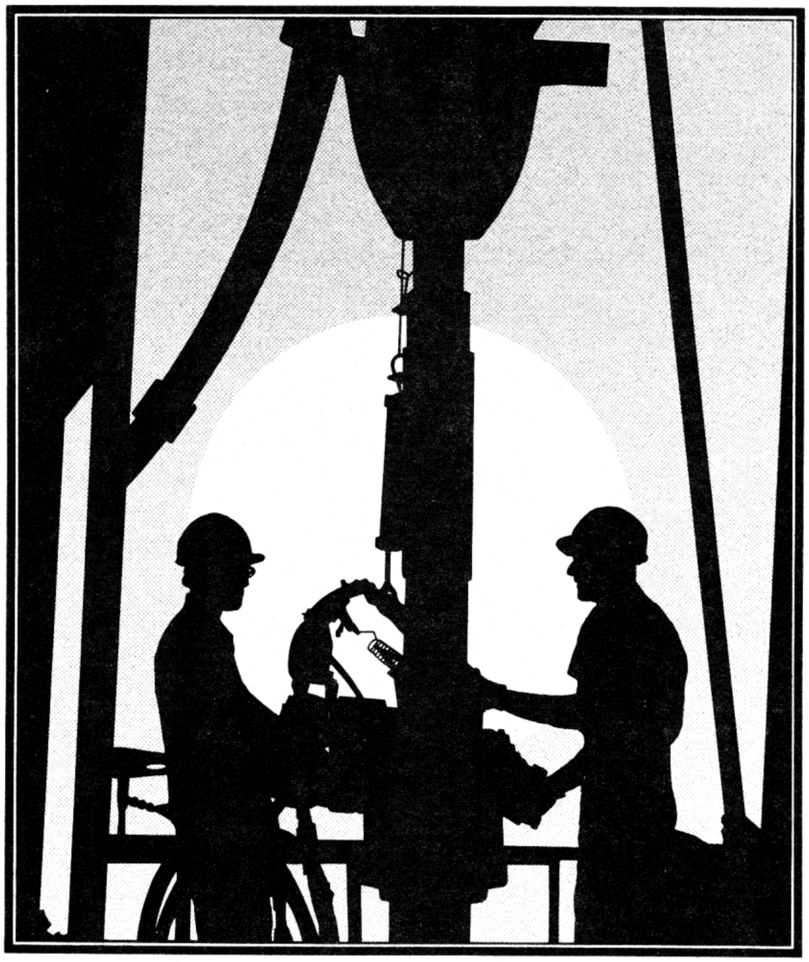
CEMENT PLUG BALANCING AND INJECTION RATE CALCULATIONS FOR THE HP41 CALCULATOR



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CEMENT PLUG BALANCING AND INJECTION RATE CALCULATIONS

FOR THE HP41 CALCULATOR

By Timothy S. Boardman

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CEMENT PLUG BALANCING AND INJECTION RATE CALCULATIONS FOR THE HP41 CALCULATOR[a]

By Timothy S. Boardman

INTRODUCTION

Accurate fluid-displacement calculations are critical in many oilfield operations. Both accuracy and speed are especially important in cementing and injection calculations. With a hand-held, programmable calculator, quick and accurate information is available at the well site without the need for cumbersome tables and/or graphs, which can be misread easily.

CEMENTING OPERATIONS

As used in this report, cementing operations refer to both plugback and abandonment operations for oil, gas, and geothermal wells. A *plugback operation* consists of setting a cement plug in the lower portion of a well so another interval can be utilized or the well can be redrilled. An *abandonment operation* consists of setting cement plugs at required intervals until a well is plugged and abandoned satisfactorily. Such plugs are usually placed across oil and gas shows, casing shoes, perforations, the base of fresh water, and at the surface.

When placing a cement plug during plugback or abandonment operations, the plug must be set at the proper depth. If the cement is overdisplaced, the plug will be too high in the well and may not properly isolate the intended zone from the rest of the well. If the cement is underdisplaced, it will not be pumped entirely out of the tubing or drill pipe. Cement will be strung up the hole as the tubing or drill pipe is pulled, and/or the tubing or drill pipe may become plugged with cement.

A cement plug that is placed properly is termed a balanced plug, or is said to be equalized. In other words, the cement in the tubing or drill pipe is equal to the level of the cement in the annulus. Normally, balancing a cement plug is a simple procedure that requires knowing the volumes of casing, tubing, and the open hole. Volumetric data are available from many sources, the best being handbooks published by the oilfield cementing companies. The handbooks are commonly referred to as cementing tables.

The normal sequence of a cementing operation is: 1) a water preflush (or sweep) ahead of the cement slurry to create a space between the hole fluid and the slurry; 2) the cement slurry; 3) a water flush behind the cement slurry to create a space between the slurry and the displacing fluid; and 4) the displacing fluid to balance the mud column or other fluid in the well.

When the cement slurry is pumped into a well, the volume of the slurry plus any preflush volume must be known to calculate the proper displacement volume. When the well is full of fluid, the displacement calculation is quite simple; however, problems arise when there is a low fluid level in a well.

A low fluid level occurs in a well when the zone pressure in the well is depleted to a point where it will no longer support a column of fluid that will reach the surface. Mistakes are commonly made in displacement calculations for bottom-hole or zone-plug operations when a well has a low fluid level.

Several techniques can be used when a zone plug is placed in a low-fluid level environment. A cementing retainer is commonly used in such situations; however, when a retainer cannot be used (e. g., bad casing), a two-wiper-plug technique should be considered. This method uses a wiper-plug catcher in the bottom of the drill pipe or tubing. The catcher permits passage of the bottom wiper plug, but stops the top wiper plug (Fig. 1).

If mechanical conditions and/or economics dictate that such methods cannot be used, it may become necessary to balance a cement plug in a low-fluid level environment.

[a]Manuscript submitted January 1988.

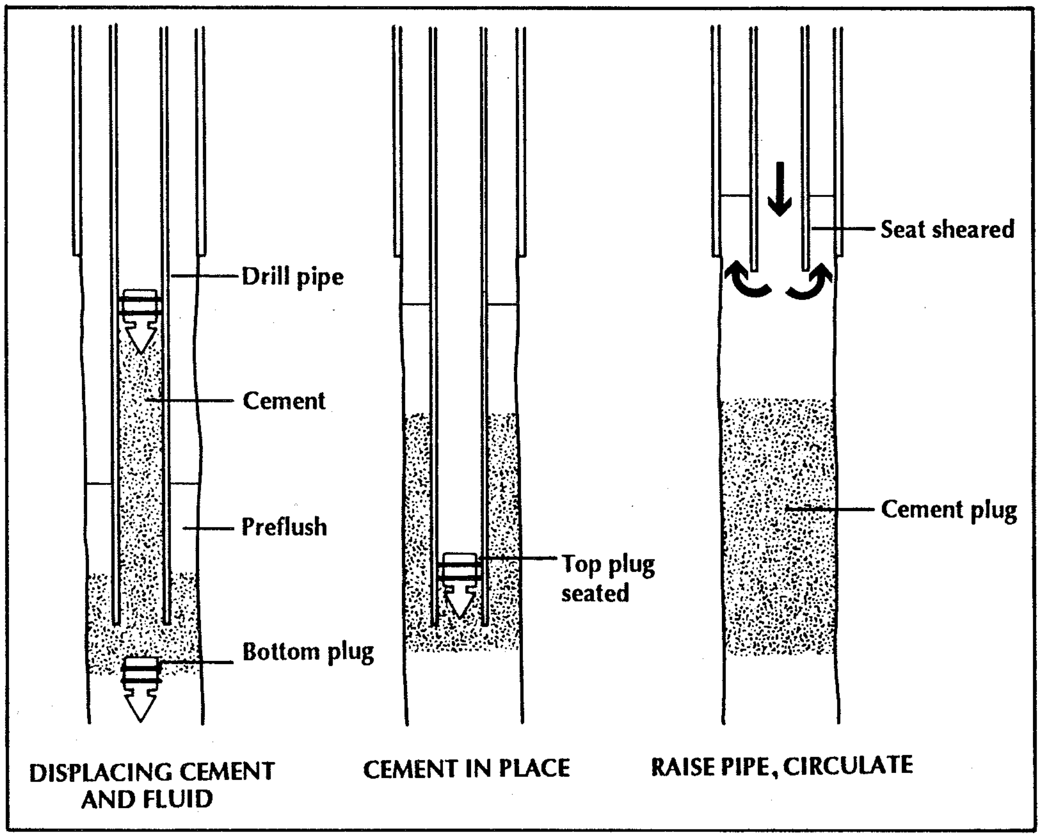

Figure 1. The two-wiper-plug method is used for deeper wells or where displacement is difficult to calculate. A seat stops the top plug to indicate when the slurry is spotted. Then, the pipe is raised. Additional pressure shears the seat to open the pipe for circulation or reverse circulation.

If the fluid in the well contains oil with an API gravity above 10°, the oil will float on top of water and less displacement fluid is needed to balance the oil. When considering a plug in a low-fluid level environment, a survey should be run to confirm the oil-water interface, if any.

In a low fluid-level environment, the fluid level normally changes as fluids and cement are pumped down the tubing or drill pipe. If this change of fluid level is not considered or calculated correctly, or if the low-fluid level is ignored and the cement is displaced as if the fluid level were at the surface, the fluids (including cement) will u-tube. This causes the cement to be overdisplaced and the plug will be higher than desired (Fig. 2).[5]

INJECTION OPERATIONS

Injection wells are used to inject fluids into a reservoir to increase oil production and/or to dispose of fluids. In California, regulations require periodic surveys on injection wells to ensure that injected fluids are entering the permitted zone and that leaks have not developed in the well.

Injection-well surveys require the injection rate to be measured or calculated. This rate is usually determined by performing a drop check to find the velocity of the fluid moving down the tubing or casing. The drop check is performed by injecting a radioactive tracer into the injection stream, quickly lowering the detection tool about 100 feet, detecting the passing tracer, and noting the elapsed time and distance traveled. To calculate the rate, the velocity is multiplied by the cross-sectional area of the tubing or casing.

PROGRAMS

The following three programs were written for the Hewlett-Packard HP-41CX or HP-41C hand-held, programmable calculators, with the manufacturer's PETROLEUM FLUIDS PAC installed. The titles of the programs are *PIPE, BAL,* and *DROP*. The *PIPE* program is a subroutine for the other two programs, but can be run independently, if desired. Additional memory modules will be required in the HP-41C model to allow the programs to be loaded simultaneously.

The three programs were written to accommodate volume calculations in cubic feet and length calculations in feet. Instructions for converting the programs to handle volume calculations in barrels are given later. Also, the user can change the programs to accommodate SI metric system values, if desired.

[5] Superior figures refer to a list of *Selected References* at the end of this report.

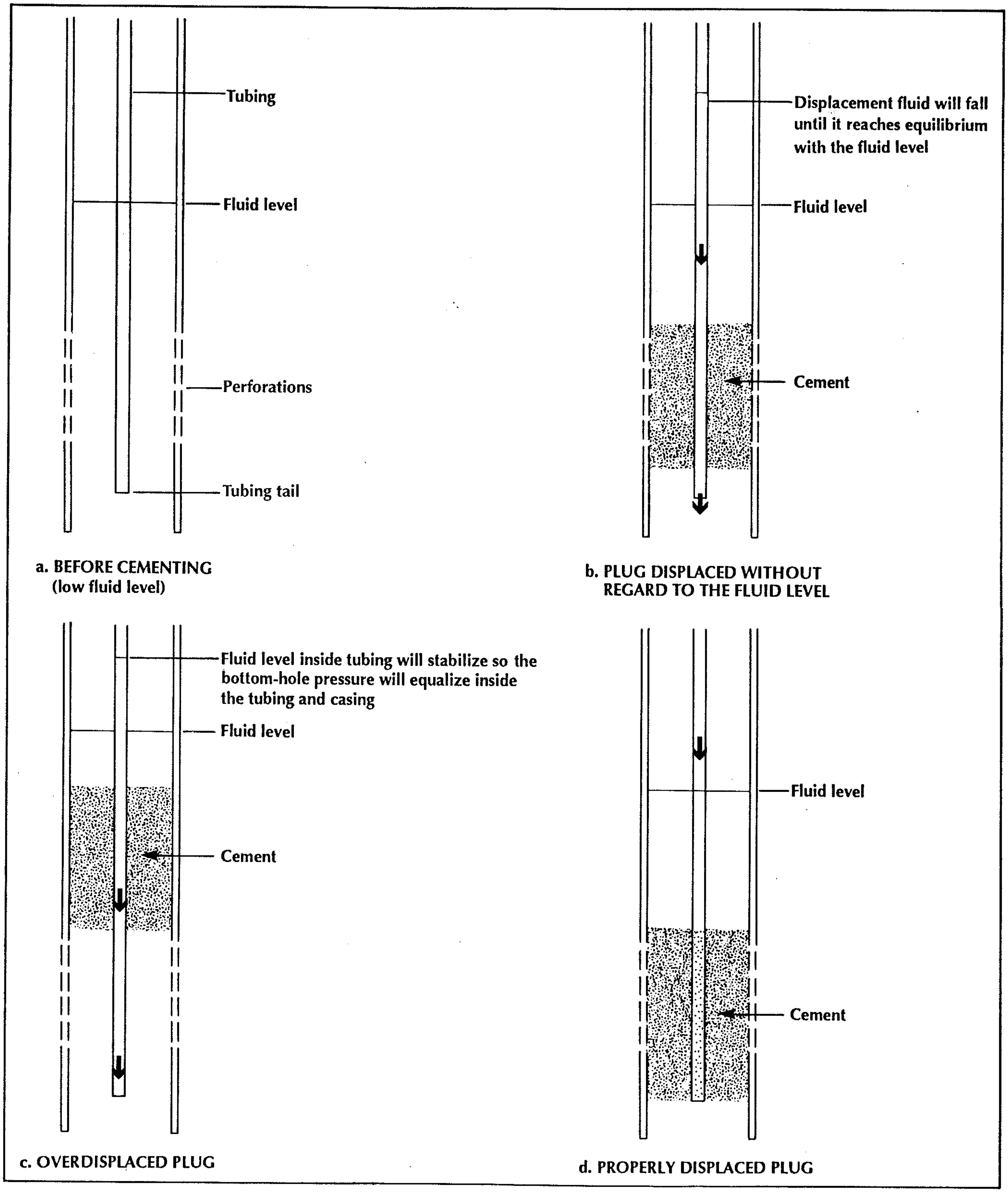

Figure 2. Plug placement examples.

PIPE

The *PIPE* program, or subroutine, calculates the internal volume factor of casing, drill pipe, or tubing when the outside diameter and the weight per linear foot are provided. *PIPE* will also calculate the volume of open hole if the diameter of the open hole is substituted for the casing diameter and the casing weight is entered as zero. *PIPE* gives the answer as cubic feet per linear foot. If an answer in linear feet per cubic foot is desired, the reciprocal can be used.

This subroutine does not rely on volume factors found in cementing tables; it calculates the internal capacity of casing, drill pipe, or tubing using 494.2 lbs./c.f. as the density of steel. (The average difference between the capacity calculated by the subroutine and cementing tables provided by Halliburton is 0.22%.) If the user prefers to use another number for the density of steel, simply change step 021 in the *PIPE* subroutine to that number.

The program requires 164 bytes (or 24 registers) of memory space, 8 data registers, and will run on a standard HP-41C without any additional memory modules (and does not require the PETROLEUM FLUIDS PAC). *PIPE* was designed to run with or without a printer.

BAL

The *BAL* program can be used to calculate the displacement volumes for both a cement plug in a well with a low fluid level and a plug in a well with the fluid level at the surface. The program uses the equalization point formula (Equation 1 in Appendix D). In a low fluid level calculation, the program assumes that none of the fluid or cement in the well will flow into the formation, and that all of the fluid will end up in the tubing/casing (or drill pipe/hole) annulus at the completion of the job. The program also calculates the *exact* displacement needed to equalize a plug; however, it is common practice to cut short the displacement by a few cubic feet so dry tubing or drill pipe will be pulled from the hole when the job is finished. This method of calculating a balanced plug in a low fluid level environment has been used with considerable success in the Kettleman North Dome oil field.

To run the *BAL* program, the PETROLEUM FLUIDS PAC must be installed and the subroutine *PIPE* must be in the main memory. The *BAL* program requires 36 storage registers for data and will inform the user if the calculator is sized for fewer than 36 registers. *BAL* and *PIPE* require 1,246 bytes, or 178 registers, of memory space. When using the HP-41C, the programs require a minimum of 4 memory modules. The program was designed to be run under field conditions with or without a printer.

Modifications are needed to run the program properly when running the *BAL* program on a HP-41C without an extended functions module. The modifications are as follows:

Modifications for the Program *BAL*

Delete Steps	Add Steps
09 00.035 10 CLRGX	CLRG
02 0 03 X < > F	CF 00 CF 01 CF 02 CF 03 CF 04

The modified program will be 585 steps in length.

DROP

The *DROP* program was written to calculate the injection rate (in barrels per day) inside tubing or casing. *DROP* will handle any variable (i.e., the number of feet the detector is dropped, the time in seconds, or the rate in barrels per day). Only two known variables need to be entered, as the program will solve for the unknown variable.

The program will calculate the factor (Equation 2 in Appendix D). This number is then divided by the time (seconds) the tracer takes to pass by the detector. The result is multiplied by the flow interval (in feet). The factor will be displayed momentarily after the necessary data have been entered. The program calculates the factor automatically.

The program will ask if a tool-compensation factor should be applied. The tool-compensation factor is calculated by subtracting the volume of the tool from the volume of the pipe in the interval where flow is measured (distance dropped). A useful rule-of-thumb is: if the flow interval (distance dropped) is equal to or less than the tool length, the tool compensation should be applied.

DROP requires the subroutine *PIPE* to be loaded in the main memory and requires the *PETROLEUM FLUIDS PAC.* The program requires 229 bytes (or 33 registers) of memory space and 8 data registers, and will run on a standard HP-41C. *DROP* was also designed to run with or without a printer.

All three programs can be modified easily in the following ways to express volume inputs and outputs in barrels:

PIPE

Change steps

From	**To**
26 CF/LF =	26 BBL/LF =
Add between steps 22 & 23:	23 5.6146 24 /
Add between steps 18 & 19:	19 5.6146 20 /

BAL

Change steps

From	**To**
318 = CF DSP	318 = BBL DSP
13 CF CEM	13 BBL CEM

DROP

Change steps

From	**To**
11 15388.4515	11 86400
Add between steps 51 & 52:	52 5.6146 53 /

APPENDIX A
Examples

The following examples demonstrate the usage of *BAL* and *DROP* while the subroutine *PIPE* is accessed automatically. The programs will provide prompts for the needed data. The prompts are defined after each example. A list of storage registers is included. Any of the solved values can be viewed by recalling that register after the calculation is performed.

EXAMPLE ONE: Low fluid-level calculation. A well has 7″ 23# casing cemented at 1725′, with a 5½″ 15# liner landed at 2005′, top at 1700′. A pressure survey was run, and the fluid level was found at 700′, with 200′ of 30° API gravity oil. A 50 cubic foot cement plug is to be placed at 2000′. The tubing string is 2⅜″, 4.6#, hung at 2000′. The cement will be preceded by a 10 cubic foot preflush. Determine the correct amount of water to be pumped behind the plug and the volume of displacement fluid.

INSTRUCTIONS	CALCULATOR DISPLAY	COMMENT
[XEQ][ALPHA] BAL [ALPHA]	CF CEM=?	Prompted
50 R/S	H2O AHEAD=?	Prompted
10 R/S	TBG TAIL=?	Prompted
2000 R/S	TBG DIA=?	Prompted
2.375 R/S	TBG WT=?	Prompted
4.6 R/S	LNR? Y/N:N	Is there a liner? Answer Y or N
Y R/S	LNR DIA=?	Prompted
5.5 R/S	LNR WT=?	Prompted
15 R/S	LNR TOP=?	Prompted
1700 R/S	CSG DIA=?	Prompted
7 R/S	CSG WT=?	Prompted
23 R/S	LO FLD? Y/N:N	Is there a low fluid level? Answer Y or N
Y R/S	FLD LEVEL=?	Prompted
700 R/S	OIL? Y/N:N	Is there oil in the fluid? Answer Y or N
Y R/S	FT OF OIL=?	Prompted
200 R/S	OIL-API?	Prompted
30 R/S	1.1=H2O BHD	Answer
	28.9=CF DSP	Answer

EXAMPLE TWO: A normal plug (fluid level at the surface). The hole is full of mud or water (no oil). A 9⅝″, 42# casing is cemented at 6000′, with a 7″, 23# liner, the shoe of which is at 6200′ and the top at 5940′. A 120 cubic foot cement plug is to be placed at 6195′. The tubing string is 2⅞″, 6.5#, hung at 6195′. The cement will be preceded by a 20 cubic foot preflush. Determine the correct spacer of water to be pumped behind the plug and the volume of displacement fluid.

INSTRUCTIONS	CALCULATOR DISPLAY	COMMENT
[XEQ][ALPHA] BAL [ALPHA]	CF CEM=?	Prompted
120 R/S	H2O AHEAD=?	Prompted
20 R/S	TBG TAIL=?	Prompted
6195 R/S	TBG DIA=?	Prompted
2.875 R/S	TBG WT=?	Prompted
6.5 R/S	LNR? Y/N:N	Is there a liner? Answer Y or N
Y R/S	LNR DIA=?	Prompted
7 R/S	LNR WT=?	Prompted
23 R/S	LNR TOP=?	Prompted
5940 R/S	CSG DIA=?	Prompted
9.625 R/S	CSG WT=?	Prompted
42 R/S	LO FLD? Y/N:N	Is there a low fluid level? Answer Y or N
N R/S	1.7=H2O BHD	Answer
	182.7=CF DSP	Answer

EXAMPLE THREE: An injection survey. A drop-check is made in 2⅞″ 6.5# tubing, a tracer (slug) is injected at 500′, and the logging tool is lowered 100′ (to 600′). The slug is detected after an elapsed time of 25 seconds. What is the injection rate?

INSTRUCTIONS	CALCULATOR DISPLAY	COMMENT
[XEQ][ALPHA] DROP [ALPHA]	TBG DIA= ?	Prompted
2.875 R/S	TBG WT=?	Prompted
6.5 R/S	TOOL? Y/N:N	Prompted Answer Y or N
N R/S *	FT DROP=?	Prompted
100 R/S	TIME-SEC=?	Prompted
25 R/S		
	1965 BBL/DY	Answer

* The tool factor is displayed momentarily after this prompt is selected.

Note: If more rates are to be calculated, simply push R/S and the program will cycle back to the prompt FT DROP=?. Rates can be calculated using data already entered.

EXAMPLE FOUR: An injection survey. A survey is being performed in a 5½″ 15# liner across perforations. The radioactive tracer (slug) has traveled 8′ in 17 seconds. The tool length is 10′ and the tool has a 1″ diameter. (Because the distance the slug traveled is less than the tool length, the tool factor should be included in the calculation.) What is the injection rate?

INSTRUCTIONS	CALCULATOR DISPLAY	COMMENT
[XEQ][ALPHA] DROP [ALPHA]	TBG DIA= ?	Prompted
5.5 R/S	TBG WT=?	Prompted
15 R/S	TOOL? Y/N:N	Prompted Answer Y or N
Y R/S	TOOL DIA=?	Prompted
1 R/S	FT DROP=?	Prompted
8 R/S	TIME-SEC=?	Prompted
17 R/S		
	935 BBL/DY	Answer

EXAMPLE FIVE: An injection survey. A well is injecting at a rate of 540 barrels per day. A 400′ radioactive-tracer drop check is going to be made inside $2\frac{7}{8}''$ 6.5# tubing. What is the time needed to make this check?

INSTRUCTIONS	CALCULATOR DISPLAY	COMMENT
[XEQ][ALPHA] DROP [ALPHA]	TBG DIA= ?	Prompted
2.875 R/S	TBG WT=?	Prompted
6.5 R/S	TOOL? Y/N:N	Prompted Answer Y or N
N R/S	FT DROP=?	Prompted
400 R/S	TIME-SEC=?	Prompted
R/S	BBL/DY=?	Prompted
540 R/S		
	364 SEC	Answer

EXAMPLE SIX: An injection survey. A well is injecting down $2\frac{3}{8}''$ 4.6# tubing at a rate of 1,400 barrels per day. How many feet will the fluid travel in 30 seconds?

INSTRUCTIONS	CALCULATOR DISPLAY	COMMENT
[XEQ][ALPHA] DROP [ALPHA]	TBG DIA= ?	Prompted
2.375 R/S	TBG WT=?	Prompted
4.6 R/S	TOOL? Y/N:N	Prompted Answer Y or N
N R/S	FT DROP=?	Prompted
R/S	TIME-SEC=?	Prompted
30 R/S	BBL/DY=?	Prompted
1400 R/S		
	127 FT	Answer

APPENDIX B
Nomenclature
(Using English Units)

PROMPTS	DEFINITION
BBL/DAY	Barrels per day.
CF CEM=?	Volume of cement in cubic feet.
=CF DSP	Volume of displacement fluid in cubic feet.
CSG DIA=?	Diameter of casing in inches. (The term CSG is used when there is one casing string. If there are two, the term applies to the upper string.)
CSG WT=?	Weight of casing in pounds per linear foot.
FLD LEVEL=?	Depth where the fluid level is found.
FT DROP	Distance the tool was lowered, in feet.
FT OF OIL=?	Linear feet of oil in well.
H2O AHEAD=?	Volume of water pumped ahead of cement (preflush) in cubic feet.
=H2O BHD	Volume of fluid spacer to be pumped behind cement, in cubic feet.
LNR DIA=?	Diameter of liner in inches. (The term *liner* is used only when there are two casing strings.)
LNR WT=?	Weight of liner in pounds per linear foot.
LNR? Y/N:N	Is there a liner in this well?
LO FLD? Y/N:N	Is there a low fluid level in this well?
OIL-API=?	Gravity of oil in well.
TBG DIA=?	Diameter of tubing or drill pipe in inches.
TBG TAIL=?	Depth of the tubing tail, in feet.
TBG WT=?	Weight of tubing or drill pipe in pounds per linear foot.
TIME-SEC	Number of seconds elapsed.
TOOL DIA=?	Diameter of tool, in inches.
TOOL? Y/N:N	Should the tool volume be subtracted in this calculation?
R/S	Run/stop command.

APPENDIX C
Storage Registers

06 scratch "CSG,TBG or LNR DIA" used in *PIPE*
07 scratch "CSG,TBG or LNR WT" used in *PIPE*
08 scratch "cylinder displacement of tubing"
09 CF CEM
10 H2O AHEAD
11 TBG TAIL
12 TBG CF/LF
13 displacement of TBG (transfer of reg 08 into reg 13)
14 CSG CF/LF
15 LNR CF/LF
16 fluid level
17 Cl-CF/LF of space between tubing and liner
18 Cc-CF/LF of space between tubing and casing
19 C+T (liner)
20 C+T (casing)
21 liner top
22 volume of fluid (includes oil) in hole plus H2O AHEAD
23 unused
24 scratch
25 top of cement
26 top of water fluid and H2O AHEAD (after cementing)
27 top of H2O AHEAD
28 FT OF OIL
29 OIL API
30 volume of oil,CF
31 ft. of oil (after cementing)
32 specific gravity of oil
33 equivalent ft. of H2O needed to displace the oil
34 volume of H2O needed to displace the oil
35 top of oil (after cementing)

APPENDIX D
Equations

Equation 1: Equalization point formula.

$$h = \frac{N}{C+T}$$

N = cubic feet of cement slurry used

h = height of balanced cement column

C = cubic feet per linear foot of space between tubing (or drill pipe) and casing (or hole)

T = cubic feet per linear foot inside tubing, drill pipe, or casing*

*See *Selected References,* Suman and Ellis.

Equation 2: Rate formula.

$$\text{FACTOR} = \frac{86400}{5.6146} \times T$$

then

$$\text{RATE (bbl/day)} = \text{FACTOR} \times \frac{d}{t}$$

or

Equation 3: Rate formula.

$$\text{RATE (bbl/day)} = 106.86424 \times A \times V$$

or

Equation 4: Rate formula.

$$\text{RATE (bbl/day)} = 106.86424 \times A \times \frac{d}{t}$$

A = Cross-sectional area (inside diameter) of tubing, casing, or drill pipe in square inches.
d = Distance tool lowered.
V = Velocity of fluid, in feet per second.
T = Cubic feet per linear foot inside tubing, drill pipe, or casing.
t = Time in seconds.

PROGRAM LISTING

PIPE

```
 01♦LBL "PIPE"
FIX 4  FS? 00  XEQ 01
FC? 00  XEQ 02  FS? 01
XEQ 03  FS? 00  XEQ 04
FC?C 00  XEQ 05  FS?C 01
XEQ 06  RCL 06  X↑2
.00545415  *  STO 08
RCL 07  494.2  /  RCL 08
-  CHS  "CF/LF="  ARCL X
AVIEW  RTN

 30♦LBL 01
"TBG DIA=?"  PROMPT
STO 06  RTN

 35♦LBL 02
FS? 01  RTN  "CSG DIA=?"
PROMPT  STO 06  RTN

 42♦LBL 03
"LNR DIA=?"  PROMPT
STO 06  RTN

 47♦LBL 04
"TBG WT=?"  PROMPT
STO 07  RTN

 52♦LBL 05
FS? 01  RTN  "CSG WT=?"
PROMPT  STO 07  RTN

 59♦LBL 06
"LNR WT=?"  PROMPT
STO 07  RTN  END
```

DROP

```
 01♦LBL "DROP"
SF 00  XEQ "PIPE"
STO 01  "TOOL"  7
XROM "Y/N?"  FS? 07
XEQ 02  RCL 01
15388.4515  *  STO 02
FIX 0  CLA  ARCL X
"⊢=FTR"  AVIEW  PSE
XEQ 01

 21♦LBL 01
0  STO 05  "FT DROP=?"
PROMPT  STO 03  0
"TIME-SEC=?"  PROMPT
STO 04  X=0?  XEQ 07
RCL 03  X=0?  XEQ 07
RCL 05  X=0?  XEQ 05
RCL 03  X=0?  XEQ 03
RCL 04  X=0?  XEQ 04

 45♦LBL 02
CF 07  "TOOL DIA=?"
PROMPT  X↑2  .00545415
*  RCL 01  -  ABS
STO 01  RTN

 57♦LBL 03
SF 03  RCL 05  RCL 04  *
RCL 02  /  XEQ 06

 65♦LBL 04
SF 04  RCL 03  RCL 05  /
RCL 02  *  XEQ 06

 73♦LBL 05
SF 02  RCL 03  RCL 04  /
RCL 02  *  XEQ 06

 81♦LBL 06
CF 00  CLA  ARCL X
FS?C 03  "⊢ FT"  FS?C 04
"⊢ SEC"  FS?C 02
"⊢ BBL/DY"  AVIEW  STOP
XEQ 01

 94♦LBL 07
"BBL/DY=?"  PROMPT
STO 05  RTN  END
```

BAL

```
 01♦LBL "BAL"
0  X<>F  "BALANCE PLUG"
36  XROM "TITLE"
FC?C 25  PROMPT  00.035
CLRGX  08  STO 00
"CF CEM"  XROM "IN"
"H2O AHEAD"  XROM "IN"
"TBG TAIL"  XROM "IN"
SF 00  XEQ "PIPE"
STO 12  RCL 08  STO 13
"LNR"  1  XROM "Y/N?"
FS? 01  XEQ 01
XEQ "PIPE"  STO 14
RCL 13  -  STO 18
RCL 12  +  STO 20
"LO FLD"  3  XROM "Y/N?"
FS? 03  XEQ 02  FC? 02
XEQ 03  RCL 16  RCL 21
X<=Y?  XEQ 04  RCL 16
RCL 21  X>Y?  XEQ 05
RCL 11  RCL 21  -
RCL 19  *  RCL 09  X<>Y
-  X>0?  STO 24  X<=0?
XEQ 07  RCL 24  X>0?
XEQ 06

 67♦LBL 01
SF 02  XEQ "PIPE"
STO 15  "LNR TOP=?"
PROMPT  STO 21  RCL 15
RCL 13  -  STO 17
RCL 12  +  STO 19  RTN

 82♦LBL 02
"FLD LEVEL=?"  PROMPT
STO 16  "OIL"  4
XROM "Y/N?"  FS? 04
XEQ 15  RTN

 92♦LBL 03
RCL 09  RCL 20  /  CHS
RCL 11  +  STO 25
RCL 10  RCL 18  /  CHS
RCL 25  +  STO 27
FC? 03  XEQ 12  RCL 11
RCL 16  -  RCL 14  *
RCL 18  /  STO 06  CHS
RCL 27  +  STO 26
FC? 02  XEQ 21  XEQ 12

124♦LBL 04
RCL 11  RCL 16  -
RCL 15  *  RCL 10  +
STO 22  RTN
```

```
134♦LBL 05
RCL 11  RCL 21  -
RCL 15  *  STO 06
RCL 21  RCL 16  -
RCL 14  *  RCL 06  +
RCL 10  +  STO 22  RTN

152♦LBL 06
RCL 24  RCL 20  /  CHS
RCL 21  +  STO 25
RCL 22  RCL 18  /  CHS
RCL 25  +  STO 26
RCL 10  RCL 18  /  CHS
RCL 25  +  STO 27
RCL 26  X<0?  XEQ 32
FS? 04  XEQ 20  XEQ 12

180♦LBL 07
RCL 09  RCL 19  /  CHS
RCL 11  +  STO 25
RCL 21  -  RCL 17  *
CHS  RCL 10  +  STO 06
X>0?  XEQ 08  X<=0?
XEQ 09  RTN

201♦LBL 08
RCL 06  RCL 18  /  CHS
RCL 21  +  STO 27
FC? 03  XEQ 12  RCL 22
RCL 10  -  STO 07
RCL 18  /  CHS  RCL 27
+  STO 26  X<0?  XEQ 32
FS? 04  XEQ 20  XEQ 12
RTN

227♦LBL 09
RCL 10  RCL 17  /  CHS
RCL 25  +  STO 27
FC? 03  XEQ 12  RCL 21
-  STO 07  RCL 17  *
STO 06  RCL 22  RCL 10
-  RCL 06  -  STO 08
X>0?  XEQ 10  RCL 08
X<=0?  XEQ 11  RTN

255♦LBL 10
RCL 08  RCL 18  /  CHS
RCL 21  +  STO 26  X<0?
XEQ 32  FS? 04  XEQ 20
XEQ 12  RTN

269♦LBL 11
RCL 22  RCL 17  /  CHS
RCL 25  +  STO 26
FS? 04  XEQ 20  XEQ 12
RTN

281♦LBL 12
SF 00  RCL 25  RCL 27  -
RCL 12  *  FIX 1  CLA
ARCL X  "⊢=H20 BHD"
AVIEW  STOP  FS?C 03
XEQ 13  RCL 27  RCL 12
*  XEQ 14

300♦LBL 13
FS? 04  XEQ 17  RCL 27
RCL 26  -  RCL 33  +
RCL 12  *  XEQ 14

311♦LBL 14
CF 00  CF 02  CF 04
FIX 1  CLA  ARCL X
"⊢=CF DSP"  AVIEW  FIX 4
STOP

322♦LBL 15
27  STO 00  "FT OF OIL"
XROM "IN"  "OIL-API"
XROM "IN"  RCL 29
"API-SPGR"  CON  STO 32
RTN

334♦LBL 22
RCL 16  RCL 28  +
STO 16  RTN

340♦LBL 16
RCL 30  RCL 17  /
STO 31  RCL 32  *
STO 33  RCL 12  *
STO 34  XEQ 12

352♦LBL 17
RCL 26  RCL 21  X<=Y?
RTN  RCL 30  RCL 18  /
STO 31  RCL 32  *
STO 33  RCL 12  *
STO 34  FS? 00  RTN
XEQ 12  RTN

371♦LBL 28
RCL 30  RCL 18  /
RCL 32  *  STO 33
RCL 12  *  STO 34
RCL 26  X=0?  STO 35
X<0?  XEQ 32  RCL 30
RCL 18  /  STO 31  X>0?
XEQ 36  XEQ 12

393♦LBL 18
RCL 26  RCL 21  -
RCL 17  *  RCL 30  -
CHS  RCL 18  /  CHS
RCL 21  +  RCL 26  X<>Y
-  STO 31  RCL 32  *
STO 33  RCL 12  *
STO 34  CF 04  XEQ 12

419♦LBL 19
RCL 08  RCL 34  +  RTN

424♦LBL 20
XEQ 22  RCL 16  RCL 28
-  STO 07  FC? 02
XEQ 21  RCL 21  RCL 16
X<=Y?  XEQ 21  RCL 07
RCL 21  X<=Y?  XEQ 23
XEQ 24  RTN

442♦LBL 21
RCL 28  RCL 14  *
STO 30  RCL 26  X<0?
XEQ 35  FC? 02  XEQ 28
FS? 04  XEQ 25  XEQ 17

455♦LBL 23
RCL 28  RCL 15  *
STO 30  XEQ 25

461♦LBL 24
RCL 07  RCL 21  -  CHS
RCL 14  *  STO 06
RCL 16  RCL 21  -
RCL 15  *  RCL 06  +
STO 30  XEQ 25

478♦LBL 25
RCL 26  X<0?  XEQ 33
STO 35  RCL 21  RCL 26
-  X>0?  XEQ 26  XEQ 27

489♦LBL 29
RCL 21  RCL 26  -  X>0?
XEQ 17  CHS  RCL 17  *
RCL 30  X<>Y  X<=Y?
XEQ 18  XEQ 16

503♦LBL 26
RCL 21  RCL 35  -
RCL 18  *  STO 08
RCL 30  X>Y?  XEQ 30
XEQ 31

514♦LBL 30
RCL 30  RCL 08  -
RCL 17  /  RCL 21  +
STO 26  XEQ 29

524♦LBL 31
RCL 30  RCL 18  /
RCL 35  +  STO 26
XEQ 29

532♦LBL 27
RCL 30  RCL 17  /
RCL 35  +  STO 26
XEQ 29

540♦LBL 32
FC? 02  RTN  FC? 02
XEQ 33  FS? 04  RTN  0
STO 26  RTN

550♦LBL 33
RCL 26  RCL 18  *
RCL 30  +  STO 30  X<=0?
XEQ 34  0  STO 35
FC? 02  XEQ 28  RTN

564♦LBL 34
0  STO 26  STO 30
FC? 02  RTN  XEQ 26

571♦LBL 35
FS? 02  RTN  XEQ 33  RTN

576♦LBL 36
RCL 26  STO 35  RCL 31
+  STO 26  RTN  END
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