★ OILWELL 1

DRILLING CALCULATIONS MANUAL

DALY DRILLING ENTERPRISES LIMITED

★OILWELL 1

NOTICE

The programme material and information associated with the ★OILWELL 1 package is supplied without representation or warranty of any kind. DALY DRILLING ENTERPRISES LTD. therefore assumes no responsibility and shall have no liability, consequential or otherwise, of any kind arising from the use of the ★OILWELL 1 Module, associated literature or any part thereof.

August, 1984 .B. Printed in Scotland.

CATALOGUE FUNCTION GROUPS

GROUP 1 "1"; "3"; "7"; "8"; "9"; "10"; "11"; "12"; "13".
GROUP 2 "DOP0"; "DOP1"; "DOP2"; "DOP3"; "DOP4"; "DOP5"; "DOP6"; "DOP7"; "PRES"; "ADJD"; "NOZA".
GROUP 3 "MSTA"; "MSTB"
GROUP 4 "MST0"; "MST1"; "MST2"; "MSTF"; "AIPT"; "NIPT"; "UNIT"; "★FC"
GROUP 5 X< >F; REGMOVE; REGSWAP; PSIZE
GROUP 6 "A"; "B"; "C"; "D"; "E"; "F".

TABLES & FLOW DIAGRAMS

USING THE ★OILWELL 1 MANUAL

The User should first familiarise her or himself with the **OPERATING INSTRUCTIONS, UNITS SELECTION and GENERAL NOTES** Sections of the Manual. Both sides of the **OPERATING INSTRUCTIONS Card** supplied with the Manual also have useful step-by-step procedures for operation of the Module.

It will then be helpful to read through the section headed **CODES Description**. This gives details as to the operation of each of the **CODED Functions** that can be executed with the ★OILWELL 1 Module. This should give the User a sound idea of the main operations that the Module can perform.

The User should now be in a position to start to use the Module. The Manual is set up to follow the **sequence** of User operation. After selecting the **CODED Function** required the Code Number of that Function is entered and the **MASTER PROGRAMME, 'MSTA'** executed. This will establish the necessary Status of the computer after which the User will be **prompted** for the required Inputs for the Function selected. The section headed **PROMPTS** follows the **CODES Description** section and alphabetically lists all the **Prompts** that are used by the Module. The User can easily look up the exact meaning of any **Prompt** that the Module uses and confirm the **Units**, in relation to a given **PARAMETER**, in which Input in response to it must be made. Though most of the **Prompts** should be self explanatory some will initially appear obscure.

Following input in response to **all** the **Prompts** the Module will perform the necessary calculations and Output the relevant data. Explanations of **HEADINGS** and **DATA LABELS** used with **Data Output** follow the section on **PROMPTS** in the Manual. Again the listings are alphabetical to help in rapidly locating a given meaning.

At the back of the Manual is a section giving details as to how the User may put Module programme routines to use in **Personal Applications.** This section requires that the User is reasonably familiar with programming of the HP 41. It contains details of routines that will have General Application and which will also allow the User comprehensive access to the **WELL GEOMETRY DATA files** created by the Module. Utilization of these routines will greatly enhance the potential of the ★OILWELL 1 Module as a Drilling and Programming aid.

THE ★OILWELL 1 MODULE

The 8 kilobyte ★OILWELL 1 module is designed as a powerful work horse for Drilling personnel to be able to effortlessly obtain the results of some of those calculations that are so important to the success and safety of their operations.

It is recognised that people generally like to know the basis of the computing software they use and for this reason a listing of the most important equations used is given. However it is not the intention of this manual to go deeply into the inner workings of the programmes that comprise the Module. However this revised edition of the manual does describe the use of individual module routines.

The minimum system required for use of the ★OILWELL 1 Module is the HP 41C plus two memory modules. The Module is designed, however, to utilise a number of HP 41 accessories and if these are present in the system Module operation is greatly enhanced.

The Card Reader and Printer are such accessories and are recommended if the Module is to be used to its full capacity.

The continuous memory capability of the HP 41 computers means that once data is loaded then, barring a "MEMORY LOST" situation or physical modification of data register contents, the ★MDATA & ★WDATA with which the Module works will remain accessible to the module at all times.

The module incorporates a powerful, logical and practical units handling routine. The aim of it is to allow the User to select the units that are to be used for normal input/output operations. Once such selection has taken place the Module will assume that all inputs are made in those units and will output all data in the same units. The selection will remain in effect until a new selection is made, assuming no data modification by the User to the contents of registers 46-136 has taken place.

The operation of the Module is designed to allow the User to retain for personal use as many as possible of the computers own facilities. In this way the User may 'maintain personal key assignments and may run personal programmes, providing always that sufficient memory is available, while still retaining ready accessbility to the Module programmes. Use of the data memory facility of the 'X-FUNCTIONS MODULE' enhances this ability by allowing the User to utilise all computer memory in personal applications.
NOTE: In General Calculations Mode use is made of the Local Label Keys. If any of these keys have been re-assigned by the User then this assignment will take preference to the key's use as a Local Label Key. To use any such re-assigned keys for use in General Calculations Mode the re-assignment must be cleared.

The Module is very straightforward to use but at the same time is powerful. The User is encouraged to experiment with the Module, as much of its potential is not fully supported in this manual

The text tries to cover most aspects of the ★OILWELL 1 Module operation and as a result, may seem lengthy and in some cases complicated. The Module is however easy to use and once the meanings of Prompts and Data Labels are understood, should be fully operational using only the plastic encapsulated reference card.

Notes

INSERTING AND REMOVING APPLICATION MODULES

Before you insert an Application Module for the first time, familiarise yourself with the following information.

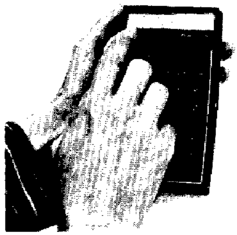
Up to four Application Modules can be plugged into the ports on the HP 41. While plugged in, the names of all programmes contained in the Module can be displayed by pressing 'SHIFT' CATALOG 2.

CAUTION

Always turn the HP 41 off before inserting or removing any plug-in extension or accessories. Failure to turn the HP 41 off could damage both the calculator and the accessory.

To insert Application Modules:

1 Turn the HP 41 off! Failure to turn the calculator off could damage both the Module and the calculator.



2 Remove the port covers. Remember to save the port covers; they should be inserted into the empty ports when no extensions are inserted.

3 Insert the Application Module with the label facing downward as shown, into any port **after** the last Memory Module. For example, if you have a Memory Module inserted in port 1, you can insert an Application Module in any of ports 2, 3 or 4. (The port numbers are shown on the back of the calculator). **Never insert an Application Module into a lower numbered port than a Memory Module.**

4 If you have additional Application Modules to insert, plug them into any port after the last Memory Module. Be sure to place port covers over unused ports.

5 Turn the calculator on and follow the instructions given in this manual for the desired application functions.

To remove Application Modules:

1 Turn the HP 41 off! Failure to do so could damage both the calculator and the Module.

2 Grasp the desired Module handle and pull it out as shown.

3 Place a port cap into the empty ports.

Mixing Memory Modules and Application Modules

Any optional accessories (such as the HP 82104A Card Reader or the HP 82153A Wand) should be treated in the same manner as Application Modules. That is, they can be plugged into any port after the last Memory Module. Also, the HP 41 should be turned off prior to insertion or removal of these extensions.

The HP 41 allows you to leave gaps in the port sequence when mixing Memory and Application Modules. For example, you can plug a Memory Module into port 1 and an Application Module into port 4, leaving ports 2 and 3 empty.

START UP OPERATIONS
(See also the quick Reference Instruction Card supplied)

1. Load module as described in text. (See pages 1.01 – 1.02)
2. Plug in required accessories as per accessory instructions.
3. Turn on accessories followed by the HP 41.
4. With the HP 41 in normal mode, ie 'USER' off, assign the module's Master Programme, 'MSTA', to the required 'USER' key.

NOTE: This manual assumes that this assignment is made to the 'XEQ' key. This is arbitrary and the User may select any key normally available for key assignments. The use of the Local Label Keys a through e and A through J should be avoided.

KEY ASSIGNMENT is made as follows:

a. Press yellow 'SHIFT' key followed by 'ASN' key.
b. Press 'ALPHA' key.
c. Key in the letters 'M','S','T','A'.
d. Press 'ALPHA' key.
e. Press 'XEQ' key (or User's own chosen key).

The Master Programme, 'MSTA,' is now assigned to the 'XEQ' key.

5. Clear all HP 41 data registers. This may be done in two ways:
   a. 'XEQ'; 'ALPHA'; 'CLRG'; 'ALPHA'.
   b. 'XEQ'; 'ALPHA'; 'S','I','Z','E'; 'ALPHA'; 000.
6. Input 0.0 from the keyboard, select **User** mode and press the 'XEQ' key. If the Card Reader is present the prompt "★MDATA CARD" will be displayed.
7. Load the 4 sides of the two Master Data cards. If the Card Reader is NOT present "NONEXISTENT" will be displayed. If a Card Reader is not available then Master Data input will need to be made manually **exactly** as per the data list given (See section: "SELECTION OF ★MDATA CARD OPTIONS" Pages 2.04 – 2.05).

The ★OILWELL 1 module is now ready for use. At this stage, the User may make her or his **Selection of the Units** that it is desired to use for **Data Input and Output**. This is achieved by operation of one of the Codes 0.4; 0.5 or 0.6.
(See section: "UNITS SELECTION" for details Pages 2.01 – 2.05).

Note, however, that certain Function Codes require the presence of WELL GEOMETRY DATA, ★WDATA. If use of such Code operations is to be made then:

Either
– A set of Rheology Data using a Code 13 routine and a set of Well Geometry Data using Code 9.2 must now be input.
Or
– Previously recorded ★WDATA must be loaded into computer memory using Function Codes 0.2 or 0.3

PROMPT OPERATIONS

Prompts are basically of two types, these are:

1. **NUMERIC PROMPTS**
   The HP 41 will be in normal 'NUMERIC' mode and the prompt will be followed in the display with "?=".
   Enter the INPUT response to the prompt then press R/S to restart the programme.
2. **ALPHA PROMPTS**
   The HP 41 will be in normal 'ALPHA' mode and the prompt will be followed in the display with "?".
   Most alpha prompts require a 'Y' or 'N' (yes or no) response (R/S key default is 'Y'). If another response is required then the prompt options will be given in the display e.g. Code 7.2 prompts "B/L/O?" for the User to choose from **B**aryte/**L**ow Gravity Solids/**O**ther options. Input should be **'B', 'L' or 'O'.**
   Follow response to the prompt with operation of the R/S key.

NOTE: When programme operation is halted for a prompt input, the keyboard may be used to perform normal H.P. functions including stack operations. **NO** programme operations, however, should be performed and operation of the R/S key will restart the running of the active programme.

IMPORTANT When operating without the printer the keyboard **MUST NOT** be used when **stepping through data outputs** using the R/S key.

AUDIBLE TONE MEANINGS

1. Short high pitch beep	:	input expected in response to prompt.
2. Short musical output (standard HP 'beep')	:	operating or input error has occured.
3. Short low pitch buzz	:	end of routine indication for Code 12 operation.
4. Long high pitch beep	:	normal end of routine indication.

USE OF FUNCTION CODES

Operation of the module is based on the use of CODE NUMBERS that correspond to various FUNCTIONS as set out in the ★OILWELL 1 USER CODES table.

After initial set up of the HP 41 as described above in 'Start Up Operations' Module programmes are accessed as follows:

1. Select the required FUNCTION to be executed.
2. Enter the corresponding CODE NUMBER of that FUNCTION into the HP 41's 'X' register.
3. Select 'USER' MODE.
4. Execute the 'MSTA' key assignment – the 'XEQ' key in the case of manual examples.

The Master Programme will then start running and:

a. Size computer Memory to give 151 Data registers.
b. Check that ★MDATA is present.
c. Set flags as appropriate for module operation and set current User selected UNITS CONTROL FLAGS. ("User" Mode is also turned off at this stage).
d. Check that ★WDATA is present (if appropriate to Code input).
e. If appropriate, prompt with the display 'RHEO OK?' to ask the User if the current MUD RHEOLOGY is satisfactory.

f. Cause branching to the programme appropriate to the input CODE.

g. The programme will then run, prompting and outputing as appropriate.

h. On completion of the programme, operation returns to the Master Programme, flags are reset and the DISPLAY will show an operation status message – generally 'O.K.'.

i. At this stage the HP 41 will be in NORMAL MODE and operation of the R/S key will not cause programme branching.

OPERATING WITHOUT THE PRINTER

To allow the User time to record results from a programme run, the Module is set up to halt operation each time an output is obtained. It is therefore necessary to effectively 'step' through programme outputs when the Printer is NOT attached.

Thus each time programme execution is halted (a) note the informmation displayed and (b) press the R/S key. With labelled outputs execution will generally halt both at the label and at the data. The User should CONTINUE with R/S key operation until the FINAL DISPLAY is 'OK' or repeats itself. During this stepping procedure **NO** KEYBOARD OPERATIONS should be made other than the R/S key.

In some cases the amount of displayed information is suppressed slightly as compared with data obtained using the Printer, for example Code 12 operations.

OPERATING WITH THE PRINTER

The printer should be set with the mode switch at **MANUAL**. If this is not the case then data formatting will be affected.

With the printer attached all programmes run to completion after input has been made to the final input prompt.

If operating with the HP-IL printer then the printer should always be switched on prior to the computer.

If HP-IL equipment is in use and is switched to STANDBY MODE, POWERUP and POWERDOWN will function at the start and finish of operations respectively.

NOTE: If a Card Reader is available it is recommended that the User makes a copy of the Master Data Cards (★MDATA). This can be done by loading the Master Data using a Code 0.0 operation and then proceeding as follows:

1 Enter 46.099 into X-REGISTER
2 Press: 'XEQ'; 'ALPHA'; 'W', 'D', 'T', 'A', 'X'; 'ALPHA'
3 Record the data onto magnetic cards as prompted. Note: If the cards have been clipped then Flag 14 will need to be SET prior to step 2. (A copy may also be stored on cassette – see the HP-IL manual mass storage section for details of creating and using a data file).

★OILWELL 1 USER CODES

CODE NO:		FUNCTION
0.0		LOAD MASTER DATA CARD
0.1		LOAD MASTER DATA
0.2		LOAD WELL GEO. DATA CARD
0.3		LOAD WELL GEO. DATA
0.4		SELECT ENGLISH UNITS
0.5		SELECT ALTERNATIVE UNITS
0.6		USER SELECT UNITS
0.7		OUTPUT CURRENT UNITS
0.8		X-MEMORY DATA STORAGE
1.0	•	ALL HOLE, PIPE & ANNULUS DATA
1.1	•	ALL HOLE DATA
1.2	•	ALL PIPE DATA
1.3	•	ALL ANNULUS DATA
1.4	•	HOLE PIPE & ANNULUS Σ DATA
1.5	•	HOLE Σ DATA
1.6	•	PIPE Σ DATA
1.7	•	ANNULUS Σ DATA
1.8	•	ALL ANN. DATA FROM CALC-D
1.9	•	ANN. Σ DATA FROM CALC-D
3.0	•	ALL PIPE & ANN. DATA + PRES
3.1	•	ALL PIPE DATA + PRES
3.2	•	ALL ANN. DATA + PRES
3.3	•	PIPE & ANN. Σ DATA + Σ PRES
3.4	•	PIPE Σ DATA + Σ PRES
3.5	•	ANN. Σ DATA + Σ PRES
3.6	•	AS 1.8 + PRES
3.7	•	AS 1.9 + Σ PRES
3.8	•	USER CALCULATIONS
3.9	•	SURGE-SWAB CALCULATIONS

OPERATION

1. Enter CODE NUMBER.
2. Select USER MODE.
3. Execute 'MSTA' KEY ASSIGNMENT.

•	UTILISES WELL GEOMETRY DATA
Φ	DEPENDENT ON OPERATION 11.0

CODE NO:		FUNCTION		
7.0		GAS CUT MUD	STRONG - WHITE EQUATION	
7.1		LEAK OFF TEST		
7.2		Effect of mud additive additions on mud wt.	ADD SOLID	→ Volume & Wt. Solid
7.3			ADD SOLID	→ Resulting Mud Wt.
7.4			ADD LIQUID	→ Volume & Wt. Liquid
7.5			ADD LIQUID	→ Resulting Mud Wt.
8.0	•	WORK DONE - ROUND TRIP		
8.1	•	WORK DONE - WIPER TRIP		
8.2	•	WORK DONE - CASING		
8.3	•	WORK DONE - DRILL-CORE-REAM		
8.4		WORK DONE - STACK		
9.0	•	CHANGE WELL GEOMETRY DATA		
9.1	•	INPUT NEW SET OF PIPE DATA		
9.2	★	INPUT WELL GEOMETRY DATA		
10.0		CRITICAL ROTARY SPEEDS		
10.1		PIPE STRETCH		
10.2		STUCK PIPE - FREE POINT		
10.3		TENSILE & TORSIONAL DATA		
10.4		TORSION UNDER TENSION		
10.5		CALC. O.D. FROM I.D. & WT.		
10.5		CALC. WT. FROM I.D. & O.D.		
10.5		CALC. I.D. FROM O.D. & WT.		
10.6		CALC. X-SECTIONAL AREA		
11.0		BIT HYDRAULICS OPTIMISATION		
11.1	Φ	CHG. MAX. PRES. & NO. NEW NOZ.		
11.2	Φ	ACTUAL HYDRAULICS		
11.3	Φ	INPUT SPECIFIC FLOW RATE		
11.4	Φ	INPUT NEW 'Q'-RATE/PRES DATA		
12		GENERAL CALCULATIONS		
13.0		RHEOLOGY FROM FANN DATA		
13.1		INPUT RHEOLOGY & MUD WT.		
13.2		OUTPUT RHEOLOGY & MUD WT.		
13.3		INPUT P.V., Y.P. & MUD WT.		
13.4		LIFTING CAPACITY OF MUD		

The Units Control System used by the ★OILWELL 1 Module is designed specifically for Drilling Applications in that it can handle the very mixed system of units that exists in the Oilfield.

Internally the Module operates in English Units, but the User has the option of selecting an ALTERNATIVE set of units in which entry and output of data is to be made.

The basis of the system is that the User sets up a required normal set of units that will be used by the Module. Once that selection has been made all subsequent entries and outputs will be according to this required selection. This means that it is not necessary to label inputs and outputs – they will always be in the in the selected units.

To achieve this aim, units are handled in relation to a specified parameter. The Module supports **6 BASIC PARAMETERS,** these, together with their internal operating units, are:

(1)	LENGTH	FEET (Ft)
(2)	DIAMETER	INCHES (ins)
(3)	VOLUME	BARRELS (U.S.) (BBL)
(4)	MUD WEIGHT	POUNDS PER GALLON (p.p.g.)
(5)	PRESSURE	POUNDS PER SQUARE INCH (p.s.i.)
(6)	WEIGHT	POUNDS FORCE (LBf)

For **each** of these parameters it is possible to specify an alternative unit in which input and output are to be made. The User is able to choose **any** one appropriate unit that is to be the alternative. The "★MDATA CARD" supplied with the module is set up to give the alternative unit for each parameter in metric units, that is:

(1)	LENGTH	METERS (M)
(2)	DIAMETER	MILLIMETERS (mm)
(3)	VOLUME	CUBIC METERS (C.MTR)
(4)	MUD WEIGHT	SPECIFIC GRAVITY (S.G.)
(5)	PRESSURE	BARS (BAR)
(6)	WEIGHT	Deca. NEWTONS (Da.n)

The User may prepare his own "MASTER DATA CARD" by changing the conversion factors and units labels in the appropriate registers. Some alternative Master Data Card options are given in the section "SELECTION OF ★MDATA CARD OPTIONS" (Pages 2.04 – 2.05).

Registers 55-60 contain the necessary conversion factor for each parameter. The conversion factor is the constant by which the standard English unit value for the parameter must be multiplied to obtain its ALTERNATIVE unit value.

Conversion factor register allocation is as follows:

R.55 – LENGTH; R.56 – DIAMETER; R.57 – VOLUME; R.58 – MUD WEIGHT; R.59 – PRESSURE; R.60 – WEIGHT.

It is important when creating a ★MDATA CARD that data entries are made exactly as the listings given and that conversion factors are correct.

EXAMPLE OF ★MDATA CARD MODIFICATION

A User wishes Mud Weight to be input/output in Pounds per Sq. Inch/FT. To do this the ALTERNATIVE unit for Mud Weight must be changed from Specific Gravity to Pounds per Sq. Inch/FT.

With the computer in Normal mode, proceed as follows:

(1) With ★MDATA in HP 41 memory, change the Alpha Data stored in R.86 to "PSI/FT" (6 characters maximum) in the following manner:
  - (a) Press 'ALPHA' (Alpha Mode on).
  - (b) Input 'P';'S';'I';'SHIFT"/';'F'; & 'T'. (The Yellow Key is the 'SHIFT' key).
  - (c) Press 'SHIFT' 'STO'86 (ASTO86)
  - (d) Press 'ALPHA' (Alpha mode off).

(2) Change the Mud Weight conversion factor in R.58 to 5.194805195E-2 (0.05194805195 x p.p.g. = p.s.i./Ft.)
  - (a) Input the conversion factor
  - (b) Press 'STO'58

(3) Record the modified ★MDATA on magnetic card (assuming that the Card Reader is in the system) as follows:
  - (a) Input 46.099 (data registers)
  - (b) Press 'XEQ'; 'ALPHA'
  - (c) Input 'W';'D';'T';'A';'X' (write data to card from R.46-99)
  - (d) Press 'ALPHA'
  - (e) Record data on two data cards as prompted for in the display.

The User has available two units possibilities for EACH Parameter. These are the operating ENGLISH unit and the ALTERNATIVE unit. The current selection is dictated by the status of the PARAMETER DEDICATED CONTROL FLAG. If it is **clear** then the ENGLISH Unit is in effect, if it is **set** the ALTERNATIVE unit.

The DEDICATED CONTROL FLAGS are:

PARAMETER	**FLAG**
(1) LENGTH	00
(2) DIAMETER	01
(3) VOLUME	02
(4) MUD WEIGHT	03
(5) PRESSURE	04
(6) WEIGHT	04

If a PARAMETER DEDICATED CONTROL FLAG is SET then its number will be displayed at the bottom of the HP 41 display panel during module programme operation. This serves as a useful indicator to the User as to the current units status. The units control flag settings are maintained in HP 41 memory in register R.101 and the module will always place the HP 41 in the current units control mode, as previously selected by the User, regardless of the state of the control flags at the time of executing a function code (Code 0.6 is the exception to this rule).

Selection of units is made using function Codes 0.4; 0.5; and 0.6· The operation of these codes is discussed fully in the section: "CODES DESCRIPTION". Basically, however, the User may use these codes to:

- (a) Select the complete ENGLISH INTERNAL units set (0.4)
- (b) Select the Current ALTERNATIVE units set (0.5)
- (c) Select any combination of the two units sets (0.6)

Option (c) is a powerful and useful capability of the Module, since, by simple SETTING of the DEDICATED UNITS CONTROL FLAGS for those parameters that it is required to have the ALTERNATIVE units ACTIVE and having the others CLEAR **PRIOR** to a Code 0.6 function execution, the User may easily have access to mixed units ability.

Flags are SET by:	Pressing 'SHIFT' 'SF' FLAG NUMBER
Flags are CLEARED by:	Pressing 'SHIFT' 'CF' FLAG NUMBER

The Units Selection may be changed at any time and such a change will NOT affect the WELL GEOMETRY as stored previously.

The Modules Unit Control System is logical in its approach to data outputs involving PARAMETERS with COMBINED UNITS e.g. a CAPACITY output involving VOLUME/unit LENGTH will be dependant on the current units selection for the parameters VOLUME and LENGTH i.e. if LENGTH is in METERS and VOLUME is in BARRELS, the CAPACITY will be BARRELS per METER.

FLAG 04 OPERATIONS

Units control flag 04 is a special case flag in that it additionally determines the units of some specific input/output parameters of combined units status. Flag 04 units determinations are ALSO dependant on the value of the conversion factor in the pressure dedicated register R.59. If this value is UNITY i.e. the alternative units of pressure are P.S.I. then, **even** if flag 04 is set, the dependant parameters' units will still be in the modules standard English units. If however the contents of R.59 are **not** Unity, then regardless of whether the Pressure Conversion factor converts to metric units, the combined units dependant parameters will be in **metric** units.

Parameters that are dependant on Flag 04 AND the content of R.59 are:

(1) The Power Law Constant in Mud Rheology . . . 'K'
(2) The Power Law Constant in Bit Hydraulics Optimisations . . . 'a'
(3) Yield Point . . . YP
(4) Hydraulic Power . . . 'PWR'

Their English/Metric Units are:

(1) K (n = Power Law Index)

English: Pounds Force-Seconds^n/100 Feet^2 . . . LBf-Sec^n/100 Ft^2

Metric: Pascals-Seconds^n . . . Pa-Sec^n

(2) a (b = Power Law Index)

English: Pounds Force per Sq.Inch Minutes^{-b}/BBl^b . . . PSI-Min^{-b}/BBl^b

Metric: Bars-Minutes^{-b}/Cu.Mtr^b . . . Bars-Min ^{b}/Cu.M^b.

(3) YP

English: Pounds Force/100 Feet^2 . . . LBf/100Ft^2
Metric: Pascales . . . Pa

(4) **PWR**
English: Horse Power . . . H.P.
Metric: Kilowatts . . .kW.

*MDATA - A	*MDATA - B	*MDATA - C
R46= 0.000000000+00	R46= 0.000000000+00	R46= 0.000000000+00
R47= 0.000000000+00	R47= 0.000000000+00	R47= 0.000000000+00
R48= "NOZ."	R48= "NOZ."	R48= "NOZ."
R49= "RIGHT"	R49= "RIGHT"	R49= "RIGHT"
R50= 7.669903940-04	R50= 7.669903940-04	R50= 7.669903940-04
R51= 7.456998700-01	R51= 7.456998700-01	R51= 7.456998700-01
R52= 2.450408401-02	R52= 2.450408401-02	R52= 2.450408401-02
R53= 6.544438248+01	R53= 6.544438248+01	R53= 6.544438248+01
R54= 1.612800000-01	R54= 1.612800000-01	R54= 1.612800000-01
R55= 3.048000000-01	R55= 3.048000000-01	R55= 3.048000000-01
R56= 2.540000000+01	R56= 2.540000000+01	R56= 2.540000000+01
R57= 1.589872949-01	► R57= 4.200000000+01 ◄	► R57= 4.200000000+01 ◄
R58= 1.198264274-01	► R58= 7.480519478+00 ◄	► R58= 5.194805195-02 ◄
R59= 6.894757293-02	R59= 6.894757293-02	R59= 6.894757293-02
R60= 4.448221615-01	R60= 4.448221615-01	R60= 4.448221615-01
R61= 9.714263000-04	R61= 9.714263000-04	R61= 9.714263000-04
R62= "O.D"	R62= "O.D"	R62= "O.D"
R63= "ID.(P)"	R63= "ID.(P)"	R63= "ID.(P)"
R64= "ID.(C)"	R64= "ID.(C)"	R64= "ID.(C)"
R65= "CAP"	R65= "CAP"	R65= "CAP"
R66= "VOL"	R66= "VOL"	R66= "VOL"
R67= "VEL"	R67= "VEL"	R67= "VEL"
R68= "DISP"	R68= "DISP"	R68= "DISP"
R69= "VOL.D"	R69= "VOL.D"	R69= "VOL.D"
R70= "VN/SEC"	R70= "VN/SEC"	R70= "VN/SEC"
R71= "WT/U.L"	R71= "WT/U.L"	R71= "WT/U.L"
R72= "Q RATE"	R72= "Q RATE"	R72= "Q RATE"
R73= 0.000000000+00	R73= 0.000000000+00	R73= 0.000000000+00
R74= "P/GRD="	R74= "P/GRD="	R74= "P/GRD="
R75= "LENGTH"	R75= "LENGTH"	R75= "LENGTH"
R76= "FEET."	R76= "FEET."	R76= "FEET."
R77= "MTRS."	R77= "MTRS."	R77= "MTRS."
R78= "DIA"	R78= "DIA"	R78= "DIA"
R79= "INS."	R79= "INS."	R79= "INS."
R80= "M.MTR."	R80= "M.MTR."	R80= "M.MTR."
R81= "VOL"	R81= "VOL"	R81= "VOL"
R82= "BBL."	R82= "BBL."	R82= "BBL."
R83= "C.MTR."	► R83= "GAL." ◄	► R83= "GAL." ◄
R84= "MUD WT"	R84= "MUD WT"	R84= "MUD WT"
R85= "P.P.G."	R85= "P.P.G."	R85= "P.P.G."
R86= "S.G."	► R86= "P/CFT." ◄	► R86= "PSI/FT" ◄
R87= "PRES"	R87= "PRES"	R87= "PRES"
R88= "P.S.I."	R88= "P.S.I."	R88= "P.S.I."
R89= "BARS."	R89= "BARS."	R89= "BARS."
R90= "WT"	R90= "WT"	R90= "WT"
R91= "LBS."	R91= "LBS."	R91= "LBS."
R92= "DA.N."	R92= "DA.N."	R92= "DA.N."
R93= "SURF. "	R93= "SURF. "	R93= "SURF. "
R94= "DATA*"	R94= "DATA*"	R94= "DATA*"
R95= "HOLE "	R95= "HOLE "	R95= "HOLE "
R96= "PIPE "	R96= "PIPE "	R96= "PIPE "
R97= "ANN. "	R97= "ANN. "	R97= "ANN. "
R98= "DEPTH"	R98= "DEPTH"	R98= "DEPTH"
R99= " SETS"	R99= " SETS"	R99= " SETS"

	*MDATA - D	*MDATA - E	*MDATA - F
R46=	0.000000000+00	0.000000000+00	0.000000000+00
R47=	0.000000000+00	0.000000000+00	0.000000000+00
R48=	"NOZ."	"NOZ."	"NOZ."
R49=	"RIGHT"	"RIGHT"	"RIGHT"
R50=	7.669903940-04	7.669903940-04	7.669903940-04
R51=	7.456998700-01	7.456998700-01	7.456998700-01
R52=	2.450408401-02	2.450408401-02	2.450408401-02
R53=	6.544438248+01	6.544438248+01	6.544438248+01
R54=	1.612800000-01	1.612800000-01	1.612800000-01
R55=	3.048000000-01	3.048000000-01	3.048000000-01
R56=	2.540000000+01	2.540000000+01	2.540000000+01
R57=	► 1.589872949+02 ◄	1.589872949-01	► 1.589872949+02 ◄
R58=	1.198264274-01	1.198264274-01	1.198264274-01
R59=	6.894757293-02	6.894757293-02	► 1.000000000+00 ◄
R60=	4.448221615-01	► 1.000000000+00 ◄	4.448221615-01
R61=	9.714263000-04	9.714263000-04	9.714263000-04
R62=	"O.D"	"O.D"	"O.D"
R63=	"ID.(P)"	"ID.(P)"	"ID.(P)"
R64=	"ID.(C)"	"ID.(C)"	"ID.(C)"
R65=	"CAP"	"CAP"	"CAP"
R66=	"VOL"	"VOL"	"VOL"
R67=	"VEL"	"VEL"	"VEL"
R68=	"DISP"	"DISP"	"DISP"
R69=	"VOL.D"	"VOL.D"	"VOL.D"
R70=	"VN/SEC"	"VN/SEC"	"VN/SEC"
R71=	"WT/U.L"	"WT/U.L"	"WT/U.L"
R72=	"Q RATE"	"Q RATE"	"Q RATE"
R73=	0.000000000+00	0.000000000+00	0.000000000+00
R74=	"P/GRD="	"P/GRD="	"P/GRD="
R75=	"LENGTH"	"LENGTH"	"LENGTH"
R76=	"FEET."	"FEET."	"FEET."
R77=	"MTRS."	"MTRS."	"MTRS."
R78=	"DIA"	"DIA"	"DIA"
R79=	"INS."	"INS."	"INS."
R80=	"M.MTR."	"M.MTR."	"M.MTR."
R81=	"VOL"	"VOL"	"VOL"
R82=	"BBL."	"BBL."	"BBL."
R83=	► "CU.DM." ◄	"C.MTR."	► "CU.DM." ◄
R84=	"MUD WT"	"MUD WT"	"MUD WT"
R85=	"P.P.G."	"P.P.G."	"P.P.G."
R86=	"S.G."	"S.G."	"S.G."
R87=	"PRES"	"PRES"	"PRES"
R88=	"P.S.I."	"P.S.I."	"P.S.I."
R89=	"BARS."	"BARS."	► "P.S.I." ◄
R90=	"WT"	"WT"	"WT"
R91=	"LBS."	"LBS."	"LBS."
R92=	"DA.N."	► "LBS." ◄	"DA.N."
R93=	"SURF. "	"SURF. "	"SURF. "
R94=	"DATA*"	"DATA*"	"DATA*"
R95=	"HOLE "	"HOLE "	"HOLE "
R96=	"PIPE "	"PIPE "	"PIPE "
R97=	"ANN. "	"ANN. "	"ANN. "
R98=	"DEPTH"	"DEPTH"	"DEPTH"
R99=	" SETS"	" SETS"	" SETS"

(1) The DEPTH RANGE for Well Geometry calculations is 1-89,999 feet.
The LENGTH inputs for Well Geometry data must be in the range 1-89,999 feet.
The SIZE inputs (ID/OD/DIA) for Well Geometry data must be in the range >0 =< 99 inches.

(2) The ★OILWELL 1 Module requires 151 data registers to run. If the Module is not able to make this number of data registers available in the HP 41, due to the presence of User programmes in HP 41 memory, then a display of 'NO ROOM' will result and execution of the selected function will cease. The User will then need to clear HP 41 memory of sufficient User programmes to ensure that a minimum of 151 registers are available for data.

NOTE: The HP 41CV has 320 User Registers hence 169 registers may be used by User programmes and still allow ★OILWELL 1 module operation.

(3) The internal checks made by the module to confirm the presence of ★MDATA and ★WDATA are far from exhaustive. In fact only the contents of one register for each data set is checked (R.99 for ★MDATA & R.136 for ★WDATA). The idea behind this is to allow the User to enter ZERO, as an indicator, into these two registers if any of the registers used for ★MDATA and/or ★WDATA (R.46-99 and R.105-136) are to be used in any USER programmes.
Thus, in GENERAL registers 46-150, inclusive, should **NOT** used by the User unless proper precautions are taken to ensure that correct ★MDATA and ★WDATA is made available prior to next usage of the ★OILWELL 1 Module. X-MEMORY is very useful in this respect.

(4) Well Geometry data inputs are rounded on input due to data storage techniques used by the module programme. The effects of this rounding are insignificant in terms of accuracy of calculation but are mentioned because in some cases output values may vary slightly from their corresponding input values.
Rounding of input Well Geometry data is as follows:

LENGTH	To the nearest foot.
PIPE O.D. HOLE DIA.	Dependant on the associate section length. At the most the input value is rounded to the third figure after the decimal point.
ID.<C> ID.<P>	Rounded to the third figure after the decimal point.

EXAMPLE OF EFFECTS OF ROUNDING

If the current units mode has the 'LENGTH' parameter in Metric Mode i.e. METERS, then input of meters in response to Well Geometry 'LENGTH?=' prompts will result in the following:

(a) Conversion of meters to FEET
(b) Rounding of input value in FEET to the nearest FOOT
(c) Storage of that **ROUNDED** value

Subsequent output will result in:

(a) Recall of the rounded input value
(b) Conversion of the **ROUNDED** value to METERS (assuming still Metric Mode).
(c) Output of the CONVERTED ROUNDED VALUE.

In the case of LENGTH inputs, this results in a MAXIMUM variation between the input and output value of **less than 0.5 feet.**

(5) Registers 00 &01 are not used for any ★OILWELL 1 Module functions.

Registers 29-42, though not used in the ★OILWELL 1 Module, are assigned for use in subsequent modules.

(7) Where Mud Weight is prompted for during a programme, other than in Code 13 functions or in response to the "RHEO OK?" prompt, then any input value will not affect the current Rheology Data Mud Weight.

(8) The module maintains the status of the User's selected decimal separator "." or "," as controlled by flag 28. The Time Module date format status, i.e. day-month-year or month-day-year, as controlled by flag 31, is also maintained.

(9) Internally the programme operates in ENGLISH UNITS.

(10) Interruption of programme execution during a running programme may well result in undesirable flag settings that adversely affect formatting of HP 41 outputs. It may then become necessary to reset some or all of the following flags depending on the User's requirements: Flags 26, 28, 29, 31 (and possibly flags 11, 12, 13 & 14) – see the HP 41's USER MANUAL.
Operation of Code 0.7 may be used to re-establish the status of most of the flags. However the status of flags 28 & 31 are maintained to the User's selected setting by the module and may need to be manually re-set to the User's required status. (Flag 28 selects a '.' or ',' as the decimal separator and flag 31 selects "D.M.Y." or "M.D.Y." modes on the TIME MODULE).

(11) ★OILWELL 1 Module calculations that require the presence of a NON-ZERO value of a particular PARAMETER will skip that calculation or its ZERO output value, e.g. in String Weight calculations the Weight of the String in Mud will be skipped if the current MUD WEIGHT value = ZERO. This applies where calculations use one or more of the following parameters: Mud weight, Q rate and n/K values.

(12) In most cases a new function may be selected and operated during a prompt routine of a running programme.
This should **not** be done during a Code 9 operation as it will result in the existence of non-valid WELL GEOMETRY DATA i.e. **ALL CODE 9 ROUTINES MUST BE RUN TO COMPLETION (OK-DISPLAY).**

(13) In those cases where a particular code operation **requires** the existence of an accessory, e.g. for Code 0.0 LOAD MASTER DATA CARD, then its absence will cause either a displayed explanation or a "NONEXISTENT" display. When the presence of an accessory is **arbitrary** then programme execution will proceed normally while making use of the accessory only if it is present. An example of this is to be found following input of WELL GEOMETRY DATA (Code 9.2). When the input operation is completed and the Card Reader is present the User will be prompted for input of a data card for recording the WELL GEOMETRY DATA on card. If the Card Reader is absent the recording routine will be skipped.

(14) A Printer greatly enhances use of the Module and is recommended as an accessory. Operation of the HP 41 varies slightly dependant on the presence or not of a Printer. If present a Printer allows output of data, without User participation, following the input in response to the final prompt. Its absence requires the User to press the 'R/S' (RUN/STOP KEY) following each displayed heading and output value. In some cases, to simplify use, data output format varies according to Printer existence.

When the Pipe Data Input of a set of Well Geometry data (as input using a Code 9.2 or 9.1) relates to a casing string that consists of more than one type of casing and/or includes a specific landing string, it is **not** possible to modify the **planned Casing Setting Depth** by using the module's depth adjustment routines. This is because any such modification will result in a re-positioning of all the Casing String Components including the Hanger. In situations where casing is run on casing and is to be set in a surface Well Head this limitation will not apply.
This limitation arises from the fact that **Pipe Data** modifications to **Depth** are accounted for at the **top** end of the pipe string.
This is not to say that during running of a casing string the normal module functions cannot be used for depths above final shoe depth, it is only the **Setting Depth** that is **critical.**

CODE NO:	DESCRIPTION

INTRODUCTION

Code numbers for the ★OILWELL 1 Module are divided into 10 main groups, each of which is divided into subdivisions. Within a group the subdivisions generally relate to the specific subject of the group.

Group subjects are as follows:

ITEM	CODE NO.	BASIC SUBJECT
1.	0	Master Programme Functions
2.	1	Well Geometry Based Calculations
3.	3	Well Geometry Based Calculations with Pressure Loss Calculations
4.	7	Miscellaneous Hydrostatic & Mud Additive Calculations
5.	8	Wireline Work Done
6.	9	Well Geometry Data Input & Change
7.	10	Pipe Specifications
8.	11	Bit Hydraulics
9.	12	General Calculations
10.	13	Mud Rheology

NOTES:

1. Codes 1, 3 and 8 require Well Geometry Data and will prompt for that data if it is not in memory.
2. Codes 1 and 3 utilise Rheology Data stored using a code 13 operation. Such Rheology remains stored for use until changed. At the start of each Code 1 and 3 operation the User is prompted to say if the Rheology Data requires changing.
3. All Code operations:
   a. Size computer memory to 151 data registers (providing memory available).
   b. Set up statistics registers starting at R.11.
   c. Check presence of ★MDATA (Check based only on contents of R.99). This check does not operate if input code is = >20.
   d. Establish appropriate flag settings for module operation. Units flags will be automatically set to the current units selection. Existing flag settings prior to operation of the 'MSTA' key assignment are immaterial and will be lost by module operation.

CODE NO:	DESCRIPTION

4. In the event of recurrent failure of the module to operate normally the following routine is recommended.

   a. XEQ 'CLRG' – Clear all registers.

   b. Reload MASTER DATA (Codes 0.0 & 0.1).

   c. Reload WELL GEOMETRY DATA (Codes 0.2 & 0.3).

5. Units flag control data is stored in register 101. If, for some reason, non-valid flag control data becomes stored in this register then "Data Error" will result for **All Code Operations** except Code 0.6. This code may be used to re-establish valid flag control data. However, unless the source of erroneous data is known, it is recommended that the procedure outlined in note 4 is followed, otherwise undetected erroneous data may exist.

6. The content of Register 101, units flag control, is not stored with either ★MDATA or ★WDATA.

★OILWELL 1 USER CODES

CODE NO:	FUNCTION	CODE NO:	FUNCTION
0.0	LOAD MASTER DATA CARD	7.0	GAS CUT MUD STRONG-WHITE EQUATION
0.1	LOAD MASTER DATA	7.1	LEAK OFF TEST
0.2	LOAD WELL GEO. DATA CARD	7.2	Effect of mud additive additions on mud wt. — ADD SOLID ← Volume & Wt Solid
0.3	LOAD WELL GEO. DATA	7.3	Effect of mud additive additions on mud wt. — ADD SOLID ← Resulting Mud Wt
0.4	SELECT ENGLISH UNITS	7.4	Effect of mud additive additions on mud wt. — ADD LIQUID ← Volume & Wt Liquid
0.5	SELECT ALTERNATIVE UNITS	7.5	Effect of mud additive additions on mud wt. — ADD LIQUID ← Resulting Mud Wt
0.6	USER SELECT UNITS	8.0 •	WORK DONE - ROUND TRIP
0.7	OUTPUT CURRENT UNITS	8.1 •	WORK DONE - WIPER TRIP
0.8	X-MEMORY DATA STORAGE	8.2 •	WORK DONE - CASING
1.0 •	ALL HOLE, PIPE & ANNULUS DATA	8.3 •	WORK DONE - DRILL-CORE-REAM
1.1 •	ALL HOLE DATA	8.4	WORK DONE - STACK
1.2 •	ALL PIPE DATA	9.0 •	CHANGE WELL GEOMETRY DATA
1.3 •	ALL ANNULUS DATA	9.1 •	INPUT NEW SET OF PIPE DATA
1.4 •	HOLE PIPE & ANNULUS ΣDATA	9.2 ★	INPUT WELL GEOMETRY DATA
1.5 •	HOLE Σ DATA	10.0	CRITICAL ROTARY SPEEDS
1.6 •	PIPE Σ DATA	10.1	PIPE STRETCH
1.7 •	ANNULUS Σ DATA	10.2	STUCK PIPE - FREE POINT
1.8 •	ALL ANN. DATA FROM CALC-D	10.3	TENSILE & TORSIONAL DATA
1.9 •	ANN. Σ DATA FROM CALC-D	10.4	TORSION UNDER TENSION
3.0 •	ALL PIPE & ANN. DATA + PRES	10.5	CALC. O.D. FROM I.D. & WT.
3.1 •	ALL PIPE DATA + PRES	10.5	CALC. WT. FROM I.D. & O.D.
3.2 •	ALL ANN. DATA + PRES	10.5	CALC. I.D. FROM O.D. & WT.
3.3 •	PIPE & ANN. Σ DATA + Σ PRES	10.6	CALC. X-SECTIONAL AREA
3.4 •	PIPE ΣDATA + Σ PRES	11.0	BIT HYDRAULICS OPTIMISATION
3.5 •	ANN. ΣDATA + Σ PRES	11.1 ⊕	CHG. MAX. PRES. & NO. NEW NOZ.
3.6 •	AS 1.8 + PRES	11.2 ⊕	ACTUAL HYDRAULICS
3.7 •	AS 1.9 + Σ PRES	11.3 ⊕	INPUT SPECIFIC FLOW RATE
3.8 •	USER CALCULATIONS	11.4 ⊕	INPUT NEW Q-RATE/PRES DATA
3.9 •	SURGE - SWAB CALCULATIONS	12	GENERAL CALCULATIONS
	OPERATION 1 Enter CODE NUMBER 2 Select USER MODE 3 Execute MSTA KEY ASSIGNMENT	13.0	RHEOLOGY FROM FANN DATA
		13.1	INPUT RHEOLOGY & MUD WT.
		13.2	OUTPUT RHEOLOGY & MUD WT.
•	UTILISES WELL GEOMETRY DATA	13.3	INPUT P.V., Y.P. & MUD WT.
⊕	DEPENDENT ON OPERATION 11.0	13.4	LIFTING CAPACITY OF MUD

CODE NO:	DESCRIPTION
0.0	**LOAD MASTER DATA CARD** Initialises the routine for loading Master Data, ★MDATA, from two Magnetic Data Cards. If the Card Reader is absent 'NONEXISTENT' will be displayed. ★MDATA is stored in Registers 46-99 inclusive. Unless these registers are changed by the User, ★MDATA will remain in memory continuously and need not be reloaded.
0.1	**LOAD MASTER DATA** Primarily for use when the 'X-Functions' ROM memory has been used for ★MDATA storage (See Code 0.8). If data is not available or if the 'X-Functions' ROM is absent then operation defaults to a Code 0.0 operation. Code 0.1 loads ★MDATA from 'X-Functions' ROM memory.
0.2	**LOAD WELL GEOMETRY DATA CARD** Initialises the routine for loading previously recorded Well Geometry Data from a Magnetic Data Card. If the Card Reader is absent 'NONEXISTENT' will be displayed. ★WDATA is stored in Registers 105-136 inclusive and includes Code 13 Rheology Data. Unless these registers are changed by the User, ★WDATA will remain in memory continuously and need not be reloaded.
0.3	**LOAD WELL GEOMETRY DATA** Primarily for use when 'X-Functions' ROM memory has been used for ★WDATA storage (see Code 0.8). If data is not available or if the 'X-Functions' ROM is absent then operation defaults to a Code 0.2 operation. Code 0.3 loads ★WDATA from 'X-Functions' ROM memory.
0.4	**SELECT ENGLISH UNITS** (Flags 0-4 inclusive CLEAR) Selects English units as the units for subsequent input and output of all data. Selection remains in effect until another units selection is made. English units are the Modules internal operating units.
0.5	**SELECT ALTERNATIVE UNITS** (Flags 0-4 inclusive SET) Selects Alternative units as the units for subsequent input and output of all data. Selection remains in effect until another units selection is made. The Alternative set of units may be **any** set of units the User decides on. The standard ★MDATA card supplies METRIC units as the Alternative set (See SELECTION of ★MDATA CARD OPTIONS Pages 2.04 and 2.05).
0.6	**USER SELECT UNITS** (Flags 0 – 4 inclusive clear or set as appropriate). This Code allows the User to individually select the units that will be used for input and output data related to each parameter. The User simply CLEARS for English units, or SETS, for alternative units, the dedicated units control flag, appropriate for parameter, PRIOR to operation of the Code 0.6 function. Dedicated Units Flags are: Length: Flag 00 Dia.: Flag 01 Vol.: Flag 02 Mud Wt.: Flag 03 Pressure: Flag 04 Weight: Flag 04 **Flag Operations** 1. To Set press: "Shift"; "SF"; Enter Flag No. 2. To Clear press: "Shift"; "CF"; Enter Flag No. (Shift key is the yellow key).

CODE NO:	DESCRIPTION
0.7	**OUTPUT CURRENT UNITS** Causes a ★KEY★ output showing the current units setting.
0.8	**X-MEMORY DATA STORAGE** Stores the current ★MDATA and ★WDATA register contents in 'X-Functions' ROM Memory. It is not necessary to create memory files prior to this routine, this is done automatically. The routine first stores the ★WDATA and then ★MDATA. If insufficient memory space in X-MEMORY exists or if X-MEMORY is not present, an output of '★WDATANOXMEM' and/or '★MDATANOXMEM' followed by a final display of "NOXMEM" will result. Each is stored in turn so that it is possible to store ★WDATA but not ★MDATA if space runs out. The advantage of 'X-MEMORY' data storage is that it allows the User to store his regular data while operating another data set (★MDATA and/or ★WDATA) and then allows ready access to the original data via Codes 0.1 and 0.3. It can also be used to good effect after operating User programmes that utilise Registers 46 and above.

CODES 1 and 3 WELL GEOMETRY CALCULATIONS

INTRODUCTION

All Code 1 & 3 operations are dependant on the presence of Well Geometry Data (★WDATA). To check that ★WDATA is present in HP 41 memory the Master Programme checks that the contents of Data Register 136 are **not** less than or equal to zero. If this is the case then computation continues based on the HOLE and PIPE DATA as stored in Data Registers 113-136 inclusive.

> **NOTE:** Input and/or modification of Well Geometry Data is made using Codes 9.0, 9.1, 9.2, 0.2 & 0.3 operations.

Some data outputs from Code 1 & 3 operations are also dependant on the **Rheology Data** as stored in registers 105-111. The Master Programme prompts the User for confirmation that the current Rheology Data is satisfactory for all those code operations that utilise it. An 'N' (No) response to the prompt causes branching to the equivalent of a Code 13.1 operation. This allows the User to input new 'hi.n/HI.K/n/K' and Mud Weight Data, after which the original code operation will continue. Alternatively the User may elect to specify a particular Code 13 operation to input the Rheology Data and then to repeat the original code selection.

> **NOTE:** If only the mud weight is to be changed then pressing R/S, without input, in response to the 'hi.n.' prompt at the start of the Rheology input routine (13.1) will cause the programme to prompt only for Mud Weight.

After the check on the **Rheology Data** the programme prompts for the FLOW RATE – Q RATE – in terms of volume per minute. A default operates for this prompt in that the last used Flow Rate is placed in the X-Register prior to prompting. Thus immediate operation of the R/S key after the prompt will cause this previous value to be used in the subsequent calculation.

CODE NO:	DESCRIPTION
	Finally, 'DEPTH' is prompted for, this may take two forms depending on the Code Operation selected. The principle of the DEPTH prompt is as follows: 1. Regardless of actual hole depth and string length used for input of the Well Geometry Data but providing that **DEPTH INCREASE** results only from: (a) An increase in the length of the **bottom** hole section. (b) An increase in the string length only from additions of pipe corresponding to the **top** section of PIPE DATA then any DEPTH between 1 and 89,999 ft. inclusive may be input. This input DEPTH corresponds to the Bit and/or Hole Depth and the programme automatically adjusts Hole and Pipe Section Data to correspond to this DEPTH input. 2. For Codes 1.8, 1.9, 3.6, & 3.7, following specification of the DEPTH of the bit, a "CALC.D" or **CALCULATION DEPTH** may be specified for ANNULUS CALCULATIONS which is to be used as the DEPTH for calculation purposes while ensuring correct pipe position relative to Hole Sections. This is particularly useful for E.C.D. calculation at a known WEAK ZONE or CASING SHOE and for ANNULUS VOLUME CALCULATION between two depths. The input CALC.D value **must be less than** the specified BIT DEPTH. After input to the DEPTH prompts the programme runs and produces data output dependant on the User Code selected. **NOTE**: T.D. in the following descriptions relates to depth input in response to the "DEPTH?=" prompt.
1.0	**ALL HOLE, PIPE & ANNULUS DATA** Outputs data for 3 MODES separately:— <u>MODE 1 HOLE DATA</u> Working from T.D. up outputs dimensions, capacity and volume data of each HOLE section. Finally displays the TOTAL HOLE VOLUME. <u>MODE 2 PIPE DATA</u> Working from T.D. up outputs dimension, capacity, displacement, volume, velocity and weight data for each PIPE section. Finally displays the following summation data for the string: TOTAL WEIGHT of string in air TOTAL WEIGHT of string in mud TOTAL DISPLACEMENT VOLUME of string TOTAL INTERNAL VOLUME of string <u>MODE 3 ANNULUS MODE</u> Working from T.D. up outputs dimensions, capacity, volume and fluid velocity data for each ANNULUS section. Finally displays the TOTAL ANNULUS volume.
1.1	**ALL HOLE DATA** Outputs as per Code 1.0 Mode 1.

CODE NO:	DESCRIPTION
1.2	**ALL PIPE DATA** Outputs as per Code 1.0 Mode 2.
1.3	**ALL ANNULUS DATA** Outputs as per Code 1.0 Mode 3.
1.4	**HOLE PIPE AND ANNULUS SUMMATION DATA** Outputs the summation data only for 3 MODES:— MODE 1 HOLE DATA Outputs: TOTAL HOLE VOLUME MODE 2 PIPE DATA Outputs: TOTAL WEIGHT of string in air TOTAL WEIGHT of string in mud TOTAL DISPLACEMENT VOLUME of string TOTAL INTERNAL VOLUME of string MODE 3 ANNULUS DATA Outputs: TOTAL ANNULUS VOLUME
1.5	**HOLE SUMMATION DATA** Outputs as per Code 1.4 Mode 1.
1.6	**PIPE SUMMATION DATA** Outputs as per Code 1.4 Mode 2.
1.7	**ANNULUS SUMMATION DATA** Outputs as per Code 1.4 Mode 3.
1.8	**ALL ANNULUS DATA FROM CALC.D** (CALC.D = Calculation Depth) Allows the User to specify the DEPTH at which the BIT is positioned and then to specify ANOTHER DEPTH (CALC.D), **less than** the BIT DEPTH from which Annulus Data output calculations are to be made. Outputs as per Code 1.3.
1.9	**ANNULUS SUMMATION DATA FROM CALC.C.** (CALC.D = Calculation Depth) Operation as per Code 1.8 Outputs: TOTAL ANNULUS VOLUME above CALC.D.
3.0	**ALL PIPE AND ANNULUS DATA PLUS PRESSURE LOSS DATA** Outputs data for 2 MODES separately:— MODE 1 PIPE DATA Working from T.D. up outputs dimension, capacity, displacement, volume, velocity, weight and pressure loss data for each PIPE section. Finally outputs the following summation data for the string: TOTAL WEIGHT of string in air TOTAL WEIGHT of string in mud TOTAL DISPLACEMENT VOLUME of string TOTAL INTERNAL VOLUME of string TOTAL PRESSURE LOSS in string

CODE NO:	DESCRIPTION
	MODE 2 ANNULUS DATA Working from T.D. up outputs dimension, capacity, volume, velocity, adjusted laminar flow critical velocity, pressure loss, annular shear rate and annular viscosity data for each ANNULUS section. Then outputs the following summation data for the ANNULUS: TOTAL ANNULUS VOLUME TOTAL ANNULUS PRESSURE LOSS EQUIVALENT CIRCULATING DENSITY in terms of Mud Weight (E.C.D. calculations assume all depths to be True Verticle). Finally followed by: The PRESSURE LOSS in the SURFACE SYSTEM and would be PRESSURE LOSS in the CHOKE/KILL LINE configuration. (The latter becomes of value in KICK situations when circulating up the Choke/Kill Lines).
3.1	**ALL PIPE DATA PLUS PIPE PRESSURE LOSS DATA** Outputs as per Code 3.0 Mode 1 – plus the SURFACE and CHOKE/KILL LINE PRESSURE LOSS data.
3.2	**ALL ANNULUS DATA PLUS ANNULUS PRESSURE LOSS DATA** Outputs as per Code 3.0 Mode 2 – plus the SURFACE and CHOKE/KILL LINE PRESSURE LOSS data.
3.3	**PIPE & ANNULUS SUMMATION DATA** Outputs summation data only for 2 MODES:– MODE 1 PIPE DATA Outputs: TOTAL WEIGHT of string in air TOTAL WEIGHT of string in mud TOTAL DISPLACEMENT VOLUME of string TOTAL INTERNAL VOLUME of string TOTAL PRESSURE LOSS in string MODE 2 ANNULUS DATA Outputs: TOTAL ANNULUS VOLUME TOTAL ANNULUS PRESSURE LOSS EQUIVALENT CIRCULATING DENSITY in terms of Mud Weight (E.C.D. calculations assume all depths to be True Verticle) Finally followed by: The PRESSURE LOSS in the SURFACE SYSTEM and the would be PRESSURE LOSS in the CHOKE/KILL LINE configuration.
3.4	**PIPE SUMMATION DATA PLUS PIPE PRESSURE LOSS DATA** Output as per Code 3.3 Mode 1 – plus the SURFACE and CHOKE/KILL LINE PRESSURE LOSS data.
3.5	**ANNULUS SUMMATION DATA PLUS ANNULUS PRESSURE LOSS DATA** Output as per Code 3.3 Mode 2 – plus the SURFACE and CHOKE/KILL LINE PRESSURE LOSS data.

CODE NO:	DESCRIPTION
3.6	**ALL ANNULUS DATA AND ANNULUS PRESSURE LOSS DATA FROM CALC.D** (CALC.D = Calculation Depth) Allows the User to specify the DEPTH at which the BIT is positioned and then to specify an ALTERNATIVE DEPTH (CALC.D) **less than** the BIT DEPTH, from which calculations are to be made. Outputs as per Code 3.2
3.7	**ANNULUS SUMMATION DATA AND ANNULUS SUMMATION PRESSURE LOSS DATA FROM CALC.D** (CALC.D = Calculation Depth) Operation as per Code 3.6 Outputs: TOTAL ANNULUS VOLUME above CALC.D TOTAL ANNULUS PRESSURE LOSS above CALC.D.
3.8	**USER CALCULATIONS** Allows the User to make PIPE **or** ANNULUS calculations for a specified data input set. The function uses current Rheology Data as required. After the "RHEO OK?" prompt the User is prompted with a "P. FLOW?" meaning: "Is the calculation for a pipe flow situation?", if the response is 'Y' (or R/S default) then the PIPE flow calculation mode is selected. If it is 'N' (NO) the mode is for ANNULUS calculation. MODE 1 PIPE FLOW Programme prompts for: (1) LENGTH?= (R/S operates a default of 1000 units) (2) P-O.D?= Pipe outside diameter (3) ID. <P> ? = Internal diameter for PRESSURE LOSS calculation (4) ID. <C> ? = Internal diameter for CAPACITY calculations (5) Q RATE?= Flow Rate (R/S operates normal Q RATE default) The programme then outputs: Dimension, capacity, volume, fluid velocity, displacement, volume of displacement, weight in air & mud, Reynolds Numbers and corresponding critical velocities for turbulent and laminar flow regimes and pressure loss for PIPE data. MODE 2 ANNULUS FLOW Programme prompts for: (1) LENGTH?= (R/S operates a default of 1000 units) (2) H-DIA? = Hole diameter (3) P-O.D?= Pipe outside diameter (4) Q RATE?= Flow rate (R/S operates normal Q RATE default) The programme then outputs: Dimension, capacity, volume, fluid velocity, Reynolds Numbers and corresponding critical velocities for turbulent and laminar flow regimes, the adjusted laminar flow critical velocity, annular pressure loss, shear rate (sec $^{-1}$)and viscosity (CPS) for ANNULUS data. Stored Well Geometry Data is unaffected by operation of this code number.

CODE NO:	DESCRIPTION

3.9 **SURGE-SWAB CALCULATION**

This function calculates the estimated gain or reduction in hydrostatic pressure that will result below the bottom of a 'closed end' string of pipe as it is being lowered or raised in a hole. Bottom hole pressure variations resulting from pipe movement can have very significant down hole effects, especially in terms of hole stability, fluid influx and fluid loss.

The principles behind the calculation are discussed in the section: "PRESSURE CALCULATION".

Programme prompts for:

(1) AV.P.VEL?= Average Pipe Velocity
(2) DEPTH?= Depth of Bit

and then outputs the SURGE-SWAB PRESSURE.

7.0 **GAS CUT MUD**

This function uses the STRONG-WHITE equation to calculate the reduction in hydrostatic pressure that will result from gas expansion in a column of mud which contains an even distribution by weight of gas.

The equation states that the bottom hole HYDROSTATIC PRESSURE REDUCTION at depth Dft is given by:

$$= \left[\left(\frac{\rho a}{\rho g}\right) - 1\right] \log_{10}\left[\frac{\rho a\, D}{14.6969}\right] \quad 33.8029 \text{ P.S.I.}$$

where ρa = density of uncontaminated mud (psi/ft)
ρg = density of contaminated mud – gas cut (psi/ft)

For this to give good results the mud sample used to obtain the density of the GAS CONTAMINATED MUD should be taken as close as possible to the flow line and every effort should be made to keep gas break out to a minimum.

Programme prompts for:

(1) TVDEPTH?= True vertical depth
(2) GCMUD WT?= Gas cut mud weight
(3) MUD WT?= Normal mud weight

NOTE: The use of TRUE VERTICAL DEPTH and **NOT** ALONG HOLE DEPTH is important.

The programme then outputs the resulting LOSS IN BOTTOM HOLE HYDROSTATIC PRESSURE.

7.1 **LEAK OFF TEST**

A LEAK OFF TEST is designed to assess the ability of an open hole section to withstand the extra pressure loadings that it may be exposed to as a result of fluid influx into the well (a kick). This is done by gradually applying SURFACE PRESSURE to the closed well until the applied pressure **initiates** FLUID LEAK OFF to the WEAK ZONE (WZ). The test is most generally done following drill out after running casing but can be performed at any stage of the drilling of an open hole section, though deciding on the depth of the weak zone in this latter case can be problematic.

CODE NO:	DESCRIPTION

This function uses the applied SURFACE PRESSURE obtained from the LEAK OFF TEST to calculate data relevant to the current depth and mud weight in use.

Programme prompts for:

(1)	TVDEPTH = ?	Current true vertical depth of the hole
(2)	TVD NC? =	Planned true vertical depth of next casing
(3)	TVD WZ? =	Estimated true vertical depth of weak zone
(4)	TMUD WT? =	Mud weight in use at time of leak off test
(5)	MUD WT? =	Current mud weight in use
(6)	TSURF. P? =	Pressure applied at surface at time of initiation of leak off

The Programme then outputs:

(1) The MAXIMUM ALLOWABLE ANNULUS STATIC SURFACE PRESSURE (M.A.A.S.S.P.) – this is the maximum surface pressure build up than can be tolerated for the present mud weight by the WEAK ZONE without formation breakdown under shut in conditions.

(2) The MAXIMUM CONTROLLABLE FORMATION PRESSURE (M.C.F.P.) and its corresponding pressure gradient and mud weight. The M.C.F.P. is the formation pressure, at a specified depth and with the specified mud weight, above which it will not be possible to shut in and kill the well without causing formation breakdown at the WEAK ZONE.

The routine aims at indicating the suitability of the present mud weight for drilling ahead while maintaining an adequate safety margin for well control.

It is suggested that, as a guideline, very careful consideration as to the advisability of drilling ahead be given when the difference between the M.C.F.P. equivalent mud weight and the actual mud weight in use varies by less than 1.0 p.p.g. (= .1198S.G.)

CODES 7.2-7.5 OPERATIONS – MUD WEIGHT CHANGE

INTRODUCTION

These codes calculate the effects of SOLID or LIQUID ADDITIONS made to the drilling fluid in terms of changes in MUD WEIGHT and MUD VOLUME.
Codes 7.2 and 7.3 operate for **SOLID** additions.
Codes 7.4 and 7.5 operate for **LIQUID** additions.
The User is given the option of specifying the INITIAL **STARTING** VOLUME of mud **or** the REQUIRED **FINAL** VOLUME.
The User may select from 3 options for both solids and liquids.
These are:

Baryte, Low Gravity Solids or Other for **SOLID ADDITIONS.**
Diesel, Water or Other for **LIQUID ADDITIONS.**

The **OTHER** option in both cases prompts the User to enter the DENSITY of the additive that is to be used in the calculation.

CODE NO:	DESCRIPTION
7.2	**SOLIDS ADDITION TO GIVE SPECIFIED WEIGHT OF DRILLING FLUID** This Code calculates the amount of SOLID required to change the Mud Weight to the input Final Mud Weight. The Programme Prompts for: (1) B/L/O? — Type of solid: **B**aryte, **L**ow Gravity Solid, **O**ther. (2) I.MUD WT?= — Initial Mud Weight prior to addition. (3) VOL I/F?= — Will the Mud Volume input be the INITIAL (I) Mud Volume to which additions are to be made **or** the FINAL (F) Mud Volume that is required after addition has been made. (4) MUD VOLUME?= — With reference to "VOL I/F?" this is the Mud Volume – INITIAL or FINAL. (5) F.MUD WT?= — Final Mud Weight required. **NOTE:** If the **Other** (O) option was selected the programme will prompt with "DENSITY?=" following the option choice. The Programme then outputs: The Volume of Additive required, the Initial and Final Mud Volumes, the Total Weight of Additive required and the Weight of Additive per Unit Volume of Initial Mud.
7.3	**MUD WEIGHT THAT WILL RESULT FROM ADDITION OF A SPECIFIED WEIGHT OF ADDITIVE** The programme prompts for the same inputs as Code 7.2 except that instead of prompting for a Final Mud Weight it prompts for: (5) ADDED WT?= The Weight of SOLID ADDITIVE being added to the Initial Mud Volume. It then outputs the Resulting Mud Weight.
7.4	**LIQUID ADDITIONS TO GIVE SPECIFIED WEIGHT OF DRILLING FLUID** This code operates in the same way as Code 7.2 except that LIQUID additions are made. The programme prompts for: (1) D/W/O? — Type of Liquid: **D**iesel, **W**ater, **O**ther The remaining prompts are as for Code 7.2. Outputs are also the same as for Code 7.2.
7.5	**MUD WEIGHT THAT WILL RESULT FROM ADDITION OF A SPECIFIED VOLUME OF LIQUID ADDITIVE** The programme prompts for the same inputs as Code 7.4 except that instead of prompting for a Final Mud Weight it prompts for: (5) ADDED VOL?= — The Volume of LIQUID ADDITIVE being added to the Initial Mud Volume.

CODE NO:	DESCRIPTION

CODE 8 OPERATIONS WORK DONE BY WIRELINE

INTRODUCTION

All Code 8 Functions calculate the WORK DONE in performing the specified operation.
The calculated WORK DONE is output in both METRIC and ENGLISH units **regardless** of the current active units mode.

When the HP 41 is operated **without the Printer** Code 8 operations **DO NOT** return to the Master Programme on completion of the routine and the data outputs are not labelled, instead operation stops with the calculated **S.TON-MILES VALUE** in the **X-REGISTER** and the calculated **TONNE KMTR VALUE** in the **Y-REGISTER** – this value is best accessed using the 'X<>Y' key.

Codes 8.0 – 8.3 inclusive all use the PIPE WELL GEOMETRY DATA. (In the case of Code 8.2 the current PIPE GEOMETRY DATA needs to be CASING data). This data is used to calculate the actual work done handling each section of pipe for the selected code function.

The calculation does not use the less accurate "EXCESS WEIGHT" method of calculation. For this reason, it is suggested that, if cut off procedures are to be based on the figures calculated by the module, then testing on specimens of wireline to confirm or modify maximum 'TON-MILE' figures are carried out.

The calculations do not make any allowance for hole drag or over pulls.

The following prompts are common to all or some of the Code 8 functions:

(1)	DEPTH?=	BIT DEPTH at start of operation.
(2)	TR.BLK.WT?=	The WEIGHT of the TRAVELLING BLOCK ASSEMBLY including the compensator etc.
(3)	MUD WT?=	The WEIGHT of the MUD in the hole at the time of the operation.
(4)	AV. LEN/STD (or JNT)?=	Average LENGTH of a **STAND** of pipe or **JOINT** of casing.

8.0 **ROUND TRIP**
Calculates the WORK DONE in pulling a string of pipe out of the hole and then running back in to the same depth.

8.1 **WIPER TRIP**
Calculates the WORK DONE in pulling the bit out of the hole to a specified depth and then running back in to the original starting depth.
In addition to the common prompts the programme also prompts for:
(1) W.TRIP TO?= Being the DEPTH to which the bit will be pulled out prior to running back in.

CODE NO:	DESCRIPTION
8.2	**CASING** Calculates the WORK DONE in **running** a casing string. Depending on the method used to handle the casing as it is being picked up the work done handling the blocks may vary. The programme assumes that block travel will be 4 times the length of the casing string. (It is assumed that the casing is not floated in).
8.3	**DRILL/CORE/REAM** Calculates the WORK DONE in drilling, coring or reaming the bit down from one depth to another, deeper, depth, when using the kelly to pick up joints. The calculation allows the User to specify the average number of times each individual joint is reamed **after** it is initially drilled, cored or reamed down, i.e. if a section of hole is being reamed then the **first** time the bit is reamed through an interval is the **initial** run, **after** which it may be picked back up and then re-reamed, in this example the input to the prompt "NO.XREAM?=" would be 1. The programme does not make allowance for any reduction in string weight that results from loading weight onto the bit. The programme prompts for: (1) DEPTH?= (2) TR.BLK.WT?= (3) MUD WT?= (4) KELLY WT?= — Weight of Kelly/Swivel assembly. (5) KELLY LEN?= — Working length of Kelly (including lower kelly cock and saver sub). (6) DRILLED?= — Length of hole drilled/cored/reamed. (7) NO.JNTS?= — The number of joints of drill pipe used to make the "DRILLED?=" progress. (8) NO.X REAM?= — Average number of times a joint is re-worked through a section **after** the initial time it is run.
8.4	**STACK** This is primarily aimed at sub-sea stack handling and calculates the WORK DONE running **or** pulling the stack. The programme prompts for: (1) DEPTH?= — DISTANCE from the derrick floor to the wellhead (2) TR.BLK WT?= (3) STK HT?= — HEIGHT of the STACK and LOWER MARINE RISER assembly. (4) STK WT?= — Weight of the B.O.P. STACK in water. (5) R+STK WT?= — WEIGHT of the B.O.P. ASSEMBLY and RISER immediately prior to landing on wellhead. (6) R.JNT WT?= — WEIGHT of a RISER JOINT in air.

CODE NO:	DESCRIPTION

CODE 8 OPERATIONS WORK DONE BY WIRELINE

INTRODUCTION

All Code 8 Functions calculate the WORK DONE in performing the specified operation.
The calculated WORK DONE is output in both METRIC and ENGLISH units **regardless** of the current active units mode.

When the HP 41 is operated **without the Printer** Code 8 operations **DO NOT** return to the Master Programme on completion of the routine and the data outputs are not labelled, instead operation stops with the calculated **S.TON-MILES VALUE** in the **X-REGISTER** and the calculated **TONNE KMTR VALUE** in the **Y-REGISTER** – this value is best accessed using the 'X<>Y' key.

Codes 8.0 – 8.3 inclusive all use the PIPE WELL GEOMETRY DATA. (In the case of Code 8.2 the current PIPE GEOMETRY DATA needs to be CASING data). This data is used to calculate the actual work done handling each section of pipe for the selected code function.

The calculation does not use the less accurate "EXCESS WEIGHT" method of calculation. For this reason, it is suggested that, if cut off procedures are to be based on the figures calculated by the module, then testing on specimens of wireline to confirm or modify maximum 'TON-MILE' figures are carried out.

The calculations do not make any allowance for hole drag or over pulls.

The following prompts are common to all or some of the Code 8 functions:

(1)	DEPTH?=	BIT DEPTH at start of operation.
(2)	TR.BLK.WT?=	The WEIGHT of the TRAVELLING BLOCK ASSEMBLY including the compensator etc.
(3)	MUD WT?=	The WEIGHT of the MUD in the hole at the time of the operation.
(4)	AV. LEN/STD (or JNT)?=	Average LENGTH of a **STAND** of pipe or **JOINT** of casing.

8.0 **ROUND TRIP**
Calculates the WORK DONE in pulling a string of pipe out of the hole and then running back in to the same depth.

8.1 **WIPER TRIP**
Calculates the WORK DONE in pulling the bit out of the hole to a specified depth and then running back in to the original starting depth.
In addition to the common prompts the programme also prompts for:
(1) W.TRIP TO?= Being the DEPTH to which the bit will be pulled out prior to running back in.

CODE NO:	DESCRIPTION
8.2	**CASING** Calculates the WORK DONE in **running** a casing string. Depending on the method used to handle the casing as it is being picked up the work done handling the blocks may vary. The programme assumes that block travel will be 4 times the length of the casing string. (It is assumed that the casing is not floated in).
8.3	**DRILL/CORE/REAM** Calculates the WORK DONE in drilling, coring or reaming the bit down from one depth to another, deeper, depth, when using the kelly to pick up joints. The calculation allows the User to specify the average number of times each individual joint is reamed **after** it is initially drilled, cored or reamed down, i.e. if a section of hole is being reamed then the **first** time the bit is reamed through an interval is the **initial** run, **after** which it may be picked back up and then re-reamed, in this example the input to the prompt "NO.XREAM?=" would be 1. The programme does not make allowance for any reduction in string weight that results from loading weight onto the bit. The programme prompts for: (1) DEPTH?= (2) TR.BLK.WT?= (3) MUD WT?= (4) KELLY WT?= — Weight of Kelly/Swivel assembly. (5) KELLY LEN?= — Working length of Kelly (including lower kelly cock and saver sub). (6) DRILLED?= — Length of hole drilled/cored/reamed. (7) NO.JNTS?= — The number of joints of drill pipe used to make the "DRILLED?=" progress. (8) NO.X REAM?= — Average number of times a joint is re-worked through a section **after** the initial time it is run.
8.4	**STACK** This is primarily aimed at sub-sea stack handling and calculates the WORK DONE running **or** pulling the stack. The programme prompts for: (1) DEPTH?= — DISTANCE from the derrick floor to the wellhead (2) TR.BLK WT?= (3) STK HT?= — HEIGHT of the STACK and LOWER MARINE RISER assembly. (4) STK WT?= — Weight of the B.O.P. STACK in water. (5) R+STK WT?= — WEIGHT of the B.O.P. ASSEMBLY and RISER immediately prior to landing on wellhead. (6) R.JNT WT?= — WEIGHT of a RISER JOINT in air.

CODE NO:	DESCRIPTION

NOTE: Because the programme works on the weight of riser and stack just prior to landing the stack i.e. in its buoyant state the programme works satisfactorily for both regular and buoyant riser joints. The differences in the joint weights in air are of little significance

CODE 9 WELL GEOMETRY DATA INPUT AND CHANGE

INTRODUCTION

Code 9 Operations are used to store and modify the WELL GEOMETRY data, ★WDATA, used in Codes 1,3 & 8 functions.
The data is divided into four sets, these are:

(a) **HOLE DATA** This covers the lengths and sizes of the different sections of HOLE that are present in the well e.g. Open hole, liner, casing, stack & riser sections. Up to **8 different sections** may be entered. Entry, section by section, MUST be made starting at the bottom of the hole and working up. Input of a full Hole data set can only be made using Code 9.2.

(b) **PIPE DATA** This covers the lengths and dimensions of the different sections of PIPE that are used in the well e.g. drill collars, hevi-weight drill pipe, drill pipe etc. Up to **6 different sections** may be entered. Entry, section by section, MUST be made starting at the bottom of the hole and working up. Input of a full Pipe data set can be made using Codes 9.1 and 9.2 but Code 9.1 acts only to CHANGE an existing Pipe data set i.e. it cannot be used to enter Pipe data if no Hole data exists. The advantage of Code 9.1 is that a completely new set of Pipe data may be entered while keeping the same Hole data set up e.g. at casing depth the DRILL STRING data can be replaced by CASING STRING data.

(c) **SURFACE DATA** This is the **EQUIVALENT LENGTH and INTERNAL DIAMETER** of the SURFACE SYSTEM components down stream of the stand pipe pressure gauge. That is to say that it is the length of the pipe which, for the specified internal diameter, will give the same pressure loss as the stand pipe, kelly hose, goose neck, swivel, kelly etc. for the same flow rate.
(For many offshore rigs a figure of 123′ x 3″ pipe has been found very satisfactory).

(d) **C/KL DATA** This is the **EQUIVALENT LENGTH and INTERNAL DIAMETER** of the CHOKE and/or KILL LINE system that would be used by a rig in event of the necessity to circulate a live well. That is to say that it is the length of pipe which, for the specified internal diameter, would give the same pressure loss as the kill and/or choke lines, fittings, hoses, etc. that comprise the connection up stream of the choke manifold to the kill/choke outlets on the B.O.P.

CODE NO:	DESCRIPTION
	NOTE: Assessment of Equivalent Length Values can be made for both **SURFACE DATA & C/KL DATA** on any rig by carrying out circulation tests and then calculating the length of pipe that for a chosen I.D. (say 3") will give the same pressure loss for a selected flow rate. (See Appendix A for calculation of Equivalent Length Values).
	After entering or changing a set of WELL GEOMETRY DATA and providing the Card Reader is present the User is prompted to store the ★WDATA (RDY 01 OF 02 will be displayed) on magnetic card. (The programme does not store data into X-memory, this can only be done manually or using Code 0.8). At the time of recording the WELL GEOMETRY data the current RHEOLOGY and FLOW RATE data is also stored. For this reason it may be advantageous to operate a Code 13 input function prior to a Code 9 function.
	If when inputing Hole or Pipe data, it is desired to terminate section data input prior to the maximum number of sections being entered then a ZERO (R/S default for LENGTH = 0 in this mode) entry will achieve this and input will jump to the next mode.
	The cumulative length of the input sections for both Hole and Pipe sets must not exceed 89,999 ft. The programme checks this and will terminate input with the displayed message "D.>MAX" if it does.
9.0	**CHANGE WELL GEOMETRY DATA** This Code allows the User to CORRECT **or** CHANGE data stored using Codes 9.1 and 9.2. It will not allow the **number of sections** to be changed i.e. if there are currently 4 SECTIONS of Hole data in memory then the User CANNOT ADD or DEDUCT ACTUAL sections. This may only be done using Code 9.2 and, in the case of Pipe data, Code 9.1
	The Code 9.0 routine is used following data input by operation of Codes 9.1 & 9.2 to allow the User to make changes to the input data following an 'N' (NO) response to the "RIGHT?"prompt at the end of these Code operations.
	The programme prompts for: (1) CHG. H/P? — Change **H**ole or **P**ipe data. The User inputs 'H' or 'P' corresponding to the data set that is to be changed. (2) SECT?= — What is the number of the section to be changed.
	The input SECTION NUMBER must correspond to a section number for which data exists **or** may be ZERO. A ZERO entry allows the User to make changes to the Surface System and Choke/Kill line data in either 'H' or 'P' change mode. A non-acceptable section number entry will default to a repeat of the "CHG.H/P?" prompt for the User to try again.

CODE NO:	DESCRIPTION

After selecting the number of the section to be changed the programme will prompt for appropriate data entry according to the selected mode. After entry of this data the programme will finally prompt for:

(1) RIGHT?	Are all sections now right A 'Y' (YES) (R/S default) input will terminate operation after prompting the User to record ★WDATA on card if the card reader is present. An 'N' (NO) input will repeat the above procedure.

WARNING Input, for any section, of a LENGTH that would cause the cumulative TOTAL LENGTH input to exceed 89,999 feet will result in incorrect programme operation for this function and should be avoided.

9.1 **INPUT A NEW SET OF PIPE DATA**

This Function operates in the same way as for the input of Pipe data in Code 9.2 operations. Its main advantage is that it allows easy modification or change of Drill String or Casing data without having to re-enter the rest of the ★WDATA.

9.2 **INPUT WELL GEOMETRY**

This is the **PRIMARY** procedure for inputting WELL GEOMETRY DATA (★WDATA). The procedure prompts for and stores data as used in all Code operations dependant on the presence of ★WDATA.

Data is input in the following order:

(1) HOLE DATA	Maximum 8 sections
(2) PIPE DATA	Maximum 6 sections
(3) SURFACE SYSTEM DATA	
(4) CHOKE/KILL LINE DATA	

Operation of this function is as follows:

(1) Outputs relevant DATA HEADINGS.
(2) Indicates, for Hole and Pipe data, that data entry is to be made from T.D. up.
(3) Indicates, for Hole and Pipe data, the section number for which data is to be entered.
(4) Prompts for data appropriate to DATA HEADING.
(5) Repeats the data input routine for each SECTION and DATA HEADING.

For **HOLE DATA** the data input prompts are:

(1) LENGTH? =	Input LENGTH of Hole section
(2) DIA? =	Input HOLE SIZE of section.

For **PIPE DATA** the data prompts are:

(1) LENGTH? =	Input LENGTH of Pipe section
(2) O.D? =	Input OUTSIDE DIAMETER of Pipe section.

CODE NO:	DESCRIPTION

This value is used in annulus capacity, pressure and string weight calculations. For pipe which has tool joints etc. use the equivalent O.D. as given in the "PIPE SPECIFICATION TABLES" (Pages D.01 – D.10).

(3) ID.< P>?=	Input INSIDE DIAMETER of Pipe that is to be used for pressure loss calculations this is an equivalent I.D. value that takes into account the presence of tool joints etc. See "PIPE SPECIFICATION TABLES" (Pages D.01 – D.10). **NOTE:** This value could be greater than the input O.D. and will still be accepted by the programme.
(4) ID.< C>?=	Input INSIDE DIAMETER of Pipe that is to be used in capacity and displacement calculations. (An R/S default operates for this input in that the same value as used for ID.< P> may be used for ID.< C> simply by pressing the R/S key without input being made). The ID.<C> value is given in the "PIPE SPECIFICATION TABLES" (Pages D.01 – D.10). **NOTE:** The programme checks that this value is less than the input O.D. value if it is not then all the data for the current section will be re-prompted for.

For **SURF DATA** the data prompts are:

(1) LENGTH?=	Input the EQUIVALENT LENGTH of the Surface System
(2) ID.< P>?=	Input the EQUIVALENT INTERNAL DIAMETER for pressure loss calculation.

For **C/KL DATA** the data prompts are the same as for **SURF. DATA.**

ERROR CHECKING

The following WELL GEOMETRY data input checking routines are performed:

(1) For section data LENGTH inputs greater than 90,000 feet the prompt will be repeated.

(2) Section data LENGTH inputs for Hole and Pipe data less than or equal to ZERO will cause the programme to skip to next data input mode.

(3) For section data LENGTH inputs for SURF. and C/KL data less than or equal to ZERO the prompts will be repeated.

CODE NO:	DESCRIPTION

(4) For section data DIA/OD/ID inputs = <0 or >99 inches the prompt will be repeated.
(5) Section data ID. <C> input values greater than the input O.D. value will result in ALL prompts for entry of data for the section concerned being repeated.
(6) A cumulative total of LENGTH inputs greater than 89,999 feet will TERMINATE data entry and cause "D. >MAX" to be displayed.

CODE 10 PIPE SPECIFICATIONS

INTRODUCTION

The functions associated with this Code group relate to the Performance Capabilities and Specifications of Tubulars. Some of the function codes (10.0, 10.1 10.2) are limited in their abilities in that they relate only to pipe of one specified size and do not allow for mixed string computations, however the results obtained are suitable for use as guide lines.

In most cases when calculating Pipe Specifications the User will be concerned with the **PIPE BODY** dimensions and **not** equivalent dimensions designed to compensate for tool joints etc. Care should be taken in selecting the correct dimensions to be used for a specific function. Outputs in this mode are made in English and Metric units regardless of the current Units Mode selection.

10.0 **CRITICAL ROTARY SPEEDS**

Calculates those R.P.M. values at which resonant vibrations set up in a string may accelerate fatigue wear in the joints. The calculations are based on two types of vibrations (a) NODE type (b) SPRING PENDULUM type, for the latter of which the first three harmonics (repeats) are output.

Programme prompts for:

(1)	OD?=	Pipe body Outside Diameter
(2)	ID?=	Pipe body Internal Diameter
(3)	JNT. LENGTH?=	Joint Length
(4)	DEPTH?=	Current length of string

Programme outputs:

(1) Node type Critical R.P.M.
(2) Spring Pendulum type Critical Velocities (Harmonics 1,2,3).

Pipe speeds within +/- 15% of these values especially when the speeds of the two types coincide, should be avoided.

10.1 **PIPE STRETCH**

Assuming that the pipe is not loaded above its MINIMUM YIELD strength this calculates the LENGTH by which a string of pipe will STRETCH under its own weight.

Programme prompts for:

(1)	LENGTH?=	Length of string
(2)	MUD WT?=	Weight of drilling fluid

Programme outputs the STRETCH (elongation) in the string
Units: Inches and Millimeters

CODE NO:	DESCRIPTION
10.2	**FREE POINT** The programme uses input values of Overpull and Resulting Stretch to calculate the LENGTH of FREE PIPE that exists above the point in the hole at which the string is stuck. **NOTE:** The function can strictly only be applied where the free pipe is of one type only, however the User may use the results to make an educated guess in cases when more than one section of pipe is in use. Programme prompts for: (1) WT/U.L? = Weight per Unit Length of the PIPE BODY (2) OVERPULL? = The Overpull applied to the string to produce the measured STRETCH (3) STRETCH? = The amount of Stretch (elongation) produced in the string by the applied OVERPULL. **NOTE:** The stretch/overpull figures for a given stuck pipe situation are best obtained by initially applying a small amount of overpull, marking the pipe and then measuring the additional stretch resulting from applying a further measured overpull load. In determining stretch figures, care should be taken not to exceed a Tensile loading of the pipe greater than 90% of the Maximum Allowable Tensile Load for the grade of pipe in question.
10.3	**TENSILE AND TORSIONAL DATA** The function accurately calculates the MAXIMUM ALLOWABLE Tensile and Torsional loadings that may **separately** be applied to pipe, of dimensions and strength as specified, without causing permanent deformation of the pipe. The values obtained are in accordance with API figures for Torsional and Tensile data for standard grades of drill pipe. **NOTES:** (1) For figures to be accurate then it is important that accurate OD & ID data is input. (2) Minor variations with figures from API tables may be noted for some output values. This is due to the rounding techniques used in the API tables. Programme prompts for: (1) OD? = Outside Diameter of PIPE BODY in question. (2) ID? = Inside Diameter of PIPE BODY in question. (3) MIN. YIELD? = Minimum Yield Strength of pipe Programme outputs the TENSILE and TORSIONAL MAXIMUM LIMITS for both NEW and PREMIUM CLASS pipe. Units: LBf and Da.Newtons – Tension Ft-LBf and M-Da. Newtons – Torsion.

CODE NO:	DESCRIPTION
10.4	**TORSION UNDER TENSION** Calculates the maximum safe Torsional load that can be applied to a pipe when UNDER TENSILE LOAD. Programme prompts for: (1) OD?= Outside Diameter of PIPE BODY in question. (2) ID?= Inside Diameter of PIPE BODY in question. (3) MIN. YIELD?= Minimum Yield Strength of Pipe. (4) HK.LOAD?= The Hook Load or Tensile pull in the section of pipe under consideration. Programme outputs the Torsional Maximum limits for both NEW and PREMIUM CLASS pipe when subjected to the specified TENSILE LOAD. Units: Ft-LBf and Da.Newtons
10.5	**OD/ID/WT CALCULATIONS** Calculates, logically, any ONE input from ONE or TWO other inputs. The unknown parameter must be indicated by a **ZERO** input in response to its prompt (R/S DEFAULT = 0). **ERRORS** will result from an input of NON-ZERO data in response to **all** prompts. Programme prompts for: (1) OD?= Outside Diameter of pipe/bar (2) ID?= Inside Diameter of pipe (3) WT/U.L?= Weight per Unit length of pipe/bar **Non-logical inputs** will result in repeat of the prompt routine. Programme outputs value of unknown parameter. Units: Inches and Millimeters – OD/ID LBf/Foot and Da.Newtons/Meter – WT/U.L
10.6	**CALCULATION OF X-SECTIONAL AREA** Programme prompts for: (1) OD?= Outside Diamter (2) ID?= Inside Diameter Programme outputs: Pipe X-SECTIONAL AREA in: sq inches and sq millimeters.

CODE NO:	DESCRIPTION

CODE 11 BIT HYDRAULICS OPTIMISATIONS

INTRODUCTION

Code 11 functions are based on the method of Bit Hydraulics Optimisation proposed by K. F. Scott. This is the optimisation of Bit Hydraulics by using actual rig floor data to obtain the Power Law Constant and Exponent for the Pressure Loss/Flow Rate equation and then to use this data to optimise the Pressure/Flow Rate relationship to obtain maximum use of available Hydraulic Energy at the bit. What constitutes Maximum Hydraulic Energy in its most effective form is subject to debate. Two ideas in current vogue are Hydraulic Power and Impact Force.

Code 11functions output data for Maximised Power, Impact Force and Power and Impact Force in Combination. The latter is recommended as the best approach as it can be demonstrated that for oilfield applications the Power and Impact Force values, when both are maximised in relation to one another, give values of **each** that represent a **minimum** of **97% of their maximum possible values.**

The programmes do not directly allow the User to calculate hydraulics optimisations at the planning stage in that they are not integrated with Well Geometry Data. However the User can easily obtain input data sets for Code 11 operations using Code 3 & 12 functions to calculate Total System Pressure Loss/Flow Rate relationships (only two sets of data are required).(See Appendix B).

Function Code 11.0 is the primary code in this group and this function **MUST** have been operated prior to use of the other functions in the group. The registers used by this code group are also used by other code groups, this means that using other codes after a Code 11.0 function will invalidate vital data required by Code 11.1, 11.2, 11.3 & 11.4 operations.

Therefore these Codes should only be used:

(a) **AFTER** a Code 11.0 operation;

(b) When **NO** Non-Code 11 group functions have been used.

11.0 **BIT HYDRAULICS OPTIMISATION**

This Code uses the input data to calculate the Circulating Pressure, that is the System Pressure Loss MINUS the Bit Pressure Loss, for the input Flow rate values (minimum 2). It then does a Power Law curve fit analysis of this data to obtain the Power Law Index and Constant in the equation $P=aQ^b$. The programme then calculates the Flow Rates corresponding to Maximum Power, Impact Force and Power/Impact Force Combination which it then uses to calculate the corresponding Circulating Pressure Losses. These are then in turn deducted from the Maximum Allowable System Pressure Loss to give Bit Pressure Loss and associated data.

The Pressure/Flow Rate relationships used as the inputs for the routine should be obtained on the Rig Floor with the following conditions being met:

CODE NO:	DESCRIPTION

1. Figures to be taken prior to pulling the bit and before dropping survey instruments.
2. The Flow Rates, usually based on pump strokes, should be taken as **accurately** as possible.
3. Before taking the Pressure reading for a particular Flow Rate time should be allowed for the Pressure to stabilise.
4. The Flow Rates chosen (recommended minimum of 4) should be such as to be fairly certain that the Flow Regime in each section of the system remains the same for each rate. For this reason it is recommended that the Lowest Flow Rate is at least 80% of the Maximum Flow Rate.
5. The mud in use at the time of taking the Flow Rates will be the same for the New Bit.

The calculated Nozzle Areas output by this function are the ACTUAL areas required to give the Bit Pressure Losses for the Flow Rates concerned and it is these values that are used to calculate Power, Impact Force and Nozzle Velocity. The Nozzle Sizes are those that **approximate** to the calculated Nozzle Area and hence have a combined Nozzle Area different from the **calculated area.** Thus they will result in Bit Pressure, Power, Impact Force and Nozzle Velocities DIFFERENT from those obtained using the **calculated area.** So that the User may know the results obtained for a particular Nozzle Set and Flow Rate the end of the Code 11.0 routine incorporates a Code 11.2 routine which allows the User to obtain results based on Nozzle Sizes and Flow Rate as specified. If the User does not wish to utilise this facility then an R/S operation without input will terminate output for this Code.

> **NOTE:** The method generally works well especially when Annulus Pressure Losses are small relative to Pipe Pressure Losses. However care must be exercised when Annulus Pressure losses increase in significance (e.g. with High Weight mud in deep small hole) because the premise that the whole Circulating System can be represented by a **single** Power Law equation ceases to be valid.

The programme prompts for:

(1)	NO. OLD NOZ.? =	Number of nozzles in the bit at time of taking Pressure/Flow Rate data sets (no limits).
(2)	noz.' – '? =	Prompts for size of each nozzle in turn then outputs the equivalent Nozzle Area.
(3)	MUD WT? =	Mud Weight in use.
(4)	MAX.PS? =	Maximum System Pressure allowed.
(5)	NO. NEW NOZ.? =	Number of Nozzles to be used in the New Bit (no limit).
(6)	NO. SETS? =	Number of sets of Pressure/Flow Rate data to be entered (minimum 2).
(7)	Q RATE? =	Flow Rate
(8)	PRES? =	Pressure Loss corresponding to Input Flow Rate.

CODE NO:	DESCRIPTION
	(9) RIGHT? = Are the Pressure/Flow Rate input values correct? If 'Y' (YES) (R/S DEFAULT) programme proceeds with outputs. If 'N' (NO) the programme briefly displays 'RPT SETS' and then prompts for input of data sets again.
	The Power Law Constant, Index and Co-efficient of Determination are then output.
	This is followed by the following data for each of: (a) Maximised Impact Force (b) Maximised Hydraulic Power (c) Maximised Hydraulic Power/Impact Force Combination:
	(1) Required Flow Rate (2) Resulting Circulating Pressure loss at required Flow Rate (3) Available Bit Pressure Loss at required Flow Rate (4) Required Nozzle Area (5) Nozzles Sizes that approximate calculated Nozzle Area (6) Hydraulic Power produced using available Bit Pressure Loss (7) Impact Force produced using available Bit Pressure Loss (8) Nozzle Velocity produced using available Bit Pressure Loss
	This is followed by "PWR%" which is the percentage of the Maximum possible Bit Hydraulic Power (or Impact Force) that is being produced when Power and Impact Force are MAXIMISED in COMBINATION ACTUAL HYDRAULICS is then prompted for (see Code 11.2).
11.1	**CHANGE MAXIMUM ALLOWABLE SYSTEM PRESSURE AND NUMBER OF NEW NOZZLES** Allows the User to change the Maximum System Pressure and the number of Nozzles to be used. Both values MUST be input. Programme prompts for: (1) MAX.PS?= Maximum Allowable System Pressure (2) NO. NEW NOZ.?= Number of New Nozzles
	Programme then outputs data as per Code 11.0 using the new data inputs.
11.2	**ACTUAL HYDRAULICS** This same routine is used automatically at the end of a Code 11.0 routine. It is designed to allow the User to specify an Actual set of Nozzle Sizes (the number is determined by the current "NO. NEW NOZ.?=" input value) and a Flow Rate and so determine a set of Pressure and Hydraulic Data for the system that it is planned to use based on the Pressure Flow Rate data obtained from the last bit run.

CODE NO:	DESCRIPTION

The programme prompts for:

(1) noz.'-'?= The sizes of each Nozzle in turn
(2) Q RATE?= The Flow Rate to be used.

The programme then outputs one set of data, including the resulting System Pressure loss, based on these input values.

11.3 **INPUT SPECIFIED FLOW RATE**
Allows the User to obtain a data output set of the type obtained in Code 11.0 operations for a specified Flow Rate and based on the constants calculated for the Power Law equation relating Flow Rate and Pressure Loss for the Code 11.0 inputs.
Programme prompts for:

(1) Q RATE?= Desired Flow Rate

11.4 **INPUT NEW Q RATE/PRESS DATA**
Allows the User to input a New Set of drill floor Pressure/Flow Rate data sets (minimum 2) while keeping the original inputs of the other Code 11.0 input data.
Data output is as for Code 11.0

CODE 12 GENERAL CALCULATIONS

INTRODUCTION

Code 12 operations differ from those of the other Codes in that once selected the module remains in the **GENERAL CALCULATIONS MODE** until another Code selection is made or a User programme is run.
In **GENERAL CALCULATIONS MODE** the calculator remains in 'USER' mode and the keys 'a' through 'e' and 'A' through 'I' become active for their specified operation as shown in the table below.

12 GENERAL CALCULATIONS 12				
a PIPE DISPLACEMENT	b FLOW RATE	c PIPE FLUID VELOCITY	d BUOYANCY FACTOR	e ANN. MUD WT. - (DRILLING)
A HOLE CAPACITY	B ANNULUS CAPACITY	C ANN. FLUID VELOCITY	D NOZZLE SIZES/AREA	E MIN.H. PWR. (FULLERTON)
F NOZ.A	G Q RATE	H PRES	I MUD WT	PRESS R/S KEY WITHOUT INPUT TO CALCULATE RESULTS
INTERACTIVE BIT HYDRAULICS				

NOTE: If any User assignments have been made to any of the keys 'a' through 'e' and 'A' through 'J' then these assignments will take preference over their use as Local Label Keys as used in Code 12, General Calculations operations. Such User assignments must be cancelled to allow full use of Code 12 functions.

CODE NO:	DESCRIPTION
	Once in this mode the User merely presses the key for the output he requires and is then prompted for the necessary inputs. The answer is returned to the X-REGISTER and is then, if appropriate, available for further calculation.
	NOTE: When performing calculations with results obtained from a GENERAL CALCULATIONS ROUTINE it is advisable to switch the HP 41 out of 'USER' mode prior to using the result in the calculation. GENERAL CALCULATIONS MODE routines may then be re-accessed by switching back to 'USER' mode.
	If the HP 41 is being operated without the printer then single answer outputs will not be labelled. The label is however available in the ALPHA register if it is required.
	User keys 'F' through 'I', INTERACTIVE BIT HYDRAULICS, operate differently from the other keys. The function of each of these keys is to input **or** calculate its designated value using the stored values of the other keys.
	When in GENERAL CALCULATIONS MODE the module maintains module operating flags and the current units control flag settings. However for **individual key** operations the User has the option to change the units to be used in that calculation, by setting or clearing relevant parameter dedicated flags as required, immediately prior to the required key operations.
	WARNING: Because programme operation exits from the GENERAL CALCULATIONS PROGRAMME during prompt routines the User must always complete a prompt call if it is required to remain in GENERAL CALCULATIONS MODE. Otherwise another Code 12 operation will be required.
	GENERAL CALCULATIONS functions are:
a.	**PIPE DISPLACEMENT** Volume of fluid displaced per unit length of pipe as a result of steel volume.
b.	**FLOW RATE** Operates in two modes (a) PIPE flow (b) ANNULAR flow. This is dependant on response to the prompt "P. FLOW?", 'Y' (YES) (R/S default) gives PIPE flow and 'N' (NO) gives ANNULAR flow. Calculates the flow rate given the fluid velocity in PIPE **or** ANNULUS of specified dimensions.
c.	**PIPE FLUID VELOCITY** Calculates fluid velocity in a pipe of given I.D. and at the specified flow rate.
d.	**BUOYANCY FACTOR** Calculates the factor by which steel weight in air must be multiplied to obtain its weight in the fluid of specified weight.

CODE NO:	DESCRIPTION
e.	**ANNULUS MUD WEIGHT** Calculates the effective weight of the drilling fluid in the annulus resulting from the addition to the input mud of drilled solids.
A.	**HOLE CAPACITY** Calculates the volume per unit length of the Hole.
B.	**ANNULUS CAPACITY** Calculates the volume per unit length of the Annulus.
C.	**ANNULUS FLUID VELOCITY** Calculates the fluid velocity in an Annulus of given hole and pipe size at a specified flow rate.
D.	**NOZZLE SIZES/AREA** This function has three operating modes: (1) If NO entry is made in response to the "NOZ.A? =" prompt, i.e. immediate R/S key operation, then the programme calculates the SIZES of NOZZLES for the number of nozzles specified, of the current **INTERACTIVE BIT HYDRAULICS** Nozzle Area. This is useful for converting a calculated nozzle area into equivalent nozzle sizes. (2) If a nozzle area entry is made to the "NOZ.A? =" prompt then the corresponding SIZES of NOZZLES are calculated. Interactive Bit Hydraulics are unaffected. (3) If ZERO (0) is entered in response to the "NOZ.A? =" prompt then the sizes of the specified number of nozzles are prompted for and their corresponding NOZZLE AREA is calculated. This value is also stored for **INTERACTIVE BIT HYDRAULICS CALCULATIONS.**
E.	**MINIMUM HYDRAULIC POWER (FULLERTON)** Calculates an estimated Minimum Hydraulic Power required to ensure sufficient bottom hole cleaning for a bit of specified size, when drilling with the input Weight on Bit and R.P.M. (English units: Horse power; Metric units: kilowatts).
F,G,H,I	**INTERACTIVE BIT HYDRAULICS** These keys are used in conjunction with one another. Any of the four keys may be used to **either** ENTER **or** CALCULATE its dedicated parameter.

CODE NO:	DESCRIPTION

Pressing any one of these keys, when GENERAL CALCULATIONS MODE is active, will result in a prompt for that parameter, if a NON-ZERO entry is made followed by operation of the R/S key then that entry will be stored as the value for that parameter and **no** calculation will take place. If ZERO or NO input is made prior to R/S key operation then the value of that parameter will be calculated using the current stored values of the other parameters.

> **WARNING:** Although the registers used by the INTERACTIVE BIT HYDRAULICS routines are not used by any of the other GENERAL CALCULATIONS routines, they are used by other MODULE routines i.e. values stored by INTERACTIVE BIT HYDRAULICS routines **will not be saved** if the User interrupts GENERAL CALCULATIONS operations by using other module functions.

An attempt to calculate the value of any one parameter when one or more of the other parameters is zero will result in a "PWR. = 0.000" output.

When a calculation is made outputs are as follows:

(1) Calculated value of selected parameter.
(2) Nozzle Velocity (Length/Sec).
(3) Hydraulic Power at the bit (Horsepower/Kilowatts)
(4) Impact Force at bit (LBf/Da-Newtons)

Finally the calculated value of the selected parameter is displayed in the X-REGISTER.

CODE 13 RHEOLOGY CALCULATIONS

INTRODUCTION

Code operations in this group mostly involve the preparation of the RHEOLOGY DATA that is to be used in PRESSURE LOSS calculations. The concepts behind the data inputs/calculations of these Codes are discussed in the section "PRESSURE CALCULATIONS"(Pages 10.01 – 10.08).
Fann Rheology calculations are based on data obtained using a Spring 1/Bob 1/Rotor 1 combination in the Rheometer.

Code 13.4 concerns the Carrying Capacity of the Drilling Fluid.

13.0 **RHEOLOGY FROM FANN DATA**

This function calculates the hi.n, Hi.K, n and K values from sets of data obtained from a Fann viscometer. Although the minimum number of R.P.M./Fann reading input sets is TWO, it is **strongly recommended** that more than two data sets are used.
(Data sets are best obtained from Fann 6 speed or multispeed viscometers).

The routine uses the **first two input data sets** to calculate the hi.n, Hi.K values that will be used in TURBULENT FLOW calculations. It is therefore important that these first two input sets are those that relate to HIGH SHEAR RATES.

CODE NO:	DESCRIPTION

In that the outputs from the routine include the PV & YP of the mud (these are not used in module calculations) and that these are also calculated using data from the FIRST TWO input sets it follows that the first two inputs should be for the **600 & 300 R.P.M.** readings.

The hi.n, Hi.K values are calculated and stored immediately after the User has confirmed correct entry of the first two data sets by a 'Y' (YES) (R/S default) response to the 'RIGHT?" prompt. Their values remain UNCHANGED by subsequent data modification routines associated with this function (see EXAMPLES OF CODE: 13).

Following hi.n, Hi.K calculation and assuming more than entry of two data sets has been indicated the User is prompted for entry of the remaining data sets. When this is completed the User is again prompted for confirmation that data, as entered, are correct. If the response is 'N' (NO) then **ALL** data entry is repeated, if 'Y' (YES) then the programme outputs the calculated hi.n, Hi.K, r^2,n, K,r^2, PV & YP values.

> **NOTE:** r^2 = the co-efficient of determination for each n/K base data set – this gives the User an idea as to how closely the input data fits a POWER LAW relationship – the closer r^2 is to unity the better the fit.

Following this the USER is prompted with "CHG.SETS?" an 'N' (NO) response ceases n/K calculations and ends the routine with a prompt for Mud Weight. A 'Y' (YES) (R/S DEFAULT) allows the User to make changes to the previously input Fann data and to then obtain a new n & K value set (hi.n & Hi,K remain unchanged).

The User is given two options either to **ADD or DEDUCT** data sets, the required option is selected by answering 'Y' (YES) or 'N' (NO) in response to the prompt "ADD?" following which the User is prompted for the number of data sets that are to be added/deducted and then the data itself.

> **NOTE:** If in **DEDUCT** mode the input data for deduction must exactly correspond to previously input data not already deducted. **Added** data must be new **not** previously entered, currently stored, data.

In this way the User may, for example, elect to calculate an n/K set using the 600, 300, 200, 100, 6 and 3 R.P.M. readings from the Fann viscometer. After input of this data set the module will return hi.n, Hi.K values based on the 600 & 300 R.P.M. readings and the n,K values based on **all** 6 readings. It could then be decided to see the effect of calculating n,K values based on only the 300, 200, 100, 6 readings, i.e. **DEDUCTING** the 600 and 3 readings with the DEDUCT option. Following input of the data to be deducted and confirmation that it is correct, the programme will calculate and output a new n/K set. The hi.n, Hi.K values will be the same, still based on the original 600, 300 readings, but n & K will now only be calculated using the 300, 200, 100, 6 readings and it will now be these values that are stored as the current RHEOLOGY DATA.

CODE NO:	DESCRIPTION
	The change option can be repeated as required by making the appropriate 'Y'/'N' input in response to the "CHG. SETS?" prompt. The 'N' (NO) response always results in the prompt for input of Mud Weight and then ends the routine.

13.1 **INPUT RHEOLOGY AND MUD WT.**

This function allows the User to input directly the hi.n, HI.K, n,K, and Mud Weight values to be used as the Rheology Data for Pressure Loss Calculations etc.

> **NOTE:** If it is required only to change the Mud Weight value then a default option operates after the "hi.n? =" prompt. If no keyboard operation has taken place then an immediate R/S key operation will cause the programme to jump directly to the Mud weight input prompt.
> The programme prompts for:

			STORED IN
(1)	hi.n? =	High Value of Power Law Index	R.108
(2)	Hi.K? =	High Value of Power Law Constant	R.109
(3)	n? =	Power Law Index	R.110
(4)	K? =	Power Law Constant	R.111
(5)	MUD WT? =	Mud Weight	R.106

13.2 **OUTPUT RHEOLOGY AND MUD WT.**

This function outputs the current Rheology data as stored in registers 106 and 108-111.
Programme outputs:

(1)	hi.n =	High value of Power Law Index
(2)	Hi.K =	High value of Power Law Constant
(3)	n =	Power Law Index
(4)	K =	Power Law Constant
(5)	PV =	Plastic Viscosity in CENTIPOISE
(6)	YP =	Yield Point
(7)	MUD WT =	Mud Weight

13.3 **INPUT P.V., Y.P. AND MUD WT**

This function allows the User to calculate a set of Rheology data from input values of Plastic Viscosity and Yield Point. The n/K values obtained are the same for both the hi.n, Hi.K and n, K sets and for this reason it is NOT a recommended procedure for obtaining Rheology data if a better alternative is available.
The programme prompts for:

(1)	PV? =	Plastic Viscosity (Centipoise)
(2)	YP? =	Yield Point
(3)	MUD WT? =	Mud Weight

CODE NO:	DESCRIPTION

Note: See section: "UNITS SELECTION" (Pages 2.01 – 2.03) for units of Yield Point.

The programme then outputs:

(1) hi.n = High Value of Power Law Index
(2) Hi.K = High Value of Power Law Constant
(3) n = Power Law Index
(4) K = Power Law Constant
(5) PV = Plastic Viscosity in CENTIPOISE
(6) YP = Yield Point
(7) MUD WT = Mud Weight

13.4 **LIFTING CAPACITY OF MUD**

This code is used to calculate the Maximum Size (O.D.) of Spherical Particle that may be expected to be removed from an annulus in which the Fluid Velocity and Viscosity are known.

It is assumed that for satisfactory removal of such a particle the Slip Velocity of the particle in the annulus must not exceed 75% of the annulus mud velocity. That is to say that the upward velocity of the particle in the annulus is 25% of the fluid velocity in the annulus.

The programme assumes a change from Laminar to Turbulent flow regime around the particle at a Reynolds Number of 2000.

The programme makes three separate calculations and then uses a set of comparison checks to determine which value is to be output as the maximum size of particle that can be removed from the annulus.
The calculations are as follows:

(1) Calculates the size of particle, D_R, that falls with a Slip Velocity of 0.75 x fluid velocity and has a particle Reynolds Number of 2000.

$$D_R = 2000 / 15.47 \rho p \, 0.75 \bar{V}$$

(2) Calculates the size of particle D_L, that will fall with a Slip Velocity of 0.75 x Fluid Velocity assuming Laminar Flow.

$$D_L = 0.75\bar{V} (\rho f \, \mu)^{.333} / 175 \, (\rho p - \rho f)^{.667}$$

(3) Calculates the size of particle, D_T, that will fall with a Slip Velocity of 0.75 x Fluid Velocity assuming Turbulent Flow.

$$D_T = (0.75\bar{V})^2 \; C_d \rho f / 113.4^2 \; (\rho p - \rho f)$$

Where:

μ = Fluid viscosity in annulus (cps) obtained from Code 3 annulus section data outputs.

CODE NO:	DESCRIPTION

$\bar{V}$ = Average fluid velocity in annulus (ft/min) obtained from Code 3 annulus section data outputs.

ρf = Mud weight in pounds/gallon.

ρp = Particle density in pounds/gallon. (22.0 p.p.g. = 1.1429S.G.)

C_d = 1.5 (drag coefficient)

The comparison checks are:

(1)	$D_L \leq D_R > D_T$	Indicates LAMINAR Particle Flow – output D_L
(2)	$D_L > D_R \leq D_T$	Indicates TURBULENT Particle FLOW – output D_T
(3)	$D_L \leq D_R \leq D_T$	Output D_T
(4)	$D_L > D_R > D_T$	Output D_L

Programme prompts for:

(1)	MUD WT?=	Mud Weight
(2)	VISC?=	Mud Viscosity in CENTIPOISE
(3)	VEL?=	Mud Velocity

Programme then outputs the Maximum Outside Diameter of a Spherical Particle of density 22.0 p.p.g. (= 1.1429 S.G.) that will be removed from the annulus at an average velocity of 25% of the fluid velocity.

NOTE: Mud Velocity refers to the fluid velocity in a specific annular section. Mud Viscosity refers to the actual fluid viscosity in the same specified annular section. Both these inputs are obtained for each annular section using a Code 3.0 or 3.2 function.

Notes

Notes

PROMPT	CODE NO:	UNITS AS FOR:	DESCRIPTION
ADDED VOL?=	7.5	VOLUME	**ADDED VOLUME?=** Refers to the Volume of Liquid Additive to be added to the drilling fluid. Used in calculation of resultant Mud Weight.
ADDED WT?=	7.3	WEIGHT	**ADDED WEIGHT?=** Refers to the Weight of Solid Additive to be added to the drilling fluid. Used in calculation of resultant Mud Weight.
AV.LEN/JNT?=	8.2	LENGTH	**AVERAGE LENGTH PER JOINT?=** Refers to the Average Length of a joint of casing. Used in Work Done calculations.
AV. LEN/STD?=	8.0 8.1	LENGTH	**AVERAGE LENGTH PER STAND?=** Refers to the Average Length of the Stands of Drill Pipe and Drill Collars (i.e. total length of string divided by total no. of stands of D.C. & D.P.) Used in Work Done calculations.
AV.P. VEL?=	3.9	LENGTH/ MIN	**AVERAGE PIPE VELOCITY?=** Refers to the Rate at which pipe is run into or pulled out of the Hole (usually calculated as the length of a joint or stand divided by the time required to pull or run it). Used in Surge-Swab calculations.
ADD?	13.0	ALPHA	**ADD?** Refers to the Addition of sets following a 'Y' (YES) response to the prompt "CHG. SETS?". If 'Y' is input Additional sets of Fann Data will be Prompted for, if 'N' (NO) is input, sets to be deducted will be Prompted for. Used in Rheology calculations from Fann Data.
BIT DIA?=	12.	DIAMETER	**BIT DIAMETER?=** Refers to the Diameter of the Drill Bit. Used in calculation of the Minimum Hydraulic Power required for drilling (Fullerton).

PROMPT	CODE NO:	UNITS AS FOR:	DESCRIPTION
B/L/O?	7.2 7.3	ALPHA	**BARYTE/LOW GRAVITY SOLIDS/ OTHER?** Refers to the type of Solid Additive to be added to the Drilling Fluid. It requests the User to select the type of solid to be used; B – Baryte (35.4ppg = 4.24 S.G) L – Low Gravity Solids (21.7ppg = 2.60 S.G.) O – Other. This will result in a prompt for the density of the solid to be added. Used in calculation of **either** required Weight & Volume of solid additive **or** resultant Mud Weight of drilling fluid.
CALC.D?=	1.8 1.9 3.6 3.7	LENGTH	**CALCULATION DEPTH?=** Refers to the depth above which Annulus data calculations are to be made when a bit depth greater than the CALC.D has been specified. Used in Annulus data calculations useful for E.C.D. calculations & cement volume calculations.
CHG. SETS?	13.0	ALPHA	**CHANGE SETS?** Refers to the sets of Fann data entered for Rheology calculations and is asking if Additions or Deductions of data sets are to be made to the current Fann data that has been entered. A 'Y' (YES) response will allow changes to be made. An 'N' (NO) response will result in a prompt for Mud Weight. Used in Rheology calculations from Fann data.
DENSITY?=	7.2 7.3 7.4 7.5	MUD WEIGHT	**DENSITY?=** Refers to the Density of either a solid or liquid that is to be added to the drilling fluid. The prompt follows selection 'O' (other) in type of solid or liquid selection. Used in calculation of either required Weight of SOLID or LIQUID additive or resultant Weight of drilling fluids.

PROMPT	CODE NO:	UNITS AS FOR:	DESCRIPTION
DEPTH?=	1.0–1.9 3.0–3.7 3.9 8.0–8.4 10.0	LENGTH	**DEPTH?=** Refers to the Depth at which the bit is to be positioned for Pipe and Annulus calculations and the Depth at which hole calculations are to be made. (In Code 8.4 operations it refers to the distance from Derrick floor to wellhead). Used in all Well Geometry calculations.
DIA?=	1.0–1.9 3.0–3.9 12	DIAMETER	**DIAMETER?=** Refers to the Diameter of a hole section (as opposed to the I.D. or O.D. of a pipe section). Used in Well Geometry calculations.
DRILLED?=	8.3	LENGTH	**DRILLED?=** Refers to the Length of Hole Made for which it is required to calculate the work done in Drilling/Coring/Reaming the section of that length. Used in calculation of Work done Drilling/Coring/Reaming.
D/W/O?	7.4 7.5	ALPHA	**DIESEL/WATER/OTHER?** Refers to the type of liquid additive to be added to the drilling fluid. It requests the User to select the type of liquid to be used: D – Diesel (6.9 ppg = 0.827 SG) W – Water (8.4 ppg = 1.007 SG) O – Other. This will result in a prompt for the density of the liquid to be added. Used in calculation of either required Weight & Volume of liquid additive **or** resultant Mud Weight of drilling fluid.
F.MUD WT?=	7.2 7.4	MUD WEIGHT	**FINAL MUD WEIGHT?=** Refers to the Final Mud Weight required for the drilling fluid on addition of a solid or liquid additive. Used in calculation of the Weight and Volume of solid or liquid additive required to achieve the Final Mud Weight.

PROMPT	CODE NO:	UNITS AS FOR:	DESCRIPTION
FANN?=	13.0	FANN METER DIAL READING	**FANN?=** Refers to the dial reading obtained for a given R.P.M., from a Fann Viscometer using a Rotor 1/Bob 1/Spring 1 combination. Used in calculation of n & K Rheology values.
GCMUD WT?=	7.0	MUD WEIGHT	**GAS CUT MUD WEIGHT?=** Refers to the Weight of the drilling fluid, as measured using a standard mud balance, when taken at the flow line and when **no** attempt to break out the gas has been made. Used in calculating the reduction of bottom hole hydrostatic pressure resulting from gas cutting of the annulus drilling fluid.
H-DIA?=	3.8	DIAMETER	**HOLE DIAMETER?=** Refers to the Diameter of a Hole section. Used in User calculation of Annulus data.
HI.K?=	13.0–13.3 1.0–1.9 3.0–3.9	ENGLISH: $\frac{LBf\text{-}SEC^n}{100FT^2}$ METRIC: $P_A\text{-}SEC^n$	**HIGH K?=** Refers to the Power Law Constant K used in mud Rheology to represent the Consistency index as obtained using the 600 & 300 R.P.M. Fann Readings. Used in the calculation of pressure losses in Turbulent and Transitional flow regimes.
hi.n?=	13.0–13.3 1.0–1.9 3.0–3.9	DIMENSION LESS	**high n?=** Refers to the Power Law Index, n, used in mud Rheology to define the type of flow profile, obtained using the 600 & 300 R.P.M. Fann readings. Used in calculation of pressure losses in Turbulent & Transitional flow regimes.
HK.LOAD?=	10.4	WEIGHT	**HOOK LOAD?=** Refers to the Weight of the drill string hanging in the hook (i.e. the weight gauge reading minus the weight of the travelling block and compensator assembly). Used in calculation of the maximum Torsion that can be applied to Pipe under tension.

PROMPT	CODE NO:	UNITS AS FOR:	DESCRIPTION
HOLE SIZE?=	12	DIAMETER	**HOLE SIZE?=** Refers to the size of Hole that is being drilled. Used in calculation of the increase in Annulus mud weight resulting from solids addition due to cuttings.
ID?=	10.0–10.6 12	DIAMETER	**INTERNAL DIAMETER?=** Refers to the actual Internal Diameter of a pipe to be used in a calculation. Used in pipe property calculations & general calculations.
ID.<C>?=	9.0–9.2 3.8	DIAMETER	**INTERNAL DIAMETER FOR CAPACITY CALCULATIONS?=** Refers to the equivalent ID of a joint of pipe taking into account the dimensions of the end preparations & tool joints (see Pipe Specification Data Sheets). Used specifically in calculation of Pipe Displacement, Capacity & Weight data.
ID.<P>?=	9.0–9.2 3.8	DIAMETER	**INTERNAL DIAMETER FOR PRESSURE LOSS CALCULATIONS?=** Refers to the equivalent I.D. of a joint of pipe taking into account the end preparation & tool joints. (See Pipe Specification Data Sheets). Used specifically in calculation of Pressure Losses.
I.MUD WT?=	7.2 7.3 7.4 7.5	MUD WEIGHT	**INITIAL MUD WEIGHT?=** Refers to the Initial Mud Weight of the drilling fluid to which liquid or solid additions are to be made. Used in calculation of the Weight & Volume of LIQUID or SOLID to be added to obtain a given Final Mud Weight and the Final Mud Weight resulting from known additions of SOLIDS or LIQUIDS.

PROMPT	CODE NO:	UNITS AS FOR:	DESCRIPTION
JNT.LENGTH?=	10.0	LENGTH	**JOINT LENGTH?=** Refers to the Average Length of a Joint of pipe used in calculation of Critical Rotary Speeds of pipe.
K?=	13.0–13.3 1.0–1.9 3.0–3.9	ENGLISH: LB-SEC^n/100 FT^2 METRIC: PA-SEC^n	**K?=** Refers to the Power Law constant K used in mud Rheology to represent the Consistency index. Obtained using selected Fann Viscometer readings. Used in the calculation of pressure losses in Laminar Flow Regimes.
KELLY LEN?=	8.3	LENGTH	**KELLY LENGTH?=** Refers to the Length of the Kelly used for drilling (includes lower kelly cock & saver sub). Used in calculation of the Work Done Drilling/Coring/Reaming.
KELLY WT?=	8.3	WEIGHT	**KELLY WEIGHT?=** Refers to the total Weight of the Kelly. Used in calculation of the Work Done Drilling/Coring/Reaming.
LENGTH?=	9.0–9.2 10.1	LENGTH	**LENGTH?=** Refers to the length of a section of Pipe or Hole. Used in all Well Geometry input routines and in calculating the Stretch in a length of Pipe.
MAX.PS?=	11.0 11.1	PRESSURE	**MAXIMUM SYSTEM PRESSURE?=** Refers to the Maximum Allowable Stand Pipe Pressure that may be used. Used in Bit Hydraulics optimisation programmes.
MIN. YIELD?=	10.3 10.4	PRESSURE	**MINIMUM YIELD?=** Refers to the Minimum Yield Strength of the steel under consideration. Used in calculation of Tensile & Torsional limits of Pipe.

PROMPT	CODE NO:	UNITS AS FOR:	DESCRIPTION
MUD VOL?=	7.2 7.3 7.4 7.5	VOLUME	**MUD VOLUME?=** Refers to either the Initial Volume of Mud or the required Final Volume of Mud. Used in calculations involving the addition of solids or liquids to the drilling fluid.
MUD WT?=	11.0 12 13 – 13.3 8.0 – 8.3	MUD WEIGHT	**MUD WEIGHT?=** Refers to the Density of the drilling fluid. **NOTE:** Entries of Mud Weight in response to prompts from programmes 11.0, 12. & 8.0 – 8.3 do not affect the value of Mud Weight as used in other programmes utilizing Well Geometry data & Rheology data as input using programmes 9.0 – 9.2 & 13.0 – 13.3.
n?=	13 – 13.3 1.0 – 1.9 3.0 – 3.9	DIMENSION LESS	**n?=** Refers to the Power Law Index, 'n', used in mud Rheology to define the type of flow profile. Obtained using selected Fann viscometer readings. Used in calculation of pressure losses in Laminar flow regimes.
NO. JNTS?=	8.3	DIMENSION LESS	**NUMBER OF JOINTS?=** Refers to the number of joints used in drilling a section of hole. Defined as the distance drilled divided by the average length of a joint (can be entered as a decimal value). Used in the calculation of Work Done when Drilling/Coring/Reaming.
NO. NEW NOZ.?=	11.0 11.1	DIMENSION LESS	**NUMBER OF NEW NOZZLES?=** Refers to the number of nozzles that are to be run in the new bit. Used in Bit Hydraulics optimisation calculations.

PROMPT	CODE NO:	UNITS AS FOR:	DESCRIPTION
NO. NOZ.?=	12	DIMENSION LESS	**NUMBER OF NOZZLES?=** Refers to the Number of Nozzles for which a calculation is to be made, either of nozzle area or nozzle sizes. Used in Nozzle calculations.
NO. OLD NOZ.?=	11.0	DIMENSION LESS	**NUMBER OF OLD NOZZLES?=** Refers to the Number of Nozzles that are in the old bit as used to obtain the sets of Flow Rate/Pressure data. Used in Bit Hydraulics optimisation calculations.
NO. SETS?=	11.0 13.0	DIMENSION LESS	**NUMBER OF SETS?=** Refers to the number of sets of data (minimum 2) that are to be entered. Used in Bit Hydraulics optimisation & Fann Rheology calculations.
NO. X REAM?=	8.3	DIMENSION LESS	**NUMBER OF TIMES REAMED?=** Refers to the number of times the bit is reamed following the drilling down of a joint. The bit is considered to have been reamed once when, **after** drilling down a joint, the kelly is picked back up & then lowered back to bottom. Used in calculation of Work Done when Drilling/Coring/Reaming.
NOZ.A?=	12	DIAMETER^2	**NOZZLE AREA?=** Refers to the Area of a set of Nozzles. **NOTE:** When using key 'D' in "General Calculations" mode, the "NOZ.A?=" prompt has **three** possible results. 1. ENTRY OF ZERO – indicates that calculation of nozzle area is required. 2. NO ENTRY – Uses current nozzle area, in use with Interactive Bit Hydraulics, to calculate equivalent nozzle sizes. 3. INPUT OF AREA – Calculates equivalent nozzle sizes. Used in bit nozzle size and area calculations.

PROMPT	CODE NO:	UNITS AS FOR:	DESCRIPTION
noz.'_'?=	11.0 12.	32nds of an inch regardless of units mode	**nozzle number '_'?=** Refers to the size of the number of the nozzle prompted for. Used in the Bit Hydraulics programmes & General Calculations to calculate nozzle areas.
O.D?=	9.0 9.1 9.2	DIAMETER	**OUTSIDE DIAMETER?=** Refers to the Outside Diameter of a joint of pipe. Out of preference the O.D. entered should be the equivalent O.D. which includes the adjustments for end preparations and tool joints. (See Pipe Specification Data Sheets). Used in Well Geometry calculations.
OD?=	10.0 10.3 10.4 10.5 10.6	DIAMETER	**OUTSIDE DIAMETER?=** Refers to the Outside Diameter of the pipe (generally the actual pipe body O.D.). Used in Pipe Specification Calculations.
O/PULL?=	10.2	WEIGHT	**OVERPULL?=** Refers to the Force in excess of the hanging weight of the pipe that is applied to the pipe to obtain a measured stretch. Used in the calculation of the Free Point of Stuck Pipe.
P.FLOW?	3.8 12	ALPHA	**PIPE FLOW?** Refers to the type of calculation to be made. If 'Y' (YES) is input the calculation that follows will be for Pipe data. If 'N' (NO) is input the calculation will be for Annulus data. Used in User Calculations of Pipe or Annulus data and in calculation of Flow Rates.
P-O.D.?=	3.8	DIAMETER	**PIPE OUTSIDE DIAMETER?=** Refers to the Outside Diameter of the pipe. Depending on the calculation being done, consideration should be made as to whether the O.D. used should be the actual or equivalent O.D. of the pipe (see Pipe Specification Data Sheet). Used in calculation of Pipe and Annulus data from direct User inputs.

PROMPT	CODE NO:	UNITS AS FOR:	DESCRIPTION
PRES?=	11.0 11.4	PRESSURE	**PRESSURE?=** Refers to the System Pressure Loss for a given Flow Rate. These Pressure/-Flow Rate relationships are obtained, as sets of data, on the drill floor prior to pulling a bit. Used in Bit Hydraulics Optimisation Programmes.
PV?=	13.3	CENTIPOISE cps. (in both English & Alternative modes)	**PLASTIC VISCOSITY?=** Refers to the drilling fluids resistance to flow. **NOTE:** Since PV relates only to the 600 & 300 R.P.M. readings obtained using the Fann Viscometer, it should not be considered a desirable parameter for pressure loss calculations (hi.n = n & HI.K = K). Used in calculation of hi.n,n,HI.K & K. values for use in pressure loss calculations.
Q RATE?=	1.0 – 1.9 3.0 – 3.9 11. – 11.4	VOLUME/ MIN	**FLOW RATE?=** Refers to the rate of circulation of the drilling fluid. **NOTE:** There is a default value to this prompt for programmes 1.0-1.9 & 3.0-3.9. This means that if no input is made in answer to the prompt prior to pressing the R/S key then the last value input for Flow Rate will be used. Used in Pipe and Annulus data calculations & in Bit Hydraulics optimisation programmes.
RHEO.OK?	1.0 – 1.9 3.0 – 3.9	ALPHA	**IS THE MUD RHEOLOGY OK?** Refers to the Rheology and Weight data of the drilling fluid. Used to check that such data is OK prior to data calculations. If 'Y' is input the data is OK and programme operation continues. If 'N' is input then the programme allows input of new Rheological data prior to continuing the chosen programme.

PROMPT	CODE NO:	UNITS AS FOR:	DESCRIPTION
RIGHT?	9.0–9.3 11.0 13.0	ALPHA	**RIGHT?** Refers to a set of data just entered. If 'Y' (YES), is entered then data input was correct & programme continues. If 'N' (NO) is entered then data input was not correct and the prompt sequence for the data in question is repeated.
R. JNT WT?=	8.4	WEIGHT	**RISER JOINT WEIGHT?=** Refers to the Weight in Air of a joint of riser. Used in calculation of the Work done running or pulling the Sack.
ROP L/HR?=	12	LENGTH/HR	**RATE OF PENETRATION IN LENGTH UNITS PER HOUR?=** Refers to the rate at which new hole is being drilled. Used in calculating the Annulus Mud Weight resulting after addition of drilled Solids to the input mud.
RPM?=	12	DIMENSION LESS	**REVOLUTIONS PER MINUTE?=** Refers to the speed at which the bit is being rotated. Used in the calculation of the Minimum Hydraulic Power required to prevent bit balling.
R+STK WT?=	8.4	WEIGHT	**RISER & STACK WEIGHT?=** Refers to the total Weight of the Riser and Stack assembly just prior to landing the Stack. This Weight is the weight gauge reading minus the weight of the travelling block (& compensator) assembly. It is the buoyant weight of the Riser & Stack. Used in calculation of the Work Done running or pulling the Stack.
STK HT?=	8.4	LENGTH	**STACK HEIGHT?=** Refers to the height of the Lower Marine Riser package and Stack assembly. Used in calculation of the Work Done running or pulling the Stack.

PROMPT	CODE NO:	UNITS AS FOR:	DESCRIPTION
STK WT?=	8.4	WEIGHT	**STACK WEIGHT?=** Refers to the weight of the Stack in water. Used in calculation of the Work Done running **or** pulling the Stack.
STRETCH?=	10.2	DIAMETER	**STRETCH?=** Refers to the Stretch measured in the pipe after applying a known force to the pipe in excess of the hanging weight of the pipe. Used in calculation of the Free Point of Stuck pipe.
TMUD WT?=	7.1	MUD WEIGHT	**MUD WEIGHT AT TIME OF FORMATION LEAK OFF TEST?=** Refers to the Weight of the drilling fluid in the hole at the time of the Leak Off Test. Used in calculation of Leak Off Test data.
TR.BLK WT?=	8.0–8.4	WEIGHT	**TRAVELLING BLOCK WEIGHT?=** Refers to the Weight of the Travelling Block assembly (i.e. including compensator if used). Used in Work Done calculations.
TSURF.P?=	7.1	PRESSURE	**SURFACE PRESSURE AT TIME OF LEAK OFF TEST?=** Refers to maximum pressure applied at surface at the time Leak Off to the formation occured. Used in Leak Off Test calculations.
TVDEPTH?=	7.0–7.1	LENGTH	**TRUE VERTICAL DEPTH?=** Refers to the True Vertical Depth of a well for calculations involving bottom hole hydrostatic pressures. Used in calculation of the effect of Gas Cutting of the drilling fluid & in Leak Off Test calculations.

PROMPT	CODE NO:	UNITS AS FOR:	DESCRIPTION
TVD NC?=	7.1	LENGTH	**TRUE VERTICAL DEPTH OF NEXT CASING?=** Refers to the planned True Vertical setting depth of the Next Casing. Used in calculation of the Maximum Controllable Formation Pressure, using the present Mud Weight, at the setting depth of the next casing.
TVD WZ?=	7.1	LENGTH	**TRUE VERTICAL DEPTH OF WEAK ZONE?=** Refers to the True Vertical Depth of the Weak Zone. Used in calculation of the Leak Off Test Data.
VEL?=	13.4	LENGTH/ MIN	**VELOCITY?=** Refers to the Velocity that the Drilling Fluid is moving at in a particular annulus. Used in calculation of Lift Capacity of the drilling fluid.
VISC?=	13.4	Alternative Units Centipoise (Cps.)	**VISCOSITY?=** Refers to the Viscosity of the drilling fluid in a particular section of the hole. This value will normally be obtained from annulus data outputs from programme codes 3.0, 3.2, 3.6 & 3.8. Used in calculation of the Lift Capacity of the drilling fluid.
VOL.I/F?	7.2 – 7.5	ALPHA	**IS VOLUME INITIAL OR FINAL VOLUME?** Refers to the Volume of Mud to be used in Mud Additive Calculations. These calculations may be made assuming an Initial Volume of mud to **which** additions are to be made **or** a Final Volume of mud that is required **after** the additions. Used in Mud Additive calculations.
W.TRIP TO?=	8.1	LENGTH	**WIPER TRIP TO WHAT DEPTH?=** Refers to the depth to which the bit was pulled when making a Wiper Trip. Used in calculation of the Work Done making a Wiper Trip.

PROMPT	CODE NO:	UNITS AS FOR:	DESCRIPTION
WOB?=	12	WEIGHT	**WEIGHT ON BIT?=** Refers to the Weight on Bit that it is planned to use. Used in calculation of Minimum Hydraulic Power requirements to prevent bit balling.
WT/U.L?=	10.2 10.5	WEIGHT/ LENGTH	**WEIGHT PER UNIT LENGTH?=** Refers to the Weight per Unit Length of the pipe in question (for the purpose of these calculations it refers to the pipe body weight). Used in Free Point and Pipe Dimension calculations.
YP?=	13.3	English: $LBf/100ft^2$ Metric: Pascale (Pa)	**YIELD POINT?-** Refers to the flow characteristics of the drilling fluid. **NOTE:** Since Y.P. relates only to the 600 & 300 R.P.N. readings obtained using the Fann viscometer, it should not be considered a desirable parameter for pressure loss calculations (hi.n, = n & HI.K = K). Used in calculation of hin, n, HI.K & K values for use in pressure loss calculations.

★OILWELL 1 'MSTA' Headings

HEADING	DESCRIPTION
D.>MAX	This means that the cummulative total length inputs made during Code 9.1 and 9.2 operations has exceeded the maximum allowable of 89,999 ft. All Well Geometry Data must be re-entered using Code 9.2.
★KEY★	This is the heading used to preceed the listing of major parameters used in the Module with their corresponding current UNITS. The parameters are: LENGTH — LENGTH — Control flag:00 DIA — DIAMETER — Control flag:01 VOL — VOLUME — Control flag:02 MUD WT — MUD WEIGHT — Control flag:03 PRES — PRESSURE — Control flag:04 WT — WEIGHT — Control flag:04 If the control flag is SET, then the appropriate units from the Alternative Unit Set are in effect for that parameter. The ★KEY★ is output to inform the User of the current units selection. It is obtained following Codes 0.4; 0.5; 0.6 and 0.7 and after loading ★MDATA and ★WDATA whether from Code operations or internal Data calls. After the latter operations it serves as a check that Data has been satisfactorily obtained.
★MDATA and ★WDATA	Both these are output with the printer following loading of the appropriate data and prior to ★KEY★ output to show what data has been loaded.
★MDATA CARD and ★WDATA CARD	These are displayed as prompts telling the User to load the appropriate magnetic data card.
★MDATANOXMEM and ★WDATANOXMEM	This is output following an attempt to store ★MDATA or ★WDATA in X-FUNCTIONS MEMORY when either no X-MEMORY exists or no more room remains in X-MEMORY (see "NOXMEM").
★MDATA⟶XMEM and ★WDATA⟶XMEM	This is output following successful storage of appropriate data in X-FUNCTIONS MEMORY. (The arrow will display as a 'star burst' character on the HP 41).
NA	This is displayed following an attempt to call a nonexistent Code routine.
NOXMEM	This is displayed following an attempt to store ★MDATA or ★WDATA in X-FUNCTIONS MEMORY when either no X-MEMORY exists or no more room remains in X-MEMORY. It is a Master Programme final display warning of an incomplete Function operation. It will be preceded by "★WDATANOXMEM" and/or "★MDATANOXMEM".
OK	This is the normal display following satisfactory completion of a routine.

HEADING	DESCRIPTION
★ACTUAL HYD★	Heading prior to calculation of ACTUAL HYDRAULICS based on previously calculated Power Law constants.
★ANN. DATA★	Heading prior to output of ANNULUS DATA based on Well Geometry Data.
★AT: –______TV★	Heading prior to output of LEAK OFF TEST data calculated at the given TRUE VERTICAL DEPTH.
ADD SETS	Heading indicating that User has chosen to ADD SETS of Fann Rheology Data.
★BIT HYD.★	Heading prior to output of BIT HYDRAULICS DATA.
★CASING★	Heading prior to calculation of WORK DONE RUNNING CASING.
★C/KL DATA★	Heading prior to input and output of CHOKE/KILL LINE DATA.
DEDUCT SETS	Heading indicating that User has chosen to DEDUCT SETS of Fann Rheology Data.
★DR/C/RM★	Heading prior to calculation of WORK DONE DRILLING, CORING OR REAMING.
★E.C.D.:-★	Heading prior to output of EQUIVALENT CIRCULATING DENSITY in terms of Mud Weight.
★G.CUT MUD★	Heading prior to calculation of reduction in hydrostatic pressure due to GAS CUTTING OF MUD COLUMN.
★GEN. CALCS★	Heading at start of Code 12 function GENERAL CALCULATIONS.
★HOLE DATA★	Heading prior to output of HOLE DATA based on Well Geometry Data.
★HOLE DATA★ TD↑	Heading prior to input of Hole Well Geometry Data indicating entries to be made section by section starting at Total Depth and working up.
★LEAK OFF★	Heading at the start of calculation of LEAK OFF DATA.
★LIFT CAP★	Heading prior to calculation of the Maximum Size of Particle that can be removed from a specific section by the drilling fluid.
★MAX. HP★	Heading prior to output of Bit Hydraulics Data calculated to MAXIMISE POWER at the bit.

HEADING	DESCRIPTION
★MAX. HP-IF★	Heading prior to output of Bit Hydraulics Data calculated to MAXIMISE POWER AND IMPACT FORCE at the bit in COMBINATION.
★MAX.IF★	Heading prior to output of Bit Hydraulics Data calculated to MAXIMISE IMPACT FORCE at the bit.
★MUD WT.CHG★	Heading prior to calculation of the effects of SOLID OR LIQUID ADDITIONS to the drilling fluid.
★NEW PIPE★	Heading prior to output of TENSILE &/OR TORSIONAL STRENGTH DATA calclated for NEW PIPE.
★OPT. HYD★	Heading prior to calculation of BIT HYDRAULICS OPTIMISATION DATA.
★PIPE DATA★	Heading prior to output of PIPE DATA based on Well Geometry Data.
★PIPE DATA★ TD↑	Heading prior to input PIPE WELL GEOMETRY DATA indicating entries to be made section by section starting at Total Depth and working up.
★PIPE SPECS★	Heading prior to calculation of various PIPE SPECIFICATIONS.
★PREM.PIPE★	Heading prior to output of TENSILE &/OR TORSIONAL STRENGTH DATA calculated for PREMIUM GRADE PIPE.
★RHEOLOGY★	Heading prior to RHEOLOGY DATA calculation, input &/or output.
★RND TRIP★	Heading prior to calculation of WORK DONE ROUND TRIPPING drill string.
RPT SETS	Heading following a 'N' (No) answer to a "RIGHT?" prompt indicating that INPUTS should be repeated. Prompts for inputs follow pause.
★SECT:-__.★	Heading prior to data input or output for the SECTION indicated.
★STACK★	Heading prior to calculation of WORK DONE RUNNING OR PULLING STACK.
★SURF. DATA★	Heading prior to input and output of SURFACE DATA.

HEADING	DESCRIPTION
★SURGE-SWAB★	Heading prior to calculation of SURGE/SWAB PRESSURES caused in the annulus by lowering and raising drill string.
★WIPER TRIP★	Heading prior to calculation of WORK DONE MAKING A WIPER TRIP to a specified depth.

DATA LABEL	UNITS AS FOR:	DESCRIPTION
a=	English: PSI/ (BBL/MIN)^b Metric: BARS/ (CU.M/ MIN)^b	**PRESSURE LOSS POWER LAW CONSTANT** Refers to the Power Law constant in the pressure loss equation relating pressure to flow rate ($P = aQ^b$).
A=	DIAMETER^2	**CALCULATED NOZZLE AREA** Refers to the calculated Total Nozzle Area required in a bit to give that Pressure Loss at the bit resulting from circulating at a specified flow rate.
ANN.CAP.=	VOLUME/ LENGTH	**CAPACITY OF THE ANNULUS PER UNIT LENGTH** Refers to the volume per unit length of hole between the outside of a pipe in the hole and the wall of the hole.
A.CV.L.=	LENGTH/ MIN	**ADJUSTED CRITICAL VELOCITY FOR LAMINAR FLOW** Refers to the recommended Maximum Fluid Velocity to be used in an annulus if a reasonable chance of maintaining a Laminar regime is to be expected. The figure is for guidance only and is calculated at 75% of the calculated Critical Velocity for Laminar flow.
ANN.MUD WT.=	MUD WEIGHT	**WEIGHT OF THE DRILLING FLUID IN THE ANNULUS AS A RESULT OF THE PRESENCE OF DRILL CUTTINGS** Refers to the actual Weight of the drilling fluid, when circulating up the annulus, as a result of the increased solids content due to the presence of drilled solids.
ANN.VEL.=	LENGTH/ MIN	**VELOCITY OF THE FLUID IN THE ANNULUS** Refers to the Velocity at which the fluid is travelling in the Annulus.

DATA LABEL	UNITS AS FOR:	DESCRIPTION
A.VOL =	VOLUME	**VOLUME OF ADDITIVE** Refers to the calculated Volume of the Additive that must be added to the specified volume of fluid to bring about the required change in mud weight.
A.WT=	WEIGHT	**WEIGHT OF ADDITIVE** Refers to the calculated Weight of the Additive that must be added to the specified volume of fluid to bring about the required change in mud weight.
A.WT/V=	WEIGHT/ VOLUME	**WEIGHT OF ADDITIVE PER UNIT VOLUME OF INITIAL MUD** Refers to the calculated Weight of the Additive that must be added per Unit Volume of Initial Mud to bring about the required change in mud weight.
b=	DIMENSION LESS	**PRESSURE LOSS POWER LAW EXPONENT** Refers to Power Law exponent in the pressure loss equation relating pressure to flow rate ($P = aQ^b$).
BUOYANCY.=	DIMENSION LESS	**BUOYANCY FACTOR FOR THE FLUID OF SPECIFIED WEIGHT** Refers to the factor by which the weight of steel in air must be multiplied to calculate its effective weight in the fluid.
CAP.=	VOLUME/ LENGTH	**CAPACITY OF A HOLE, PIPE OR ANNULUS SECTION PER UNIT LENGTH OF SECTION** Refers to the Volume per unit Length of a section of Hole, Pipe or Annulus as calculated during a Code 1 or 3 operation.

DATA LABEL	UNITS AS FOR:	DESCRIPTION
CRIT.RPM =	1. ______ 2. ______, ______, ______	**CRITICAL PIPE ROTATION VELOCITIES IN R.P.M.** **1. NODE TYPE VIBRATIONS** **2. SPRING PENDULUM TYPE VIBRATIONS 1st, 2nd and 3rd HARMONICS** Refers to those pipe rotation speeds that are most likely to cause pipe fatigue problems. Node type vibrations are probably the most critical and speeds within +/- 15% of those indicated should be avoided.
CV.T. =	LENGTH/ MIN	**CRITICAL VELOCITY FOR TURBULENT FLOW** Refers to the Velocity of a fluid corresponding to the Reynolds Number at which the flow regime of the fluid is calculated to become Turbulent.
CV.L. =	LENGTH/ MIN	**CRITICAL VELOCITY FOR LAMINAR FLOW** Refers to the Velocity of a fluid corresponding to the Reynolds Number at which the flow regime of the fluid is calculated to become Laminar.
DIA. =	DIAMETER	**DIAMETER OF HOLE SECTION** Refers to the Diameter of a section of hole as used in Code 1 and 3 operations.
DISP. = & DISP. CAP =	VOLUME/ LENGTH	**DISPLACEMENT OF PIPE PER UNIT LENGTH OF PIPE** Refers to the steel in a unit length of pipe i.e. the volume of fluid that will be displaced when a unit length of pipe is immersed in the fluid.
E MUD WT =	MUD WEIGHT	**CORRESPONDING EQUIVALENT MUD GRADIENT** Refers to the Weight of a drilling mud that would be required to balance an estimated Maximum Controllable Formation Pressure at a specified depth as obtained during Leak Off Test calculations.

DATA LABEL	UNITS AS FOR:	DESCRIPTION
E P/GRD=	PRESSURE/ LENGTH	**CORRESPONDING EQUIVALENT MUD GRADIENT** Refers to the weight of a drilling mud, in terms of a pressure gradient, that would be required to balance an estimated Maximum Controllable Formation Pressure at a specified depth as obtained during Leak Off Test calculations.
EQ.MWT.=	MUD WEIGHT	**EQUIVALENT MUD WEIGHT** Refers to the Effective Weight of the drilling fluid in the annulus when circulating annulus pressure losses have been accounted for. It does not include any correction for drilled solids. (Related depths are assumed verticle).
F.MUD WT=	MUD WEIGHT	**FINAL MUD WEIGHT** Refers to the Final Mud Weight resulting after making solid or liquid additions to the drilling fluid.
F.VOL=	VOLUME	**FINAL VOLUME** Refers to the Final Mud Volume resulting after making solid or liquid additions to the drilling fluid.
FREE POINT=	LENGTH	**FREE POINT OF STUCK PIPE** Refers to the depth at which a string of pipe is stuck in a hole above which the body of the pipe is calculated to be free. There are two outputs associated with this data label, one is in feet and the other in metres.
hi.n=	DIMENSION LESS	**HIGH RHEOLOGY POWER LAW EXPONENT** Refers to the Power Law index 'n', used in Mud Rheology to define the type of flow profile. This 'hi.n' value is obtained using the 600 and 300 rpm FANN Meter readings and is used in the pressure loss calculation to calculate the pressure losses in transitional and turbulent flow regimes.

DATA LABEL	UNITS AS FOR:	DESCRIPTION
HI.K=	English: LB-SEC^n/ 100 FT^2 Metric: PASCALE-SEC^n	**HIGH RHEOLOGY POWER LAW CONSTANT** Refers to the Power Law constant 'K' used in Mud Rheology to describe the consistency of the drilling fluid. This 'HI.K' value is obtained using the 600 and 300 rpm FANN Meter readings and is used in the pressure loss calculation to calculate the pressure losses in transitional and turbulent flow regimes.
HOLE CAP.=	VOLUME/ LENGTH	**HOLE CAPACITY** Refers to the Volume per unit length of an open hole section.
ID.<C>.=	DIAMETER	**INTERNAL DIAMETER OF PIPE FOR CAPACITY CALCULATIONS** Refers to the equivalent Internal Diameter of a joint of pipe for Capacity calculations. It is the internal diameter of a uniform section of pipe of the same length as a joint that would give the same internal volume as the joint. It thus makes allowance for 'end preparation' and 'tool joint' internal dimension changes that may be present in the joint. (Refer to the Pipe Specification tables).
ID.<P>.=	DIAMETER	**INTERNAL DIAMETER OF PIPE FOR PRESSURE CALCULATIONS** Refers to the equivalent Internal Diameter of a joint of pipe for Pressure Loss calculations. It is the internal diameter of a uniform section of pipe of the same length as a joint that, for a given flow rate, would give the same pressure loss as the joint. It thus makes allowance for 'end preparation' and 'tool joint' internal dimension changes that may be present in the joint. (Refer to the Pipe Specification tables).
IF.=	WEIGHT	**IMPACT FORCE** Refers to the Hydraulic Impact Force resulting from fluid flow through a jet bit. It is effectively a measure of the energy available at the bit for bottom hole cleaning.

DATA LABEL	UNITS AS FOR:	DESCRIPTION
ID PIPE=	DIAMETER	**INTERNAL DIAMETER OF PIPE** Refers to the Internal Diameter of a pipe as calculated from the Outside Diameter and Weight per unit length of the pipe. There are two outputs associated with this data label, one is in inches, the other in millimeters.
I.VOL=	VOLUME	**INITIAL VOLUME** Refers to the Initial Volume of drilling fluid to which solid or liquid additions are to be made.
K=	English: $LB\text{-}SEC^n/100\ FT^2$ Metric: $PASCALE\text{-}SEC^n$	**RHEOLOGY POWER LAW CONSTANT** Refers to the Power Law constant 'K' used in Mud Rheology to describe the consistency of the drilling fluid. The value of 'K' used should be that value calculated from Fann Rheology data obtained at shear rates that most closely approximate to expected Laminar Annular flow rates. This value of 'K' is used in the pressure loss calculation to calculate the pressure losses in laminar flow regimes.
LENGTH.=	LENGTH	**LENGTH OF A HOLE, PIPE OR ANNULUS SECTION** Refers to the Length of a particular section of Hole, Pipe or Annulus.
L.PRES=	PRESSURE	**PRESSURE LOSS CALCULATED FOR LAMINAR FLOW REGIME** Refers to the Pressure Loss in a pipe or annulus section. The 'L.' indicates that the flow regime in the section has been assessed as Laminar and that the calculation had been made accordingly.
M.A.A.S.S.P.=	PRESSURE	**MAXIMUM ALLOWABLE ANNULUS STATIC SURFACE PRESSURE** Refers to Maximum Annulus Surface Pressure that can be safetly handled on a Shut In well without causing formation fracture of a Weak Zone. It is calculated directly from input data and does not include any safety factor.

DATA LABEL	UNITS AS FOR:	DESCRIPTION
MAX.OD=	DIAMETER	**MAXIMUM DIAMETER OF A SPHERICAL PARTICLE** Refers to the maximum diameter of a spherical particle of formation (22.0 ppg/1.143 sq), having a slip velocity of 75% of the fluid velocity, that can be expected will be removed from an annulus section.
M.C.F.P.=	PRESSURE	**MAXIMUM CONTROLLABLE FORMATION PRESSURE** Refers to the Maximum Formation Pressure, at a specified depth and for the mud weight in use, that can be theoretically Controlled without causing breakdown of the formation at the Weak Zone.
MIN. PWR=	English: Horse Power Metric: Kilowatts	**MINIMUM POWER** Refers to the Hydraulic Power required at the bit to prevent bit balling and ensure bottom hole cuttings removal from around the bit. The equations used are based on curves originally developed by Fullerton.
MUD WT.=	MUD WEIGHT	**MUD WEIGHT** Refers to the current Mud Weight being used for Well Geometry calculations.
n=	DIMENSION LESS	**RHEOLOGY POWER LAW EXPONENT** Refers to the Power Law index 'n' used in mud Rheology to define the type of flow profile. The value of 'n' used should be that value calculated from Fann Rheology data obtained at shear rates that most closely approximate to expected Laminar Annular flow rates. This value of 'n' is used in the pressure loss calculation to calculate the pressure losses in Laminar flow regimes.

DATA LABEL	UNITS AS FOR:	DESCRIPTION
noz._.=	32nds OF AN INCH (all units systems)	**SIZE OF SPECIFIED NOZZLE NUMBER** Refers to the size, in 32nds of an inch, of the specified nozzle number. The value of the last nozzle will be correct to within 1/64". Output values are rounded to the nearest 32nd of an inch.
NOZ.A.=	DIAMETER^2	**NOZZLE AREA** Refers to the Total Nozzle Flow Area of a given set of nozzles.
O.D.=	DIAMETER	**OUTSIDE DIAMETER OF PIPE** Refers to the equivalent Outside Diameter of a section of pipe as used in Code 1 and 3 operations. It is the external diameter of a uniform section of pipe of the same length as a joint that would give the same annular capacity and pressure loss, in a given hole size, as the joint. It thus makes allowance for 'end preparation' and 'tool joint' external dimension changes that may be present on the joint. (Refer to the Pipe Specification tables).
OD PIPE=	DIAMETER	**EXTERNAL DIAMETER OF PIPE** Refers to the External Diameter of a pipe as calculated from the internal diameter and weight per unit length of pipe. There are two outputs associated with this data label, one is in inches, the other in millimeters.
P.BIT.=	PRESSURE	**BIT PRESSURE LOSS** Refers to the Pressure Loss through Bit nozzles.
P.C.=	PRESSURE	**CIRCULATING PRESSURE** Refers to the circulating pressure loss in the drill string, annulus and surface system only, i.e. does not include the bit pressure loss.
PIPE VEL.=	LENGTH/ MIN	**FLUID VELOCITY IN A PIPE** Refers to the Velocity at which the fluid is travelling in the pipe.

DATA LABEL	UNITS AS FOR:	DESCRIPTION
P.LOSS=	PRESSURE	**PRESSURE LOSS** Refers to the reduction in bottom hole Hydrostatic Pressure that results from Gas Cutting of the drilling fluid column in the hole. It is based on the Strong-White equation.
P.S.=	PRESSURE	**SYSTEM PRESSURE LOSS** Refers to the Total Pressure Loss in the circulating system.
PWR.=	English: Horse Power Metric: Kilowatts	**HYDRAULIC POWER** Refers to the Hydraulic Power developed at the bit as a result of fluid flow through the bit.
PWR%=	DIMENSION LESS	**POWER PERCENTAGE** Refers to the Percentage of Maximum Power that can be produced at the bit when Power and Impact Force are maximised in Combination.
PV=	CENTIPOISE (all units systems)	**PLASTIC VISCOSITY** Refers to the Plastic Viscosity of the drilling fluid as calculated from Fann Rheology meter data.
Q RATE.=	VOLUME/ MIN	**FLUID FLOW RATE** Refers to the Rate at which fluid is being pumped.
r^2 =	DIMENSION LESS	**COEFFICIENT OF DETERMINATION** Refers to the Degree to which a set of input data may be regarded as fitting a Power Law curve. The closer the value is to 1 the better the fit may be regarded. The curve fitting is based on the least squares method of determination.
RE.L.=	DIMENSION LESS	**REYNOLDS NUMBER FOR LAMINAR FLOW** Refers to the Reynolds Number at which it is estimated that the flow type will convert from Laminar to Transitional flow.

DATA LABEL	UNITS AS FOR:	DESCRIPTION
RE.T.=	DIMENSION LESS	**REYNOLDS NUMBER FOR TURBULENT FLOW** Refers to the Reynolds Number at which it is estimated that the flow type will convert from Transitional to Turbulent flow.
S.RATE=	SECONDS^{-1}	**ANNULUS SHEAR RATE** Refers to Rate at which fluid, flowing in an Annulus in Laminar flow, is Shearing. The value can be used, after appropriate conversion, for comparison with the Fann meter shear rate values used in calculating the 'n' and 'K' Rheology constants to assess the validity of the Fann data selection for current applications.
STRETCH=		**STRETCH OF PIPE** Refers to the amount of Stretch that results when a length of pipe of uniform cross section is subjected to a specified tension. (Providing that the minimum yield strength of the pipe is not exceeded). There are two outputs associated with this data label, one is in inches, the other in millimeters.
TENSILE=	WEIGHT	**TENSILE STRENGTH OF PIPE** Refers to the maximum Tensile load that can be applied to a pipe of given dimensions, yield strength and class without exceeding the minimum yield strength of the pipe. For practical applications a figure of 90% of the calculated value should be used. There are two outputs associated with this data label, one is in English units the other in Metric units.

DATA LABEL	UNITS AS FOR:	DESCRIPTION
TORSION=	LENGTH/ WEIGHT	**TORSIONAL STRENGTH OF PIPE** Refers to the maximum Torsional load that can be applied to a pipe of given dimensions, yield strength and class without exceeding the minimum yield strength of the pipe. Depending on the code number of the operation used to obtain the result it may include correction for the tensile load in the pipe. There are two outputs associated with this data label, one is in English units and the other in Metric units.
T.PRES.=	PRESSURE	**PRESSURE LOSS CALCULATED FOR TURBULENT FLOW REGIME** Refers to the Pressure Loss in a Pipe or Annulus section. The 'T.' indicates that the flow regime in the section has been assessed as Turbulent and that the calculation has been made accordingly.
TR.PRE.=	PRESSURE	**PRESSURE LOSS CALCULATED FOR TRANSITIONAL FLOW REGIME** Refers to the Pressure Loss in a Pipe or Annulus section. The 'TR.' indicates that the flow regime in the section has been assessed as Transitional and that the calculation has been made accordingly.
VEL.=	LENGTH/ MIN	**FLUID VELOCITY** Refers to Velocity at which the fluid is travelling in an annulus or pipe section.
VISC.=	CENTIPOISE (all units systems)	**VISCOSITY** Refers to the actual viscosity of the drilling fluid in a particular Annulus section. This viscosity should be used, together with its associated fluid velocity, in Code 13.4 operations to calculate the Carrying Capacity of the fluidin the section. (In Pipe Mode it is the velocity calculated assuming I.D. = ID.<C>)
VN/SEC.=	LENGTH/ SEC	**NOZZLE VELOCITY** Refers to the Velocity of the fluid through the bit nozzles.

DATA LABEL	UNITS AS FOR:	DESCRIPTION
VOL.=	VOLUME	**TOTAL FLUID VOLUME IN A PARTICULAR SECTION OF HOLE, PIPE OR ANNULUS** Refers to amount of fluid in a specific section of hole, pipe or annulus as calculated from section capacity and length.
VOL.D.=	VOLUME	**TOTAL VOLUME OF DISPLACEMENT OF A PARTICULAR SECTION OF PIPE** Refers to amount of steel in a specific section of pipe as calculated from section displacement and length, i.e. the total Volume of fluid that is Displaced by the pipe in the section.
WORK DONE	English: S.Ton Miles Metric: Tonne-Kmtr.	**WORK DONE BY WIRE LINE** Refers to the Work Done by the draw-works wireline when performing a specified drilling operation. The calculation is not based on the standard approximated equations for Work Done. The value is calculated from the input Well Geometry Pipe data for the depth in question as the total Work Done handling each section as appropriate.
WT.A.=	WEIGHT	**TOTAL WEIGHT OF A PIPE IN AIR.** Refers to the Weight of a section of pipe in air.
WT.M.=	WEIGHT	**TOTAL WEIGHT OF A PIPE SECTION IN MUD** Refers to the Weight of a section of pipe in mud.
WT/U.L=	WEIGHT/ LENGTH	**WEIGHT OF A SECTION PER UNIT LENGTH** Refers to the weight per unit length of a section. There are two outputs associated with this data label, one is in LBf/foot the other in DaN/meter.

DATA LABEL	UNITS AS FOR:	DESCRIPTION
X-SECT=	DIAMETER^2	**CROSS SECTIONAL AREA OF PIPE** Refers to the Cross Sectional Area of a section of pipe. There are two outputs associated with this data label, one is in square inches the other in square millimeters.
YP=	English: LBf/100FT ^{2} Metric: PASCALE	**YIELD POINT** Refers to the Yield Point of the drilling fluid as calculated from Fann Rheology meter data.
Σ PRES.=	PRESSURE	**CUMMULATIVE PRESSURE LOSS** Refers to the total Pressure Loss of all pipe **or** annulus sections above the specified depth.
Σ VOL.=	VOLUME	**CUMMULATIVE VOLUME** Refers to the Total Volume of mud in all the sections of the hole, pipe **or** annulus above the specified depth.
Σ VOL.D.=	VOLUME	**CUMMULATIVE DISPLACEMENT VOLUME** Refers to the Total Volume of steel in all the sections of pipe above the specified depth, i.e. the total volume of fluid that will be Displaced by the drill string.
Σ WT.A.=	WEIGHT	**CUMMULATIVE WEIGHT OF THE DRILL STRING IN AIR** Refers to the Total Weight of the drill string in Air.
Σ WT.M.=	WEIGHT	**CUMMULATIVE WEIGHT OF THE DRILL STRING IN MUD** Refers to the Total Weight of the drill string in Mud of specified density.

PRESSURE LOSS CALCULATIONS

DETERMINATION OF FLOW REGIME

$$\mathrm{Re} > R_T = 4270 - 1370(\mathrm{hi.}\,n) \rightarrow \text{turbulent flow}$$

$$\mathrm{Re} \leqslant R_L = 3470 - 1370\,n \rightarrow \text{laminar flow}$$

$$R_T \geqslant \mathrm{Re} > R_L \rightarrow \text{transitional flow}$$

DETERMINATION OF FRICTION FACTOR f

laminar flow: $$f = \frac{16}{\mathrm{Re}}$$

transitional flow: $$f = \frac{16}{R_L} + \left[\frac{\mathrm{Re} - R_L}{800}\right]\left[\frac{a}{R_T^b} - \frac{16}{R_L}\right]$$

turbulent flow: $$f = \frac{a}{\mathrm{Re}^b}$$

$$a = \frac{3{\cdot}93 + \log \mathrm{hi.}\,n}{50}$$

$$b = \frac{1{\cdot}75 - \log \mathrm{hi.}\,n}{7}$$

PRESSURE CALCULATION ΔP

$$\Delta P = L\,\frac{f\ \mathrm{p.p.g.}\ v^2}{93\,000\,D'}$$

CALCULATION OF REYNOLDS NUMBER Re

$$\mathrm{Re} = V^{(2-n')}\left[\frac{\mathrm{p.p.g.}}{19{\cdot}35K'}\left(\frac{2{\cdot}5D'}{\left(c + \frac{1}{n'}\right)}\right)^{n'}\right]$$

DETERMINATION OF CRITICAL VELOCITIES V_c

$$V_c = \left[\frac{R'\ 19{\cdot}35K'}{\mathrm{p.p.g.}}\right]^{\frac{1}{(2-n')}}\left[\frac{\left(c + \frac{1}{n'}\right)}{2{\cdot}5D'}\right]^{\frac{n'}{(2-n')}}$$

SHEAR STRESS τ

$$\tau = \frac{\Delta P}{L}\,300D' = K\gamma^n$$

SHEAR RATE γ

$$\gamma = \frac{0{\cdot}4V\left(5 + \frac{1}{n}\right)}{D'}$$

VISCOSITY μ

$$\mu = \frac{478{\cdot}79931\,\tau}{\gamma}$$

WHERE		UNITS
Re	= actual Reynolds number	dimensionless
R_T	= critical Reynolds number for turbulent flow	dimensionless
R_L	= critical Reynolds Number for laminar flow	dimensionless
R'	= R_T OR R_L as appropriate	dimensionless
hi. n	= mud rheology power law exponent. For use in transitional and turbulent flow calculations. Usually based on Fann 600 and 300 readings	dimensionless
n	= mud rheology power law exponent. For use in laminar flow calculations	dimensionless
HI. K	= mud rheology power law constant. For use in transitional and turbulent flow calculations. Usually based on Fann 600 and 300 readings	lbf-sec^n/100 ft^2
K	= mud rheology power law constant. For use in laminar flow calculations	lbf-sec^n/100 ft^2
n', K'	= mud rheology power law exponent and constant as appropriate to calculation. Either hi. n and HI. K OR n and K as above	
c	= Constant = 3 for pipe flow = 5 for annular flow	dimensionless
D'	= diameter factor = I.D. for pipe flow = (Dia − O.D.) for annular flow	inches
p.p.g.	= weight of drilling fluid	lbf/U.S. gallon
Dia.	= hole diameter	inches
O.D.	= outside diameter of pipe	inches
I.D.	= inside diameter of pipe	inches
ΔP	= pressure loss in given section	lbf/inch^2
V	= fluid velocity in given section	feet/min
V_c	= fluid velocity in a given section corresponding to the critical Reynolds Number (either R_T or R_L as appropriate)	feet/min
L	= length of section	feet
τ	= shear stress in given section	lbf/100 feet^2
γ	= shear stress in given section	seconds^{-1}
μ	= viscosity in given section	centipoise

BIT HYDRAULICS

BIT PRESSURE LOSS

$$P_{bit} = \frac{\text{p.p.g.}\ Q^2}{A^2}\ 0{\cdot}16128$$

BIT NOZZLE VELOCITY

$$V_n = \frac{13{\cdot}44Q}{A}$$

BIT HORSE POWER

$$\text{H.P.} = 0{\cdot}0245041\, P_{bit} Q$$

IMPACT FORCE

$$\text{I.F.} = \frac{\text{p.p.g.}\ Q V_n}{46}$$

BIT HYDRAULICS OPTIMISATIONS

$$P_c = P_s - P_{bit}; \quad P_c = aQ^b$$

FOR MAXIMISED H.P.

$$Q = \left(\frac{P_s}{a}\right)^{\frac{1}{b}} \left[\frac{1}{(1+b)}\right]^{\frac{1}{b}}$$

FOR MAXIMISED I.F.

$$Q = \left(\frac{P_s}{a}\right)^{\frac{1}{b}} \left[\frac{2}{(2+b)}\right]^{\frac{1}{b}}$$

FOR MAXIMISED H.P.-I.F. COMBINATION

$$Q = \left(\frac{P_s}{a}\right)^{\frac{1}{b}} \left[1 - \frac{b(2+b)^{\frac{2}{b}+1}}{2^{\frac{2}{b}}(1+b)^{\frac{2}{b}+2}}\right]^{\frac{1}{b}}$$

WHERE		UNITS
p.p.g.	= weight of drilling fluid	lbf/U.S. gallon
Q	= flow rate	barrels/minute
A	= bit nozzle area	inches^2
V_n	= fluid velocity through bit nozzles	feet/second
P_s	= total system pressure loss	lbf/inch^2
P_{bit}	= bit pressure loss	lbf/inch^2
P_c	= circulating pressure loss	lbf/inch^2
a	= power law constant	lbf/inch^2 (barrel/min)^b
b	= power law exponent	dimensionless

Notes

PIPE SPECIFICATION CALCULATIONS

CRITICAL SPEEDS

$$\text{R.P.M.}_c = \frac{476\,000}{l^2}\left[\text{O.D.}^2 + \text{I.D.}^2\right]^{1/2}$$

$$\text{R.P.M.}'_c = \frac{x\,258\,000}{L}$$

STRETCH

$$e = \frac{L^2}{9{\cdot}625 \times 10^7}\left[65{\cdot}44438248 - 1{\cdot}44\ \text{p.p.g.}\right]$$

FREE POINT

$$L = \frac{735\,294\,e\,W'_{DP}}{T}$$

TENSILE STRENGTH

$$S = Y_m \times A$$

TORSIONAL STRENGTH

$$Q = \frac{0{\cdot}096167(0{\cdot}098175(\text{O.D.}^4 - \text{I.D.}^4))\,Y_m}{\text{O.D.}}$$

TORSIONAL STRENGTH UNDER TENSION

$$Q_T = \frac{0{\cdot}096167(0{\cdot}098175(\text{O.D.}^4 - \text{I.D.}^4))}{\text{O.D.}}\left[Y_m^2 - \frac{P^2}{A^2}\right]^{1/2}$$

× -SECTIONAL AREA

$$A = (\text{O.D.}^2 - \text{I.D.}^2)\frac{\pi}{4}$$

WEIGHT OF STEEL PIPE

$$W = 0{\cdot}283315393\,Al$$

WHERE		UNITS
R.P.M._c	= critical pipe rotation speed for node type vibrations	rev/min
$\text{R.P.M.}'_c$	= critical pipe rotation speed for spring pendulum type vibrations	rev/min
l	= length of a section of pipe	inches
L	= length of string (free pipe)	feet
e	= stretch (elongation)	inches
p.p.g.	= weight of drilling fluid	lbf/U.S. gallon
W	= weight of steel pipe	lbf
W'_{DP}	= weight per foot of pipe body	lbf/foot
Y_m	= minimum yield strength of steel	lbf/inch^2
A	= pipe × -sectional area	inches^2
S	= tensile strength of pipe body	lbf
P	= tensile load in pipe body	lbf
Q	= torsional strength of pipe body	lbf-feet
T	= over pull tension in pipe	lbf
Q_T	= torsional strength of pipe body under tension	lbf-feet
O.D.	= outside diameter of pipe body	inches
I.D.	= inside diameter of pipe body	inches
x	= the square of the primary, secondary or tertiary harmonic vibration, i.e. 1, 4 or 9	dimensionless

Notes

WIRELINE WORK DONE CALCULATIONS

RAISE AND LOWER A SECTION OF PIPE (NOT STOOD BACK)

$$\text{Work done} = W'(L - L_1 - L_2 - \ldots - L')$$

STAND BACK AND RUN A SECTION OF PIPE

$$\text{Work done} = L'(W' + W'_{ST}(2 - B))$$

RAISE AND LOWER BLOCKS

$$\text{Work done} = 4W_B L$$

(Running casing assumes blocks raised 2 × joint length)

DRILLING/CASING/REAMING

$$\text{Work done} = \frac{1}{1{\cdot}18272 \times 10^7}\left[2L_K(W_B + W_K) + D(W_B + W_K + W_J) + NL_K + \frac{D(1+2a)}{2}\right][2W_X + (N-1)W_J B]$$

RUNNING STACK

$$\text{Work done} = \frac{D'}{2 \times 1{\cdot}18272 \times 10^7}[4W_B + 2W_{bop} + W_{ris} + W_J(4 - B)]$$

WHERE		UNITS
L_1, L_2	= lengths of each individual section	feet
L'	= length of a specific section	feet
L	= total length of string	feet
D'	= depth from derrick floor to well head minus height of stack assembly	feet
D	= drilled footage	feet
L_K	= length of Kelly	feet
W_B	= weight of travelling block assembly in air	lbf
W_K	= weight of Kelly in air	lbf
W_J	= weight of a joint of pipe or riser in air	lbf
W'_{ST}	= weight of a stand of section in air	lbf
W'	= total weight of a section in mud	lbf
W_X	= total weight of the drill string in mud plus the weight of the Kelly and travelling block assembly in air	lbf
W_{bop}	= weight of the stack in water	lbf
W_{ris}	= weight of the riser in water	lbf
B	= buoyancy factor for steel in given fluid	dimensionless
a	= number of times a joint is reamed (up + down = 1 time)	dimensionless
N	= number of joints picked up to drill D feet	dimensionless

Notes

GENERAL CALCULATIONS

HOLE VOLUME $= L \times \text{Dia.}^2 \times c$	barrels
ANNULAR VOLUME $= L \times (\text{Dia.}^2 - \text{O.D.}^2) \times c$	barrels
DISPLACEMENT VOLUME $= L \times (\text{O.D.}^2 - \text{I.D.}^2) \times c$	barrels
ANNULAR FLOW VELOCITY $= \dfrac{Q}{(\text{Dia.}^2 - \text{O.D.}^2)c}$	feet/minute
PIPE FLOW VELOCITY $= \dfrac{Q}{\text{I.D.}^2 \times c}$	feet/minute
BUOYANCY FACTOR FOR STEEL $= \dfrac{65{\cdot}44438248 - \text{p.p.g.}}{65{\cdot}44438248}$	Dimensionless
ANNULUS MUD WEIGHT $\doteq \dfrac{(60 \times Q \times \text{p.p.g.}) + (\text{Dia.}^2 \times c \times R \times 21{\cdot}684)}{(\text{Dia.}^2 \times c \times R) + 60Q}$	lbf/U.S. gallon

WHERE		UNITS
L	= length of section	feet
Dia.	= hole diameter	inches
O.D.	= outside diameter of pipe	inches
I.D.	= inside diameter of pipe	inches
Q	= fluid flow rate	barrels/min
p.p.g.	= weight of drilling fluid	lbf/U.S. gallon
R	= rate of penetration	feet/hour
c	$= 9{\cdot}714263 \times 10^{-4}$	—
21·684	= formation density	lbf/U.S. gallon
65·444 . . .	= steel density	lbf/U.S. gallon

Notes

The Pressure Calculation used by the module, while found in practice to give very satisfactory results, especially with water based muds, may not meet with the approval of all Users. For this reason a listing and explanation of the programme is supplied.

The module is specially designed to allow the User to write his or her own pressure programme, which, providing it is labelled 'PRES', will be used by the module in preference to the ROM programme.

To write such a programme will require very careful study of the module 'PRES' programme to ensure use of correct data. Flag settings may cause problems, basically flag operations are as follows:

	CLEAR	**SET**
Flag 6	Annulus mode	Pipe mode
Flag 7	Pipe mode	Annulus mode
Flag 9	All data output mode	Σ data output mode
Flag 11	Not Code 3.8 mode	Code 3.8 User calcs.
Flag 12	Not Code 3.9 mode	Code 3.9 Surge Swab calcs.
Flag 13	used internally in the 'PRES' programme.	

NOTE: If Flag 12 is set, so too are flags 7 and 9.

USE OF RHEOLOGY IN PRESSURE CALCULATIONS

The module utilises two sets of n/K Rheology values, they are hi.n. & HI.K and n & K. They remain stored in memory for repeated use and form part of the ★WDATA. Using Codes 13.0; 13.1; and 13.3 the User has a range of possibilities for entering these n and K values. They are:

Code 13.0 Allows the User to enter Fann Rheology Meter Readings which are then processed by the module to output and store, in reg. 108-111, the two sets of n/K data. Using this Code the module takes the first two sets of input Fann data, which should normally be for the **600RPM & 300RPM** readings, and uses these to calculate the hi.n & HI.K values used in TURBULENT and TRANSITIONAL regime pressure calculations. These values will remain in effect, regardless of subsequent data manipulations that can be performed using this code, to obtain the n/K set used for LAMINAR flow calculations.

Initially the n & K values used for LAMINAR flow calculations are calculated, using the least squares method of curve fitting, on **all** the Fann data input sets. However as part of code 13.0 operations the User has the option of changing the Fann data input sets to be used in the calculation of the second n & K values set. This option allows the User to select, for calculation of n & K, the Fann readings for those RPM's (shear rates) that most closely reflect actual ANNULAR conditions.

NOTE: Shear rates in Sec-1 are output for each annulus section using codes 3.0; 3.2; and 3.6. These may be compared with the Fann meter shear rates used in n & K calculation to assess their appropriateness for the current situation.

(The module calculates Rheology Data for a Fann Rheometer set up with a Bob 1/Rotor 1/Spring 1 combination which results in a conversion factor of 0.5871 with which to multiply R.P.M. to obtain Shear Rate in Sec-1).

CODE 13.1 Allows the User to input directly the values of hi.n, HI.K., n & K to be used in pressure calculations: This allows Rheology Data obtained from other sources to be utilised.

CODE 13.3 Calculates n/K values using PV. & YP. input data. This is not a very satisfactory method of n/K calculation as it results in the hi.n and HI.K values being used for **all** flow regimes. It can however be handy when Fann data is not readily available.
The use of two different sets of n/K data is an important aspect in obtaining pressure loss results since it effectively results in the creation of two separate Power Law equations relating pressure loss to flow rate (of the type $P = KQ^n$) dependent on the flow regime of the system in question

It must be stressed that pressure loss calculation is dependant on many variables and that any calculated value is at best a working approximation as to the true value.

In assessing the flow regime the programme uses hi.n & HiK values to determine the CRITICAL REYNOLDS NUMBER for TURBULENT FLOW and the n & K values for determination of the LAMINAR FLOW CRITICAL REYNOLDS NUMBER. This can lead to an apparent annomoly when CRITICAL VELOCITY calculated for LAMINAR flow exceeds the CRITICAL VELOCITY for TURBULENT flow. The effect of this is really academic.

SURGE AND SWAB CALCULATIONS CODE 3.9

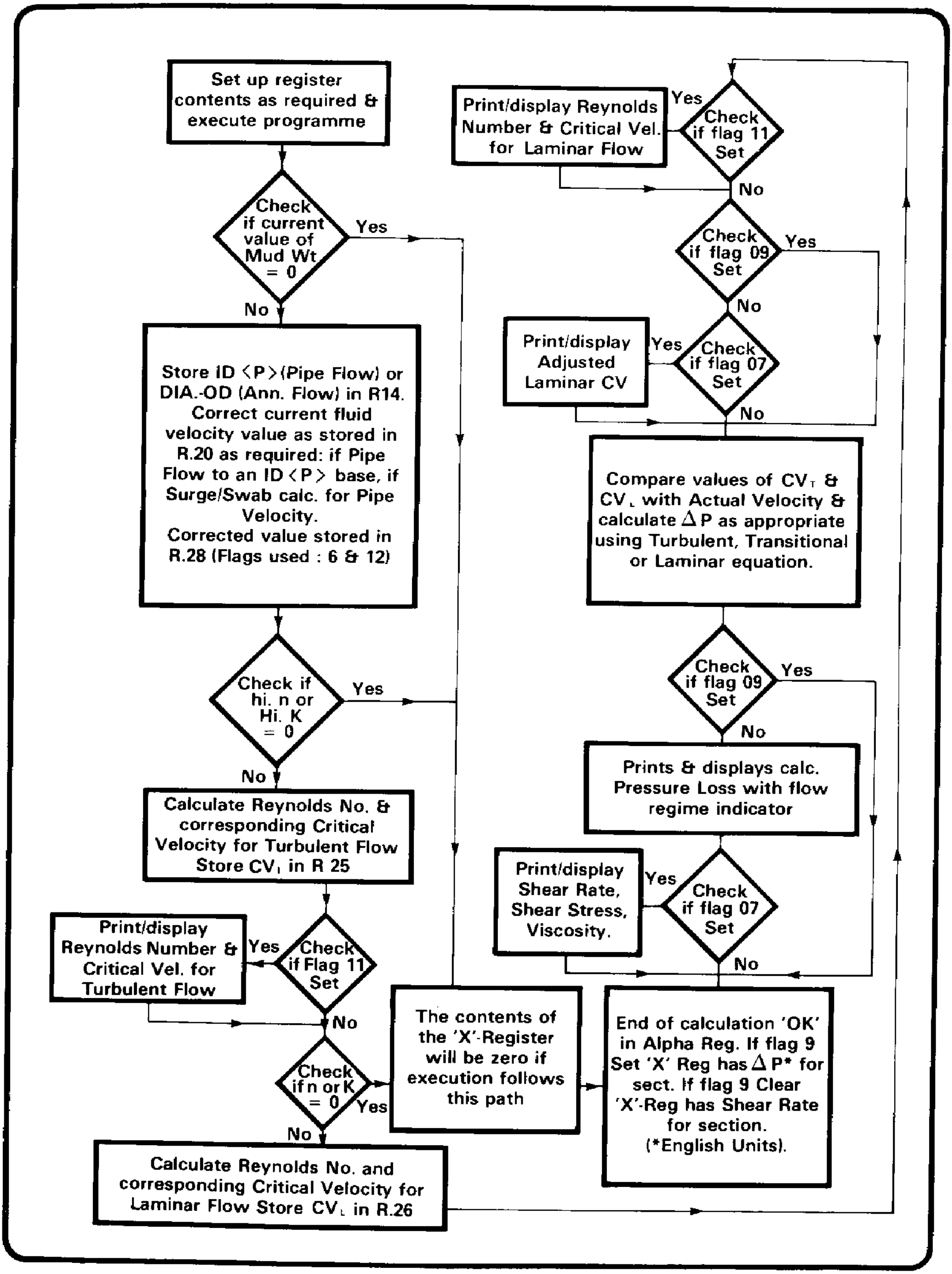
This function utilises the same pressure programme 'PRES' as the other pressure calculations in the module but in this case a FLUID VELOCITY ADJUSTMENT (stored in R.27) is made to compensate for the speed at which the string is travelling.

For SURGE-SWAB calculation the module programme first calculates an Equivalent Flow Rate based on the rate of fluid displacement assuming a MAXIMUM PIPE SPEED equal to 1.5 x the input "AV.P.VEL". (average pipe velocity). This flow rate value is then used in Well Geometry calculations to calculate the actual fluid velocity, relative to the hole, in each annulus section as the pipe is lowered. For calculation of the pressure loss in each section a factor of .45 x MAXIMUM PIPE SPEED is added to the calculated fluid velocity in the section to correct for the effect of the speed of the pipe.

The Surge-Swab calculation is based on a **CLOSED PIPE SITUATION** and it is left to the User to assess the significance of the result for a particular application. Basically, however, a CLOSED PIPE calculation will generally most closely approximate situations where the effects of SURGE-SWAB are likely to be significant.

⋆OILWELL 1

Pressure Calc. Flow Diagram



```
♦LBL "PRES"
RCL E          p.p.g.
X<=0?
GTO 14
FC? 09
ADV
RCL 11         ID<P>.ID<C>  <--+
STO [                           |
INT                             |
ST- [                           |
 E5                             |   RECALL + PROCESS
/                               |
FS? 06                          |   STORED VALUES
ST/ [                           |
RCL 09         L.DIA            |   OF: ID.<P> - PIPE MODE
FRC                             |
RCL 10         L. O.D.          |       (DIA - O.D.) - ANNULUS MODE
FRC                             |
-                               |
FS? 06                          |
X<>Y                            |
 E2                             |
*                           <---+
STO 14         ID<P> or (DIA. - O.D.)
RCL 27         SURGE - SWAB VELOCITY ADJUSTMENT
RCL 20         VELOCITY (ID. <C>BASED IN PIPE MODE)
FS? 12
+
X<> [          }
X↑2            }   VELOCITY CORRECTED
FS? 06         }   TO ID. <P>BASE IN PIPE MODE
ST* [
RCL [
STO 28         VELOCITY FOR PRESSURE CALC
RCL H          HI. K
X=0?
GTO 14
STO 16
4270
RCL G          hi.n
X=0?
GTO 14
"RE.T"         }   CALCULATE CRITICAL VELOCITY FOR START
XEQ 10         }   OF TURBULENT FLOW REGIME
STO 25         V_T
RCL 55         }
FS? 00         }
ST* Y          }        IF CODE 3.8 OPERATION
"CV.T.="       }   OUTPUT CV.T. IN APPROPRIATE UNITS
ARCL Y         }        CV.T. = V_T
FS? 11         }
AVIEW
RCL J          K
X=0?
GTO 14
STO 16
3470
RCL I          n
```

```
 59 X=0?
 60 GTO 14
 61 "RE.L"      } CALCULATE CRITICAL VELOCITY FOR START OF
 62 XEQ 10      } TRANSITIONAL FLOW REGIME
 63 STO 26      V_L
 64 RCL 55
 65 X<>Y
 66 FS? 00                  IF CODE 3.8 OPERATION
 67 *
 68 "CV.L.="                OUTPUT CV.L IN APPROPRIATE UNITS
 69 ARCL X
 70 FS?C 11                 CV.L = V_L
 71 AVIEW
 72 .75                     IF CODE 3.0, 3.2, 3.6 OR 3.8
 73 *
 74 "A.CV.L.
       ="                   OPERATION OUTPUT A. CV.L
 75 ARCL X
 76 FS? 09
 77 GTO 11
 78 FS? 07
 79 AVIEW
 80*LBL 11
 81 CLD
 82 RCL 26      V_L
 83 RCL 28      V
 84 X=0?
 85 GTO 14
 86 2           } FLAG CONTROL. USING SYNTHETIC PROGRAMMING.
 87 FC? 06      } BEST SKIPPED IN ANY USER DEVELOPED
 88 CLX         } PRESSURE PROGRAMME. ASSOCIATED STEPS ARE
 89 X<> d       } MARKED *.
 90 STO ]
 91 RDN
 92 X>Y?
 93 GTO 11      GTO TURBULENT/TRANSITION FLOW CALC.
 94 XEQ 09      CALCULATE ACTUAL REYNOLDS NUMBER Re.
 95 1/X         } CALCULATE LAMINAR FLOW FRICTION FACTOR
 96 16          }              16/Re
 97 *           }
 98 STO 16
 99 RCL ]
100 X<> d
101 "L"         } DATA OUTPUT
102 GTO 12
103*LBL 11
104 RCL G       } hi.n
105 STO 15
106 RCL H       } HI.K
107 STO 16
108 XEQ 09        CALCULATE ACTUAL REYNOLDS NUMBER
109 3.93          CALCULATE:
110 RCL G
111 LOG
112 +
113 50
114 /
115 STO 12
```

$$a = \frac{3.93 + \log hi.n}{50}$$

```
116 X<>Y
117 1.75
118 RCL [
119 LOG
120 -
121 7
122 /
```

CALCULATE:

$$b = \frac{1.75 - \log \text{hi. n}}{7}$$

```
123 CHS
124 STO 13
```

STORE − b

```
125 Y↑X
```

CALCULATE $a/{Re^b}$

```
126 *
127 STO 16
128 RCL ]
129 X<> d
130 "T"
131 RCL 25
132 RCL 28
```

V_T
V

```
133 X>Y?
```

GTO TURBULENT FLOW CALCULATION

```
134 GTO 12
```

ACTUAL REYNOLDS NUMBER

```
135 "TR"
136 RCL 73
137 RCL 02
138 -
139 800
140 /
141 4270
142 1370
143 RCL 15
144 *
145 -
146 RCL 13
147 Y↑X
148 RCL 12
149 *
150 16
151 RCL 02
152 /
153 STO T
154 -
155 *
156 +
157 STO 16
```

CALCULATE TRANSITIONAL FLOW

FRICTION FACTOR

$$f = \frac{16}{R_L} + \left(\frac{Re - R_L}{800}\right)\left(\frac{a}{R_T^b} - \frac{16}{R_L}\right)$$

```
158♦LBL 12
159 FIX 2
160 "⊢."
161 ARCL 87
162 ASTO 73
163 73
```

PREPARE DATA LABEL FOR OUTPUT OF

CALCULATED PRESSURE

```
164 STO 05
165 RCL 16
166 RCL E
167 *
168 RCL 28
169 X↑2
170 *
171 93 E3
172 /
173 RCL 14
174 /
175 STO 15
176 RCL 08
177 *
```

CALCULATE PRESSURE LOSS

IN A SECTION

$$\Delta P = L\left(\frac{f.ppg.\ \ V^2}{D'\ \ 93{,}000}\right)$$

D′ = (DIA − O.D.) ANNULUS MODE

= ID. <P> PIPE MODE

```
178 ST+ 24
179 FS? 09
180 GTO 14
181 4
182 XROM "UN
         IT"
```

ACCUMULATE PRESSURE LOSS

OUTPUT PRESSURE IF IN AN ALL DATA OUTPUT MODE, or END CALCULATION

```
183 143640
184 RCL 14
185 *
186 ST* 15
187 RCL 28
188 .4
189 *
190 5
191 RCL I
192 1/X
193 +
194 *
195 RCL 14
196 /
197 ST/ 15
```

D'

V

CALCULATE ANNULUS SECTION

VISCOSITY

$$\mu = \frac{\Delta P\ 143670}{L} \left(\frac{DIA - O.D.}{.4V\,(5 + 1/n)}\right)$$

$$\left[\frac{DIA - O.D.}{.4V\,(5 + 1/n)}\right] = \text{SHEAR RATE}$$

```
198 FIX 0
199 CLD
200 FC? 07
201 GTO 14
```

CHECK IF ANNULUS MODE, IF NOT, END PRESSURE CALCULATION

```
202 "S.RATE=
         "
203 ARCL X
204 "⊢SEC-1"
205 AVIEW
206 "VISC.="
207 ARCL 15
208 "⊢CPS."
209 AVIEW
```

OUTPUT SHEAR RATE + VISCOSITY IN ANNULUS SECTION.

```
210◆LBL 14
211 CLD
212 "OK"
213 RTN
```

END PRESSURE CALCULATION ROUTINE

```
214◆LBL 10
215 "⊢.="
216 STO 15
217 1370
218 *
219 -
220 STO 02
221 FIX 0
222 ARCL X
223 FS? 11
224 AVIEW
225 2
226 FC? 06
227 CLX
228 X<> d
229 STO J
```

hi.n or n

CALCULATE APPROPRIATE CRITICAL REYNOLDS NUMBER R_T or R_L.

OUTPUT R_T or R_L VALUE IF CODE 3.8 OPERATION.

```
SF 13
XEQ 09
1/X
RCL 02
*
2
RCL [
-
1/X
Y↑X
RCL ]
X<> d
RDN
RTN
```

CALCULATE CRITICAL VELOCITY

CORRESPONDING TO R_T or R_L

$$V_{T \text{ or } L} = \left[\frac{R_T \text{ or } R_L \; 19.35\,K'}{\text{p.p.g.}}\right]^{\frac{1}{2-n'}} \left[\frac{(C + \frac{1}{n'})}{2.5\,D'}\right]^{\frac{n'}{2-n'}}$$

K' = HI.K or K AS APPROPRIATE

n' = hi.n. or n AS APPROPRIATE

C = 3 FOR PIPE MODE AND 5 FOR ANNULUS MODE

```
♦LBL 09
3
5
FS? 06
X<>Y
RCL 15
STO [
1/X
+
1/X
2.5
*
RCL 14
*
RCL [
Y↑X
RCL E
*
RCL 16
/
19.35
/
FS?C 13
RTN
```

CALCULATE

$$\frac{ppg}{19.35\,K'} \left[\frac{2.5\,D'}{(C + \frac{1}{n'})}\right]^{n'}$$

```
RCL 28    V
2
RCL [
-
Y↑X
*
STO 73
END
```

CALCULATE ACTUAL REYNOLDS

NUMBER Re

$$Re = \left[\frac{ppg}{19.35\,K'}\right]\left[\frac{2.5\,D'}{(C + \frac{1}{n'})}\right]^{n'} V^{(2-n')}$$

The set of example Module operations included in this manual is designed to familiarise the User with the type of input/output format and operation associated with each Function Code. It is advisable for first time Users to work through the examples.

The output set was obtained using the standard ★MDATA Card with the units control set for English units as indicated by the final code operation of the Code 0 example sheet.

The WELL GEOMETRY DATA as input using Code 9.2 (see Code 9 example sheet) is based on the following:

HOLE DATA

D.F. to top of STACK = 1142 ft	Riser I.D. = 20 inches
Top of STACK to WELLHEAD = 34 ft	Stack I.D. = 18.75 inches
9 5/8in. CASING set at 13,067 ft	Casing I.D. = 8.535 inches
Oversize OPEN HOLE section 13,067 – 13,218 ft	Hole size = 14 inches
OPEN HOLE section 13,218 – 13451 ft	Hole size = 8.5 inches

PIPE DATA

754 feet of 6.5 inch COLLARS 2.5 inch I.D.
363 feet of 5 inch HEVI-WEIGHT D.P.
3687 feet of 5 inch grade 'G' 19.5 lb/ft DRILL PIPE
8647 feet of 5 inch grade 'E' 19.5 lb/ft DRILL PIPE

SURFACE DATA

Surface equipment equivalent length after adjustment for bends and fittings etc. = 123 feet x 3 inch pipe
These figues are based on:

ITEM	ADJUSTED FOR BENDS/FITTINGS
10 feet of STAND PIPE MANIFOLD	= 10 feet x 4 inch pipe
75 feet of STAND PIPE	= 95 feet x 4 inch pipe
10 feet of SWIVEL	= 28 feet x 3.5 inch pipe
75 feet of ROTARY HOSE	= 93 feet x 3.5 inch pipe
58 feet of KELLY	= 40 feet x 3.5 inch pipe

CHOKE/KILL LINE DATA

WATER DEPTH = 1092 feet
CHOKE/KILL LINE length adjusted for bends and surface fittings etc.
= 1500 feet x 3 inch pipe.

Some examples of data correction and checking are included in the examples.

The Rheology of the drilling fluid was obtained using the following input data for the function "Rheology from Fann Data" – Code 13.0:

R.P.M.	FANN*
600	71
300	43
200	28
100	23
6	6
3	3

*Obtained using Spring 1/Bob 1/Rotor 1.

hi.n + Hi.K — Based on the 600 & 300 Fann Readings.

n + k — Based on the 300, 200, 100 & 6 Fann Readings.

MUD WEIGHT — 9.931 ppg (10.5 ppg is used in the examples for Codes 1.4 – 1.9 Inclusive).

PROGRAMMER'S NOTE

Each example is followed by a statement of the number of sub-routine levels that are required to run that particular code number. The HP 41 can store a maximum of six sub-routine returns. This means that any User Programme executing a function code that required six sub-routine levels will not have programme execution returned to it on completion of the function code routine. Instead execution will stop at the end of the 'MSTA' or 'MSTB' routine used to call the routine. The sub-levels given with each example are those required when accessing functions with the **NORMAL 'MSTA' MASTER PROGRAMME.** (See the Catalogue Function Reference Tables Pages 22.01 – 22.08).

CODE:–0.0

```
*DDEL*

*WDATA
*KEY*
LENGTH:-FEET.
DIA:-INS.
VOL:-BBL.
MUD WT:-P.P.G.
PRES:-P.S.I.
WT:-LBS.
```

2. SUBLEVELS

CODE:–0.1

```
*DDEL*

*MDATA
*KEY*
LENGTH:-FEET.
DIA:-INS.
VOL:-BBL.
MUD WT:-P.P.G.
PRES:-P.S.I.
WT:-LBS.
```

2. SUBLEVELS

CODE.–0.2

```
*DDEL*

*WDATA
*KEY*
LENGTH:-FEET.
DIA:-INS.
VOL:-BBL.
MUD WT:-P.P.G.
PRES:-P.S.I.
WT:-LBS.
```

2. SUBLEVELS

CODE:–0.3

```
*DDEL*

*WDATA
*KEY*
LENGTH:-FEET.
DIA:-INS.
VOL:-BBL.
MUD WT:-P.P.G.
PRES:-P.S.I.
WT:-LBS.
```

2. SUBLEVELS

CODE:–0.4

```
*DDEL*

*KEY*
LENGTH:-FEET.
DIA:-INS.
VOL:-BBL.
MUD WT:-P.P.G.
PRES:-P.S.I.
WT:-LBS.
```

2. SUBLEVELS

CODE:–0.5

```
*DDEL*

*KEY*
LENGTH:-MTRS.
DIA:-M.MTR.
VOL:-C.MTR.
MUD WT:-S.G.
PRES:-BARS.
WT:-DA.N.
```

2. SUBLEVELS

PRE-SET FLAGS PRIOR TO CODE 0.6 OPERATION (FLAGS NEED NOT BE RESET IF STATES ALREADY O.K.)

```
SF 00
CF 01
CF 02
SF 03
CF 04
```

CODE:–0.6

```
*DDEL*

*KEY*
LENGTH:-MTRS.
DIA:-INS.
VOL:-BBL.
MUD WT:-S.G.
PRES:-P.S.I.
WT:-LBS.
```

2. SUBLEVELS

USING THE X<> F FUNCTION TO CLEAR UNITS CONTROL FLAGS

```
0.
X<>F
```

CODE;–0.6

```
*DDEL*

*KEY*
LENGTH:-FEET.
DIA:-INS.
VOL:-BBL.
MUD WT:-P.P.G.
PRES:-P.S.I.
WT:-LBS.
```

2. SUBLEVELS

CODE:–0.7

```
*DDEL*

*KEY*
LENGTH:-FEET.
DIA:-INS.
VOL:-BBL.
MUD WT:-P.P.G.
PRES:-P.S.I.
WT:-LBS.
```

2. SUBLEVELS

CODE:–0.8

```
*DDEL*

*WDATA→XMEM
*MDATA→XMEM
```

2. SUBLEVELS

CODE: – 1.0

```
*DDEL*

      RHEO. OK?"Y"
    Q RATE?= 8.405
DEPTH?= 13,451.000

*HOLE DATA*

*SECT:-1.*
LENGTH.=233.00
DIA.=8.500
CAP.=0.07019
VOL.=16.35

*SECT:-2.*
LENGTH.=151.00
DIA.=14.000
CAP.=0.19040
VOL.=28.75

*SECT:-3.*
LENGTH.=11,891.00
DIA.=8.535
CAP.=0.07076
VOL.=841.46

*SECT:-4.*
LENGTH.=34.00
DIA.=18.750
CAP.=0.34152
VOL.=11.61

*SECT:-5.*
LENGTH.=1,142.00
DIA.=20.000
CAP.=0.38857
VOL.=443.75

ΣVOL.=1,341.93

*PIPE DATA*

*SECT:-1.*
LENGTH.=754.00
O.D.=6.500
ID.(P).=2.500
ID.(C).=2.500
CAP.=0.00607
VOL.=4.58
VEL.=1,384.32
DISP.=0.03497
VOL.D.=26.37
WT.A.=72,477.86
WT.M.=61,479.55
```

Cont . . .

```
*SECT:-2.*
LENGTH.=363.00
O.D.=5.254
ID.(P).=3.017
ID.(C).=3.019
CAP.=0.00885
VOL.=3.21
VEL.=949.27
DISP.=0.01796
VOL.D.=6.52
WT.A.=17,921.68
WT.M.=15,202.12

*SECT:-3.*
LENGTH.=3,687.00
O.D.=5.094
ID.(P).=4.234
ID.(C).=4.249
CAP.=0.01754
VOL.=64.66
VEL.=479.23
DISP.=0.00767
VOL.D.=28.28
WT.A.=77,722.67
WT.M.=65,928.48

*SECT:-4.*
LENGTH.=8,647.00
O.D.=5.098
ID.(P).=4.153
ID.(C).=4.226
CAP.=0.01735
VOL.=150.01
VEL.=484.46
DISP.=0.00790
VOL.D.=68.30
WT.A.=187,722.24
WT.M.=159,235.92

ΣWT.A.=355,844.45
ΣWT.M.=301,846.06
ΣVOL.D.=129.46

ΣVOL.=222.47

*ANN. DATA*

*SECT:-1.*
LENGTH.=233.00
DIA.=8.500
O.D.=6.500
CAP.=0.02914
VOL.=6.79
VEL.=288.40
```

Cont . . .

```
*SECT:-2.*
LENGTH.=151.00
DIA.=14.000
O.D.=6.500
CAP.=0.14936
VOL.=22.55
VEL.=56.27

*SECT:-3.*
LENGTH.=370.00
DIA.=8.535
O.D.=6.500
CAP.=0.02972
VOL.=11.00
VEL.=282.78

*SECT:-4.*
LENGTH.=363.00
DIA.=8.535
O.D.=5.254
CAP.=0.04395
VOL.=15.95
VEL.=191.24

*SECT:-5.*
LENGTH.=3,687.00
DIA.=8.535
O.D.=5.094
CAP.=0.04556
VOL.=167.97
VEL.=184.49

*SECT:-6.*
LENGTH.=7,471.00
DIA.=8.535
O.D.=5.098
CAP.=0.04552
VOL.=340.06
VEL.=184.65

*SECT:-7.*
LENGTH.=34.00
DIA.=18.750
O.D.=5.098
CAP.=0.31627
VOL.=10.75
VEL.=26.57

*SECT:-8.*
LENGTH.=1,142.00
DIA.=20.000
O.D.=5.098
CAP.=0.36332
VOL.=414.92
VEL.=23.13

ΣVOL.=990.00
```

4. SUBLEVELS

CODE:-0.0

```
**DDEL**

*MDATA
*KEY*
LENGTH:-FEET.
DIA:-INS.
VOL:-BBL.
MUD WT:-P.P.G.
PRES:-P.S.I.
WT:-LBS.
```

2. SUBLEVELS

CODE:-0.1

```
**DDEL**

*MDATA
*KEY*
LENGTH:-FEET.
DIA:-INS.
VOL:-BBL.
MUD WT:-P.P.G.
PRES:-P.S.I.
WT:-LBS.
```

2. SUBLEVELS

CODE.-0.2

```
**DDEL**

*MDATA
*KEY*
LENGTH:-FEET.
DIA:-INS.
VOL:-BBL.
MUD WT:-P.P.G.
PRES:-P.S.I.
WT:-LBS.
```

2. SUBLEVELS

CODE:-0.3

```
**DDEL**

*MDATA
*KEY*
LENGTH:-FEET.
DIA:-INS.
VOL:-BBL.
MUD WT:-P.P.G.
PRES:-P.S.I.
WT:-LBS.
```

2. SUBLEVELS

CODE:-0.4

```
**DDEL**

*KEY*
LENGTH:-FEET.
DIA:-INS.
VOL:-BBL.
MUD WT:-P.P.G.
PRES:-P.S.I.
WT:-LBS.
```

2. SUBLEVELS

CODE:-0.5

```
**DDEL**

*KEY*
LENGTH:-MTRS.
DIA:-M.MTR.
VOL:-C.MTR.
MUD WT:-S.G.
PRES:-BARS.
WT:-DA.N.
```

2. SUBLEVELS

PRE-SET FLAGS **PRIOR** TO CODE 0.6 OPERATION (FLAGS NEED NOT BE RESET IF STATES ALREADY O.K.)

```
SF 00
CF 01
CF 02
SF 03
CF 04
```

CODE:-0.6

```
**DDEL**

*KEY*
LENGTH:-MTRS.
DIA:-INS.
VOL:-BBL.
MUD WT:-S.G.
PRES:-P.S.I.
WT:-LBS.
```

2. SUBLEVELS

USING THE X<> F FUNCTION TO CLEAR UNITS CONTROL FLAGS

```
0.
X<>F
```

CODE;-0.6

```
**DDEL**

*KEY*
LENGTH:-FEET.
DIA:-INS.
VOL:-BBL.
MUD WT:-P.P.G.
PRES:-P.S.I.
WT:-LBS.
```

2. SUBLEVELS

CODE:-0.7

```
**DDEL**

*KEY*
LENGTH:-FEET.
DIA:-INS.
VOL:-BBL.
MUD WT:-P.P.G.
PRES:-P.S.I.
WT:-LBS.
```

2. SUBLEVELS

CODE:-0.8

```
**DDEL**

*WDATA+XMEM
*MDATA+XMEM
```

2. SUBLEVELS

CODE: – 1.0

MODEL

PHEO. OK?"Y"
Q RATE?= 8.405
DEPTH?= 13,451.000

HOLE DATA

SECT:-1.
LENGTH.=233.00
DIA.=8.500
CAP.=0.07019
VOL.=16.35

SECT:-2.
LENGTH.=151.00
DIA.=14.000
CAP.=0.19040
VOL.=28.75

SECT:-3.
LENGTH.=11,891.00
DIA.=8.535
CAP.=0.07076
VOL.=841.46

SECT:-4.
LENGTH.=34.00
DIA.=18.750
CAP.=0.34152
VOL.=11.61

SECT:-5.
LENGTH.=1,142.00
DIA.=20.000
CAP.=0.38857
VOL.=443.75

ΣVOL.=1,341.93

PIPE DATA

SECT:-1.
LENGTH.=754.00
O.D.=6.500
ID.(P).=2.500
ID.(C).=2.500
CAP.=0.00607
VOL.=4.58
VEL.=1,384.32
DISP.=0.03497
VOL.D.=26.37
WT.A.=72,477.86
WT.M.=61,479.55

Cont . . .

SECT:-2.
LENGTH.=363.00
O.D.=5.254
ID.(P).=3.017
ID.(C).=3.019
CAP.=0.00885
VOL.=3.21
VEL.=949.27
DISP.=0.01796
VOL.D.=6.52
WT.A.=17,921.68
WT.M.=15,202.12

SECT:-3.
LENGTH.=3,687.00
O.D.=5.094
ID.(P).=4.234
ID.(C).=4.249
CAP.=0.0175'
VOL.=64.66
VEL.=479.23
DISP.=0.00767
VOL.D.=28.28
WT.A.=77,722.67
WT.M.=65,928.48

SECT:-4.
LENGTH.=8,647.00
O.D.=5.098
ID.(P).=4.153
ID.(C).=4.226
CAP.=0.01735
VOL.=150.01
VEL.=484.46
DISP.=0.00790
VOL.D.=68.30
WT.A.=187,722.24
WT.M.=159,235.92

ΣWT.A.=355,844.45
ΣWT.M.=301,846.06
ΣVOL.D.=129.46

ΣVOL.=222.47

ANN. DATA

SECT:-1.
LENGTH.=233.00
DIA.=8.500
O.D.=6.500
CAP.=0.02914
VOL.=6.79
VEL.=288.40

Cont . . .

SECT:-2.
LENGTH.=151.00
DIA.=14.000
O.D.=6.500
CAP.=0.14936
VOL.=22.55
VEL.=56.27

SECT:-3.
LENGTH.=370.00
DIA.=8.535
O.D.=6.500
CAP.=0.02972
VOL.=11.00
VEL.=282.76

SECT:-4.
LENGTH.=363.00
DIA.=8.535
O.D.=5.254
CAP.=0.04395
VOL.=15.95
VEL.=191.24

SECT:-5.
LENGTH.=3,687.00
DIA.=8.535
O.D.=5.094
CAP.=0.04556
VOL.=167.97
VEL.=184.49

SECT:-6.
LENGTH.=7,471.00
DIA.=8.535
O.D.=5.098
CAP.=0.04552
VOL.=340.06
VEL.=184.65

SECT:-7.
LENGTH.=34.00
DIA.=18.750
O.D.=5.098
CAP.=0.31627
VOL.=10.75
VEL.=26.57

SECT:-8.
LENGTH.=1,142.00
DIA.=20.000
O.D.=5.098
CAP.=0.36332
VOL.=414.92
VEL.=23.13

ΣVOL.=990.00

4. SUBLEVELS

CODE:–1.1

ꕥDDELꕥ

RHEO. OK?"Y"
Q RATE?= 8.405
DEPTH?= 5,000.000

HOLE DATA

SECT:-1.
LENGTH.=3,824.00
DIA.=8.535
CAP.=0.07076
VOL.=270.60

SECT:-2.
LENGTH.=34.00
DIA.=18.750
CAP.=0.34152
VOL.=11.61

SECT:-3.
LENGTH.=1,142.00
DIA.=20.000
CAP.=0.38857
VOL.=443.75

ΣVOL.=725.96

4. SUBLEVELS

CODE:–1.2

ꕥDDELꕥ

RHEO. OK?"Y"
Q RATE?= 8.405
DEPTH?= 5,000.000

PIPE DATA

SECT:-1.
LENGTH.=754.00
O.D.=6.500
ID.(P).=2.500
ID.(C).=2.500
CAP.=0.00607
VOL.=4.58
VEL.=1,384.32
DISP.=0.03497
VOL.D.=26.37
WT.A.=72,477.86
WT.M.=61,479.55

Cont . . .

SECT:-2.
LENGTH.=363.00
O.D.=5.254
ID.(P).=3.017
ID.(C).=3.019
CAP.=0.00885
VOL.=3.21
VEL.=949.27
DISP.=0.01796
VOL.D.=6.52
WT.A.=17,921.68
WT.M.=15,202.12

SECT:-3.
LENGTH.=3,687.00
O.D.=5.094
ID.(P).=4.234
ID.(C).=4.249
CAP.=0.01754
VOL.=64.66
VEL.=479.23
DISP.=0.00767
VOL.D.=28.28
WT.A.=77,722.67
WT.M.=65,928.48

SECT:-4.
LENGTH.=196.00
O.D.=5.098
ID.(P).=4.153
ID.(C).=4.226
CAP.=0.01735
VOL.=3.40
VEL.=484.46
DISP.=0.00790
VOL.D.=1.55
WT.A.=4,255.07
WT.M.=3,609.37

ΣWT.A.=172,377.28
ΣWT.M.=146,219.51
ΣVOL.D.=62.71

ΣVOL.=75.86

4. SUBLEVELS

CODE:–1.3

ꕥDDELꕥ

RHEO. OK?"Y"
Q RATE?= 8.405
DEPTH?= 5,000.000

ANN. DATA

SECT:-1.
LENGTH.=754.00
DIA.=8.535
O.D.=6.500
CAP.=0.02972
VOL.=22.41
VEL.=282.78

SECT:-2.
LENGTH.=363.00
DIA.=8.535
O.D.=5.254
CAP.=0.04395
VOL.=15.95
VEL.=191.24

SECT:-3.
LENGTH.=2,707.00
DIA.=8.535
O.D.=5.094
CAP.=0.04556
VOL.=123.32
VEL.=184.49

SECT:-4.
LENGTH.=34.00
DIA.=18.750
O.D.=5.094
CAP.=0.31631
VOL.=10.75
VEL.=26.57

SECT:-5.
LENGTH.=946.00
DIA.=20.000
O.D.=5.094
CAP.=0.36336
VOL.=343.74
VEL.=23.13

SECT:-6.
LENGTH.=196.00
DIA.=20.000
O.D.=5.098
CAP.=0.36332
VOL.=71.21
VEL.=23.13

ΣVOL.=587.40

4. SUBLEVELS

CODE: – 1.4

```
⊕DDEL⊕
```

CHANGE RHEOLOGY

```
RHEO. OK?"N"
*RHEOLOGY*
```

CHANGE MUD WT RHEOLOGY REMAINS THE SAME.

```
hi.n?= 0.723
MUD WT?= 10.500
Q RATE?= 8.405
DEPTH?= 7,350.000

*HOLE DATA*

ΣVOL.=892.26

*PIPE DATA*

ΣWT.A.=223,394.66
ΣWT.M.=187,552.86
ΣVOL.D.=81.27

ΣVOL.=116.62

*ANN. DATA*

ΣVOL.=694.36
```

4. SUBLEVELS

CODE: – 1.5

```
⊕DDEL⊕

RHEO. OK?"Y"
Q RATE?= 8.405
DEPTH?= 7,350.000

*HOLE DATA*

ΣVOL.=892.26
```

4. SUBLEVELS

CODE: – 1.6

```
⊕DDEL⊕

RHEO. OK?"Y"
Q RATE?= 8.405
DEPTH?= 7,350.000

*PIPE DATA*

ΣWT.A.=223,394.66
ΣWT.M.=187,552.86
ΣVOL.D.=81.27

ΣVOL.=116.62
```

4. SUBLEVELS

CODE: – 1.7

```
⊕DDEL⊕

RHEO. OK?"Y"
Q RATE?= 8.405
DEPTH?= 13,451.000

*ANN. DATA*

ΣVOL.=990.00
```

4. SUBLEVELS

CODE: – 1.8

```
⊕DDEL⊕

RHEO. OK?"Y"
Q RATE?= 8.405
DEPTH?= 13,451.000
CALC.D?= 10,000.000

*ANN. DATA*

*SECT:-1.*
LENGTH.=1,353.00
DIA.=8.535
O.D.=5.094
CAP.=0.04556
VOL.=61.64
VEL.=184.49

*SECT:-2.*
LENGTH.=7,471.00
DIA.=8.535
O.D.=5.098
CAP.=0.04552
VOL.=340.06
VEL.=184.65

*SECT:-3.*
LENGTH.=34.00
DIA.=18.750
O.D.=5.098
CAP.=0.31627
VOL.=10.75
VEL.=26.57

*SECT:-4.*
LENGTH.=1,142.00
DIA.=20.000
O.D.=5.098
CAP.=0.36332
VOL.=414.92
VEL.=23.13

ΣVOL.=827.37
```

4. SUBLEVELS

CODE: – 1.9

```
⊕DDEL⊕

RHEO. OK?"Y"
Q RATE?= 8.405
DEPTH?= 13,451.000
CALC.D?= 10,000.000

*ANN. DATA*

ΣVOL.=827.37
```

4. SUBLEVELS

CODE: – 3.0

```
*MODEL*
CHANGE
RHEOLOGY        RHEO. OK?"N"
   *RHEOLOGY*

CHANGE MUD      hi.n?= 0.723
WT ONLY         MUD WT?= 9.931
               Q RATE?= 8.405
            DEPTH?= 13,451.000

   *PIPE DATA*

*SECT:-1.*
LENGTH.=754.00
O.D.=6.500
ID.(P).=2.500
ID.(C).=2.500
CAP.=0.00607
VOL.=4.58
VEL.=1,384.32
DISP.=0.03497
VOL.D.=26.37
WT.A.=72,477.86
WT.M.=61,479.55

T.PRES.=358.67

*SECT:-2.*
LENGTH.=363.00
O.D.=5.254
ID.(P).=3.017
ID.(C).=3.019
CAP.=0.00885
VOL.=3.21
VEL.=949.27
DISP.=0.01796
VOL.D.=6.52
WT.A.=17,921.68
WT.M.=15,202.12

T.PRES.=74.03

*SECT:-3.*
LENGTH.=3,687.00
O.D.=5.094
ID.(P).=4.234
ID.(C).=4.249
CAP.=0.01754
VOL.=64.66
VEL.=479.23
DISP.=0.00767
VOL.D.=28.28
WT.A.=77,722.67
WT.M.=65,928.48

T.PRES.=163.31

*SECT:-4.*
LENGTH.=8,647.00
O.D.=5.098
ID.(P).=4.153
ID.(C).=4.226
CAP.=0.01735
VOL.=150.01
VEL.=484.46
DISP.=0.00790
VOL.D.=68.30
WT.A.=187,722.24
WT.M.=159,235.92

T.PRES.=417.83

ΣWT.A.=355,844.45
ΣWT.M.=301,846.06
ΣVOL.D.=129.46

ΣVOL.=222.47
ΣPRES.=1,013.84

   *ANN. DATA*

*SECT:-1.*
LENGTH.=233.00
DIA.=8.500
O.D.=6.500
CAP.=0.02914
VOL.=6.79
VEL.=288.40

A.CV.L.=389.
L.PRES.=14.36
S.RATE=409.SEC-1
VISC.=43.CPS.

*SECT:-2.*
LENGTH.=151.00
DIA.=14.000
O.D.=6.500
CAP.=0.14936
VOL.=22.55
VEL.=56.27

A.CV.L.=257.
L.PRES.=0.60
S.RATE=21.SEC-1
VISC.=202.CPS.

*SECT:-3.*
LENGTH.=370.00
DIA.=8.535
O.D.=6.500
CAP.=0.02972
VOL.=11.00
VEL.=282.78

A.CV.L.=387.
L.PRES.=22.01
S.RATE=394.SEC-1
VISC.=44.CPS.

*SECT:-4.*
LENGTH.=363.00
DIA.=8.535
O.D.=5.254
CAP.=0.04395
VOL.=15.95
VEL.=191.24

A.CV.L.=333.
L.PRES.=8.84
S.RATE=165.SEC-1
VISC.=69.CPS.

*SECT:-5.*
LENGTH.=3,687.00
DIA.=8.535
O.D.=5.094
CAP.=0.04556
VOL.=167.97
VEL.=184.49

A.CV.L.=328.
L.PRES.=82.24
S.RATE=152.SEC-1
VISC.=73.CPS.

*SECT:-6.*
LENGTH.=7,471.00
DIA.=8.535
O.D.=5.098
CAP.=0.04552
VOL.=340.06
VEL.=184.65

A.CV.L.=328.
L.PRES.=167.00
S.RATE=152.SEC-1
VISC.=72.CPS.
```

Cont . . .

NOTE USE OF PREFIX TO "PRES". DATA LABEL TO INDICATE TYPE OF FLOW REGIME USED TO CALCULATE THAT PRESSURE

CODE: – 3.0 continued

SECT:-7.
LENGTH.=34.00
DIA.=18.750
O.D.=5.098
CAP.=0.31627
VOL.=10.75
VEL.=26.57

A.CV.L.=212.
L.PRES.=0.04
S.RATE=6.SEC-1
VISC.=409.CPS.

SECT:-8.
LENGTH.=1,142.00
DIA.=20.000
O.D.=5.098
CAP.=0.36332
VOL.=414.92
VEL.=23.13

A.CV.L.=207.
L.PRES.=1.08
S.RATE=4.SEC-1
VISC.=460.CPS.

ΣVOL.=990.00
ΣPRES.=296.16

E.C.D.:-
EQ.MWT.=10.354

SURF. DATA

T.PRES.=25.73

C/KL DATA

T.PRES.=313.79

6. SUBLEVELS

CODE: – 3.1

MDDEL

RHEO. OK?"Y"
Q RATE?= 8.405
DEPTH?= 13,451.000

PIPE DATA

SECT:-1.
LENGTH.=754.00
O.D.=6.500
ID.(P).=2.500
ID.(C).=2.500
CAP.=0.00607
VOL.=4.58
VEL.=1,384.32
DISP.=0.03497
VOL.D.=26.37
WT.A.=72,477.86
WT.M.=61,479.55

T.PRES.=358.67

SECT:-2.
LENGTH.=363.00
O.D.=5.254
ID.(P).=3.017
ID.(C).=3.019
CAP.=0.00885
VOL.=3.21
VEL.=949.27
DISP.=0.01796
VOL.D.=6.52
WT.A.=17,921.68
WT.M.=15,202.12

T.PRES.=74.03

SECT:-3.
LENGTH.=3,687.00
O.D.=5.094
ID.(P).=4.234
ID.(C).=4.249
CAP.=0.01754
VOL.=64.66
VEL.=479.23
DISP.=0.00767
VOL.D.=28.28
WT.A.=77,722.67
WT.M.=65,928.48

T.PRES.=163.31

SECT:-4.
LENGTH.=8,647.00
O.D.=5.098
ID.(P).=4.153
ID.(C).=4.226
CAP.=0.01735
VOL.=150.01
VEL.=484.46
DISP.=0.00790
VOL.D.=68.30
WT.A.=187,722.24
WT.M.=159,235.92

T.PRES.=417.83

ΣWT.A.=355,844.45
ΣWT.M.=301,846.06
ΣVOL.D.=129.46

ΣVOL.=222.47
ΣPRES.=1,013.84

SURF. DATA

T.PRES.=25.73

C/KL DATA

T.PRES.=313.79

5. SUBLEVELS

CODE:- 3.2

MDDEL

RHEO. OK?"Y"
Q RATE?= 8.405
DEPTH?= 13,451.000

ANN. DATA

SECT:-1.
LENGTH.=233.00
DIA.=8.500
O.D.=6.500
CAP.=0.02914
VOL.=6.79
VEL.=288.40

A.CV.L.=389.
L.PRES.=14.36
S.RATE=409.SEC-1
VISC.=43.CPS.

Cont . . .

CODE: – 3.2 Continued

```
*SECT:-2.*
LENGTH.=151.00
DIA.=14.000
O.D.=6.500
CAP.=0.14936
VOL.=22.55
VEL.=56.27

A.CV.L.=257.
L.PRES.=0.60
S.RATE=21.SEC-1
VISC.=202.CPS.

*SECT:-3.*
LENGTH.=370.00
DIA.=8.535
O.D.=6.500
CAP.=0.02972
VOL.=11.00
VEL.=282.78

A.CV.L.=387.
L.PRES.=22.01
S.RATE=394.SEC-1
VISC.=44.CPS.

*SECT:-4.*
LENGTH.=363.00
DIA.=8.535
O.D.=5.254
CAP.=0.04395
VOL.=15.95
VEL.=191.24

A.CV.L.=333.
L.PRES.=8.84
S.RATE=165.SEC-1
VISC.=69.CPS.

*SECT:-5.*
LENGTH.=3,687.00
DIA.=8.535
O.D.=5.094
CAP.=0.04556
VOL.=167.97
VEL.=184.49

A.CV.L.=328.
L.PRES.=82.24
S.RATE=152.SEC-1
VISC.=73.CPS.
```

Cont . . .

```
*SECT:-6.*
LENGTH.=7,471.00
DIA.=8.535
O.D.=5.098
CAP.=0.04552
VOL.=340.06
VEL.=184.65

A.CV.L.=328.
L.PRES.=167.00
S.RATE=152.SEC-1
VISC.=72.CPS.

*SECT:-7.*
LENGTH.=34.00
DIA.=18.750
O.D.=5.098
CAP.=0.31627
VOL.=10.75
VEL.=26.57

A.CV.L.=212.
L.PRES.=0.04
S.RATE=6.SEC-1
VISC.=409.CPS.

*SECT:-8.*
LENGTH.=1,142.00
DIA.=20.000
O.D.=5.098
CAP.=0.36332
VOL.=414.92
VEL.=23.13

A.CV.L.=207.
L.PRES.=1.08
S.RATE=4.SEC-1
VISC.=460.CPS.

ΣVOL.=990.00
ΣPRES.=296.16

*E.C.D.:-*
EQ.MWT.=10.354

*SURF. DATA*

T.PRES.=25.73

*C/KL DATA*

T.PRES.=313.79
```

6. SUBLEVELS

CODE: – 3.3

```
*MODEL*

RHEO. OK?"Y"
Q RATE?= 8.405
DEPTH?= 13,451.000

*PIPE DATA*

ΣWT.A.=355,844.45
ΣWT.M.=301,846.06
ΣVOL.D.=129.46

ΣVOL.=222.47
ΣPRES.=1,013.84

*ANN. DATA*

ΣVOL.=990.00
ΣPRES.=296.16

*E.C.D.:-*
EQ.MWT.=10.354

*SURF. DATA*

T.PRES.=25.73

*C/KL DATA*

T.PRES.=313.79
```

6. SUBLEVELS

CODE: – 3.4

ODDEL

RHEO. OK?"Y"
Q RATE?= 8.405
DEPTH?= 13,451.000

PIPE DATA

ΣWT.A.=355,844.45
ΣWT.M.=301,846.06
ΣVOL.D.=129.46

ΣVOL.=222.47
ΣPRES.=1,013.84

SURF. DATA

T.PRES.=25.73

C/KL DATA

T.PRES.=313.79

5. SUBLEVELS

CODE: – 3.5

ODDEL

RHEO. OK?"Y"
Q RATE?= 8.405
DEPTH?= 13,451.000

ANN. DATA

ΣVOL.=990.00
ΣPRES.=296.16

E.C.D.:-
EQ.MWT.=10.354

SURF. DATA

T.PRES.=25.73

C/KL DATA

T.PRES.=313.79

6. SUBLEVELS

CODE: – 3.6

ODDEL

RHEO. OK?"Y"
Q RATE?= 8.405
DEPTH?= 13,451.000
CALC.D?= 10,000.000

ANN. DATA

SECT:-1.
LENGTH.=1,353.00
DIA.=8.535
O.D.=5.094
CAP.=0.04556
VOL.=61.64
VEL.=184.49

A.CV.L.=328.
L.PRES.=30.18
S.RATE=152.SEC-1
VISC.=73.CPS.

SECT:-2.
LENGTH.=7,471.00
DIA.=8.535
O.D.=5.098
CAP.=0.04552
VOL.=340.06
VEL.=184.65

A.CV.L.=328.
L.PRES.=167.00
S.RATE=152.SEC-1
VISC.=72.CPS.

SECT:-3.
LENGTH.=34.00
DIA.=18.750
O.D.=5.098
CAP.=0.31627
VOL.=10.75
VEL.=26.57

A.CV.L.=212.
L.PRES.=0.04
S.RATE=6.SEC-1
VISC.=409.CPS.

Cont . . .

SECT:-4.
LENGTH.=1,142.00
DIA.=20.000
O.D.=5.098
CAP.=0.36332
VOL.=414.92
VEL.=23.13

A.CV.L.=207.
L.PRES.=1.08
S.RATE=4.SEC-1
VISC.=460.CPS.

ΣVOL.=827.37
ΣPRES.=198.29

E.C.D.:-
EQ.MWT.=10.312

SURF. DATA

T.PRES.=25.73

C/KL DATA

T.PRES.=313.79

6. SUBLEVELS

CODE: – 3.7

ODDEL

RHEO. OK?"Y"
Q RATE?= 8.405
DEPTH?= 13,451.000
CALC.D?= 10,000.000

ANN. DATA

ΣVOL.=827.37
ΣPRES.=198.29

E.C.D.:-
EQ.MWT.=10.312

SURF. DATA

T.PRES.=25.73

C/KL DATA

T.PRES.=313.79

6. SUBLEVELS

CODE: – 3.8

```
@DDEL@

                RHEO. OK?"Y"
SELECT PIPE FLOW   P. FLOW?"Y"
         LENGTH?= 1,000.000
              P-O.D?= 8.000
            ID.(P)?= 2.813
            ID.(C)?= 2.813
           Q RATE?= 10.000

*SECT:-1.*
LENGTH.=1,000.00
O.D.=8.000
ID.(P).=2.813
ID.(C).=2.813
CAP.=0.00768
VOL.=7.68
VEL.=1,301.38
DISP.=0.05449
VOL.D.=54.49
WT.A.=149,766.87
WT.M.=127,040.17

RE.T.=3,279.
CV.T.=428.
RE.L.=2,814.
CV.L.=420.
T.PRES.=372.75
```

4. SUBLEVELS

CODE: – 3.8

```
@DDEL@

SELECT ANNULUS   RHEO. OK?"Y"
FLOW              P. FLOW?"N"
         LENGTH?= 1,000.000
              H-DIA?= 12.250
              P-O.D?= 8.000
           Q RATE?= 10.000

*SECT:-1.*
LENGTH.=1,000.00
DIA.=12.250
O.D.=8.000
CAP.=0.08360
VOL.=83.60
VEL.=119.61

RE.T.=3,279.
CV.T.=419.
RE.L.=2,814.
CV.L.=409.
A.CV.L.=307.
L.PRES.=13.27
S.RATE=80.SEC-1
VISC.=101.CPS.
```

4. SUBLEVELS

CODE: – 3.9

```
@DDEL@

          RHEO. OK?"Y"

*SURGE-SWAB*

   AV.P.VEL?= 100.000
  DEPTH?= 13,451.000

ΣPRES.=308.58
```

6. SUBLEVELS

CODE: – 7.0

ⱭDDELⱭ

G.CUT MUD

```
  TVDEPTH?= 10,000.000
    GCMUD WT?= 9.000
      MUD WT?= 11.000

P.LOSS=19.45
```

3. SUBLEVELS

CODE: – 7.0

ⱭDDELⱭ

G.CUT MUD

```
  TVDEPTH?= 15,000.000
    GCMUD WT?= 6.500
      MUD WT?= 14.500

P.LOSS=120.05
```

3. SUBLEVELS

CODE: – 7.1

ⱭDDELⱭ

LEAK OFF

```
  TVDEPTH?= 10,500.000
    TVD HC?= 12,000.000
     TVD WZ?= 8,000.000
     TMUD WT?= 10.200
       MUD WT?= 11.600
  TSURF. P?= 1,200.000

M.A.A.S.S.P.=618.15

*AT:- 8,000.00 TV*
M.C.F.P.=5,439.18
E P/GRD=0.680
E MUD WT=13.087

*AT:- 10,500.00 TV*
M.C.F.P.=6,945.75
E P/GRD=0.662
E MUD WT=12.733

*AT:- 12,000.00 TV*
M.C.F.P.=7,849.70
E P/GRD=0.654
E MUD WT=12.592
```

3. SUBLEVELS

CODE: – 7.2

ⱭDDELⱭ

MUD WT.CHG

```
              B/L/O?"B"
      I.MUD WT?= 11.000
            VOL.I/F?"F"
   MUD VOL?= 1,000.000
      F.MUD WT?= 14.000

A.VOL=123.0
I.VOL=877.0
F.VOL=1,000.0

A.WT=182,803.3
A.WT/V=208.4
```

3. SUBLEVELS

CODE: – 7.2

ⱭDDELⱭ

MUD WT.CHG

```
              B/L/O?"L"
      I.MUD WT?= 11.000
            VOL.I/F?"F"
   MUD VOL?= 1,000.000
      F.MUD WT?= 11.600

A.VOL=56.1
I.VOL=943.9
F.VOL=1,000.0

A.WT=51,106.5
A.WT/V=54.1
```

3. SUBLEVELS

CODE: – 7.2

ⱭDDELⱭ

MUD WT.CHG

```
              B/L/O?"D"
       DENSITY?= 22.400
      I.MUD WT?= 11.000
            VOL.I/F?"I"
     MUD VOL?= 500.000
      F.MUD WT?= 11.800

A.VOL=37.7
I.VOL=500.0
F.VOL=537.7

A.WT=35,501.9
A.WT/V=71.0
```

3. SUBLEVELS

CODE:-7.3

```
        ⁂DDEL⁂

*MUD  WT.CHG*

              B/L/O?"B"
     I.MUD WT?= 11.000
             VOL.I/F?"I"
   MUD VOL?= 1,000.000
  ADDED WT?= 20,000.000

F.MUD WT=11.324
```

3. SUBLEVELS

CODE:-7.4

```
        ⁂DDEL⁂

*MUD  WT.CHG*

              D/W/O?"D"
     I.MUD WT?= 11.000
             VOL.I/F?"F"
   MUD VOL?= 1,000.000
      F.MUD WT?= 9.600

A.VOL=341.5
I.VOL=658.5
F.VOL=1,000.0

A.WT=98,956.1
A.WT/V=150.3
```

3. SUBLEVELS

CODE:-7.5

```
        ⁂DDEL⁂

*MUD  WT.CHG*

              D/W/O?"O"
      DENSITY?= 9.500
     I.MUD WT?= 10.300
             VOL.I/F?"I"
       MUD VOL?= 350.000
   ADDED VOL?= 200.000

F.MUD WT=10.009
```

3. SUBLEVELS

Examples of Code – 8 *OILWELL 1

CODE: –8.0

```
&DDEL&

*RND TRIP*

      DEPTH?= 13,451.000
 TR.BLK WT?= 80,000.000
      MUD WT?= 10.656
  AV.LEN/STD?= 92.281

WORK DONE
1,248. TONNE-KMTR.
855. S.TON-MILES.
```

4. SUBLEVELS

CODE: –8.1

```
&DDEL&

*WIPER TRIP*

      DEPTH?= 13,451.000
 TR.BLK WT?= 80,000.000
      MUD WT?= 10.686
  AV.LEN/STD?= 92.281
 W.TRIP TO?= 9,500.000

WORK DONE
462. TONNE-KMTR.
317. S.TON-MILES.
```

4. SUBLEVELS

CODE: –8.1

```
&DDEL&

*WIPER TRIP*

      DEPTH?= 13,451.000
 TR.BLK WT?= 80,000.000
      MUD WT?= 10.686
  AV.LEN/STD?= 92.281
 W.TRIP TO?= 0.000
```

DEMONSTRATED W. TRIP TO SURFACE = RND. TRIP

```
WORK DONE
1,248. TONNE-KMTR.
855. S.TON-MILES.
```

4. SUBLEVELS

CODE: –8.2

```
&DDEL&

*CASING*

      DEPTH?= 16,300.000
 TR.BLK WT?= 80,000.000
      MUD WT?= 10.500
  AV.LEN/JNT?= 41.250

WORK DONE
1,211. TONNE-KMTR.
829. S.TON-MILES.
```

4. SUBLEVELS

CODE: –8.3

```
&DDEL&

*DR/C/RM*

      DEPTH?= 15,000.000
 TR.BLK WT?= 80,000.000
      MUD WT?= 10.686
  KELLY WT?= 15,000.000
  KELLY LEN?= 52.000
   DRILLED?= 1,130.000
   NO. JNTS?= 36.000
   NO.X REAM?= 2.000

WORK DONE
577. TONNE-KMTR.
395. S.TON-MILES.
```

4. SUBLEVELS

CODE: –8.4

```
&DDEL&

*STACK*

      DEPTH?= 1,142.000
 TR.BLK WT?= 80,000.000
      STK HT?= 34.000
    STK WT?= 350,000.000
  R+STK WT?= 407,000.000
   R.JNT WT?= 10,000.000

WORK DONE
81. TONNE-KMTR.
56. S.TON-MILES.
```

4. SUBLEVELS

CODE: – 9.0

DDEL

CHG. H/P?"P"

PIPE DATA

SECT?= 1.000

SECT:-1.
LENGTH?= 825.000
O.D?= 6.500
ID.(P)?= 2.500
ID.(C)?= 2.500
RIGHT?"Y"

5. SUBLEVELS

CODE: – 9.0

DDEL

SPECIFY CHANGE IN DATA HERE — CHG. H/P?"H"

HOLE DATA

CALL FOR NON EXISTENT SECTION REPEAT FUNCTION — SECT?= 6.000
CHG. H/P?"H"

HOLE DATA

CORRECT NUMBER OF SECTION OF HOLE DATA TO BE CHANGED — SECT?= 4.000

SECT:-4.
LENGTH?= 37.000
DIA?= 18.750
RIGHT?"Y"

5. SUBLEVELS

CODE: – 9.1

DDEL

EXAMPLE OF A CHANGE OF EXISTING PIPE DATA TO CASING DATA

PIPE DATA
TD↑

SECT:-1.
LENGTH?= 15,000.000
O.D?= 7.000
ID.(P)?= 6.094
ID.(C)?= 6.094

SECT:-2.
LENGTH?= 1,300.000
O.D?= 5.105
ID.(P)?= 3.919
ID.(C)?= 3.959

SECT:-3.
LENGTH?= 0.000

SURF. DATA

LENGTH?= 123.000
ID.(P)?= 3.000

C/KL DATA

LENGTH?= 1,500.000
ID.(P)?= 3.000
RIGHT?"Y"

5. SUBLEVELS

INPUT OF WELL GEOMETRY DATA

CODE: – 9.2

DDEL

HOLE DATA
TD↑

SECT:-1.
LENGTH?= 233.000
DIA?= 8.500

SECT:-2.
LENGTH?= 151.000
DIA?= 14.000

SECT:-3.
LENGTH?= 11,891.000
INPUT OUT OF RANGE – REPEAT INPUT PROMPT — DIA?= 8,535.000
DIA?= 8.535

SECT:-4.
LENGTH?= 34.000
DIA?= 18.750

SECT:-5.
LENGTH?= 1,142.000
DIA?= 20.000

SECT:-6.
LENGTH?= 0.000
ZERO INPUT SECTION DOES NOT EXIST GO TO PIPE DATA INPUT

PIPE DATA
TD↑

SECT:-1.
LENGTH?= 754.000
O.D?= 6.500
ID.(P)?= 2.500
ID.(C)?= 2.500

SECT:-2.
LENGTH?= 363.000
O.D?= 5.254
ID.(P)?= 3.017
ID.(C)?= 3.019

SECT:-3.
LENGTH?= 3,687.000
ID (C) INPUT >O.D. REPEAT COMPLETE INPUT FOR SECTION — O.D?= 5.094
ID.(P)?= 4.234
ID.(C)?= 5.249

SECT:-3.
LENGTH?= 3,687.000
O.D?= 5.094
ID.(P)?= 4.234
ID.(C)?= 4.249

SECT:-4.
LENGTH?= 8,647.000
O.D?= 5.098
ID.(P)?= 4.153
ID.(C)?= 4.226

SECT:-5.
LENGTH?= 0.000

SURF. DATA

LENGTH?= 123.000
ID.(P)?= 3.000

C/KL DATA

LENGTH?= 1,500.000
ID.(P)?= 3.000
CHECK ALL INPUT DATA CORRECT — RIGHT?"Y"

5. SUBLEVELS

CODE: – 10.0

ODDEL

PIPE SPECS

OD?= 5.000
ID?= 4.276
JNT. LENGTH?= 31.330
DEPTH?= 12,000.000

CRIT. RPM=
1. 222
2. 22, 86, 194

4. SUBLEVELS

CODE: – 10.1

ODDEL

PIPE SPECS

LENGTH?= 12,500.000
MUD WT?= 11.200

STRETCH=
80.06 IN
2,033.50 MM

3. SUBLEVELS

CODE: – 10.2

ODDEL

PIPE SPECS

WT/U.L?= 23.420
O/PULL?= 80,000.000
STRETCH?= 48.000

FREE PT=
10,332. FT
3,149. M

3. SUBLEVELS

CODE: – 10.3

ODDEL

PIPE SPECS

OD?= 5.000
ID?= 4.276
MIN.YIELD?= 75,000.000

NEW PIPE
TENSILE=
395,595. LB
175,969. DAN
TORSION=
41,167. FT-LB
5,581. M-DAN

PREM. PIPE
TENSILE=
311,536. LB
138,578. DAN
TORSION=
32,285. FT-LB
4,377. M-DAN

4. SUBLEVELS

CODE: – 10.4

ODDEL

PIPE SPECS

OD?= 5.000
ID?= 4.276
MIN.YIELD?= 135,000.000
HK.LOAD?= 250,000.000

NEW PIPE
TORSION=
69,383. FT-LB
9,407. M-DAN

PREM. PIPE
TORSION=
52,019. FT-LB
7,053. M-DAN

4. SUBLEVELS

CODE:-10.5

ODDEL

PIPE SPECS

OD?= 0.000
ID?= 4.276
WT/U.L?= 17.930

OD PIPE =
5.000 IN
126.998 MM

4. SUBLEVELS

CODE: – 10.5

ODDEL

PIPE SPECS

OD?= 5.000
ID?= 4.276
WT/U.L?= 0.000

WT/U.L=
17.93 LB/FT
26.17 DAN/M

4. SUBLEVELS

CODE: – 10.5

ODDEL

PIPE SPECS

OD?= 5.000
ID?= 0.000
WT/U.L?= 17.930

ID PIPE =
4.276 IN
108.613 MM

4. SUBLEVELS

CODE: – 10.5

```
   *DDEL*

*PIPE SPECS*

          OD?= 0.000
          ID?= 0.000
      WT/U.L?= 56.000
OD PIPE =
4.580 IN
116.322 MM
```

ASSUMES SOLID BAR

4. SUBLEVELS

CODE: – 10.6

```
   *DDEL*

*PIPE SPECS*

          OD?= 5.000
          ID?= 4.276
X-SECT=
5.2746 IN2
3,402.9583 MM2
```

4. SUBLEVELS

CODE:−11.0

```
@DDEL@

*OPT. HYD*

     NO.OLD NOZ.?= 3.000
         noz.3.?= 14.000
         noz.2.?= 14.000
         noz.1.?= 14.000

NOZ.A.=0.450990

         MUD WT?= 13.200
     MAX.PS?= 3,300.000
    NO.NEW NOZ.?= 4.000
       NO. SETS?= 3.000

      Q RATE?= 11.905
     PRES?= 3,272.000
      Q RATE?= 10.714
     PRES?= 2,693.000
       Q RATE?= 9.524
     PRES?= 2,165.000
             RIGHT?"Y"

a=24.59310
b=1.73074
r↑2=0.99999

*MAX. IF*

Q RATE.=11.828
P.C.=1,769.087
P.BIT.=1,530.913

A=0.441080

noz.4.= 12.
noz.3.= 12.
noz.2.= 12.
noz.1.= 12.

PWR.=443.72
IF.=1,223.29
VN/SEC.=360.41
```

Cont . . .

```
*MAX. HP*

Q RATE.=9.490
P.C.=1,208.464
P.BIT.=2,091.536

A=0.302780

noz.4.= 10.
noz.3.= 10.
noz.2.= 10.
noz.1.= 10.

PWR.=486.39
IF.=1,147.24
VN/SEC.=421.26

*MAX. HP-IF*

Q RATE.=10.588
P.C.=1,460.438
P.BIT.=1,839.562

A=0.360185

noz.4.= 11.
noz.3.= 11.
noz.2.= 11.
noz.1.= 10.

PWR.=477.26
IF.=1,200.33
VN/SEC.=395.07
PWR%=98.12


*ACTUAL HYD*

        noz.4.?= 11.000
        noz.3.?= 11.000
        noz.2.?= 11.000
        noz.1.?= 10.000
        Q RATE?= 10.500

Q RATE.=10.500
P.C.=1,439.544
P.BIT.=1,861.192
P.S.=3,300.736

A=0.355117

PWR.=478.87
IF.=1,197.36
VN/SEC.=397.39
```

3. SUBLEVELS

CODE:−11.1

```
@DDEL@

     MAX.PS?= 3,500.000
    NO.NEW NOZ.?= 3.000

a=24.59310
b=1.73074
r↑2=0.99999

*MAX. IF*

Q RATE.=12.237
P.C.=1,876.304
P.BIT.=1,623.696

A=0.443103

noz.3.= 14.
noz.2.= 14.
noz.1.= 14.

PWR.=486.88
IF.=1,303.38
VN/SEC.=371.17

*MAX. HP*

Q RATE.=9.819
P.C.=1,281.705
P.BIT.=2,218.295

A=0.304169

noz.3.= 11.
noz.2.= 12.
noz.1.= 11.

PWR.=533.71
IF.=1,222.35
VN/SEC.=433.84

*MAX. HP-IF*

Q RATE.=10.954
P.C.=1,548.949
P.BIT.=1,951.051

A=0.361837

noz.3.= 13.
noz.2.= 12.
noz.1.= 13.

PWR.=523.69
IF.=1,278.92
VN/SEC.=406.87
PWR%=98.12
```

Cont . . .

CODE: –11.1 continued

```
*ACTUAL HYD*

        noz.3.?= 14.000
        noz.2.?= 14.000
        noz.1.?= 14.000
        Q RATE?= 12.000

Q RATE.=12.000
P.C.=1,813.818
P.BIT.=1,507.240
P.S.=3,321.058

A=0.450990

PWR.=443.20
IF.=1,231.43
VN/SEC.=357.61
```

3. SUBLEVELS

CODE: –11.2

```
*MODEL*

*ACTUAL HYD*

        noz.3.?= 13.000
        noz.2.?= 12.000
        noz.1.?= 12.000
        Q RATE?= 11.500

Q RATE.=11.500
P.C.=1,685.015
P.BIT.=2,291.595
P.S.=3,976.610

A=0.350515

PWR.=645.76
IF.=1,455.14
VN/SEC.=440.95
```

3. SUBLEVELS

CODE: –11.3

```
*MODEL*

        Q RATE?= 14.000

Q RATE.=14.000
P.C.=2,368.433
P.BIT.=1,131.567

A=0.607247

noz.3.= 16.
noz.2.= 16.
noz.1.= 17.

PWR.=388.19
IF.=1,244.82
VN/SEC.=309.86

*ACTUAL HYD*

        noz.3.?= 0.000
```

3. SUBLEVELS

CODE: –11.4

```
*MODEL*

        NO. SETS?= 4.000

        Q RATE?= 11.905
        PRES?= 3,272.000
        Q RATE?= 10.714
        PRES?= 2,693.000
        Q RATE?= 9.524
        PRES?= 2,165.000
        Q RATE?= 8.929
        PRES?= 1,922.000
        RIGHT?"Y"

a=24.60271
b=1.73058
r↑2=1.00000
```

Cont . . .

```
*MAX. IF*

Q RATE.=12.238
P.C.=1,876.386
P.BIT.=1,623.614

A=0.443129

noz.3.= 14.
noz.2.= 14.
noz.1.= 14.

PWR.=486.87
IF.=1,303.39
VN/SEC.=371.16

*MAX. HP*

Q RATE.=9.819
P.C.=1,281.781
P.BIT.=2,218.219

A=0.304181

noz.3.= 11.
noz.2.= 12.
noz.1.= 11.

PWR.=533.70
IF.=1,222.36
VN/SEC.=433.83

*MAX. HP-IF*

Q RATE.=10.954
P.C.=1,549.030
P.BIT.=1,950.970

A=0.361855

noz.3.= 13.
noz.2.= 12.
noz.1.= 13.

PWR.=523.69
IF.=1,278.93
VN/SEC.=406.86
PWR%=98.12
```

Cont . . .

CODE: – 11.4 continued

```
*ACTUAL HYD*

        noz.3.?= 14.000
        noz.2.?= 14.000
        noz.1.?= 14.000
        Q RATE?= 12.230

Q RATE.=12.230
P.C.=1,874.380
P.BIT.=1,565.571
P.S.=3,439.952

A=0.450990

PWR.=469.18
IF.=1,279.09
VN/SEC.=364.47
```

3. SUBLEVELS

```
*DDEL*

*GEN. CALCS*

        OD?= 5.000
        ID?= 4.276
DISP. CAP.=
0.00652
```

KEY:–b

```
      P. FLOW?"N"
    VEL?= 120.000
     DIA?= 12.250
       OD?= 9.500
Q RATE.=
6.97

      P. FLOW?"Y"
  VEL?= 1,200.000
       ID?= 4.276
Q RATE.=
21.31
```

KEY:–c

```
Q RATE?= 11.000
     ID?= 3.000
PIPE VEL.=
1,258.17
```

KEY:–d

```
MUD WT?= 13.200
BUOYANCY.=
0.7983
```

KEY:–e

```
   Q RATE?= 11.000
   MUD WT?= 13.200
HOLE SIZE?= 12.250
ROP L/HR?= 100.000
ANN.MUD WT.=
13.383
```

KEY:–A

```
DIA?= 12.250
HOLE CAP.=
0.14577
```

KEY:–B

```
DIA?= 12.250
   OD?= 8.000
ANN. CAP.=
0.08360
```

KEY:–C

```
Q RATE?= 11.000
   DIA?= 12.250
     OD?= 5.000
ANN. VEL.=
131.57
```

KEY:–D

OPTION 1

ALSO STORE NOZZLE AREA IN REGISTER ACCESSED WITH KEY F

```
NO. NOZ.?= 3.000
  NOZ.A?= 0.000
noz.3.?= 14.000
noz.2.?= 14.000
noz.1.?= 14.000
NOZ.A.=
0.450990
```

OPTION 2

```
NO. NOZ.?= 4.000
  NOZ.A?= 0.452
noz.4.= 12.
noz.3.= 12.
noz.2.= 12.
noz.1.= 13.
```

OPTION 3

```
NO. NOZ.?= 6.000
  NOZ.A?= 0.451
noz.6.= 10.
noz.5.= 10.
noz.4.= 10.
noz.3.= 10.
noz.2.= 10.
noz.1.= 9.
```

KEY:–E

```
BIT DIA?= 12.250
WOB?= 50,000.000
   RPM?= 120.000
MIN. PWR.=
595.39
```

KEYS:– F, G, H, I

EXAMPLE OF INSUFFICIENT DATA INPUT.

```
Q RATE?= 11.000
MUD WT?= 13.200
  PRES?= 0.000

*BIT HYD.*

PWR.=0.000
```

```
  NOZ.A?= 0.451
Q RATE?= 11.000
MUD WT?= 13.200
  PRES?= 0.000

*BIT HYD.*

PRES.=1,266.502

VN/SEC.=327.812
PWR.=341.379
IF.=1,034.746
```

```
PRES?= 1,500.000
  NOZ.A?= 0.000

*BIT HYD.*

NOZ.A.=0.414404

VN/SEC.=356.753
PWR.=404.317
IF.=1,126.099
```

KEY:–D

```
NO. NOZ.?= 3.000
  NOZ.A?= 0.414
noz.3.= 13.
noz.2.= 14.
noz.1.= 13.
```

NOTE USE OF KEY 'D' FOLLOWING USE OF F,G,H,I KEYS TO CALCULATE THE NOZZLE SIZES FOR THE NOZZLE AREA LAST CALCULATED BY F, G, H & I KEY OPERATIONS. NO ENTRY IS MADE IN RESPONSE TO "NOZ.A?="

CODE: – 13.0

```
ΦDDELΦ
*RHEOLOGY*
NO. SETS?= 6.000

RPM?= 600.000
FANN?= 71.000
RPM?= 300.000
FANN?= 43.000
RIGHT?"Y"

RPM?= 200.000
FANN?= 28.000
RPM?= 100.000
FANN?= 23.000
RPM?= 6.000
FANN?= 6.000
RPM?= 3.000
FANN?= 3.000
RIGHT?"Y"

hi.n=0.72348
HI.K=0.50367
r↑2=1.00000

n=0.54959
K=1.47531
r↑2=0.98539

PV=28.CPS.
YP=15.
CHG. SETS?"Y"
ADD?"N"
DEDUCT SETS
NO. SETS?= 2.000
```

MODIFY INPUT FANN DATA SET TO CALCULATE n & k VALUES FOR LAMINA FLOW CALCULATIONS

```
RPM?= 600.000
FANN?= 71.000
RPM?= 3.000
FANN?= 3.000
RIGHT?"Y"

hi.n=0.72348
HI.K=0.50367
r↑2=1.00000

n=0.47861
K=2.08188
r↑2=0.98710

PV=28.CPS.
YP=15.
CHG. SETS?"N"
MUD WT?= 9.931
```

3. SUBLEVELS

CODE: – 13.1

```
ΦDDELΦ
*RHEOLOGY*
hi.n?= 0.723
HI.K?= 0.504
n?= 0.550
K?= 1.475
MUD WT?= 9.931
```

3. SUBLEVELS

CODE: – 13.2

```
ΦDDELΦ
*RHEOLOGY*
hi.n=0.72348
HI.K=0.50367

n=0.47861
K=2.08188

PV=28.CPS.
YP=15.

MUD WT.=9.931
```

2. SUBLEVELS

CODE: – 13.3

```
ΦDDELΦ
*RHEOLOGY*
PV?= 28.000
YP?= 15.000
MUD WT?= 9.931
hi.n=0.72348
HI.K=0.50366

n=0.72348
K=0.50366

PV=28.CPS.
YP=15.

MUD WT.=9.931
```

4. SUBLEVELS

CODE: – 13.4

```
ΦDDELΦ
*LIFT CAP*
```

DATA OBTAINED FROM A CODE 3 OUTPUT ROUTINE

```
MUD WT?= 9.931
VISC?= 43.000
VEL?= 288.400

MAX.OD=4.49
```

3. SUBLEVELS

Notes

Notes

CATALOGUE FUNCTIONS

Introduction

The ★OILWELL 1 Module is an **8K ROM** (Read Only Memory) programmed with a set of programmes designed **primarily** for access through the **MASTER PROGRAMME, 'MSTA'**, contained in the Module, using Specific Code Numbers corresponding to the Coded Functions. The **MASTER PROGRAMME** processes the Input Code Number and directs operation to the required programme routines. It is accessed in the Module through its **Alpha Mnemonic Label Name 'MSTA'** (MASTER PROGRAMME 'A'). The **'MSTA'** programme also **ensures** that the **Status** of the computer is correct prior to transferring execution to the Coded Function routine.

The ★OILWELL 1 Module however contains a number of **Alpha Labelled** programmes and routines that can be accessed, in the same way as the **MASTER PROGRAMME**, using their **'Alpha Mnemonic Label Names'**.

This ability to be able to **directly** access these other programmes and routines greatly enhances the use and value of the Module. The User may access these routines and make use of them in her/his **own programming** to perform some very useful functions, not necessarily oil-related.

Because normal operation of the ★OILWELL 1 Module, using the Function Code Numbers and the **'MSTA'** programme, itself ensures that the correct Flag and System Status exists for the required routine to run correctly, it is **essential** that, when directly accessing other Alpha Labelled programmes, **GREAT CARE IS TAKEN by the User** to **ensure** that **prior** to execution the correct Flag and System Status is in effect.

The Alpha Labelled programmes in the Module will be collectively referred to as the **CATALOGUE FUNCTIONS.**

The Manual Sections that follow describe the operation of these **CATALOGUE FUNCTIONS** and explain how they may be accessed and utilized by the User.

The ★Oilwell 1 Catalogue Functions

A list of the Alpha Labelled programmes and routines in the Module may be obtained using the **CATALOGUE 2 (CAT 2)** function of the HP 41. (Press **SHIFT ENTER 2**).
These **CATALOGUE FUNCTIONS** can be divided into **6 GROUPS** as follows:

GROUP 1 **PRIMARY MODULE PROGRAMMES** (Drilling Calculations)

GROUP 2 **SECONDARY PROGRAMMES and SUB-PROGRAMMES** (Drilling Calculations)

GROUP 3 **MASTER PROGRAMMES**

GROUP 4 **UTILITY PROGRAMMES**

GROUP 5 **HEWLETT PACKARD MICRO CODE ROUTINES**

GROUP 6 **SPECIAL UTILITY PROGRAMMES ACCESSED THROUGH SYNTHETIC PROGRAMME LABELS**

The programmes in each group are as follows:

GROUP 1 "1"; "3"; "7"; "8"; "9"; "10"; "11"; "12"; "13".

GROUP 2 "DOP0"; "DOP1"; "DOP2"; "DOP3"; "DOP4"; "DOP5"; "DOP6"; "DOP7"; "PRES"; "ADJD"; "NOZA".

GROUP 3 "MSTA"; "MSTB"

GROUP 4 "MST0"; "MST1"; "MST2"; "MSTF"; "AIPT"; "NIPT"; "UNIT"; "★FC"

GROUP 5 X<>F; REGMOVE; REGSWAP; PSIZE

GROUP 6 "A"; "B"; "C"; "D"; "E"; "F".

NOTES

1. **Groups 1, 2, 3 and 4** Programmes are all Normal Global Alpha Label programmes and may be accessed with **GTO** and **XEQ** Functions in the normal way or may be assigned to a User Key.

e.g. To run "**DOP7**" press **XEQ ALPHA "DOP" SHIFT "7" ALPHA.**

They may be accessed from the keyboard direct or in User programmes. However before accessing them it is important that computer status and register contents are as required by the routine for the operation to be correctly executed.

2. **Group 5** routines are Hewlett Packard Micro Code routines that act in the same way as other normal HP 41 Functions. They are **not** Alpha Labelled programmes. They may be executed from the Keyboard or used in programmes by using the **XEQ** function or with a Key Assignment of the function in User Mode.

They are all single parameter functions with the required input being in the '**X**'-Register, they are not dependant on Flag Status and are also independant of Data Memory Size and contents.

3. **Group 6** Programmes are **GLOBAL ALPHA LABELLED** programmes using single **ALPHA CHARACTERS** normally associated only with **LOCAL LABELS.** This is achieved using Synthetic Programming. The effect is that the User can only directly access these routines using Synthetic Programming techniques. They may however be indirectly accessed. This is covered more fully in the introduction to this group.

GENERAL NOTES

1. The Module operates internally in **ENGLISH UNITS** for all the Units Parameters (See UNITS SELECTION Section Page 2.01 – 2.05) hence **all** Data prepared and stored in registers for use by **directly** accessed Catalogue Functions **must also** be stored in these units.

2. Normal operation of the Module using the standard **'MSTA'** Programme ensures correct Flag and System Status prior to calling the specified programme. For most **directly** accessed Catalogue Functions the Status of certain Flags will be critical to the response of the function.
(Refer to the Flag Status Tables Pages 20.3 – 20.5).

For example a Function Code that causes **Prompting** for a numeric input, of which units are significant, will process that input according to the **current status** of the appropriate Units Control Flag. This status may **not** be the Status as selected by the User for his required operating Units.

It follows that **great care must** be exercised when **direct** access to Catalogue Functions is made.

3. Data stored in the 'Scratch' or 'Usable' Registers R.02-R.45 by any directly accessed Function may not be the 'Normal' Data expected at the end of a 'normal' execution of that Function. When **using** Data from Registers following a **direct** call to a Catalogue Function be sure that the Data is as expected.

4. Data is accessed by many Catalogue Functions from specific Registers. For the Functions to run as expected such Data must be valid for the selected operation.

5. The contents of Registers R.46-R.99 **MASTER DATA (★MDATA)**, R.100-R.104 **STATUS DATA**, R.105-R.136 **WELL GEOMETRY DATA (★WDATA)** and R.137-R.150 the **ACTIVE WELL GEOMETRY DATA** should be regarded as **Permanent** or **Semi-permanent Data** that must not be modified by the User or his programmes.
The Data in this block of registers is either Permanent Data only used by Module recall Functions or Semi-Permanent data initially set up by a **Specific Module Function** (e.g. Codes 9 & 13 and the ADJD Function) and then remaining unchanged and used only by recall Functions until modified by a **Specific Module Function** again.
Directly accessed module functions assume that existence of Data in these blocks is as expected. No checks for correctness are made.
(see "USE OF DATA REGISTERS" section Pages 21.01 – 21.03).

6. Sizing of the computer Memory is carried out automatically by the **'MSTA' & 'MSTB'** programmes. When **direct** access is made to Catalogue Functions no such Sizing occurs. Since Sizing may well affect function operation and existence of data the User **must ensure** that Memory is correctly Sized prior to calling a routine.

7. It must be clearly understood that **interruption** of a running routine or programme using the R/S Key or during Breaks for Input or Output of Data **may well** leave the computer in a **Status other then expected** at the 'normal' END of the routine.

8. Execution of Catalogue Functions will stop at the normal END of the called routine. If the routine was called as a **sub-routine** from another routine (i.e. with an **XEQ** function) then, providing that the maximum of FIVE dependant Sub-level routine calls has not been exceeded by execution of the routine, the programme execution will return to the original calling programme. On the other hand, if the Catalogue Function routine was initiated by a **GTO** or Keyboard call, the execution will END in the Main Programme itself. Operation of the R/S Key at the end of the routine will then probably cause the subsequent section of Main Programme to execute with meaningless results.

9. Except for the Group 5 Functions all the ★OILWELL 1 Catalogue Functions are Global Label Programmes. The User should be aware of the effects of **GTO** and **XEQ** statements when used in programmes and from the Keyboard.

10. To execute any of the ★OILWELL 1 Catalogue Functions set up the Register contents and computer Status and **XEQ** the Alpha Label. Alternatively the Functions may be assigned to a Key for use in USER Mode.

11. The ★OILWELL 1 Module must be present in a HP 41 Port for a Function to operate.

12. It is not possible to **COPY** any of the ★OILWELL 1 Catalogue Functions into Main Memory or other peripheral storage device.

This group of programmes comprising the ALPHA labelled programmes '1', '3', '7', '8', '9', '10', '11', '12' and '13' is formed of the **Main** programmes normally accessed as sub-programmes through the **'MSTA'** programme. Such access is achieved using the **integer** portion of the input 'Numeric Code Number' to identify the specific Main programme with the corresponding Numeric character(s) ALPHA label.

Each of these Main programmes is divided into a number of sub-routines, accessible through a numeric label, which perform the specific operations identified by the **fractional** part of the input Code Number. The fractional part of the input Code Number is converted by the Master programme to an integer resulting from multiplication of the fractional part of the input Code by 10 (i.e. INT(FRAC(CODE)x10). This value is stored by the Master programme in Register R.02, then, after transfer of programme execution, the accessed Main programme processes the value in Register R.02 and directs Main programme execution accordingly.

In all the Main programmes failure to supply a **valid** Routine Selection Code in Register R.02 will cause one of the following:

1. Immediate return to the calling programme.
2. A halt in the Main programme, if it was not itself executed as a sub-programme.
3. The adoption of a default value for the Register R.02 code.

When Main programmes are accessed through the module's Master programmes checks are performed to ensure that calculator status and the presence of relevant data are as required by the Main programme. This is not done, of course, when these Main programmes are accessed **directly**. In addition, at the end of Main programme, execution, as instigated from the **'MSTA'** Master programme, returns to the Main programme which in turn will reset all the Flags to the Module's Basic end of routine status and display a status indicator (NORMALLY **'OK'**).

When Main programmes are accessed **directly** these ancillary Master programme operations are not performed and it becomes necessary for the User to ensure that data and status, before and after the operation of the Main programme, are as required.

To perform any Main programme routine **directly** the User simply selects the Code Number corresponding to the function required and proceeds as follows:

1. Multiply the **fractional** part of the Code Number by 10 and store the **integer portion** of the result in Register R.02

2. Ensure that the correct computer **status** (Size, Flags, Format and Statistics Register allocation) is active

3. Ensure that **data** required by the routine is correctly stored

4. Execute the appropriate Alpha labelled Main programme – **XEQ'...'**

e.g. To perform a Code 10.5 routine **directly**.

1. Select Code 10.5 and store 5 in Register R.02
   (Frac of 10.5 = .5, multiplied by 10 = 5.0 and integer 5.0 = 5)

2. Check that the status of the Units Control Flags, **as indicated by the HP 41C display panel**, is correct for the User's current requirements.

3. Clear Flag 08 and Set Flag 21.

4. Execute Alpha labelled programme **'10' (XEQ ALPHA '10' ALPHA)**

Since operation of each Code Number function is covered in the section on **CODES DESCRIPTION** it will not be further covered here.

Direct access to the Main programmes is basically limited to **directly** performing the **normal** ★OILWELL 1 Code Functions with the advantage that the operating times are reduced and the number of sub-level programme returns is reduced by one. This latter point has particular advantage when accessing the Code 3 Annulus calculation Functions.

Those Functions marked on the ★OILWELL 1 USER CODES table with a **dot** require the presence of the Well Geometry Data for them to run correctly. Otherwise all the programmes in this group will PROMPT for the data input required for their operation.

Introduction

The programmes in this group form a very useful set of utility routines that perform operations related directly to Drilling calculations. With the ★OILWELL 1 module in the HP 41 these routines can be put to very good use in User programmes.

The so called '**DOP**' routines and the '**ADJD**' routine all work with the Well Geometry Data and give the User a very wide range of options as to how this data may be used. The other routines in the group are more specific in their operation but can still be put to good application.

The following descriptions try to put across some of the potential of the routines but the User is urged to experiment with them and thereby to discover individual applications.

THE 'DOP' ROUTINES

There are 8 '**DOP**' (Data Output) routines in the ★OILWELL 1 Module. All the routines deal with the manipulation of the Active Well Geometry Data (Registers R.137 – R.150) relating to the current '**ADJD**' DEPTH or DEPTH/CALC.D status. The output of data from each routine is governed by the status of certain Flags as determined prior to the execution (**XEQ**) of a routine. Data output may be in several forms:

1. Displayed/printed data output.
2. Stored data into temporary storage Registers where it may be accessed by other routines.
3. Combinations of forms 1. and 2.
4. Forms 1. and 2. as obtained for a **completed** data output routine. In this case Data other than the summation data in the temporary Registers R.08 – R.28 may be other than expected (see the following note).
5. Forms 1. and/or 2. data accessed on a **section by section** basis, allowing the User to use sectional data for all or specific Hole, Pipe or Annulus sections.

> **NOTE:**The user should check the contents of those temporary storage Registers (R.2 – R.29) which he may be interested in using Data from, to ensure that the Data is indeed the Data expected. Some of these Registers are used as scratch Registers by certain routines and the final content of a Register may well have been altered from its expected value. The table headed "★OILWELL 1 REGISTER USAGE" indicates the probable contents of the temporary storage Registers. The indications are intended as a guide. Additional information as to Register contents is available in the tables on pages 22.01 – 22.08 headed "REGISTER USAGE CATALOGUE FUNCTIONS".

All the '**DOP**' routines only process Data that is already in memory. That is to say that they do not PROMPT for any Data input. In this way it is possible for a User to write personal programmes that either calculate and store and/or input and store relevant Data and then utilize one of the '**DOP**' routines to process and output the data as required.

Flags play an important part in the way in which Data is handled and execution of a routine is performed. These are discussed more fully in the individual descriptions of the routines.

'DOP0'
'DOP1'
'DOP2'
'DOP3'

These four routines are all similar in operation in that they require the same Data to be present in memory for them to operate. They differ in operation only in the way that this Data is handled.

The Data required by these routines is as follows

1. A set of Active Well Geometry Data in Registers R.137 – R.150
2. The Data Access Control Values to the Active Well Geometry Data as stored in Registers R.103 – R.104
3. The current **'Q RATE'** (Mud Flow Rate) as stored in Register R.23
4. The existence of a valid set of ★MDATA.

The handling of Data for these four programmes is controlled by the **'DOP4'** and **'DOP5'** routines and their descriptions should be read as regard to the significance of computer and Flag status on their operation.
Operation of these four programmes consists of the selection of the required output Mode (Annulus, Pipe, Hole or all three) and output of data relevant to the chosen Mode. Since Mode selection is dependant on the Status of Flags 06 and 07, it is **essential** that both these Flags are **Clear prior** to calling any of the programmes.

The Status of Flag 10 prior to calling these programmes determines if the Pressure Loss calculation is to be performed. If Set, it will be, if Clear, it will not.
Flag 10 should **always** be **Clear** when calculations involve Hole Data Mode.

'DOP3'
This routine selects HOLE Data Mode. (Flag 06 and 07 Clear)

'DOP2'
This routine selects PIPE Data Mode. (Flag 06 Set Flag 07 Clear)

'DOP1'
This routine selects ANNULUS Data Mode. (Flag 07 Set Flag 06 Clear)

'DOPO'
This routine selects each of the above Modes in turn adjusting Flag settings as required.

To operate the programmes:

1. The User must have previously operated an '**ADJD**' routine for the DEPTH or DEPTH/CALC.D inputs required.

2. Store in Register R.23 the required Fluid Flow Rate (Q. RATE).

3. Clear Flags 06 and 07 and set the status of Flag 10 as required. The status of Flags as required by the '**DOP4**' and '**DOP5**' must also be prepared at this time.

4. Set Flag 21 and set the required status of Flag 22. (Note: Flag 21 must be set if output of data is to be displayed or printed).

5. **XEQ 'DOP...'** (as required).

The programme will output Data according to the pre-set status of the relevant control Flags in a manner similar to Data output expected with normal ★OILWELL 1 Code 1 and Code 3 Functions.

'DOP4'

This routine is used to prepare data from the Active Well Geometry data Registers ready for use by the '**DOP5**' routine in Hole and Pipe Data Modes and by the '**DOP6**' routine at the start of an Annulus Data Mode.
The routine uses the contents of Registers R.06 and R.07 to indirectly recall the Hole and Pipe Data from the Active Well Geometry Data block. The values stored in Registers R.06 and R.07 may be in two forms:

1. SIMPLE FORM
In this case the value in each corresponds to the **actual** Register number that the Hole and Pipe Data respectively (in the forms L.(DIA x 0.01) and L.(OD x 0.01)) are stored in the Active Well Geometry Data block.
With regard to the operating status for the '**DOP5**' routine these types of values in Registers R.06 and R.07 will result in the computation and as appropriate, output of data for **only** the **single** section specified, which, in the case of Annulus Data Mode will be of length equal to the **shortest** of the Hole and Pipe section lengths.

2. CONTROL FORM
In this case the stored values in Registers R.06 and R.07 are the **starting** and **finishing** Register numbers of those Registers in the Active Well Geometry Data block that contain the Hole and Pipe Data, respectively, of those sections for which data output and/or computation is sought. The format of each is **'start.(finish x 0.01)'**

e.g. A value of 137.139 in Register R.06 would specify access to Hole Data to be recalled **starting** at Register R.137 and **finishing** with R.139.

Again the way in which **'DOP4'** will compute and output data is entirely dependant on the **'DOP5'** routine reaction to current significant Flag status.

NOTE:

'DOP4' is not an independant routine. It always immediately causes operation of either the **'DOP5'** routine, in Hole and Pipe Data Mode, or the **'DOP6'** routine, in Annulus Data Mode.

Most commonly, the stored values in Registers R.06 and R.07 will be the current Active Hole and Pipe Data Access Control Values stored in Registers R.103 and R.104. For the current **'ADJD'** DEPTH or DEPTH/CALC.D status, these values correspond to the numbers of the Registers currently active for Data handling in the well from the specified depth to surface. Further, it should be understood that an **'ADJD'** routine always sets up Registers R.06 and R.07 with the current values of R.103 and R.104 so that they are immediately available for use after execution of the **'ADJD'** routine.

In that **'DOP5'** is an integral part of **'DOP4'** the requirements for **'DOP5'** operation also apply to **'DOP4'** operation.

To use **'DOP4'** the correct data access values must be stored in R.06 and R.07 and the correct Flag status and Register contents required by **'DOP5'** must be ensured.

The routine does not clear the Data summation Registers or reset the section number count in Register R.03.

To operate the routine:

1. Operate or have previously operated an **'ADJD'** routine for the required DEPTH or DEPTH/CALC.D inputs

2. Unless an **'ADJD'** routine has just been performed, store the following Data in the Registers specified:

1. R.06 – Active Hole Data Access Control Value

2. R.07 – Active Pipe Data Access Control Value

3 Clear the Data Summation Registers R.17, R.18 and R.19

4. Store the required value of Fluid Flow Rate in Register R.23 and the required Section starting number **minus** one in R.03

5. **XEQ 'DOP4'**

The routine will then use this Data and output results according to the status of the relevant control Flags used in the **'DOP5'** routine.

'DOP5'

This routine is the main routine for the processing of Well Geometry Data to give the Capacity and Volume related outputs that are obtained during Code 1 and 3 operations with the ★OILWELL 1 module. For the routine to operate, it must have been set up with the correct status and operating data. This is normally done with one of the other **'DOP'** routines but may be achieved in a User's own programme.

The routine utilizes the previously prepared data to calculate and store data output values. The calculations made and the exact utilization of the prepared data are dependant on the current status of Flags 06,07, 09, 10 and 22.

The **Status of Flags 06 and 07** determines the operating mode:

Flags 06 and 07 CLEAR: Hole Data Mode
Flag 06 SET and 07 CLEAR: Pipe Data Mode
Flag 07 SET and 06 CLEAR: Annulus Data Mode

The **Status of Flag 09** determines the extent of data output display/printing:

Flag 09 SET: Only summation data output
Flag 09 CLEAR: All section and summation data output

The **Status of Flag 10** determines whether or not the Pressure calculation will be performed:

Flag 10 SET: Programme execution calls the Pressure Programme as a subprogramme.
Flag 10 CLEAR: No Pressure calculation is performed.

The **status of Flag 22** determines the sequence of programme operation:

Flag 22 SET: calculations for all Mode sections are performed in sequence followed by normal routine termination. For this to operate **'DOP5'** utilizes the **'DOP4'** routine, which is really an integral part of the **'DOP5'** routine
Flag 22 CLEAR: in all **'DOP5'** Operating Modes this will cause execution of the **'DOP5'** routine to **stop** after each section of the current Mode has been handled in accordance with current control Flag status. If **'DOP5'** was called with the **XEQ** function then programme operation returns to the initiating programme.

The effect of the controllable status of these Flags means that the User has a considerable selection from which to decide how data output and manipulation are to be performed.

With regard to the handling of data output, the User may:

1. Select displayed or printed output of **all section** data and **summation** data, with or without pressure loss calculation, as appropriate, for each and any mode. Flag 22 Set and Flag 09 Clear.

2. Select displayed or printed output of **summation** data **only**, with or without pressure loss calculation, as appropriate, for each and any mode. Flag 22 Set and Flag 09 Set.

3. Select **single section** calculation for each and every mode, with or without pressure loss calculation as appropriate and with or without output data displayed or printed. Flag 22 Clear (Pipe and Hole Data Modes) or Flag 24 Set (Annulus Data Mode) and Flag 09 as required. (Flag 24 controls the operation of the '**DOP6**' routine not the '**DOP5**' routine).

4. Select **all Annulus** Data Mode **section** and **summation** data calculation, with or without pressure loss calculation as appropriate, but **without** any data displayed or printed. Flag 22 Clear and Flag 09 Set (Flag 24 Clear).

5. Select utilization of correctly formatted data as stored in **any** available Registers and accessed through indirect operations using Registers R.06 and R.07.

The '**DOP5**' routine can be used **purely** as a data calculation routine with or without printed or displayed data output or as a routine to process stored Well Geometry Data leaving data stored in the appropriate Registers for access and utilization by other routines.

For use purely as a calculation routine it is not necessary to use the data accessing Registers R.06 and R.07 but only to have correctly formatted data in Registers R.X, R.09, R.10, R.11, and R.23 and to operate it with Flag 22 Clear.

To use the '**DOP5**' routine the User must ensure that the following data, in Module English Operating Units, is available and that the required Flag status has been created prior to calling the '**DOP5**' routine.

1. The 'X'-Register must contain the current LENGTH of the section for the current Mode status for which computation is to be performed.

2. The required Flow Rate must be stored in R.23.

3. In **sequential** operations the Data Access Control Values must be correctly stored in Registers R.06 and R.07 as these will be used in second and subsequent loops of the routine to ensure correct Register contents for R.09, R10 and R.11. It follows that the correct set of Active Well Geometry Data **must** also be stored in the Registers R.137 – R.150.

4. Register R.09 **must** contain the current Hole Data section LENGTH and Hole DIAMETER in the form LENGTH . (DIA x 0.01)
(e.g. The value 1000.1225 representing 1000 feet of 12.25" Hole).

5. Register R.10 **must** contain the current Pipe Data section LENGTH and Pipe OUTSIDE DIAMETER in the form of LENGTH. (O.D. x 0.01)
(e.g. The value 1000.0800 representing 1000 feet of 8" O.D. Pipe).

6. Register R.11 **must** contain the current Pipe Data section ID.<P> and ID.< C >values in the form (ID.<P>x 1000) . (ID.<C>x 0.01)
(e.g. The value 4234.04249 representing Drill Pipe of ID.<P > = 4.234" and ID.<C >= 4.249").

NOTE:
All this data may be obtained from the Active Well Geometry Data block, in which a record of the currently significant Registers is kept in Registers R.103 & R.104.

In addition to the Data required for **'DOP5'** operation it may also be necessary to ensure that the following Registers are either **clear** or contain the required sub-total values prior to execution.

R.03: Used in the numbering of sections for which data output is applicable. If it is required to give a **specific number** to a section then that number **minus** one should be stored in Register R.03.

R.17: Summation for all sections of Pipe Weight in Air.

R.18: Summation of Total Steel Displacement of all Pipe sections.

R.19: Summation of Total Hole, Pipe or Annulus section Volumes.

NOTES:

1. The labelling of data output and the correctness of the units is dependant on the presence of the Master Data ★MDATA in Registers R.46 – R.99. The units set used for data output is of course dependant on current status of the Units Selection Flags 00 – 04.

2. A zero value in the 'X'-Register when **'DOP5'** is executed will result in display/printing of the current summation data values in accordance with the current operating mode status. Flag 08 must be Set for this data output to occur. This will normally be the case when a 'zero' value occurs after a sequence of data outputs but Flag 08 will normally be clear, unless User set, prior to first operation of the routine.

To operate the routine:

1. Set up the Flag status and Data Register contents as required.

2. Enter the LENGTH of the first section for which calculation is to be performed into the 'X'-Register.

3. **XEQ 'DOP5'**

The programme will execute in accordance with the status Flags as selected.

'DOP6'

This routine handles **Annulus Mode** Data calculations. Its function is to utilize the stored Pipe and Hole Data to create, on a section by section basis, a set of **Annulus** Length and Dimension Data. To do this it compares the Hole and Pipe Data **lengths** as currently stored in Registers R.09 and R.10 and uses the lesser of these for the LENGTH of the **next** Annulus section. At the same time, it deducts this value from the longer of the two sections in preparation for the next comparison check. The calculated LENGTH of the Annulus section is then passed by the **'DOP6'** routine to the **'DOP5'** routine for calculations of the related Data for that section. This is followed by return of execution to the **'DOP6'** routine for the next comparison check. This procedure is repeated, as required, until all sections specified have been handled.

Prior to execution, the **'DOP6'** routine requires that the Active Well Geometry Data Access Control values, as stored in Registers R.103 and R.104, are also stored in Registers R.06 and R.07 and also that Registers R.09 and R.10 contain, respectively, the Hole (L.(Dia. x .001)) and Pipe (L.(O.D. x .001)) Data for the first section of each.

NOTE:

In that the **'DOP6'** routine uses the **'DOP5'** routine and therefore requires the presence of the Active Well Geometry Data set and that this must have been created with an **'ADJD'** routine, it is interesting to note that this latter routine automatically sets up Registers R.06 – R.10, with the normally required contents for **'DOP'** operations, before termination. Hence, unless altered by an intervening operation, this Data will be available for immediate **'DOP6'** utilization.

In situations where the data handled does not relate to the **whole** of the Active Well Geometry Data the **final** data output will relate to the shortest section of either Hole or Pipe Data currently Active in Register R.09 or R.10.

Operation of **'DOP6'** is dependant on the status of Flags 05 and 24.
It controls the status of Flag 05 within the running of the routine and Flag 05 **must** be Clear at the start of this routine.
The status of Flag 24 is selected **prior** to calling the routine. If this Flag is Set then the calculation of Annulus Data is performed **one section** at a time with execution being returned to the calling programme at the end of each section. With Flag 24 Clear the routine processes the entire data set, as indicated by the Active Data Access Control Values.

As already mentioned, the **'DOP6'** routine utilizes the **'DOP5'** routine and its operation is consequently dependant on the normal Flag status and Data Register access requirements of the **'DOP5'** routine.

'DOP6' is the "ANN. DATA" Mode routine to which the **'DOP3'** routine directs execution and as such must be operated with Flag 07 Set prior to operation. It is the SET status of this Flag that subsequently directs execution of the **'DOP5'** routine to perform Annulus Mode calculations.

The routine does not clear the Data summation Registers or reset the section number count in Register R.03.

To operate the routine:

1. Clear Flag 05 and Set Flag 07

2. Select the required computer and Flag status for **'DOP5'** operation and ensure that the **'DOP5'** Data Acquisition Registers contain the required Data. This means that an **'ADJD'** for the required Depth of calculation must have been previously performed.

3. Select the required status of Flag 24

4. Unless an **'ADJD'** routine had just been performed, store the following data in the Registers specified:

    1. R.06 – Active Hole Data Access Control Value

    2. R.07 – Active Pipe Data Access Control Value

    3. R.09 – Length and Diameter Data for the 1st section of Hole Data

    4. R.10 – Length and Internal Diameter Data for the 1st section of Pipe Data.

5. Clear the Data Summation Registers R.17, R.18 and R.19

6. Store the required value of Fluid Flow Rate in Register R.23 and required Section starting number **minus** one in R.03

7. **XEQ 'DOP6'**

The routine will output Annulus Data according to the status of the controlling Flags at the time of calling the routine.

RESUME OF 'DOP4', '5' and '6' OPERATIONS

1. **'DOP5'** is the main calculating and data output routine

2. **'DOP4'** prepares data for **'DOP5'** operation in Hole & Pipe Data Modes for all sections, and for the initiation of **'DOP6'** operation

3. **'DOP6'** prepares data for **'DOP5'** operation in Annulus Data Mode and determines the end of execution.

See the Flow Diagrams which follow the descriptions of the **'DOP'** routines for a better understanding and further details of the sequence of **'DOP'** operations.

'DOP7'

This routine is used to calculate the LENGTH of a column of fluid resulting from the introduction into the Annulus of a given volume of the fluid.

The Annulus concerned is as defined by the current Active Well Geometry Data set in Registers R.137 – R.150. This Active Well Geometry Data set may be BASED ON **either** the **DEPTH** or **DEPTH/CALC.D** inputs. As this implies, the routine works for calculations using either the Specified Bit DEPTH as the starting point or the CALC.D DEPTH (see the description of the **'ADJD'** routine). This means that for any given volume of fluid that is less than the total annulus volume above the depth of interest, it is possible to calculate the length of the column of fluid in the annulus from **any** specified depth.

Prior to utilizing the routine an **'ADJD'** routine must have been executed to specify the DEPTH of the bit and, if applicable, the CALC.D Depth above which calculation is to be made.
This prior use of the **'ADJD'** routine need not be **immediately** prior to the **'DOP7'** routine but may have been performed at any previous time.

The routine utilizes the **'DOP4'**, **'DOP5'** and **'DOP6'** routines and it follows that Computer and Flag status prior to calling the routine must be as required by these routines.
'DOP7' itself sets Flag 07 for **Annulus** Mode, Flag 09 for Data output **suppression** and Flag 24 for **single** section operation of the **'DOP6'** routine.

To utilize the **'DOP7'** routine proceed as follows:

1. Operate (or have previously operated) a suitable **'ADJD'** routine

2. Set Flag status.
   (**Note:** The Flag Status as existing immediately after an **'ADJD'** routine will be correct if the **'ADJD'** routine was itself operated with the correct status).

3. Enter the VOLUME of Fluid into the 'X'-Register.

4. **XEQ 'DOP7'**

Providing that the input VOLUME was less than the available annulus volume above the Depth of interest, the routine will end with the LENGTH of the Fluid Column in **feet** in the 'X'-Register and in the 'N' Status Register and Flag 24 will be Clear.
If the input volume was too large then a zero will be in the 'X'-Register and Flag 24 will be Set, indicating that the input VOLUME has overflowed the Annulus capacity.

NOTES:

1. At the end of the routine the status of Flags is not returned to Module Basic status.
i.e. Flags 07, 08 & 09 will be **Set**. The status of Flag 08, which affects operation of the **'UNIT'** routine and hence Data Input and Output where UNITS are of importance must be reset as appropriate to the next operation.
(A Master Programme operation will **always** re-establish correct Flag status for all Flags automatically).

2. Flag 10 **must** be Clear prior to **'DOP7'** operation. The routine will not function correctly if an attempt at associated pressure loss calculation is made.

An example of a useful application of the **'DOP7'** routine follows:

Assume Well Geometry as per the Example of Code 9.2 operation in the EXAMPLES Section (Page 11.15).

Calculate the LENGTH of the fluid column resulting from a 25 BBl Fluid Influx into the annulus from an over pressured section 2000 Ft **above** the Bit with the Bit at 16,300'.

Assuming that the current required Unit's status is English default Units, proceed as follows:

A). Set Flag status to module Basic Status (assumes prior use of the module using an **'MSTB'** or **'MSTA'** routine)

1. **CLX**, (0 in 'X'-Register)
2. **XEQ X< >F** (ensure English Units Mode)
3. **XEQ 'MSTF'** (set module Basic Flag status)

B). Specify DEPTHS

4. 2 (2 in 'X'-Register)
5. **XEQ 'ADJD'**
6. In response to the **'DEPTH?='** PROMPT input 16,300 Ft then press R/S
7. In response to the **'CALC.D?='** PROMPT input 14,300 Ft then press R/S

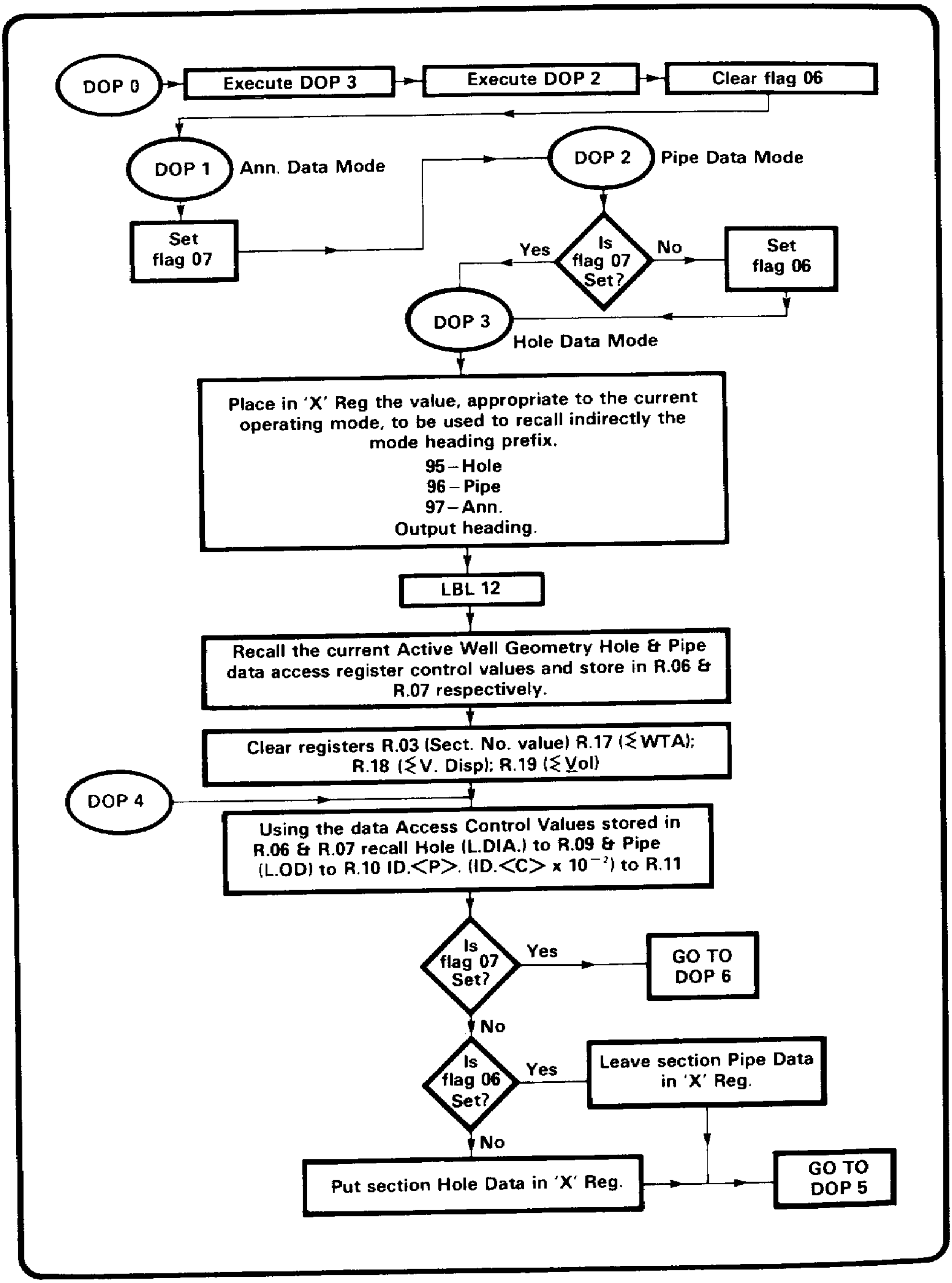
C). Input VOLUME of influx and execute **'DOP7'**

8. 25 (25 in 'X'-Register)
9. **XEQ 'DOP7'**

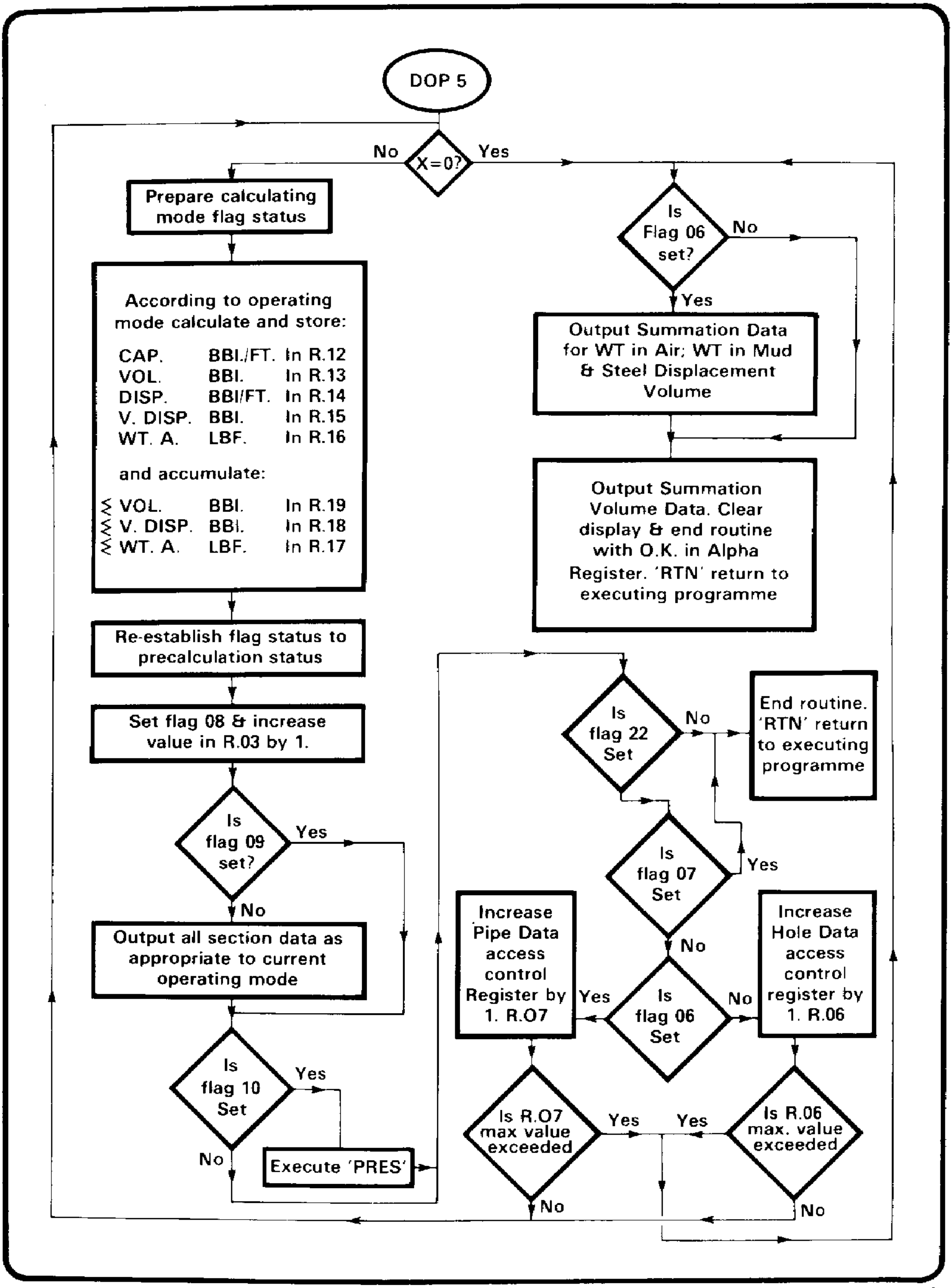
The value of 556 (Feet) returned in the 'X'-Register = LENGTH of Fluid Column in the Annulus above 14,300 Ft with the Bit at 16,300 Ft

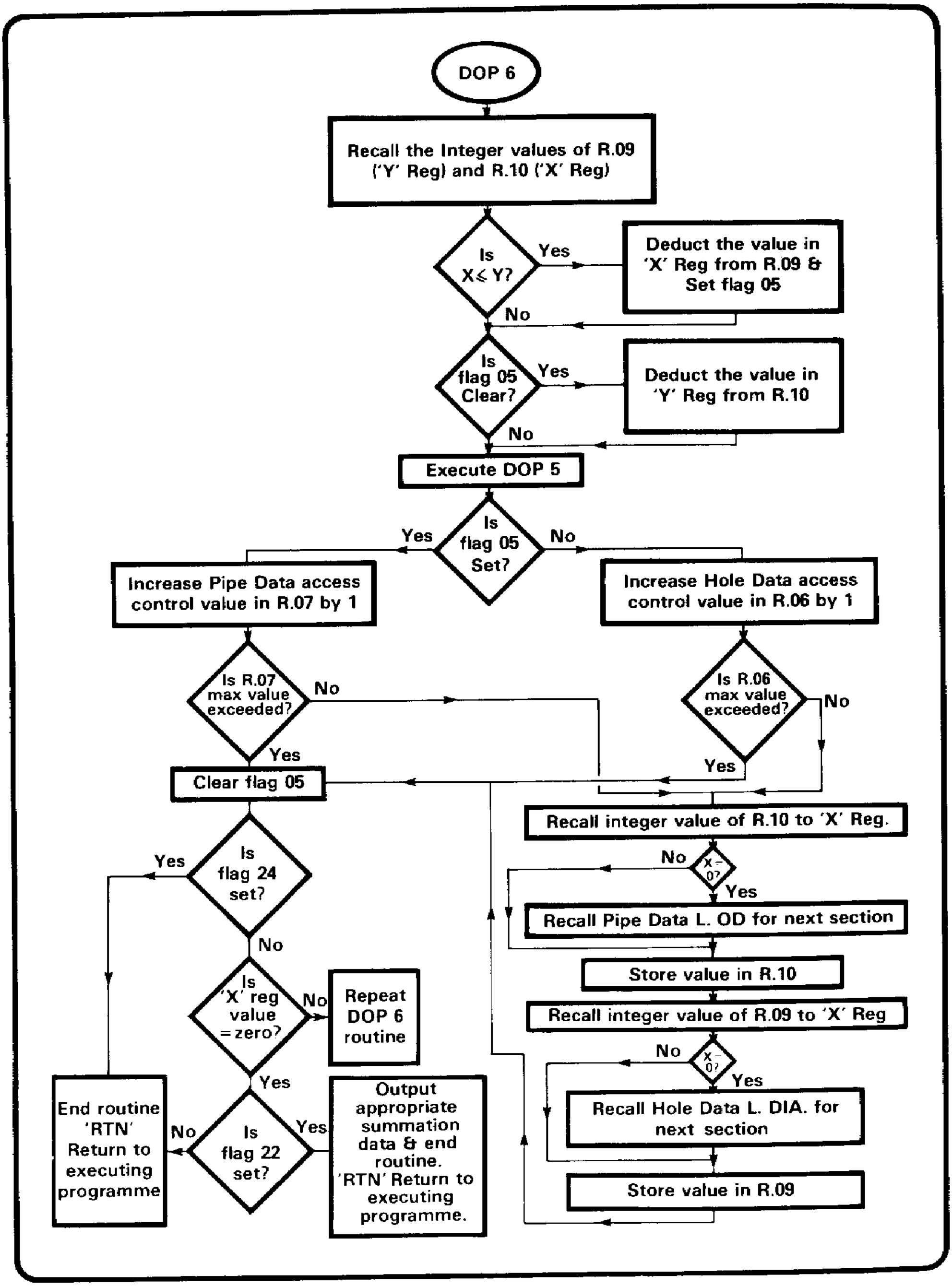
To re-establish Flag status, operation A). may be repeated.

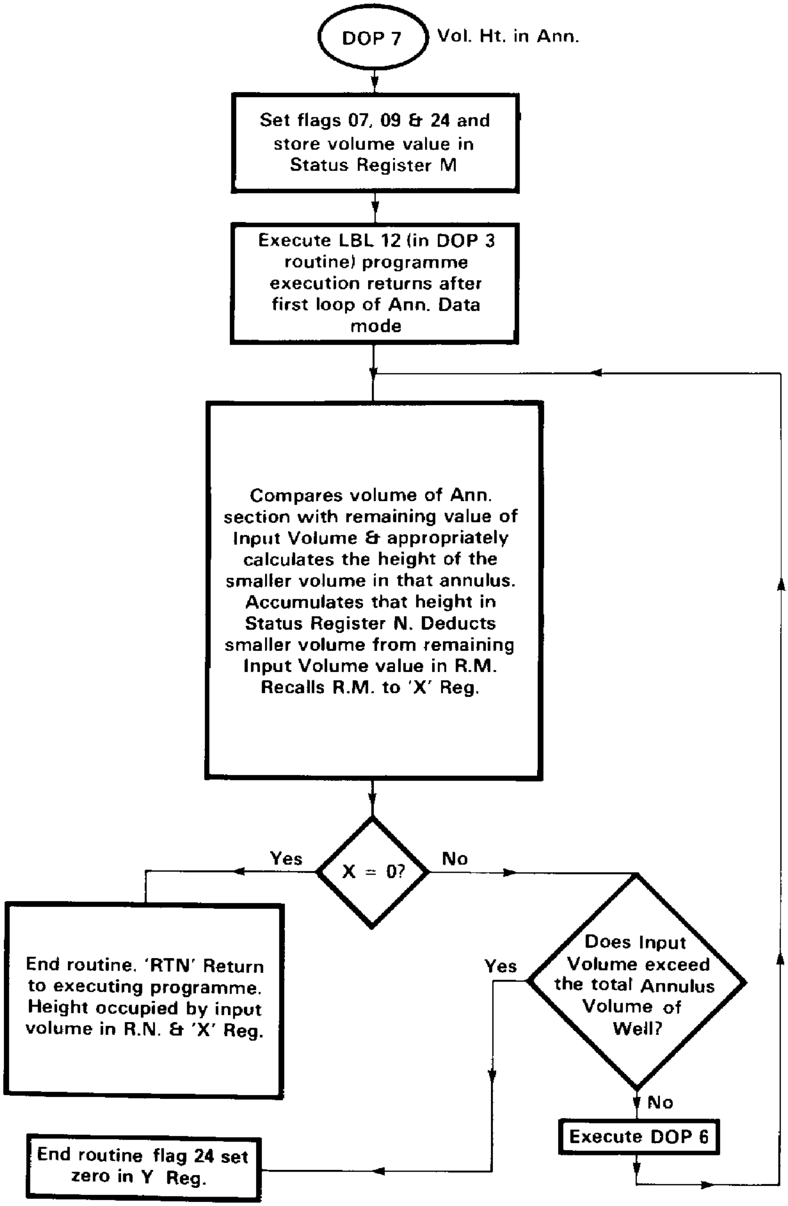
This User sequence could as well have been executed as a Programme Sequence and it is this sort of capability that can make the module a very useful drilling aid.



DOP 0
Execute DOP 3
Execute DOP 2
Clear flag 06
DOP 1
Ann. Data Mode
Set flag 07
DOP 2
Pipe Data Mode
Is flag 07 Set?
Yes
No
Set flag 06
DOP 3
Hole Data Mode
Place in 'X' Reg the value, appropriate to the current operating mode, to be used to recall indirectly the mode heading prefix.
95 – Hole
96 – Pipe
97 – Ann.
Output heading.
LBL 12
Recall the current Active Well Geometry Hole & Pipe data access register control values and store in R.06 & R.07 respectively.
Clear registers R.03 (Sect. No. value) R.17 (ΣWTA); R.18 (ΣV. Disp); R.19 (ΣVol)
DOP 4
Using the data Access Control Values stored in R.06 & R.07 recall Hole (L.DIA.) to R.09 & Pipe (L.OD) to R.10 ID.<P>. (ID.<C> x 10^{-2}) to R.11
Is flag 07 Set?
Yes
GO TO DOP 6
No
Is flag 06 Set?
Yes
Leave section Pipe Data in 'X' Reg.
No
Put section Hole Data in 'X' Reg.
GO TO DOP 5


DOP 5
X=0?
No
Yes
Prepare calculating mode flag status
According to operating mode calculate and store:
CAP. BBl./FT. In R.12
VOL. BBl. In R.13
DISP. BBl/FT. In R.14
V. DISP. BBl. In R.15
WT. A. LBF. In R.16
and accumulate:
VOL. BBl. In R.19
V. DISP. BBl. In R.18
WT. A. LBF. In R.17
Re-establish flag status to precalculation status
Set flag 08 & increase value in R.03 by 1.
Is flag 09 set?
Yes
No
Output all section data as appropriate to current operating mode
Is flag 10 Set
Yes
No
Execute 'PRES'
Is Flag 06 set?
No
Yes
Output Summation Data for WT in Air; WT in Mud & Steel Displacement Volume
Output Summation Volume Data. Clear display & end routine with O.K. in Alpha Register. 'RTN' return to executing programme
Is flag 22 Set
No
End routine. 'RTN' return to executing programme
Is flag 07 Set
Yes
No
Increase Pipe Data access control Register by 1. R.07
Yes
Is flag 06 Set
No
Increase Hole Data access control register by 1. R.06
Is R.07 max value exceeded
Yes
No
Is R.06 max. value exceeded
Yes
No


DOP 6
Recall the Integer values of R.09 ('Y' Reg) and R.10 ('X' Reg)
Is X≤Y?
Yes
Deduct the value in 'X' Reg from R.09 & Set flag 05
No
Is flag 05 Clear?
Yes
Deduct the value in 'Y' Reg from R.10
No
Execute DOP 5
Is flag 05 Set?
Yes
No
Increase Pipe Data access control value in R.07 by 1
Increase Hole Data access control value in R.06 by 1
Is R.07 max value exceeded?
No
Yes
Is R.06 max value exceeded?
No
Yes
Clear flag 05
Recall integer value of R.10 to 'X' Reg.
No
X=0?
Yes
Recall Pipe Data L. OD for next section
Store value in R.10
Recall integer value of R.09 to 'X' Reg
No
X=0?
Yes
Recall Hole Data L. DIA. for next section
Store value in R.09
Is flag 24 set?
Yes
No
Is 'X' reg value =zero?
No
Repeat DOP 6 routine
Yes
Is flag 22 set?
No
Yes
End routine 'RTN' Return to executing programme
Output appropriate summation data & end routine. 'RTN' Return to executing programme.


DOP 7
Vol. Ht. in Ann.
Set flags 07, 09 & 24 and store volume value in Status Register M
Execute LBL 12 (in DOP 3 routine) programme execution returns after first loop of Ann. Data mode
Compares volume of Ann. section with remaining value of Input Volume & appropriately calculates the height of the smaller volume in that annulus. Accumulates that height in Status Register N. Deducts smaller volume from remaining Input Volume value in R.M. Recalls R.M. to 'X' Reg.
X = 0?
Yes
No
End routine. 'RTN' Return to executing programme. Height occupied by input volume in R.N. & 'X' Reg.
Does Input Volume exceed the total Annulus Volume of Well?
Yes
No
Execute DOP 6
End routine flag 24 set zero in Y Reg.

'ADJD' – Adjust Depth Programme.

The operation of this routine is dependant on the CODE number present in the 'X'-Register at the time of calling the routine.
The main CODE numbers are: 0, 1, 2, 3 & 10 and it is only the integer portion of the current 'X'-Register value that is interpreted as the CODE. CODE numbers 8 & 9 will also cause operation of the **'ADJD'** routine but have a more specialist use with more programming being required in association with them. Operation of CODE 8 may also **totally** upset the status of the HP 41 by affecting the System Flag Settings.

The primary function of the **'ADJD'** routine is to use the current **Well Geometry Data** as stored in Registers R.105 – R.136 to set up the **ACTIVE** Hole & Pipe Section Data Registers (R.137 – 150) with the necessary data, corresponding to DEPTH or DEPTH/CALC.D inputs, for correct operation of the module. Once these ACTIVE Registers have been set up for the current DEPTH or DEPTH/CALC.D values they remain **unchanged** by subsequent ★OILWELL 1 operations until re-adjusted with an **'ADJD'** routine. In addition the **'ADJD'** routines calculate & store the Data Access Control Values used for accessing the Active Hole and Pipe data Registers.
The current Active Hole Data Access Control Value is stored in Register R.103 (R.B).
The current Active Pipe Data Access Control Value is stored in Register R.104 (R.C).
For use of the **'ADJD'** routines the Well Geometry Data, input using Code 9 operations, must be correctly stored in the Well Geometry Data Registers (R.105 – R.136) and, where appropriate for the Code number to be used, the necessary operating depth values must have been pre-stored prior to calling the routine. The **'ADJD'** routine utilizes the Well Geometry data to create the ACTIVE set of Well Geometry Data based on specific DEPTH or DEPTH/CALC.D values required by the User.

DEPTH refers to the depth at which it is required to position the Bit in the Hole. For a Specified DEPTH of the Bit it is possible to **additionally** specify a depth, CALC.D, shallower than the Bit DEPTH, which is to be used as the Depth from which calculation is to be made.

The effect of this is that all routines that utilize the Hole and Pipe sectional data will do so only on that section of the Hole & Pipe Data starting at the Specified CALC.D Depth but with the Bit at a deeper Specified DEPTH. This means that the User has a very wide range of options for selecting how a set of Well Geometry Data may be used.

Specific ★OILWELL 1 standard Code operations adjust DEPTH and CALC.D values as necessary. It is important to realise that CALC.D, although specified as for use in Annulus calculations in the PROMPTS definition section, can, when not used in relation to ★OILWELL 1 standard Code operations, equally well be applied to Hole, Pipe **and** Annulus situations.

One application of the CALC.D ability is the calculation of Annulus volumes between specified Annulus depths as required, for example, in Cement calculations.

Code operations 0 – 4 & 8 also set up some of the data Registers as used in '**DOP**' operations. That is to say that for the current Active Data the first sections of Hole and Pipe data (L. (ID x 0.01) & L. (OD x 0.01)) are stored in Registers R.09 and R.10 respectively and the Active Data Access Control Values are stored in Registers R.06 for Hole and R.07 for Pipe data.

'**ADJD**' Operations with the following 'X'-Register Code values:

0. Zero in the 'X'-Register at the time of executing the '**ADJD**' routine will perform the modification of Active Hole and Pipe data in the Active Well Data Registers without the routine stopping to PROMPT for input of DEPTH and/or CALC.D values.
The following data storage must have taken place prior to calling this routine with a zero Code:

DEPTH of Bit in Register R.46
CALC.D depth in Register R.100

NOTE:

The DEPTH input **must** have been **previously** made using a Code 1 '**ADJD**' routine. This is because a Code 0 '**ADJD**' routine will only **adjust** the Active Pipe and Hole Data Registers as previously created using the standard DEPTH routine (Code 1) for the required DEPTH of Bit. This means that CALC.D may only be used **once** after each Code 1 '**ADJD**' routine.

1. This Code number causes the '**DEPTH?=**' PROMPT to be displayed and then causes the input response to create a **new** set of ACTIVE Hole and Pipe Data in Registers R.137 – R.150 as appropriate.

2. This routine first PROMPTS for input of a new Bit DEPTH with the PROMPT '**DEPTH?=**' as in Code 1 operation and in so doing creates a new set of Active Section Data for Hole and Pipe. It then goes on to PROMPT for '**CALC.D?=**' (Calculation Depth) which is then used for adaptation of the Active Registers to meet the CALC.D requirements.

3. This routine assumes a previous Code 1 '**ADJD**' operation and only PROMPTS for '**CALC.D?=**' thus allowing a previously created set of Active Data to be adjusted to a data set for use in a CALC.D procedure.

10. This routine has no effect on Well Geometry Data. It is used in other '**ADJD**' routines when a non-valid input in response to a '**DEPTH?=**' or '**CALC.D?=**' PROMPT has been made and it is then used to **restart** the '**ADJD**' by recalling the operating Code for a repeat of the routine.
However if Code 10 is used as the input code then programme operation will enter a continuous loop causing repeated beeping. It could be used as a type of alarm routine.

8. and 9. These Codes are mentioned only insofar as they will cause an operation in conjunction with the '**ADJD**' routine. They in fact form sub-routines, used by the other functions of the '**ADJD**' programme. Operation of '**ADJD**' with these Codes, especially with Code 8 may cause significant changes to the HP 41 status as a result of changes to the systems Flag settings not usually accessible to the User.

To operate the programme:

1. Store depth values, if necessary, in Registers R.46 and R.100
2. Put the required Code Number in the 'X'-Register
3. **XEQ 'ADJD'**

The Programme will:

1. Create or modify a set of Active Well Geometry data.
2. Store the Access Control Values for the new Active Data set in Registers R.06 and R.104 (Pipe) and R.07 and R.103 (Annulus)
3. Store the Length and Diameter data for the first section of Hole in Register R.09 (L. (DIA x 0.01)).
4. Store the Length and Outside Diameter data for the first section of Pipe in Register R.10 (L. (OD x 0.01)).
5. If Codes 1 or 2 were used or if input was made during the '**ADJD**' routine then Flag 22 will be Set.
If no input was made Flag 22 will be Clear
This is significant if the next function operation is a '**DOP**' routine as Flag 22 has a significant effect on their operation.

'PRES' – Pressure Loss Calculation Programme

This programme calculates the Pressure Loss in **either** a Pipe **or** an Annulus section using the equation for one of the following three flow regimes:

1. Laminar
2. Transitional
3. Turbulent

The type of data output depends on the settings of Flags 06, 07, 09, 11 and 12. The status of these Flags must be prepared prior to calling **'PRES'**.

Flag 06 is **SET** if the calculation to be performed is for a **Pipe** flow situation. Flag 07 is **SET** if it is to be an **Annulus** flow calculation.
Either Flag 06 **or** Flag 07 **must be** set, **both** cannot be Clear **or both** Set at the time of calling **'PRES'**.

Flag 08, the **'UNIT'** input/output control Flag, must always be Set.

If Flag 09 is Set and Flag 11 is Clear **only** the Pressure Loss is calculated for both Pipe and Annulus mode and there is no displayed or printed output made by the programme.

If Flag 09 is Set and Flag 11 is Set then only the Reynolds Numbers and associated Critical Velocities for Laminar and Turbulent flow will be output.

Flag 11 controls the output of the Reynolds Numbers and Critical Velocities. If it is Set, the values will be output. If it is Clear, they will not. The Flag is Cleared by the routine.

If Flag 12 is Set, this results in the value of the fluid velocity, as used in the calculation of Pressure Loss, being increased by the current value in Register R.27. The value in R.27 is intended to be a correction factor for use in Surge-Swab calculations which compensates for the velocity of the pipe in the hole.

'PRES' only calculates the Pressure Loss for one section of Pipe **or** Annulus at a time. If data output is suppressed by a Set Flag 09 then the calculated value of Pressure Loss per Foot of Section will be in Register R.15 at the end of the routine and the Pressure Loss for the section will have been **added** to the current contents of Register R.24 and will be in the 'X'-Register. If Flag 09 is Clear then the Pressure Loss is added to the value currently in Register R.24 and is not available in any other Register.

The **'PRES'** programme utilizes the Mud Weight and Rheology data stored in Registers R.106 (R.E) and R.108 – 111 (R.G – J) and the Pipe and Annulus data as stored in Registers R.08, R.09, R.10, R.11, R.20 and (R.27). The contents of the latter group are as follows:

R.08 – LENGTH of current section of Pipe or Annulus.

R.09 – LENGTH and DIAMETER of Hole section. (L. (DIA x 0.01)).

R.10 – LENGTH and O.D. of Pipe section. (L. (ID x 0.01)).

R.11 – ID.<P> and ID.< C >values for Pipe section. (ID.<P>.(ID.<C> x 0.01)).

R.20 – FLUID VELOCITY in Pipe or Annulus section.

R.27 – PIPE SPEED VELOCITY CORRECTION for adjusting fluid velocity value (Surge/Swab calculations only)

All this data must be present for **'PRES'** to run correctly. It can be made ready with (Catalogue Functions **'DOP4'–5–6**).

The programme listing for **'PRES'** is given in the ★OILWELL 1 Manual (pages 10.04 – 10.08). The routine performs several checks to confirm the status of the Mud data in Registers R.106 and R.109 – 111 and data output will be adjusted accordingly.
e.g. if Mud Weight = 0 the Pressure calculation will not be performed.

Operation of the programme is as follows:

1. Accesses the Annulus or Pipe data.

2. If in Pipe data mode corrects the velocity of the fluid in the pipe as previously calculated using an ID.<C> value to a velocity calculated using an ID.<P> value.

3. If a Surge/Swab calculation adds Pipe speed velocity adjustment factor to fluid velocity and stores result in Register R.28.

4. Calculates the Critical Velocity for Turbulent flow.

5. Calculates the Critical Velocity for Laminar flow.

6. By comparing the Actual Fluid Velocity (R.28) with the Turbulent and Laminar Critical Velocities checks which flow regime applies to the Actual Velocity and calculates the FRICTION FACTOR accordingly.

7. Uses this FRICTION FACTOR to calculate the Pressure Loss in the section.

8. If Flag 09 Set then ENDs the calculation.

9. If Flag 09 Clear then outputs the Pressure Loss in the section and, if Flag 07 Set (Annulus mode) outputs the Shear Rate, and Viscosity in the section.

This may be better understood with reference to the '**PRES**' flow diagram.

To operate the programme:

1. Set up the required section data.

2. Set the required status for Flags 06 and 07 corresponding to Pipe or Annulus mode.

3. Set the status of Flags 09 and 11 according to the type of output required.

4. Set Flag 08 and Clear Flag 12 (see item 5).

5. If the routine is to be used for Surge-Swab calculations store the required velocity correction in Register R.27 and Set Flag 12.

6. **XEQ 'PRES'**

The programme will perform the pressure calculation and output data according to its mode as decided by Flag status.

'NOZA' – Nozzle Area Calculation.

This is a utility routine used to prompt for the input of Nozzle Sizes and to calculate the corresponding Nozzle Area.
The number of Nozzles prompted for is dependant on the number as stored in Register R.08 prior to calling the routine.
At the end of the routine the calculated Nozzle Area value will be in Register R.06 in Module Operating English Units and in the 'X'-Register in units according to the Current Units Selection Status. The Alpha Register has the data label **'NOZ.A'** ready for subsequent output if the calling programme requires it.
If Flag 22 was cleared prior to calling the **'NOZ.A'** function then operation of the R/S Key, without prior input, in response to the first PROMPT for a Nozzle Size will result in termination of the routine operation and return to the calling programme with 'ZERO' in the 'X'-Register.

To operate the routine:

1. Store in Register R.08 the required number of Nozzles that are to be prompted for in the routine.

2. If required, set the status of Flag 22.

3. **XEQ 'NOZA'**

The routine will:

1. Prompt for the Sizes of each Nozzle.

2. Calculate the corresponding Nozzle Area for these Nozzles storing the value in Register R.06 in default English Units and in the 'X'-Register in Current Units as dictated by the settings of the Units Control Flags 00 – 04 when the routine was called.

THE MASTER PROGRAMMES

There are two Master Programmes, **'MSTA'** and **'MSTB'**, in the ★OILWELL 1 Module. The function of these programmes is to **control** the Status of the HP 41 and to **direct** programme execution as dictated by the Code Number supplied in the 'X'-Register prior to execution of the Master Programme. **Normal** usage of the module involves access to all Module functions through the Master Programme **'MSTA'**, but this can be by-passed by directly accessing Module programmes by using their Catalogue Function Names.

The Master Programmes may be used to access **ANY** programme that has been labelled with ALPHA characters corresponding to Integer Numbers in the range 1 to 999,999 inclusive.
This means that a User can write **ANY** programme with an Alpha Label of this type, access it with a Master Programme and ensure that the Module's Basic Status is in effect at the start of the User's programme.

NOTES:

1. Operation of the HP 41 is such that Programme Label search after **XEQ** and **GTO** instructions begins in the Main Memory. This means that any Main Memory Programme Labelled with an Alpha Label the **same** as a ROM Programme will be accessed **in preference** to the ROM Programme following **XEQ** and **GTO** instructions. The consequence of this is that any ★OILWELL 1 Alpha Character Numerical Labelled Programme (as indicated on a CAT 2 output) can be **replaced** by a programme of the **same** Label in Main Memory when access to it is through a Master Programme. The Master Programme uses an Indirect **GTO** instruction to direct execution to the Main Programme.

   The same will occur with programmes in any other Module which is located in a lower numbered Port than the ★Oilwell 1 Module.

2. For the purpose of this explanation the programme that is to be accessed through the Master Programme will be referred to as the **Main** Programme.

The Master Programme makes programme selection according to the **numerical value** entered in the 'X'-Register prior to its execution. This value in the 'X'-Register is processed as two parts:

(a) The Integer Portion
(b) The Fractional Portion

(a) THE INTEGER PORTION
This portion determines the Alpha Character Label to which programme execution is to be passed.
i.e. If a User wishes to run a programme labelled with the **Alpha Characters** "24" then he inputs the numerical value 24 into the 'X'-Register and then executes a Master Programme. This will direct execution to the programme labelled with these Alpha characters.

(b) THE FRACTIONAL PORTION

This portion allows the User further flexibility in his programme in that the Fractional Part can be used to automatically select that part of the Main Programme that is to be used for computation.
The Master Programme stores the Fractional part of the input 'X'-Register value, multiplied by 10, in Register R.02. Then, once programme execution has been transferred to the Main Programme, the Main Programme can itself be used to further direct programme execution, to the specified section, by appropriate use of Register R.02 in an indirect **XEQ** or **GTO** Function.

This is best illustrated by an example:

Consider an Alpha Labelled Programme '123' which performs several functions. Each of these functions is identified by a normal Numerical Label in the programme i.e. Lbl 01, Lbl 02 . . . etc. If the User wishes to perform that function specified by Label 02 then to access it through a Master Programme he must place into the 'X'-Register the Code number **123.2.** The **123** identifies the Main Programme and **.2** identifies the particular Label in the Main Programme.

NOTE:

When using a register for indirect addressing only the integer portion of the value in the Register is used. This means that the contents of Register R.02, as prepared by the Master Programme, will only access Main programme labels 00 through 09. However, the initial routines in the Main programme could be used to further adjust the contents of Register R.02.

For Example:

If the initial 'X'-Register input was 123.29 then at the time of transfer to the Main Programme Lbl '123' the R.02 content would be 2.9. Immediate execution of a **GTO IND 02** would then transfer programme execution to Lbl 02 of the Main programme. However, if Register R.02 was **first** multiplied by 10 then the **GTO IND 02** would access Lbl 29 instead.
The initial routines of the main programme can also be designed to check that the contents of Register R.02 are appropriate to the Main programme.

NOTE: 'MSTA' and 'MSTB' routines effectively transfer execution to the programme dictated by the Code number on an **execute (XEQ)** basis. That is to say that on encountering a final **'END'** or **'RTN'** instruction, programme execution will return to the Master programme. This is where **'MSTA'** and **'MSTB'** differ in their operation. This return to the Master programme will only occur when the total number of active **Sub-routine Levels** does not exceed six, i.e. any Main programme accessed by the master programme may go to 5 levels of sub-routines and will still return to the Master programme.

For Users who plan to use the Catalogue Functions directly it is worth noting that operation of a simple **'MSTA/B'** routine (e.g. Code 0.7) prior to direct execution of such a Function will ensure correct Flag and computer Status prior to the routine. That is providing that they are not disturbed by the User's calling programme.

NOTE:

This does not apply to the Units Control Flags which will need to be reset as appropriate prior to execution of the Catalogue Function.
This may be simply done by:

1. Recall of Register R.101
2. Execution of **X< >F.**

OPERATION OF 'MSTA' and 'MSTB' ROUTINES

'MSTA' and **'MSTB'** are identical in their initiation instructions and routines. However at the end of a Main programme run, when execution returns to the Master programme, operation of the two routines differs:

'MSTA'
This routine stores the current Alpha Register contents in Register R.73 for use as the end of routine Status output. In this way the end of Main programme operation can be used to supply an Alpha message for display by the HP 41 at the end of a programme run that can indicate programme status at the time of leaving the Main programme, e.g. on successful completion **'OK'** can be supplied. If a non-existent code number was used **'NA'** might be returned etc.
'MSTA' then **resets all** Flags to the ★OILWELL 1 Module's Basic Status with regard being taken of DMY and display status conditions.
The contents of the 'X'-Register as existing at the time of leaving the Main programme are returned to the 'X'-Register.
The programme does end with a **RTN** function and will therefore return execution to a calling programme.

'MSTB'
When the Master Programme has been accessed with this Label no resetting of Flags occurs at the end of the routine. It merely encounters a **RTN** function which will return execution to an initiating programme if this was a result of an **XEQ** function.

The initial function of the Master programmes in the ★OILWELL 1 Module is to ensure the correct status of the calculator prior to initiating a routine. By status is meant the Size of the Data Storage Register Block, the allocation of Statistics Register Block, the Status of the User **and** System Flags and the existence where appropriate, of Master Data and Well Geometry Data. Subsequent to this no ★OILWELL 1 functions will affect the Size of the Data Register Block or Statistics Register allocation. Flag status, however, is obviously changed, to correct for this all **'MSTA'** routines reset the status of all flags on completion of an operation. This reset is based on the contents of Register R.102 (R.A.) which, at the end of a Master programme execution, contains the Coded data necessary to reset all Flags to their ★OILWELL 1 Basic Status allowing the **User's** current preferred status of Day-Month-Year format in the Time Module and the punctuation mark, comma or full stop, to be used as the decimal integer and fraction separator. Following preparation by the Master programme the module directs execution to the required programme which will then make any necessary adjustment to Specific Flag settings.
Exact operation of the Master programme is also dependant on the value of the integer portion of the input Code. Operation in this respect can be summarised as follows:

1. If the Input Code is greater than or equal to 20 it DOES NOT:
   a. Check for Master Data existence.
   b. Check if User requires changes to the Rheology Data.
   c. Check for Well Geometry Data existence.
   d. Change status of the Units Control Flags prior to transferring execution to the Main programme.

   Basically the operation of the Master programme for Codes in this category is to set Flags to the Module's Basic Status and to process the Input Code in preparation for and to access the Main programme.
2. If the Input Code is 0.6 go direct to the routine performing this function after first confirming that Master Data exists.
3. If the Input Code is less than 1, greater than or equal to 9.2, or a Code 7.0 Function then:
   a. Check that Master Data exists
   b. Set the Units Control Flags to the current required status,
   c. DO NOT check for the Presence of Well Geometry Data or Rheology acceptability.
   d. Transfer execution to the appropriate Main Programme or routine for the Input Code.
4. If the Input Code is less than 9.2 and greater than or equal to 1 then:
   a. Check that Master Data exists.
   b. Check that Well Geometry Data exists.
   c. Check that Rheology Data is satisfactory.
   d. Set the Units Control Flags to the current required status.
   e. Transfer execution to the appropriate Main Programme for the Input Code.

MASTER PROGRAMME BASIC FLAG AND CALCULATION STATUS

The master programme performs the following status operations:

1. Sizes Data Memory to **151** Registers R.00 – R.150
2. Sets the start of the Summation Registers at Register R.11
3. Selects Degree Mode.
4. Selects Fix Four format.
5. Sets the Module's **Basic** Flag Status as follows:

FLAGS 00-20	CLEAR
FLAG 21	SET
FLAGS 22-25	CLEAR
FLAG 26	SET
FLAG 27	CLEAR
FLAGS 28 & 29	SET
FLAGS 30-36	CLEAR
FLAG 37	SET
FLAG 38 & 39	CLEAR
FLAG 40	SET
FLAGS 41-54	CLEAR
FLAG 55	SET if Printer in use, CLEAR if no Printer.

This Basic Status may be modified to meet certain local conditions for example:-

FLAGS 00 – 04 will have their status adjusted to the current User Units Selection Status prior to executing a Main programme. At the **end** of the routine the final status of them all will be **CLEAR**.

FLAGS 28 & 31 will have the User's current status selection maintained.

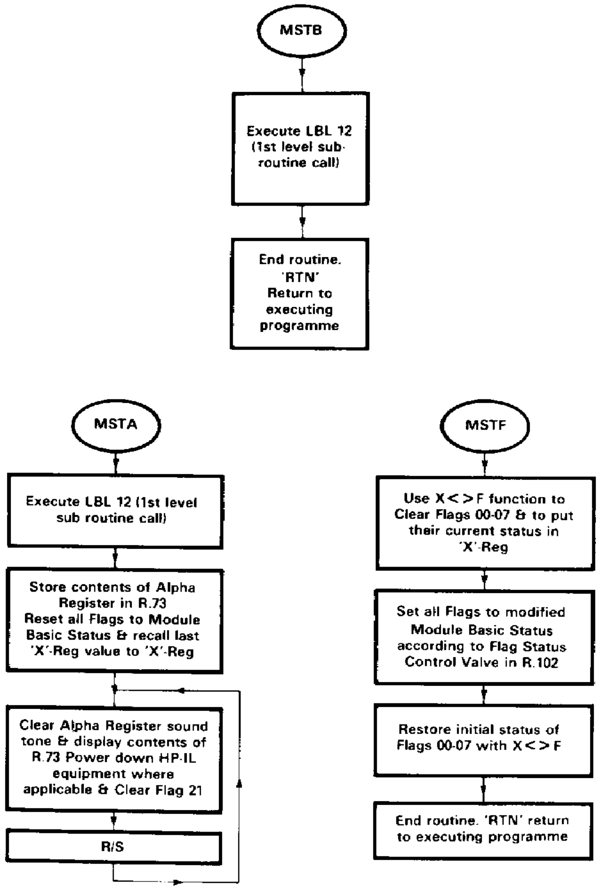
FLAG 21 will be clear at the end of '**MSTA**' routines.

NOTE:

'**MSTA**' routines cause a return of Flag Status to the Basic Status at the end of the routine.
'**MSTB**' does not result in return to the Module's Basic Flag Status.

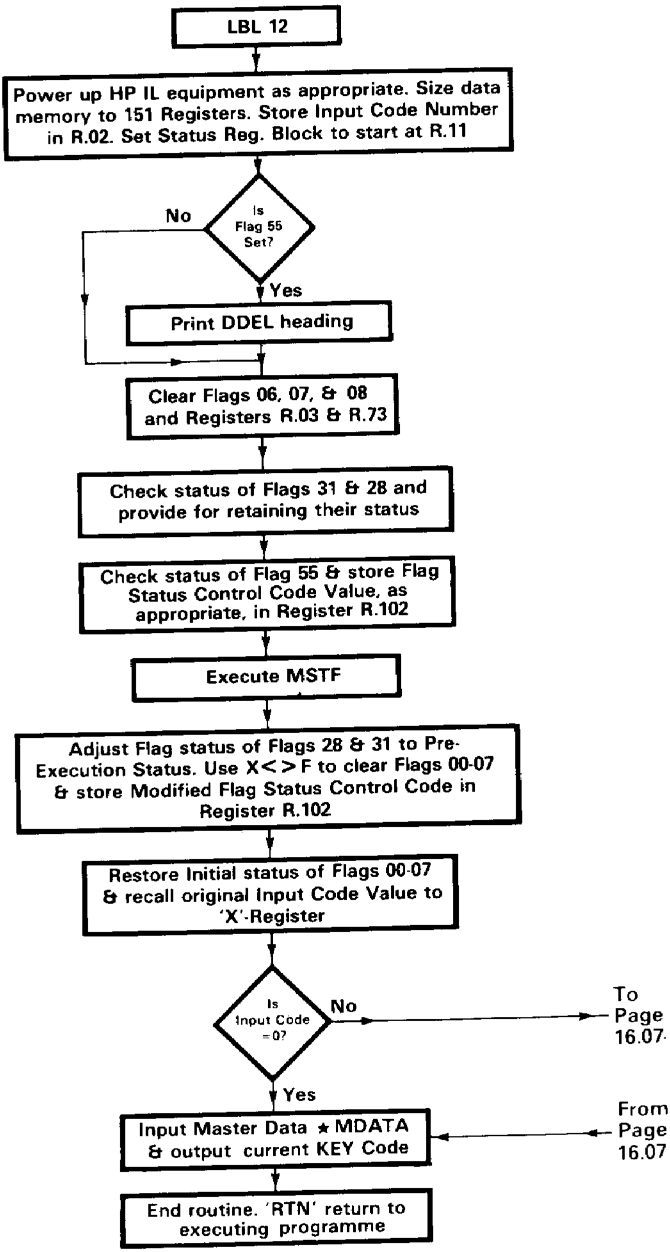
The following Flow Diagrams help to clarify Master programme operation.
Note however that the diagrams are not complete in that the Master Programme also incorporates some utility Functions that are not shown.

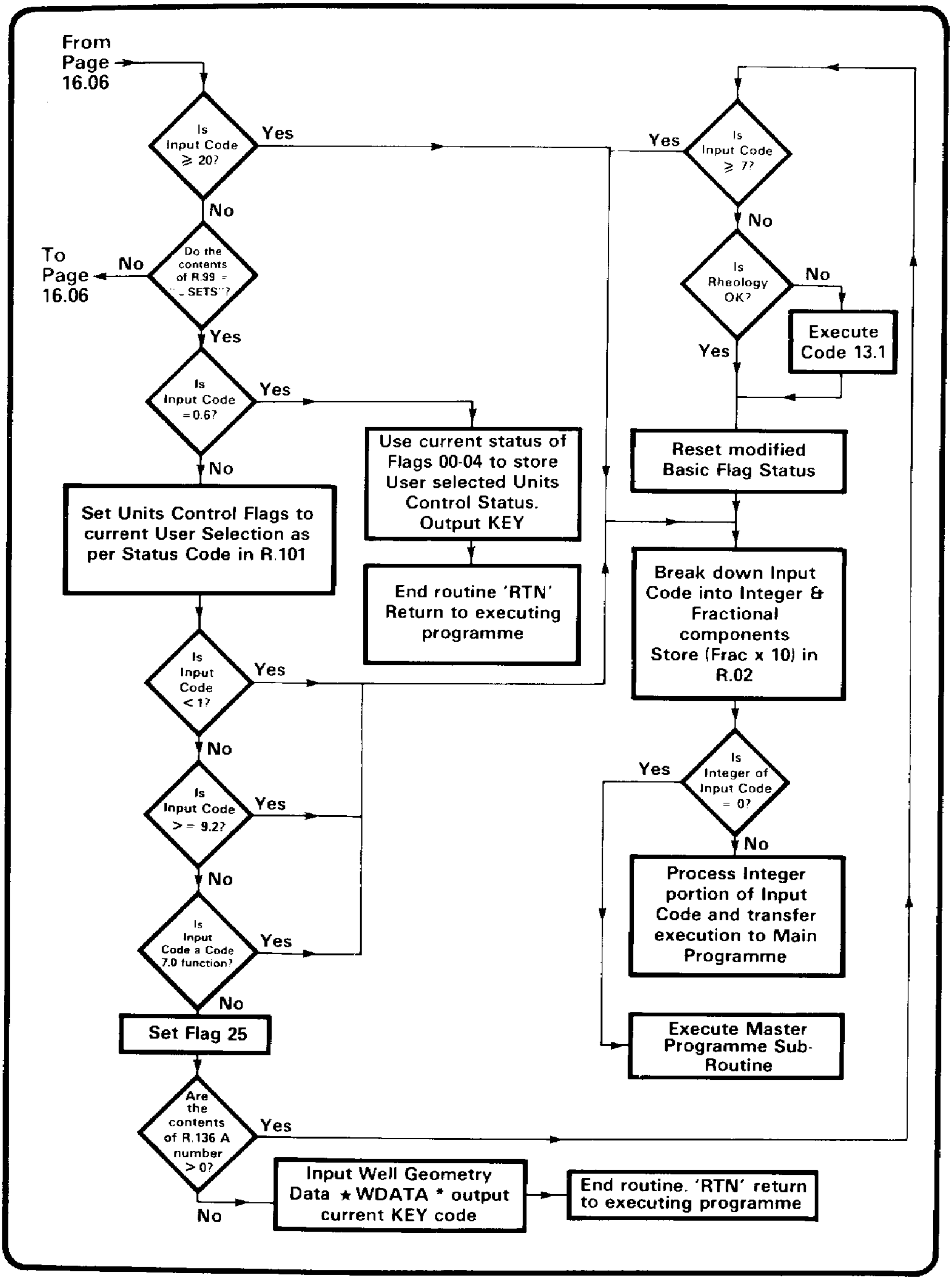
MSTA, B, F FLOW DIAGRAMS



Group 3 Master Programme Flow Diagram

★OILWELL 1




From Page 16.06
Is Input Code ≥ 20?
Yes
No
To Page 16.06
No
Do the contents of R.99 = "_SETS"?
Yes
Is Input Code = 0.6?
Yes
No
Use current status of Flags 00-04 to store User selected Units Control Status. Output KEY
End routine 'RTN' Return to executing programme
Set Units Control Flags to current User Selection as per Status Code in R.101
Is Input Code < 1?
Yes
No
Is Input Code >= 9.2?
Yes
No
Is Input Code a Code 7.0 function?
Yes
No
Set Flag 25
Are the contents of R.136 A number > 0?
Yes
No
Input Well Geometry Data ★WDATA * output current KEY code
End routine. 'RTN' return to executing programme
Yes
Is Input Code ≥ 7?
No
Is Rheology OK?
No
Execute Code 13.1
Yes
Reset modified Basic Flag Status
Break down Input Code into Integer & Fractional components Store (Frac x 10) in R.02
Yes
Is Integer of Input Code = 0?
No
Process Integer portion of Input Code and transfer execution to Main Programme
Execute Master Programme Sub-Routine

Notes

This is a group of programmes that perform various **Utility Functions** of a **general nature.** They are not specifically related to Drilling Calculations.
To execute any of these Functions set up the Data Registers and Flag Status as required and **XEQ ALPHA** 'NAME' **ALPHA.**

The Routines are:

'MST0'

This programme uses a Flag Control Code Number as stored in Register R.101 to set Flags 00 through 07 according to the Active Units Selection Status for Data Input and Ouput and then outputs the appropriate **Parameter – Units** ★KEY★. This operation is dependant on the stored value in Register R.101 being a valid Flag Status Code number in the range 0 <= X <= 255 otherwise a **DATA ERROR** will result. The module uses Codes 0.4, 0.5 and 0.6 to select the Units required for Inputing and Outputing Data for each of the Units Parameters supported by the module.
(For an explanation of the Flag Control Code Number refer to the **X<>F** Function in the Group 5 CATALOGUE FUNCTION section).
The Flag Control Code value stored in Register R.101 during **'MSTA'** or **'MSTB'** operations will **always** be **<=31** since Flags 05, 06 & 07 are **always** Cleared by the Master Programmes prior to their transferring execution to the Main Programme.
As Units Control is only governed by Flags 00 through 04 it is **advisable to ensure** that when storing values in R.101, that will be used in relation to Units Control, **only values<=31 are used (i.e. Flags 05, 06 & 07 are Clear)**. Failure to do this may cause erroneous operation of other ★OILWELL 1 routines that rely on Flags 05, 06 & 07 being **Clear** at the start of their operation.
Operation of this programme is **independant** of the Flag settings at the time of execution. On completion the Status of the Units Control Flags will be in accordance with their Current Units Control Flag selection and Flags 12 and 21 will be Set. No other Flags will have been affected.

To operate this Programme:

1. Ensure that a valid Flag Control Code Number is stored in Register R.101.

2. **XEQ 'MST0'**

The Programme will output the current Units ★KEY★, return 4 to the 'X'-Register and place the Alpha string 'OK' in the Alpha Register.

'MST1'

This Programme is used to Output a **Sub-heading** giving **'the Number of the Section'** for which the subsequent Output Data is applicable. The output is in the form "**★SECT:-n.★**" where 'n' represents the Number of the relevant section. This Section Number **must be stored** in Register **R.03 prior** to execution of the programme. Flag 21 **must** be **Set** prior to operation of the routine. In this way the Sub-heading will be printed, if the printer is in use, **or** , if not, programme execution will halt to allow the User to read and record the output. The 'R/S' Key is used to continue the execution. A printer advance is activated prior to the Sub-heading if a printer is active.
If Flag 12 is **Set** prior to executing the programme and a printer is in use then the printout will be Double Wide, if it is **Clear** it will be Single Wide.

To operate this Programme:

1. Store the required Section Number in Register R.03
2. Select the required status of Flag 12.
3. **XEQ 'MST1'**

The Programme will Output the Section Number Heading. The Stack Registers remain unchanged and the Display and Alpha Registers will be Clear.

'MST2'

This Programme is used to Output a Double Wide **Data Heading.** The Alpha String describing the Data to be Output is stored in any register as a six (maximum) Character String. The number of the Register containing this string is then entered into the 'X'-Register followed by execution of the Programme. Operation of the routine is to **prefix** the Alpha Data as recalled indirectly using the register number in the 'X'-Register with the "★" symbol and then to **postfix** it with **'DATA★'**. The entire string is then printed or displayed as a Data Heading. Flag 21 **must** be **Set prior** to this routine for the Output to be observed. After Output, the Display and Alpha Registers are Cleared.

> **NOTE:** The ★OILWELL 1 Module uses Alpha Data stored from the ★MDATA Cards to supply Headings for this Programme. If ★MDATA is present but does not contain a suitable Alpha String for the Heading required then Register R.73 can be used for storage of a suitable character string without invalidating the ★MDATA. It will not however be retained in memory after a Master Programme routine, as this Clears Register R.73.

To operate the Programme:

1. Select the Register number to be used to store the required Data Heading and input this value into the 'X'-Register.
2. Using **ALPHA** mode and the function **ASTO** store the required Alpha String for the Heading in the selected register (a maximum of six characters may be used).
3. **XEQ 'MST2'**

The programme will output the Data Heading, in Double Wide mode if printed. The Stack Registers remain unchanged and the Display and Alpha Registers will be Clear.

'MSTF'

This Programme uses the contents of Register R.102 to control the setting of Flags 08-55 (i.e. including the HP 41 System Flags). This is accomplished by re-calling the major Flag Status Control Code from Register R.102 and storing it into the Flag Status Control Register R.'d' in the **Status Register Block** of the HP 41, which is not normally available to the User.

Execution of the Master Programmes from the ★OILWELL 1 module will always re-establish the Flag Status Control Code in R.102 to the **Module's Basic Required Flag Status** prior to executing the Input Function Code. This Programme will **always maintain** the Status of Flags 00-07. If it is required to alter these to a predetermined status then the **X< >F** Function can be used either before or after the **'MSTF'** Programme.

THEORY
The basis of Flag Control using Register R.'d' is that each HP 41 Register is able to hold 7 **bytes** of information, each **byte** in turn is made up of 8 **bits** which can individually be represented by a Binary Digit **1** or **0**. Hence **one** register can be considered as holding (7 x 8) = 56 **individual bits** of information. For Flag Control the Status of each **bit** value is related to the current setting of the Flag. If the **bit** value is **1** the Flag is **SET**. If it is **0** the Flag is **CLEAR**. The Flag Number is represented by its **bit** position in the Register the **left most bit** is Flag 00 the **right most bit** is Flag 55.

This Programme can be put to good use **prior** to executing other functions, that are Flag dependant, by using it, in combination with the **X< >F** Function, to establish **Module Basic Flag Status** thereby ensuring that correct Flag Status exists when the desired function is executed.

To operate this Programme:

1. Ensure that Register R.102 contains the desired Flag Status Code.
2. Set the required Status of Flags 00 through 04 (Flags 05-07 must be **Clear**).
3. **XEQ 'MSTF'**

The Programme will return 'Zero' to the 'X'-Register when complete. The original contents of Register R.'T' and R.'Z' will have been lost and the original contents of R.'X' and R.'Y' will be in R.'Y' and R.'Z' respectively.

'NIPT'
'AIPT'

These are two very useful **General Purpose** Input routines that Prompt for Data Input and utilize the Printer, if present **and** in **Manual Mode**, to print out the Prompt and Input response, right justified, on one line.

'**NIPT**' is the **Numerical** Input routine
'**AIPT**' is the **Alpha** Input routine

Both routines utilize the **current contents** of the **Alpha** Register as **the Prompt message** to which is appended a '**?**' and in the case of the '**NIPT**' routine also an '=' sign. When a '?' alone appears at the end of the Prompt the calculators **ALPHA Mode** will be active and the Prompt response required will be an **ALPHA STRING.** If '?=' has been appended then **NORMAL** mode will be active and a **NUMERIC** Input is required.

Neither routine preserves the contents of the STACK Registers as they existed prior to calling the routine. Hence, if the User wishes to make use of the STACK while a **Prompt Input Stop** is in effect, then provision to store, elsewhere, Data that is in the STACK must have been made prior to calling either routine.

For both '**NIPT**' and '**AIPT**' routines the Input response is in the 'X'-Register at the end of the routine.

In addition when using the '**AIPT**' routine a '**Y**' is **automatically** placed in the 'X'-Register if **NO** Input response was made prior to R/S key operation. The '**AIPT**' routine also puts a '**Y**' in the 'Y'-Register. This is to facilitate subsequent checking of an ALPHA Input response to a Prompt requiring a **Yes/No** Input. The '**NIPT**' routine additionally stores the Input value into the 'Y'-Register.

> **NOTE:** When using the '**AIPT**' routine for DATA Input, only the **first** 6 Alpha characters input will be recognised by the routine. These will be placed in the 'X'-Register. After executing an "**AIPT**' routine the User can check the Input string against a pre-selected **comparison string** by placing the **comparison string** in the 'Y'-Register and by then using an Alpha acceptable **Conditional Test** e.g. "**X**=Y?".

GENERAL NOTES

1. The '**NIPT**' routine **must** only be accessed when the calculation is **NOT** in Alpha Mode.
2. Flag 27 is always **Cleared** by '**AIPT**' and '**NIPT**' routines.
3. Flag 21 is always set by '**AIPT**' and '**NIPT**' routines.
4. '**AIPT**' initially **Clears** Flag 23.
   It is always **Clear** at the end of '**AIPT**' and '**NIPT**' routines.
5. The Alpha Register and Display are always **CLEARED** at the end of both routines.

To operate the Routines:

1. Place the required Prompt Message in the Alpha Register.
If an **'NIPT'** routine is being used a default value may be placed in the 'X'-Register.

2. **XEQ 'NIPT'** or **'AIPT'**.

The Routine will Prompt for Data Input as required and print out the Prompt and Response if a Printer is attached.

'UNIT'

This routine works in conjunction with the User's **Selection of Units** in which **Input** and **Output** of Data is to be made for each of the **Basic Parameters** handled by the module (see the section UNITS SELECTION pages 2.01 – 2.05). At the time of executing the routine the **Status of the Units Control Flag** for the Basic Parameter to be associated with the value to be operated on **MUST** be in accordance with the User's requirements.
For each of these Flags that is **Clear** the associated Basic Parameter's units are in English units, as per the modules internal operating units.

For each Flag that is **Set** the routine will convert **INPUT** values **to** internal English operating units **from** the alternative units in which Input was made and **OUTPUT** values **to** Alternative units **from** internal English operating units.
The routine will only **directly** handle simple conversions for the Basic Parameters. Conversions requiring handling of combined units systems (e.g. Volume/Length) must be handled by separate repeats of the routine.

The selection of either INPUT or OUTPUT Mode is dependant on the Status of Flag 08.

If Flag 08 is Clear then the Routine is in **INPUT MODE** and:

The 'X'-Register value is used to check the status of the corresponding dedicated Basic Parameter Flag and if it is **Set** the 'Y'-Register value is **divided** by the appropriate conversion factor (contained in Register R.55 + the 'X'-Register value) to convert it to internal English operating units. The **converted value** is then available in the **'X'-Register** and in Register R.04 for User application as required.

If Flag 08 is Set then the Routine is in **OUTPUT MODE** and:

The 'X'-Register value is used to check the status of the corresponding dedicated Basic Parameter Flag and if **Set** the 'Y'-Register value is **multiplied** by the appropriate conversion factor to convert it to the alternative units for the Basic Parameter. The **converted value** is stored in Register R.04.
This **converted value** is then prefixed with a **Data Label** previously stored by the User in a Register of the User's choice. The number of this Register is stored in Register R.05 prior to calling the **'UNIT'** routine.
Register R.05 is used to indirectly recall, to a Cleared Alpha Register, the **Data Label** for the output value. To this is appended ". =" followed by the **converted value.** This is then Output with an 'AVIEW' statement.

NOTE: the number of figures after the decimal point for the value recalled to the Alpha Register from Register R.04 will depend on the current numerical display format (e.g. Fix 4) which must have been set **prior** to execution of the **'UNIT'** routine.

GENERAL NOTES

1. If Flag 11 is **Set prior** to executing the **'UNIT'** routine then the value of the conversion factor will be **squared** prior to conversion of the value in question. This has application in for example Inputs and Outputs involving **areas.**
Flag 11 is automatically Cleared by the routine.

2. If, when in **OUTPUT** Mode, the value to be Output is 'ZERO' then NO Data Output will take place.

3. The value in Register R.05 when in **OUTPUT** Mode is increased by 1 at the end of each routine. This means that for sequences of outputs whose Data Labels have been sequentially stored in a set of Registers there is no need to restore a new Register R.05 value prior to the next execution of the **'UNIT'** routine.

To Operate the Routine:

1. For **OUTPUT** Mode only, the number of the Register to be used to supply the Data Label for use with the Output value is stored in Register R.05.

2. The value to be operated on in **INPUT** and **OUTPUT** Mode is placed in the 'Y'-Register.

3. The number of the Flag dedicated to the Basic Parameter of the same units as the value to be handled is placed in the 'X'-Register.

   NOTE: 5 Flags (00-04) control the units of the six Basic Parameters. Flag 04 is a special purpose flag (see the section UNITS SELECTION on pages 2.01 – 2.05).
   Pressure and Weight units are **BOTH** controlled by Flag 04 which means that if Flag 04 is Set then both **Pressure** and **Weight** will be Input and Output in the Alternative Units. However for conversion purposes using the **'UNIT'** routine **4** is placed in the 'X'-Register for **Pressure** conversions and **5** for **Weight** conversions.

4. The STATUS of Flag 08 is decided for the operation required:

   a. **CLEAR** to convert an Input value to English units for programme internal use.

   b. **SET** to Output a programme generated English units value in units appropriate to the **current status** of the dedicated units control flag as indicated by the 'X'-Register value.

5. **XEQ 'UNIT'.**

The Routine will either convert an Input Value to internal English operating units (Flag 08 Clear) or convert an internally generated value to units appropriate to Output units selection and Output the value with a Data Label (Flag 08 Set).

'★FC'

This routine allows **Clearing** and **Setting** of **any** of the **30** 'User' controllable Flags (Nos. 00-29) by the use of a Code Value.
As discussed in the section describing operation of the function **X<>F** (Page 18.01) flags can be regarded as being represented by the value of a Binary Digit in a Binary number. If the digit is **'0'** the Flag is **Clear** if it is **'1'** the Flag is **Set.** The Decimal value of the Binary Digit in a Binary number is determined by its position in the number. If, starting from the right, it is the **first** digit its Decimal value is 2^0 x its value **'0'** or **'1'** i.e. it is **'0'** or **'1'**, if it is the **second** digit its Decimal value is 2^1 x its value **'0'** or **'1'** i.e., it is **'0'** or **'2'**. If it is the **sixth** digit its Decimal value is 2^5 or **'0'** or **'1'** i.e. it is **'0'** or **'32'** etc. This means that for any Flag that is **Clear** its Status code is **'zero'** and for any Flag that is **Set** its Status code is unique and $= 2^n$ x '1'. Where n = the Flag number, this **STATUS CODE** can **only** apply to that **ONE** Flag. For a number of flags the **SUMMATION** of their individual **STATUS CODES** can still only represent **uniquely** the STATUS of those individual Flags.

It is therefore possible to build a **STATUS CODE** number and to specify the **HIGHEST** and **LOWEST** numbers of the Flags which are to be used and then to use this data to **SET** and **CLEAR all** the Flags **between and including** the specified Flags according to the **STATUS CODE.**
The **'★FC'** routine does this when executed with the 'Z', 'Y' & 'X'-Registers set up as follows:

'Z' – contains the **STATUS CODE** number.

'Y' – Contains the Number of the **LOWEST** Flag.

'X' – Contains the Number of the **HIGHEST** Flag.

For Example:

Say that it is required to **SET** Flags 18, 17, 15, 11, 10, 08, 05 & 04 and to have all flags above Number 18 and below Number 03 unchanged with the unspecified flags between and including Flags 18 & 03 **CLEARED** then proceed as follows:

1. Calculate the **STATUS CODE** Number:

   $= 2^{18} + 2^{17} + 2^{15} + 2^{11} + 2^{10} + 2^8 + 2^5 + 2^4 = 429360$

2. Enter this **STATUS CODE** Number into 'X'-Register

3. Press **ENTER** and enter **3** (being the Number of the **LOWEST** Flag)

4. Press **ENTER** and enter **18** (being the Number of the **HIGHEST** Flag)

5. XEQ '★FC'

Programme will **SET** and **CLEAR** the Flags as specified.
The User can confirm the STATUS of the Flags using the **FS?**– –Function.

This is a set of four functions developed by Hewlett Packard and incorporated in the ★OILWELL 1 Module. These are functions additional to normal HP 41 functions and are **only** accessed using the **'XEQ'** function or by assignment to a **USER** Key. These functions are **microcode** routines and are **independant** of Flag Status. They operate only on data in the 'X'-Register, no other Data Registers are used.

The Routines are:

X< >F – EXCHANGE CONTENTS OF THE 'X'-REGISTER WITH THE STATUS OF FLAGS 00-07.

This routine takes the Flag Status Code Number as stored in the 'X'-Register and uses it to establish the Status of Flags 00-07 inclusive according to the value of that Code Number. At the same time it places the Code Number corresponding to the **previous** setting of these Flags in the 'X'-Register. Operation of the routine with an invalid Code will result in **DATA ERROR.**
In this way it is possible to have access to a vast number of flags because at different stages of a programme it is possible to change Flag Settings according to **STORED** Flag Codes, thus making it possible for the significance and setting of a flag in one sub-routine to be quite independant of its operation in another sub-routine, each sub-routine being controlled by the same Flags whose Status is manipulated by an **X< >F** Function and Flag Code number within the **'0'** routine.

THEORY
The 8 flags controlled by this routine can be considered as represented by a single **byte** of information. A **byte** is composed of 8 **bits**. Each bit can be represented by either a **'1'** or a **'0'**. Thus for flag operations each **bit** of a single **byte** of information may be considered representative of a flag's status **'0'** for **Clear** **'1'** for **Set**.
A number formed from a string of **1s** and **0s** is called a **Binary Number** (a number to the base 2), a **byte** of information is represented by an **8 bit Binary Number**. The significance of each bit depends on its **position** in the number just as in Decimal Numbers the position of a digit in the number dictates its significance.

e.g. Take the decimal number 345 – this means:

3 groups of 100 units – Hundreds i.e. 3×10^2

4 groups of 10 units – Tens i.e. 4×10

5 single units – Units i.e. 5×10^0 or 5×1

i.e. In decimal numbers we deal in the summation of the numbers of individual groups of powers of **10** thus $345 = (3 \times 10^2) + (4 \times 10^1) + (5 \times 10^0)$

In binary numbers the concept is the same except that instead of dealing with individual groups of powers of **10** we deal in individual groups of powers of 2. Hence the 8 bit binary number **10011001** can be represented in decimal form by:

$(1 \times 2^7) + (0 \times 2^6) + (0 \times 2^5) + (1 \times 2^4) + (1 \times 2^3) + (0 \times 2^2) + (0 \times 2^1) + (1 \times 2^0)$

or:

$2^7 + 2^4 + 2^3 + 2^0 = 128 + 16 + 8 + 1 = 153$

It follows from this that the **maximum** decimal number that can be represented by an 8 bit Binary Number is 255, i.e. with all bits set to **1s**

It is not possible to have **any** combination of binary digits represented by **more than one** decimal number. Hence an 8 bit binary positive number will uniquely represent a specific decimal number of value in the range 0 to 255.
For flag operations **each bit** of the 8 binary number can be associated with a **Specific Flag.**
For X**< >**F operations the Flag number is related to the **power** of Base **2** hence working from right to left of the Binary Number Flag 00 is represented by the value of the 2^0 column Flag 01 by the 2^1 column and Flag 07 by the value of the 2^7 column. It follows that a decimal value of 153 in the 'X'-Register will result in a **X< >F** Function causing Flags 07, 04, 03, and 00 to be **Set** and Flags 06,05,02 and 01 to be **Clear.**

> **NOTE:** This concept is extended logically for use in the '★FC' Flag routine (See: Group 4 CATALOGUE FUNCTIONS section).

REG MOVE – MOVE THE SPECIFIED REGISTERS
REGSWAP – SWAP THE SPECIFIED REGISTERS

Both these functions allow the User to **manipulate** the contents of the Data Registers in HP 41 Main Memory.
The manipulations are performed according to the value contained in the 'X'-Register prior to executing the Function. This 'X'-Register value is called the Control Number and is in the form **sss.dddnnn.**
Where:

'sss' is the number of the lowest numbered **Source** Register.

'ddd' is the number of the lowest numbered **Destination** Register.

'nnn' is the **Number** of Registers to be moved, starting with Register number **'sss'.**

> **NOTE:** The **start** of the Destination block **must not** overlap with the **end** of the Source block.

REGMOVE serves to **copy** the contents of the Source block into the Destination block **over-writing** any data currently in the Destination Registers. The Source data remains unchanged.

REGSWAP as the name implies **swaps** the contents of two Data Blocks keeping **both** sets of data **intact**. Either block may be regarded as the source.

PSIZE – PROGRAMMABLE SIZE FUNCTION

This Function makes possible **Sizing** of HP 41 Data Memory from a programme. The number of Data Registers required is placed in the 'X'-Register and programme execution of the Function **PSIZE** then **Sizes** Data Memory to that number of registers starting at Register R.00.
The routine may also be used direct from the Keyboard providing that the 'X'-Register has been correctly set up with value of the number of registers required.

NOTE:
Although these routines **act** identically to the **'X-Functions'** routines of the same names, they will not be **recognised** by the **'X-Functions'** module. They can **only** be used with the ★OILWELL 1 Module in place in a H.P. 41 Port.

This group of six Catalogue Functions differs from the other groups in that the Functions in this group cannot be **directly** accessed using the standard HP functions. This is because **direct** operation HP functions do not recognise the single letters 'a,b,c,d,e,A,B,C,D,E,F,G,H,I or J' as **Global Labels** in the way they would other individual Alpha Characters but rather as the names of **Local Labels** (see HP hand book).

However, using what is known as "Synthetic Programming", it is then possible to utilize these characters in **Global Labels** and to call them directly with Synthetic Functions. No attempt will be made here to explain Synthetic Programming techniques. However, there are some excellent books available on the subject, two of which are:

Synthetic Programming by W.C. Wicks from Larken Publications, 4517 N.W. Queens Avenue, Corvallis, Oregon 97330 U.S.A.
H.P. 41 Synthetic Programming Made Easy by Keith Jarett from Synthetics 1540 Mathews Ave., Manhattan Beach, CA 90266 U.S.A.

The Functions in this group perform the **combined** operations of enabling Input of Numeric Data and Conversion (if required) of the Input Value to **ENGLISH UNITS** for **Internal** use by the HP 41. Thus calling a label from this group will perform both an '**NIPT**' and an '**UNIT**' operation. For those without a knowledge of Synthetic Programming '**NIPT**' and '**UNIT**' can of course be used individually or alternatively the function may be called **indirectly** by placing the appropriate letter in the Register that is to be used for **indirect** execution.

NOTE: Flag 08 **must** be Clear **prior** to operation of any of these Functions.

The specific operations of each routine are as follows:

"A" Using the current contents of the Alpha Register this executes an '**NIPT**' routine and processes the Input Value for **LENGTH** parameter units ("**UNIT**" code 0).

"B" Using the current contents of the Alpha Register this executes an "**NIPT**" routine and processes the Input Value for **DIAMETER** parameter units. ('**UNIT**' code 1).

"C" Prompts for input of "Flow Rate Data" (Q RATE?=) using an "**NIPT**" routine with Alpha Data recalled from Register R.72. It processes the Input Value for **VOLUME** parameter units. ('**UNIT**' code 2).

"D" Prompts for input of "Mud Weight Data" (MUD WT?=) using an "**NIPT**" routine with Alpha Data recalled from Register R.84 and processes the Input Value for **MUD WEIGHT** parameter units ('**UNIT**' code 3).

"E" Using the current contents of the Alpha Register this executes an "**NIPT**" routine and processes the Input Value for **PRESSURE** parameter units. ('**UNIT**' code 4).

"F" Using the current contents of the Alpha Register this executes an "**NIPT**" routine and processes the Input Value for **WEIGHT** parameter units ('**UNIT**' code 5).

USER NOTES

1. Flag 08 **must** be **Clear prior** to each programme call to Catalogue Functions of this group.

2. Flag 22 (Numeric Input) **must** be **Cleared prior** to programme calls to Catalogue Functions of this group if it is subsequently required to **test** if Numeric Input has been made.

3. If **No** Input is made in response to the Input prompt then the current 'X'-Register value will be used as the Input. Since units conversion will be performed on this value the value in the 'X'-Register **must be** in units appropriate to the current status of the Units Control Flags.

4. The User will not be able to create or call Alpha Labels which use the single Alpha characters designated for use as **Local Labels** without using Synthetic Programming. However, it is quite possible to **access** these labels using the **Indirect** Command facility of the HP 41.

For example:
If it was required to utilize Catalogue Function **'A'** from the ★OILWELL 1 Module to prompt for and Input a LENGTH then this could be done by:

1. Storing the letter 'A' in ,say, the 'Y'-Register,
2. Puting the required prompt into the Alpha register,
3. Puting the required default value into the 'X'-Register,
4. **Indirectly** accessing the **'A'** Function, e.g. XEQ IND. Y.

A possible programme might be:

01 CF08
02 CF22 – Flag status preparation
03 1000 – Default value in 'X'-Register
04 'A' – Label character in Alpha Register
05 ASTO.Y – Store Function Name in 'Y'-Register for use in **indirect** access.
06 LENGTH – Put prompt in Alpha Register.
07 XEQ IND Y. – Execute **indirectly** the Function Name as indicated by the contents of the 'Y'-Register.

NOTE: The status of Flag 00 in this example will determine if it is necessary to convert the value input in response to the prompt for LENGTH to ENGLISH UNITS prior to storage.

The User should read the descriptions for the **'NIPT'** and **'UNIT'** routines for details of their operations.

FLAG OPERATIONS AND FLAG USAGE

For a full understanding of available Flags, their significance and usage, the User should consult the HP 41 User's Manual.

The purpose of Flags in programming is to allow decision making within a programme based on the current status of a Flag. This Flag status will have been pre-determined at an earlier stage to meet the needs of the programme as executed. Interrogating Flag Status can be used to re-direct programme execution or to modify available data or related computer status.

Since the Module utilizes a number of Flags in its operations it is important that the status of all Flags that will be interrogated by a routine will be as required to ensure the routine's proper operation. For ★OILWELL 1 operations this will always be the case providing that Functions are accessed through the **normal** channels of executing ('XEQ') the Master Programmes 'A' or 'B'. The Master Programmes establish a default status for all Flags which ensures correct subsequent execution of the Main programme selected. However, when Catalogue Functions are accessed and used **directly** then **NO** Flag status check is performed. It then becomes essential that Flags, whose status is not established by the routine but is interrogated by it, are in their required state **prior** to executing the function. This is the User's responsibility in this type of operation. To enable the User to do this a set of Flag Usage Tables follows. These give details of the required status of Flags prior to execution of each Function and information as to the final status at termination.

When Catalogue Function routines are to be accessed directly and providing selection of the required Units Control status has been previously made using a Master Programme routine, Basic Flag status prior to executing the Catalogue Function can **initially** be assured using the Flag Control codes. These codes are stored in Registers R.101 and R.102 during the Master Programme routine. The value in Register R.102 (R.A.) is used to control the status of **all** Flags and the value in Register R.101 to control the status of Flags 00 to 07.

> **NOTE:**
> Rather than using the R.101 value the User may elect to set the status of Flags 00 to 04 (inclusive) directly from the keyboard but if this is done then Flags 05, 06 and 07 **must** be **Clear.**

This setting of Flag status can be achieved as follows:

1. Indirectly recall R.101
2. **XEQ X< >F.** SETS Units Control Flag status
3. Indirectly recall R.102
4. **XEQ 'MSTF'** Sets **all** Flags to Basic Module Status maintaining current status of Flags 00-07 (inclusive)

With this **initial** status set up the User **must** then make any required adjustments to the status of **specific Flags** as required by the particular Function to be used.

ADVANCED USER NOTE

For Users with an Extended Functions Module it is possible to create the **Coded Alpha String** used for setting up Basic Flag Status by using the **XTOA** function in the module. To do this follow the following procedure:

1. Clear the Alpha Register

2. Use **XTOA** with each of the following Character Codes as follows:

   4,**XTOA**;44,**XTOA**;4,**XTOA**;128,**XTOA**;

   then:

   either
   0,**XTOA** if Flag 55, the printer existence Flag, is to be Clear
   or
   1,**XTOA** if Flag 55 is to be Set.

3. The Alpha Register will now contain the Flag Control code necessary for setting the Flag status of all Flags to the Module's Basic setting.

4. Store the Alpha String in Register R.102 by puting 102 into the 'X'-register and executing **ASTO IND.X.**

The coded Flag Control value stored in R.102 may be used for setting Flag status in two ways:

1. As already discussed by using the **'MSTF'** routine which retains the current settings of Flags 00-07 (inclusive) that are in effect when the routine is called.

2. By directly executing Code **'12'** (i.e. **XEQ ALPHA** '1', '2' **ALPHA**) followed by pressing the 'R/S' key when **"GEN CALCS"** is displayed. This will take the current contents of Register R.102, set the status of all flags using this Code and then use the contents of Register R.101 to set the status of Flags 00 to 07 (inclusive) using the **X<>F** function.

Both these routines have access to the operating system status Register R.d. which is the Flag control Status Register. They can be useful for Flag control but may well cause some unexpected results if used with data stored in R.102 that is not a Flag status control Code.

FLAG STATUS AT INITIATION AND TERMINATION

The tables that follow give details of the status of Flags prior to and after operation of the relevant routine. Every effort has been made to make these tables accurate but under **specific circumstances** Flag status may be different from that given. The User will need to experiment with personal programmes to ensure that operation is as it should be.

Flag Status at Initiation and Termination

⋆OILWELL 1

FLAGS	'1'	'DOP0'	'DOP1'	'DOP2'	'DOP3'	'DOP4'	'DOP5'	'DOP6'	'DOP7'	'3'	'12'	'NOZA'	'PRES'	'ADJD'	'MSTA'	'MSTB'
USER FLAGS																
Flag 00	UUO	UUO	UUO	UUO	UUO	UUO	UUO	UUO	*O	UUO	UUO	*	UUO	UUO	IC	I C
Flag 01	UUO	UUO	UUO	UUO	UUO	UUO	UUO	UUO	*O	UUO	UUO	UU	*O	*O	IC	I C
Flag 02	UUO	UUO	UUO	UUO	UUO	UUO	UUO	UUO	*O	UUO	UUO	UC	*O	*O	IC	I C
Flag 03	UUO	UUO	UUO	UUO	UUO	UUO	UUO	UUO	*O	UUO	UUO	UC	*O	*O	IC	I C
Flag 04	UUO	UUO	UUO	UUO	UUO	UUO	UUO	UUO	*O	UUO	UUO	UC	UUO	*O	IC	I C
Flag 05	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	KKO	*	*O	ICO	IC	I C
Flag 06	CVO	CCO	C*O	S*O	C*O	C*O	C*O	C*O	*O	CVO	*O	*	**O	*O	IC	I C
Flag 07	CVO	CSO	S*O	C*O	C*O	C*O	C*O	C*O	ISO	CVO	*O	*	**O	*O	IC	I C
Flag 08	ISO	ISO	ISO	ISO	ISO	ISO	ISO	ISO	ISO	ISO	*O	*	SSO	CCO	IC	I C
Flag 09	*VO	**O	**O	**O	**O	**O	**O	**O	ISO	*VO	*O	*	**O	*O	IC	I C
Flag 10	**O	**O	**O	**O	**O	**O	**O	**O	CCO	ISO	*O	*	*O	*O	IC	I C
Flag 11	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	*	*CO	ICO	IC	I C
Flag 12	ICO	ICO	ICO	ICO	ICO	IVO	IVO	IVO	*O	ICO	ICO	*	**O	*O	IC	I C
Flag 13	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	IC	CCO	CCO	CC	CC
Flag 14	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*	*O	*O	IC	I C
Flag 15	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*	*O	*O	IC	I C
Flag 16	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*	*O	*O	IC	I C
Flag 17	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*	*O	*O	IC	I C
Flag 18	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*	*O	*O	IC	I C
Flag 19	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*	*O	*O	IC	I C
Flag 20	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*	*O	*O	IC	I C
Flag 21	ISO	SSO	SSO	SSO	SSO	SSO	SSO	SSO	SSO	SSO	ISO	IS	*O	SSO	IS	I S
Flag 22	ISO	**O	**O	**O	**O	**O	**O	**O	*O	IVO	ICO	CS	*O	ISO	IC	I C
Flag 23	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CVO	CC	CCO	CCO	IC	I C
Flag 24	*VO	**O	**O	**O	**O	**O	**O	**O	ICO	*VO	CCO	CC	CCO	CCO	IC	I C
Flag 25	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CC	CCO	CCO	IC	I C
Flag 26	SSO	SSO	SSO	SSO	SSO	SSO	SSO	SSO	SSO	SSO	SSO	SS	SSO	SSO	IS	I S
Flag 27	ICO	*O	*O	*O	*O	*O	*O	*O	*O	ICO	ISO	IC	*O	ICO	IC	I C
Flag 28	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*	*O	*O	**	* *
Flag 29	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*	*O	*O	IS	I S
SYS. FLAGS																
Flag 31	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*O	*	*O	*O	**	* *
Flag 48	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CCO	CC	CCO	CCO	CC	CC
Flag 55	**O	**O	**O	**O	**O	**O	**O	**O	**O	**O	**O	**	**O	**O	**	**

FLAGS	'MST0'	'MST1'	'MST2'	'MSTF'	'A'	'B'	'C'	'D'	'E'	'F'	'AIPT'	'NIPT'	'UNIT'	PSIZE	RMOVE	RSWAP
USER FLAGS																
Flag 00	IU	*	*	*	UU	UU	UU	UU	UU	UU	*	*	UU	N/A	N/A	N/A
Flag 01	IU	*	*	*	UU	UU	UU	UU	UU	UU	*	*	UU	N/A	N/A	N/A
Flag 02	IU	*	*	*	UU	UU	UU	UU	UU	UU	*	*	UU	N/A	N/A	N/A
Flag 03	IU	*	*	*	UU	UU	UU	UU	UU	UU	*	*	UU	N/A	N/A	N/A
Flag 04	IU	*	*	*	UU	UU	UU	UU	UU	UU	*	*	UU	N/A	N/A	N/A
Flag 05	*	*	*	*	*	*	*	*	*	*	*	*	*	N/A	N/A	N/A
Flag 06	*	*	*	*	*	*	*	*	*	*	*	*	*	N/A	N/A	N/A
Flag 07	*	*	*	*	*	*	*	*	*	*	*	*	*	N/A	N/A	N/A
Flag 08	*	*	*	IC	CC	CC	CC	CC	CC	CC	*	*	**	N/A	N/A	N/A
Flag 09	*	*	*	IC	*	*	*	*	*	*	*	*	*	N/A	N/A	N/A
Flag 10	*	*	*	IC	*	*	*	*	*	*	*	*	*	N/A	N/A	N/A
Flag 11	*	*	*	IC	CC	CC	CC	CC	CC	CC	*	*	*C	N/A	N/A	N/A
Flag 12	IS	*C	IC	IC	*	*	*	*	*	*	*	*	*	N/A	N/A	N/A
Flag 13	CC	CC	CC	CC	CC	CC	CC	CC	CC	CC	CC	CC	CC	N/A	N/A	N/A
Flag 14	*	*	*	IC	*	*	*	*	*	*	*	*	*	N/A	N/A	N/A
Flag 15	*	*	*	IC	*	*	*	*	*	*	*	*	*	N/A	N/A	N/A
Flag 16	*	*	*	IC	*	*	*	*	*	*	*	*	*	N/A	N/A	N/A
Flag 17	*	*	*	IC	*	*	*	*	*	*	*	*	*	N/A	N/A	N/A
Flag 18	*	*	*	IC	*	*	*	*	*	*	*	*	*	N/A	N/A	N/A
Flag 19	*	*	*	IC	*	*	*	*	*	*	*	*	*	N/A	N/A	N/A
Flag 20	*	*	*	IC	*	*	*	*	*	*	*	*	*	N/A	N/A	N/A
Flag 21	IS	SS	SS	IS	IS	IS	IS	IS	IS	IS	IS	IS	SS	N/A	N/A	N/A
Flag 22	*	*	*	IC	CS	CS	CS	CS	CS	CS	CC	CV	*	N/A	N/A	N/A
Flag 23	*	*	*	IC	CC	CC	CC	CC	CC	CC	CC	CC	*	N/A	N/A	N/A
Flag 24	*	*	*	IC	CC	CC	CC	CC	CC	CC	CC	CC	CC	N/A	N/A	N/A
Flag 25	*	*	*	IC	CC	CC	CC	CC	CC	CC	CC	CC	CC	N/A	N/A	N/A
Flag 26	*	*	*	IS	SS	SS	SS	SS	SS	SS	SS	SS	SS	N/A	N/A	N/A
Flag 27	*	*	*	IC	IC	IC	IC	IC	IC	IC	IC	IC	*	N/A	N/A	N/A
Flag 28	*	*	*	IV	*	*	*	*	*	*	*	*	*	N/A	N/A	N/A
Flag 29	*	*	*	IS	*	*	*	*	*	*	*	*	*	N/A	N/A	N/A
SYS. FLAGS																
Flag 31	*	*	*	*	*	*	*	*	*	*	*	*	*	N/A	N/A	N/A
Flag 48	CC	CC	CC	CC	CC	CC	CC	CC	CC	CC	CC	CC	CC	N/A	N/A	N/A
Flag 55	**	**	**	**	**	**	**	**	**	**	**	**	**	N/A	N/A	N/A

FLAGS	X<>F	'*FC'	'7'	'8'	'9'	'10'	'11'	'13'
USER FLAGS								
Flag 00	N/A	IV	UU	UUO	UU	UU	UUO	UU
Flag 01	N/A	IV	UU	UUO	UU	UU	UUO	UU
Flag 02	N/A	IV	UU	UUO	UU	UU	UUO	UU
Flag 03	N/A	IV	UU	UUO	UU	UU	UUO	UU
Flag 04	N/A	IV	UU	UUO	UU	UU	UUO	UU
Flag 05	N/A	IV	CV	ICO	CC	CC	*O	CC
Flag 06	N/A	IV	CV	C*O	CV	CV	CCO	*
Flag 07	N/A	IV	CV	C*O	CV	CC	CSO	*
Flag 08	N/A	IV	CS	ISO	CS	CS	CSO	CS
Flag 09	N/A	IV	*	ISO	CC	*	CCO	*
Flag 10	N/A	IV	*	C*O	CV	*	*	*
Flag 11	N/A	IV	CC	CCO	CC	CC	CC	IC
Flag 12	N/A	IV	IC	ICO	CC	IC	ICO	IC
Flag 13	N/A	CV	CC	CCO	CC	CC	CCO	CC
Flag 14	N/A	IV	*	*O	*	*	*	*
Flag 15	N/A	IV	*	*O	*	*	*	*
Flag 16	N/A	IV	*	*O	*	*	*	*
Flag 17	N/A	IV	*	*O	*	*	*	*
Flag 18	N/A	IV	*	*O	*	*	*	*
Flag 19	N/A	IV	*	*O	*	*	*	*
Flag 20	N/A	IV	*	*O	*	*	*	*
Flag 21	N/A	IV	IS	SSO	SS	SS	SS	SS
Flag 22	N/A	IV	CS	ICO	IS	IS	IV	*
Flag 23	N/A	IV	CS	CVO	CS	CC	CS	CS
Flag 24	N/A	IV	CC	CCO	CC	CC	CC	CC
Flag 25	N/A	IV	CC	CCO	CV	CC	CC	CC
Flag 26	N/A	IV	SS	SSO	SS	SS	SS	SS
Flag 27	N/A	IV	IC	*O	IC	IC	IC	IC
Flag 28	N/A	IV	*	*O	*	*	*	*
Flag 29	N/A	IV	*	*O	*	IS	*	*
SYS. FLAGS								
Flag 31	N/A	*	*	*O	*	*	*	*
Flag 48	N/A	CC	CC	CCO	CC	CC	CC	CC
Flag 55	N/A	##	##	##O	##	##	##	##

SYMBOL KEY

U = UNITS CONTROL IS DEFENDANT ON STATUS.
S = FLAG MUST BE SET.
C = FLAG MUST BE CLEAR.
* = NOT USED OR IF IN COMBINATION NOT CHANGED.
I = STATUS IS NOT IMPORTANT.
V = FINAL STATUS IS VARIABLE.
# = STATUS IS CRITICAL TO ROUTINE RESPONSE.
O = FLAG WILL BE OPERATED ON DURING THE ROUTINE.

NOTES:-

1. THE FIRST SYMBOL RELATES TO THE REQUIRED STATUS AT INITATION.
THE SECOND SYMBOL RELATES TO THE FINAL STATUS AT TERMINATION.

2. THE 'MSTR' ROUTINE DOES NOT RESET FLAGS AT THE END OF THE ROUTINE. THE STATUS IN THE SECOND COLUMN FOR THIS FUNCTION REFERS TO THE STATUS WHEN IT EXECUTES THE MAIN PROGRAMME.

SUMMARY

Registers 0–1	Unused by Module.
Register 2–7	Module Programme control and operation.
Registers 8–20	Well Geometry individual section data and summation data – working Registers.
Registers 21–28	Working Registers for Module operation.
Registers 29–42	Unused in ★OILWELL 1 operations but dedicated to use in future modules.
Register 43	Stored value of Total Pipe Pressure Loss as obtained from a Code 3 operation.
Register 44	Stored value of Total Annulus Pressure Loss as obtained from a Code 3 operation.
Register 45	Stored value of Total Pipe or Annulus and Surface System Pressure Loss as obtained from a Code 3 operation.

NOTE: All the above Registers may be used by the User in personal programmes etc. The contents of these registers prior to a Module Code Operation are generally immaterial to the operation of the function. However the presence of 'ALPHA' Data in some registers may cause a display of 'ALPHA DATA' and stop module operation. This can be corrected by:

Either

1. Setting Flag 25 and pressing R/S

Or

1. Pressing: 'XEQ'; 'ALPHA'; 'C','L','R','G'; 'ALPHA';
2. Then reloading ★MDATA and ★WDATA.

The Module is designed to allow the User to run HP67/97 programmes without interference to its operation.

Data contained in **Registers 46–136** (inclusive) should be regarded as data **ESSENTIAL** to module operation. All the data is either loaded from data cards or stored during module operation, except Registers R.100–R.104.

Registers 46–99	Used for storage of **MASTER DATA**, ★MDATA. Information includes conversion factors, data labels, "KEY" information. The data in these registers **MUST** be correct at each Code operation. Modification to the data can be made by the User in creation of specific alternative units selections. (See:- "Units Selection").
Registers 100–104	Data used in Flag Control operations and Well Geometry usage control. This data is **not** stored with either ★MDATA or ★WDATA.

Registers 105–136 Used for storage of **WELL GEOMETRY DATA, ★**WDATA. Data comprises Rheology, Flow Rate, Mud Weight, Hole and Pipe information.

NOTE: The User must be very careful in using registers 46–136 (inclusive) as incorrect data in these registers can cause the module to give invalid outputs. The module is designed to check the contents of registers 99 & 136. The idea being that if the User plans to use any of the registers 46–136 then ZERO (0) can be stored in 99 and/or 136 as an indication to the module that the ★MDATA and/or ★WDATA requires re-entering either automatically from 'X-FUNCTIONS MEMORY' or from a data card or manually.

Registers 137–150 Used during module operations for storage of **ACTIVE** Well Geometry Data.

GENERAL NOTES ON REGISTER USAGE

1. Between ★OILWELL 1 operations Register 00–45 may be used freely.

2. Following module operation certain data calculated by the function may be available in Registers 08–45.

3. Data contained in registers 46–136 is vital to module operations and these registers should only be used with proper precautionary measures.

4. A print out of register contents may be obtained by execution:-

   Either
   1. 'XEQ' 'ALPHA' 'P','R','R','E','G', 'ALPHA'

   Or
   1. Enter **S**tarting and **F**inishing Register numbers in the form 'SSS.FFF' into the X-REGISTER.
   2. Press 'XEQ', 'ALPHA', 'P', 'R', 'R', 'E', 'G', 'X', 'ALPHA'

5. Data stored in Registers 02–045 prior to operation of a function Code will most likely be lost during the operation of the Code routine.

6. Further details on use of data registers is given in the section related to use of module catalogue functions (Pages 22.01–22.08).

★OILWELL 1 Register Usage

R. No	CONTENT	R. No	CONTENT	R. No	CONTENT	R. No	CONTENT	R. No	CONTENT
0/1	USER	31		61	9-714263 −4	91	LBS.	121	H – L:DIA. 6
2	CODE OPS.	32		62	O.D.	92	DA.N.	122	H – L:DIA. 7
3	SEC NO/KEYOP	33		63	I D.<P>	93	SURF. _	123	H – L:DIA. 8
4	UNITS Control	34		64	I D.<C>	94	DATA ★	124	P – L:O.D. 1
5	Data Labelling	35		65	CAP	95	HOLE _	125	P – L:O.D. 2
6	CALCS. Control	36		66	VOL	96	PIPE _	126	P – L:O.D. 3
7	CALCS. Control	37		67	VEL	97	ANN. _	127	P – L:O.D. 4
8	LENGTH H.P.A.	38		68	DISP	98	DEPTH	128	P – L:O.D. 5
9	L.DIA. H.P.A.	39		69	VOL.D	99	_ SETS	129	P – L:O.D. 6
10	L.O.D. P	40		70	Vn/Sec	100 00	DEPTH/CALC.D	130	P-I.D. P-C 1
11	I D<P><C> ΣX	41		71	Wt/U.L	101 01	X<>F CONTROL	131	P-I.D.P-C 2
12	CAP.H.P.A. ΣX²	42		72	Q RATE	102 A	STOFLAG CONTROL	132	P-I.D.P-C 3
13	VOL H.P.A. ΣY	43	Σ PIPE PRES.	73	VARIABLE ALPHA DATA	103 B	ACTIVE HOLE CONTROL	133	P-I.D.P-C 4
14	DISP. P. ΣY²	44	Σ ANN. PRES.	74	P/GRD=	104 C	ACTIVE PIPE CONTROL	134	P-I.D.P-C 5
15	V. DISP. P. ΣXY	45	ΣP/A.+ SURF.PR	75	LENGTH	105 D	Q – RATE	135	P-I.D.P-C 6
16	WTA. P. n	46	CURRENT DEPTH	76	FEET.	106 E	P.P.G.	136	OPS. CONTROL
17	Σ WTA. P.	47	No. old nozzles	77	MTRS.	107 F	BUOYANCY FACTOR	137	ACTIVE H. 1
18	Σ VOL. D. P.	48	NOZ.	78	DIA	108 G	hi.n	138	ACTIVE H. 2
19	ΣVOL. H.P.A.	49	RIGHT	79	INS.	109 H	HI.K	139	ACTIVE H. 3
20	VEL. P.A.	50	7.66990394 −4	80	M.MTR.	110 I	n	140	ACTIVE H. 4
21	(mud wt)	51	7.4569987 −1	81	VOL	111 J	K	141	ACTIVE H. 5
22	(buoyancy)	52	2.450408401 −2	82	BBL.	112	MODULE OPERATIONS	142	ACTIVE H. 6
23	CALCS.	53	6.544438248 +1	83	C.MTR.	113	CALCS.	143	ACTIVE H. 7
24	Σ PRES.	54	1.6128 −1	84	MUD WT	114	CH/K DATA.	144	ACTIVE H. 8
25	CALCS. CVT	55	3.048 −1	85	P.P.G.	115	SURF DATA.	145	ACTIVE P. 9
26	Pcal. CVL	56	2.54 +1	86	S.G.	116	H – L:DIA. 1	146	ACTIVE P. 2
27	Pcal. Vs/s.	57	1.589872949 −1	87	PRES	117	H – L:DIA. 2	147	ACTIVE P. 3
28	Pcal. V.act	58	1.198264274 -1	88	P.S.I.	118	H – L:DIA. 3	148	ACTIVE P. 4
29		59	6.894757293 −2	89	BARS.	119	H – L:DIA. 4	149	ACTIVE P. 5
30		60	4.448221615 −1	90	WT	120	H – L:DIA. 5	150	ACTIVE P. 6

Notes

The Tables given in this section are designed to give the User assistance in making use of the Catalogue Functions.
Where a Function makes use of other routines the User will need to check the Register requirements of these additional routines.
It is stressed that the User should always carefully check that data used and output by all the routines is as expected.
Very careful consideration must also be given to the **Units** that data is represented in as individual use of Catalogue Functions will normally handle Units according to the status of Flags 00-04 **at the time** that the **routine is called.**

CATFREG	PRGM.CALLS TO:-	OP.TIMES	S.LEVELS	DATA RECALL FROM:-	REGISTERS USED:-	DATA STORED IN:-
'1'	[DOP0 DOP1 DOP2] [DOP3 DOP4 DOP5] [DOP6 DOP7] MST1 MST2 UNIT PRES ADJD C	VARIABLE	ALL CODES:-3	02 - OPERATING CODE 53 - *MDATA 57 - *MDATA 60-69 - *MDATA 75 - *MDATA 90 - *MDATA 95 - *MDATA 96 - *MDATA 97 - *MDATA 103 - ACTIVE H.CONTOL 104 - ACTIVE P.CONTROL 105-150 - *WDATA	STACK 02 - INDIRECT GOTO 03 - SECTION NUMBER 05 - DATA LABELING 06 - ACTIVE H.CONTROL 07 - ACTIVE P.CONTROL 08-20 - CALCULATIONS d - FLAG CONTROL M - CALCULATIONS N - FLAG CONTROL O - FLAG CONTROL ALPHA	08-16 - LAST SECTIONS DATA 17-19 - SUMMATION DATA 20 - FLUID VELOCITY 105 - Q-RATE N - DOP7 COLUMN HEIGHT
'DOP0' 'DOP1' 'DOP2' 'DOP3'	[DOP1 DOP2 DOP3] [DOP4 DOP5 DOP6] MST1 MST2 UNIT PRES	VARIABLE VARIABLE VARIABLE VARIABLE	3 (F.10 CLR) 4 (F.10 SET)	53 - *MDATA 60-69 - *MDATA 75 - *MDATA 90 - *MDATA 95 - *MDATA 96 - *MDATA 97 - *MDATA 103 - ACTIVE H.CONTOL 104 - ACTIVE P.CONTROL 105-150 - *WDATA	STACK 03 - SECTION NUMBER 05 - DATA LABELING 06 - ACTIVE H.CONTROL 07 - ACTIVE P.CONTROL 08-20 - CALCULATIONS d - FLAG CONTROL M - CALCULATIONS N - FLAG CONTROL O - FLAG CONTROL ALPHA	08-16 - LAST SECTIONS DATA 17-19 - SUMMATION DATA 20 - FLUID VELOCITY
'DOP4'	[DOP5] MST1 UNIT PRES	VARIBLE	2 (F.10 CLR) 3 (F.10 CLR)	03 - SECTION NUMBER 06 - ACTIVE H.CONTROL 07 - ACTIVE P.CONTROL 23 - Q-RATE 53 - *MDATA 60-69 - *MDATA 75 - *MDATA 90 - *MDATA 105-150 - *WDATA	STACK 03 - SECTION NUMBER 05 - DATA LABELING 06 - ACTIVE H.CONTROL 07 - ACTIVE P.CONTROL 08-20 - CALCULATIONS d - FLAG CONTROL M - CALCULATIONS N - FLAG CONTROL O - FLAG CONTROL ALPHA	08-16 - LAST SECTIONS DATA 17-19 - SUMMATION DATA 20 - FLUID VELOCITY

CATFREG	PRGM.CALLS TO:-	OP.TIMES	S.LEVELS	DATA RECALL FROM:-	REGISTERS USED:-	DATA STORED IN:-
'DOP5'	MST1 UNIT PRES	VARIBLE	2 (F.10 CLR) 3 (F.10 SET)	03 - SECTION NUMBER 06 - ACTIVE H.CONTROL 07 - ACTIVE P.CONTROL 09 - HOLE L.DIA 10 - FIRST PIPE L.OD 11 - FIRST ID.(P).ID.(C) 23 - Q-RATE 53 - *MDATA 60-69 - *MDATA 75 - *MDATA 90 - *MDATA 105-150 - *WDATA	STACK 03 - SECTION NUMBER 05 - DATA LABELING 06 - ACTIVE H.CONTROL 07 - ACTIVE P.CONTROL 08-20 - CALCULATIONS d - FLAG CONTROL M - CALCULATIONS N - FLAG CONTROL O - FLAG CONTROL ALPHA	08-16 - LAST SECTIONS DATA 17-19 - SUMMATION DATA 20 - FLUID VELOCITY
'DOP6'	[DOP5]MST1 UNIT PRES	VARIABLE	3 (F.10 CLR) 4 (F.10 SET)	03 - SECTION NUMBER 06 - ACTIVE H.CONTROL 07 - ACTIVE P.CONTROL 09 - HOLE L.DIA 10 - FIRST PIPE L.OD 11 - FIRST ID.(P).ID.(C) 23 - Q-RATE 53 - *MDATA 60-69 - *MDATA 75 - *MDATA 90 - *MDATA 105-150 - *WDATA	STACK 03 - SECTION NUMBER 05 - DATA LABELING 06 - ACTIVE H.CONTROL 07 - ACTIVE P.CONTROL 08-20 - CALCULATIONS d - FLAG CONTROL M - CALCULATIONS N - FLAG CONTROL O - FLAG CONTROL ALPHA	08-16 - LAST SECTIONS DATA 17-19 - SUMMATION DATA 20 - FLUID VELOCITY
'DOP7'	[DOP4 DOP5 DOP6]	VARIBLE	3	X - VOLUME 23 - Q-RATE 53 - *MDATA 103 - ACTIVE H.CONTOL 104 - ACTIVE P.CONTROL 105-150 - *WDATA	STACK 03 - SECTION NUMBER 05 - DATA LABELING 06 - ACTIVE H.CONTROL 07 - ACTIVE P.CONTROL 08-20 - CALCULATIONS d - FLAG CONTROL M - CALCULATIONS N - FLAG CONTROL O - FLAG CONTROL	08-16 - LAST SECTIONS DATA 17-19 - SUMMATION DATA 20 - FLUID VELOCITY N - COLUMN HEIGHT

CATFREG:	PRGM.CALLS TO:-	OP.TIMES	S.LEVELS	DATA RECALL FROM:-	REGISTERS USED:-	DATA STORED IN:-
'PRES'	UNIT	VARIABLE	2 (F.09 SET) 3 (F.09 CLR)	08 - SECTION LENGTH 09 - HOLE L.DIA 10 - PIPE L.OD 11 - PIPE ID.<P>.ID.<C> 20 - FLUID VELOCITY 24 - TOTAL PRESSURE LOSS 27 - S-SWAB VEL. ADJST. (ONLY USED IF F.12 SET) 55 - *MDATA 87 - *MDATA 106 - *WDATA 108-111 - *WDATA	STACK 02&05 - CALCULATIONS 12-16 - CALCULATIONS 24-26 - CALCULATIONS 28&73 - CALCULATIONS d - FLAG CONTROL 0 - FLAG CONTROL M - CALCULATIONS ALPHA	X - SECT.PRES. LOSS (F.9 SET) 15 - SECT.PSI/FT (F.9 SET) 24 - CUMULATIVE PRES. LOSS 25 - TURB. CRITICAL VEL. 26 - LAMINAR CRITICAL VEL.
'MSTA' 'MSTB'	MSTF AIPT 13	VARIABLE	2	X - INPUT CODE 99 - *MDATA CHECK 101 - UNITS FLAG CONTROL 136 - *WDATA CHECK	STACK 02 - CALCULATIONS d - FLAG CONTROL M - LOGO OUTPUT ALPHA	02 - OPERATING CODE 03&73 - CLEARED 102 - FLAG CONTROL CODE
'MSTO'	NA	8.8 SEC	0	75-92 - *MDATA	03&04 - CALCULATIONS 101 - UNITS FLAG CONTROL ALPHA	NONE
'MST1'	NA	2.0 SEC	0	03 - SECTION NUMBER	ALPHA	NONE
'MST2'	NA	1.9 SEC	0	X - INDIRECT REG. RECALL ? - RECALLED REG. BY R.X 94 - *MDATA	X - INDIRECT RECALL ALPHA	NONE
'MSTF'	NA	1.5 SEC	0	102 - FLAG CONTROL	X&Y - CALCULATIONS d - FLAG CONTROL	NONE

CATFREG:	PRGM.CALLS TO:-	OP:TIMES	S.LEVELS	DATA RECALL FROM:-	REGISTERS USED:-	DATA STORED IN:-
'3'	1 DOP1 DOP5 DOP6 MST2 PRES UNIT NIPT A C	VARIBLE	3 (CODE 3.8) 4 (PIPE CALCS) 5 (ANN. CALCS)	02 - OPERATING CODE 57 - *MDATA 61 - *MDATA 87 - *MDATA 100 - LAST DEPTH/CALC.D 105-150 - *WDATA	STACK 02 - CALCULATIONS 04 - CALCULATIONS 08 - CALCULATIONS 09 - HOLE L.DIA 10 - PIPE L.OD 11 - PIPE ID.<P>.ID.<C> 20 - FLUID VELOCITY 23 - Q-RATE 24 - .PRESSURE LOSS 27 - VEL. CORR. S-SWAB ALPHA	24 - PRES.LOSS P/A+SURF.+CH/K 43 - PIPE PRES. LOSS 44 - ANNULUS PRES. LOSS 45 - PIPE or ANN.+SURF. PRES.
'7'	AIPT NIPT UNIT A D E	VARIBLE	2	02 - OPERATING CODE 55 - *MDATA 57 - *MDATA 58 - *MDATA 59 - *MDATA 60 - *MDATA 74 - *MDATA 81 - *MDATA 84 - *MDATA 90 - *MDATA 93 - *MDATA 98 - *MDATA	STACK 02 - INDIRECT GOTO 06-15 - CALCULATIONS 17-18 - CALCULATIONS 21-22 - CALCULATIONS ALPHA	VARIBLE DEPENDING ON CODE
'8'	DOP4 NIPT UNIT ADJD A	VARIABLE	3	02 - OPERATIONS CODE 46 - DEPTH 53 - *MDATA 105-150 - *WDATA	STACK 02 - INDIRECT GOTO 05 - CALCULATIONS 06-07 - ACTIVE PIPE CTRL 08 - CALCULATIONS 16-17 - CALCULATIONS 21-22 - CALCULATIONS 24-28 - CALCULATIONS M - CALCULATIONS N - CALCULATIONS ALPHA	Y - WORK DONE (METRIC) X - WORK DONE (ENGLISH)

CATFREG	PRGM.CALLS TO:-	OP.TIMES	S.LEVELS	DATA RECALL FROM:-	REGISTERS USED:-	DATA STORED IN:-
'9'	MST1 MST2 AIPT NIPT UNIT A	VARIABLE	4	02 - OPERATING CODE 62-64 - #MDATA 73&75 - #MDATA 93 - #MDATA 95-96 - #MDATA	STACK 02 - INDIRECT GOTO 03 - SECTION NUMBER 04 - SECTION LENGTH CHK. 05 - PIPE ID. STORAGE 06 - STORE H/P L.DIA/ID 15 - PIPE ID.(C) DEFAULT 26 - DEPTH CHK.& STORAGE 47 - DEPTH CHECK M - CALCULATIONS ALPHA	114 - CH/K LINE L.ID.(P) 115 - SURF. SYS. L.ID.(P) 116-123 - HOLE L.DIA 124-129 - PIPE L.OD 130-135 - PIPE ID.(P).ID.(C) 136 - #WDATA DEPTH CHECK
'10'	A B D E F	VARIABLE	2 (CODES 1&2) 3	53 - #MDATA 61 - #MDATA 71 - #MDATA 96 - #MDATA	STACK 03-15 - CALCULATIONS 03-15 - CALCULATIONS 18 - 0.3048 (#FT - M) 19 - 25.4 (#INS - MM) 20 - 0.444822 (#LBf-DaN) ALPHA	VARIABLE DEPENDING ON CODE
'11'	AIPT NIPT UNIT NOZA C D E	VARIABLE	2	02 - OP. CODE & CALCS. 48-52 - #MDATA 54 - #MDATA 56-57 - #MDATA 59 - #MDATA 70 - #MDATA 72 - #MDATA 87 - #MDATA 99 - #MDATA	STACK 02 - INDIRECT GOTO 03-28 - CALCULATIONS 47 - NO. OLD NOZZELS d - FLAG CONTROL M - CALCULATIONS N - CALCULATIONS O - FLAG CONTROL ALPHA	04 - LAST NOZZEL VELOCITY 08 - NO. NOZZELS IN NEW BIT 17 - POWER LAW COSTANT (a) 18 - POWER LAW INDEX (b) 19 - COEF. OF DETERMINATION 20 - MAX. SYSTEM PRESSURE 21 - MUD WEIGHT 22 - LAST BIT PRESSURE LOSS 23 - LAST FLOW RATE USED 26 - Q.RATE FOR MAX.HP/IF 27 - Q.RATE FOR MAX.POWER 28 - Q.RATE FOR MAX.IF 47 - NO. NOZZELS IN OLD BIT

CATFREG	PRGM.CALLS TO:-	OP.TIMES	S.LEVELS	DATA RECALL FROM:-	REGISTERS USED:-	DATA STORED IN:-
'12'	AIPT NIPT UNIT NOZA A B C D F	VARIABLE	NA	48-61 - *MDATA 65&67 - *MDATA 70&72 - *MDATA 84 - *MDATA 95-97 - *MDATA 99 - *MDATA 101 - UNITS FLAG CONTROL 102 - FLAG CONTROL	STACK 06 - CALCULATIONS 08-14 - CALCULATIONS d - FLAG CONTROL M - CALCULATIONS ALPHA	X - LAST CALCULATED VALUE 06 - NOZZEL AREA 10 - Q-RATE 11 - BIT PRESSURE LOSS 12 - MUD WEIGHT
'NOZA'	NIPT	VARIABLE	1	08 - NUMBER OF NOZZELS 48 - *MDATA 50 - *MDATA 56 - *MDATA	STACK 06 - CALCULATIONS	ALPHA - 'NOZ.A'
'13'	AIPT NIPT UNIT A D	VARIABLE	1 (CODE 2) 2 (CODE 0,1&4) 3 (CODE 3)	48&49 - *MDATA 56&59 - *MDATA 99 - *MDATA	STACK 02 - INDIRECT GOTO 06 - CALCULATIONS 08-11 - CALCULATIONS 15&16 - CALCULATIONS 25&26 - CALCULATIONS ALPHA	106 - MUD WEIGHT 107 - BUOYANCY FACTOR 108 - 'hi.n' POWER LAW INDEX 109 - 'HI.K' POWER LAW CONST. 108 - 'n' POWER LAW INDEX 109 - 'K' POWER LAW CONSTANT
'ADJD'	A	4.1 (0) VAR(1,2,3)	1 (0) 2 (1,2,3)	X - OPERATING CODE 46 - DEFAULT BIT DEPTH (REQD. FOR CODES 0&3) 55 - *MDATA 98 - *MDATA 100 - CALC.D (CODE 0 ONLY) 103 - ACTIVE H.CONTROL (REQD. FOR CODES 0&3) 104 - ACTIVE P.CONTROL (REQD. FOR CODES 0&3)	STACK 08 - CALCULATIONS 13 - OPERATING CODE 26 - CALCULATIONS 46 - BIT DEPTH 100 - BIT DEPTH/CALC.D d - FLAG CONTROL M - CALCULATIONS N - CALCULATIONS ALPHA	Y - ACTIVE H.CONTROL Z - ACTIVE P.CONTROL 06 - ACTIVE H.CONTROL 07 - ACTIVE P.CONTROL 09 - 1ST.HOLE L.DIA 10 - 1ST.PIPE L.OD 46 - CURRENT BIT DEPTH 100 - BIT DEPTH or CALC.D 103 - ACTIVE H.CONTROL 104 - ACTIVE P.CONTROL

CATFREG	PRGM.CALLS TO:-	OP.TIMES	S.LEVELS	DATA RECALL FROM:-	REGISTERS USED:-	DATA STORED IN:-
'A'	NIPT UNIT	VARIABLE	1	55 - *MDATA	STACK & ALPHA	FOR 'A','B','C','D','E','F' RESULTS ARE IN:-
'B'	NIPT UNIT	VARIABLE	1	56 - *MDATA	STACK & ALPHA	X&04 - ENG.UNITS (F.8 CLR)
'C'	NIPT UNIT	VARIABLE	1	57&72 - *MDATA	STACK & ALPHA	04 - ALTERNATIVE UNITS (F.08 SET)
'D'	NIPT UNIT	VARIABLE	1	58&84 - *MDATA	STACK & ALPHA	
'E'	NIPT UNIT	VARIABLE	1	59 - *MDATA	STACK & ALPHA	
'F'	NIPT UNIT	VARIABLE	1	60 - *MDATA	STACK & ALPHA	
'AIPT'	NIPT	VARIABLE	0	ALPHA	STACK	Y - 'Y' X - INPUT STRING
'NIPT'		VARIABLE	0	ALPHA	STACK	X&Y - INPUT VALUE
'UNIT'	NA	VAR(F8SET) 1.8(F8CLR)	0	55-60 - *MDATA BY UNITS	STACK 04 - CALCULATIONS 05 - DATA LABEL RECALL ALPHA	X - INPUT IN ENG.UNITS (FLAG 08 CLEAR) 04 - INPUT IN ENG.UNITS (FLAG 08 CLEAR) 04 - OUTPUT IN ALT.UNITS (FLAG 08 SET) 05 - ORIG.VALUE PLUS 1
'*FC'	NA	VARIABLE	0	Z - FLAG CODE NUMBER Y - LOW NUMBERED FLAG X - HIGH NUMBERED FLAG	STACK 0 - CALCULATIONS	X - CLEARED
REGMOVE	NA	VARIABLE	0	X - SSS.DDDNNN	X - SSS.DDDNNN	X - SSS.DDDNNN
REGSWAP	NA	VARIABLE	0	X - SSS.DDDNNN	X - SSS.DDDNNN	X - SSS.DDDNNN
X<>F	NA	1.27SEC	0	X - FLAG CODE	X - FLAG CODE	X - FLAG CODE
PSIZE	NA	2.47SEC	0	X - REQUIRED NUMBER REGS	X - REQUIRED NUMBER REGS	X - REQUIRED NUMBER REGS

NOTES:-

1. WHERE SUB-ROUTINES ARE CALLED, THEIR USE OF REGISTERS SHOULD ALSO BE CHECKED.
2. PROVIDING THAT REGISTERS R.46-R.150 ARE MAINTAINED FOR THE USE OF *MDATA/*WDATA/STATUS DATA THEN RECALL OF DATA FROM THESE REGISTERS WILL NORMALLY BE THE REQUIRED DATA.

CALCULATION OF EQUIVALENT LENGTH VALUES FOR STANDPIPE AND KILL/CHOKE LINE SYSTEMS

Introduction

To aid in the calculation of Pressure Losses in a rig's permanently installed sections of the Circulating System, it is convenient to utilize the concept of **equating** such sections with the **fixed length** of a **Single Straight Pipe** of **Specified Diameter**. This **fixed length** is chosen such that the Pressure Loss occuring when pumping through it at a **Specified Flow Rate** will be the **same** as would occur in the **Actual System.** This **fixed length** of Pipe is referred to as the **EQUIVALENT LENGTH** of Pipe of **Specified Diameter** for the Actual System concerned. It should be necessary to establish the **EQUIVALENT LENGTH** for a given section of the Circulating System of a rig **only once.**

It must be understood that the use of an **EQUIVALENT LENGTH** for a **Specified Diameter** is only an **approximation** aimed at giving usable Pressure Loss results for the part of the system concerned. Strictly an **EQUIVALENT LENGTH** should be established for **each Flow Regime** – Turbulent, Transitional and Laminar, but it is proposed here that, with consideration of the normal I.D.s and Lengths of the parts of the system involved, only the **EQUIVALENT LENGTHS** based on the Turbulent Flow need be established.

The selection of the **Specified Diameter** is not too critical, but it should be chosen to be close to the I.D.'s of the Actual Pipe in the system. The following examples use a **Specified Diameter** of 3" and since it relates to pressure calculation it is referred to by the 'ID.< P >' mnemonic.

It should be clearly understood that this value will **NOT** give accurate **VOLUME DATA** related to the system.

METHODS OF EQUIVALENT LENGTH CALCULATION

Two methods are available for the calculation of **EQUIVALENT LENGTHS** of Surface and Kill/Choke Line Systems. In using either method it should be noted that Flow Rates used should be such as to ensure Turbulent Flow in the system in question. A check on this for calculated values can be made by observing the prefix attached to the Data Label '__.PRES=' for the Pressure Loss Output Data obtained using the module.

METHOD 1 – CIRCULATION TEST

In this method Drilling Fluid of **known** Mud Weight and Rheology is circulated around the System in question (e.g. down the Kill/Choke Line and back up the Riser or through the Kelly with it in the Rotary Table and with no Drill String attached).

The Mud Engineer should supply the necessary data to be used for a Code 13 Rheology Input using the ★OILWELL 1 Module.

Proceed as follows:

1. With the circulating system set up, **Record** the **PRESSURE LOSSES (ΔP_r)** that result from circulating at **FOUR** different **FLOW RATES.**
Use the pump stroke counter and Choke Manifold or Stand-pipe Pressure Gauge as appropriate to take the readings and record them as accurately as possible.
The **FLOW RATES** used should be within the normal operating range in which Turbulent Flow would be expected (say >4BBl/Min).

2. For **each** of the **Flow Rates** use the ★OILWELL 1 Module, Code 3.8, to calculate the resulting **Pressure Loss (ΔP_c)** when circulating through 1000 Length Units (R/S default value in response to **'LENGTH?='** Prompt) of Pipe of Internal Diameter ID.< P > = 3" (or User specified value).

3. Use these 'ΔPr' and 'ΔPc' values to calculate the **EQUIVALENT LENGTHS** 'L_e' for each **Flow Rate** using the following equation:

$$L_e = \frac{\Delta P_r}{\Delta P_c} \times 1000$$

4. **Average** the four 'L_e' values obtained, by adding all four values and dividing by four. This will give the **EQUIVALENT LENGTH** of the Pipe of Internal Diameter ID.< P >as used to calculate the 'ΔPc' values of the system in question.

A small table like the one following can be used to assist in the calculation:

	A	B	C	D
	FLOW RATE BBl/MIN	**MEASURED PRESSURE LOSS ΔP_r P.S.I.**	**CALCULATED ΔP_c FOR 1000' OF PIPE P.S.I.**	**EQUIVALENT LENGTH' B/C x 1000**
1	4			
2	8			
3	12			
4	16			

$$\text{AVERAGE EQUIVALENT LENGTH} = \left(\frac{D1 + D2 + D3 + D4}{4}\right)$$

Ideally the values of **EQUIVALENT LENGTHS** obtained should be equal for each **FLOW RATE providing that** the **Flow Regimes** remain the **same.** Any results that are significantly different should be re-checked or discarded.
A change in Flow Regimes will probably be the cause of any significant variations.

> **NOTE:** Prior to operating Code 3.8 to obtain the above results the Rheology **must** have been adjusted to the specifications of the Mud in use in the test using a Code 13 Function.

METHOD 2 – SYSTEM MEASUREMENT

This method requires the use of accurate drawings of the System in question giving Lengths and Dimensions of the system components. Then, using the Table on page A.06 where necessary, a list of **EQUIVALENT LENGTHS** of each System Component is put together.
The **Total Pressure Loss** of the System 'ΔP_S' for a given, arbitrary **Flow Rate** and set of **Rheology Data** is then **calculated** as the sum of the Pressure Losses in all of the component parts.

These Pressure Losses are calculated using the ★OILWELL 1 Module Code 3.8 (or alternatively using Code 9.1 followed by Code 3.1 or 3.4).

Having obtained this **Total Pressure Loss** the User calculates the Pressure Loss 'ΔP_C' using Code 3.8 again for 1000 Length Units of Pipe using the **same Flow Rate** and the **required Specified Diameter** to be used for the **EQUIVALENT LENGTH.**

The **EQUIVALENT LENGTH** 'L_e' is then calculated using:

$$L_e = \frac{\Delta P_s}{\Delta P_c} \times 1000$$

Where:
'ΔP_S' = The **Total System Pressure Loss** as calculated from the **summation** of **Pressure Losses** for a given **Flow Rate** for **each** component part of the System.

'ΔP_C' = The **Pressure Loss** per 1000 length units of Pipe of **Specified Diameter** at the **same Flow Rate** used to calculate 'ΔP_s' with the same Drilling Fluid.

'L_e' = The **EQUIVALENT LENGTH** of Pipe of **Specified Diameter** ID.< P>for the System in Question.

The example on Page A.07 demonstrates the use of this Second Method.

NOTES

1. **EQUIVALENT LENGTH** values for Kill and Choke Line systems are, of course, related to **Water Depth.** It is therefore recommended that an **EQUIVALENT LENGTH** and **Specified Diameter** is calculated for the **NON-STRAIGHT** or **FIXED PORTION** of the Kill/Choke Line System. This value **will remain constant** for the rig in question and can be used at **each new location** by combining it with the **Length** of the **Straight Portion** of the Kill/Choke Line, from the Gooseneck to the Flex Joint, for that location.
The calculation of this **EQUIVALENT LENGTH** of the **FIXED PORTION** of the Kill/Choke Line System can be done using an established **EQUIVALENT LENGTH**'L_e'and **Specified Diameter** ID.< P > as obtained using Method 1. or 2. for the **Entire** Kill/Choke System at a **particular Rig location** (i.e. from B.O.P. to Choke) as follows:

1. Use the computer, Code 3.8, to establish the Pressure Loss 'ΔP_t' at a given **Flow Rate** for the established **EQUIVALENT LENGTH.**

2. Use the computer, Code 3.8, to establish the Pressure Loss 'ΔP_s' in the **Straight Portion** of the Kill/Choke Line (i.e. gooseneck to flex joint) for the given **Flow Rate.**

3. Deduct the result in 2, from the result in 1, to establish the **Pressure Loss** ('ΔP_t − 'ΔP_s') in the remainder or **FIXED PORTION** of the System.

4. Calculate the **EQUIVALENT LENGTH** for this **FIXED PORTION** of the System as follows:

$$L_f = \frac{(\Delta P_t - \Delta P_s)}{\Delta P_t} L_e \quad \text{Equation 1}$$

Where:

'L_f' = The **EQUIVALENT LENGTH** of the **FIXED** PORTION, i.e. non straight section, of the Kill/Choke Line System.

'L_e' = The **EQUIVALENT LENGTH** of the **Entire** Kill/CHOKE Line System of **Specified Diameter** ID.< P >.

'ΔP_t' = The **PRESSURE LOSS** at the given **Flow Rate** (Turbulent Flow) in the **Entire** Kill/Choke Line System.

'ΔP_s' = The **PRESSURE LOSS** at the given **Flow Rate** (Turbulent Flow) in the **Straight Portion** (Gooseneck to Flex Joint) of the Kill/Choke Line System.

This **EQUIVALENT LENGTH** 'L_f' value for the **Specified Diameter** will be a **constant value** for the rig in question.

Using this value it will be possible to establish a new **EQUIVALENT LENGTH** for the **Entire** Kill/Choke System at **any location** by proceeding as follows:

1. Use the computer, Code 3.8, to calculate the **Pressure Loss** 'ΔP_s' in the **Straight Portion** of the Kill/Choke Line System for a given **Flow Rate.**

2. Use the computer, Code 3.8, to calculate the **Pressure Loss** 'ΔP_f' in the **FIXED PORTION** of the Kill/CHOKE Line System using the pre-determined **EQUIVALENT LENGTH** 'L_f' value and the same **Flow Rate.**

3. Calculate the **new EQUIVALENT LENGTH** 'L_e' for the **Specified Diameter** ID.$<P>$ at the new location for the **Entire** Kill/Choke Line System using the following equation:

$$L_e = \frac{(\Delta P_f + \Delta P_s)L_f}{\Delta P_f} \quad \text{(Equation 2)}$$

This procedure can be simplified by using a **constant Flow Rate** value in all computations.
i.e. 'ΔP_f', as calculated in the original computation of 'L_f' for a fixed **Flow Rate,** can be recorded **with** the 'L_f' value and can be used directly in Equation 2 providing 'ΔP_s' is calculated using that **same** fixed **Flow Rate.**

Continued .....

The following table gives some **approximated** values of **EQUIVALENT LENGTHS** for various Valves and Fittings that may be present in a System. The inclusion of the table in this Manual is to enable personnel to formulate an **approximate value** of the **EQUIVALENT LENGTH** of the System. The table **does not** give **EXACT EQUIVALENTS.**

VALVE/FITTING TYPE	STATUS	EQUIVALENT LENGTH (I.D. INCHES)	
		NOS OF PIPE I.D.s	VALUE (Ft)
GATE	FULLY OPEN	$13 \times \frac{I.D.}{12}$	1·083 x I.D.
BUTTERFLY	FULLY OPEN	$20 \times \frac{I.D.}{12}$	1·667 x I.D.
90° ELBOW	STANDARD CURVE	$30 \times \frac{I.D.}{12}$	2·5 x I.D.
90° ELBOW	SQUARE CORNERED	$50 \times \frac{I.D.}{12}$	4·167 x I.D.
90° ELBOW	LONG RADIUS CURVE	$20 \times \frac{I.D.}{12}$	1·667 x I.D.
45° ELBOW	STANDARD CURVE	$16 \times \frac{I.D.}{12}$	1·333 x I.D.
45° ELBOW	ANGLED CORNER	$26 \times \frac{I.D.}{12}$	2·167 x I.D.
180° BEND	RADIUS CURVE	$50 \times \frac{I.D.}{12}$	4·167 x I.D.
TEE	ALONG STRAIGHT	$20 \times \frac{I.D.}{12}$	1·667 x I.D.
TEE	AROUND BRANCH	$60 \times \frac{I.D.}{12}$	5 x I.D.

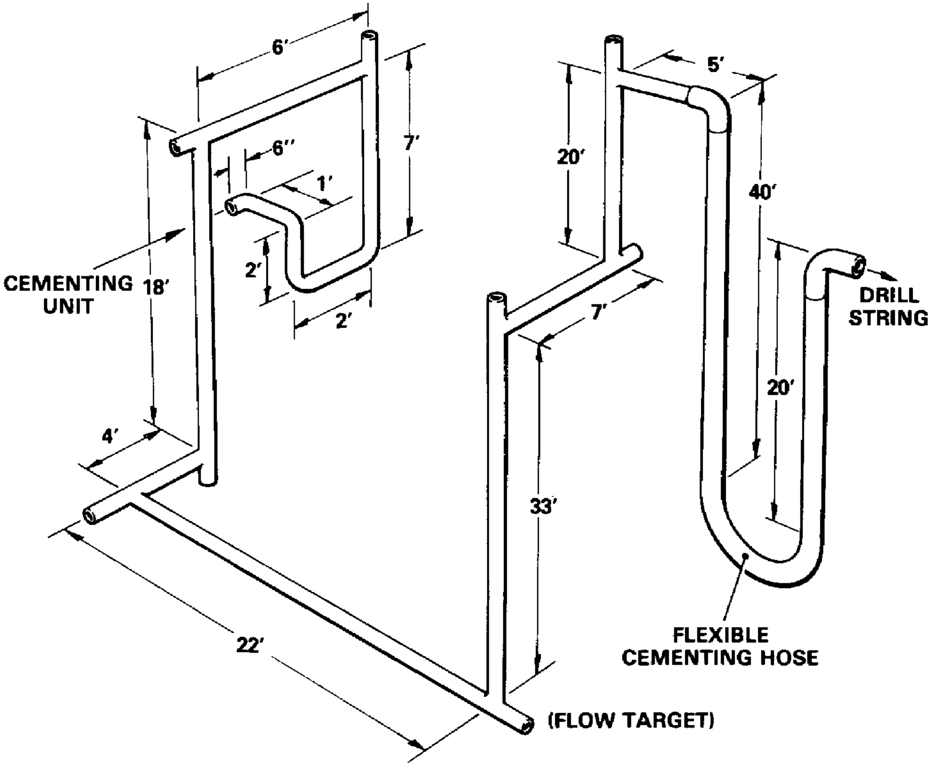
Example: determine what length of pipe of the same I.D. as a 3" 90° Square cornered Elbow will give the same Pressure Loss as the fitting for a given Flow Rate.

Look on the Table for the 90° Square Cornered elbow. The **EQUIVALENT LENGTH** is given as:

50 x the INTERNAL DIAMETER of the fitting in INCHES
which is equivalent to (50 x 3/12) = 12.5 feet.

EXAMPLE OF A METHOD 2 CALCULATION OF A CEMENTING SYSTEM EQUIVALENT LENGTH

Schematic of a Rig's Cementing Line



TOTAL PIPE WORK LENGTH = 127·5′
PIPE WORK I.D. = 2·25″
HOSE LENGTH = 75′
HOSE I.D. = 3″

Assumptions:

1. The 180^{O} bend in the Flexible Hose connection to the Drill String will be assumed to be a 180^{O} Radius Curve
   i.e. it has an Equivalent Length of (50 x I.D.) inches = (4.167 x 3) feet = 12.5′

2. The Flow Targets are assumed equivalent to standard 90^{O} Elbows i.e. the Equivalent Length of each 90^{O} Elbow and Flow Target = (30 x I.D.) inches = (2.5 x 2.25) feet = 5.625′ per Elbow or Flow Target.

3. In this example it is assumed that the **TOTAL EQUIVALENT LENGTH** for all fittings and bends etc. forms an **addition** to the **Total Measured Length** of **all** the Pipe and Hose work.
   i.e. in the case of the Hose the Pressure Loss will be calculated on 75' of hose (not 60') + the **EQUIVALENT LENGTH** of the bend 12.5'.

4. Assume the following **Mud Data** (Input using Code 13.1):

   hi.n = 0.72348 and **n** = 0.47861
   Hi.K = 0.50367 and **K** = 2.08188 LBf-Sec^n/100Sq. Ft
   Mud Weight = 9.931 p.p.g.
   Flow Rate = 5BBl/min

CALCULATION

The number of **Flow Targets** = 8.
The number of **2.25" I.D. 90° Elbows** = 4.
The number of **3.00 "I.D. 90° Elbows** = 2.

TOTAL EQUIVALENT LENGTH of **Flow Targets** and **Elbows** = (**12** x 2.5 x 2.25) + (**2** x 2.5 x 3) = 82.5' by 2.25" Pipe
TOTAL LENGTH of **Straight Pipework** = 127.5' by 2.25" Pipe
TOTAL LENGTH of **Hose** = 75' x 3.00" Hose
TOTAL EQUIVALENT LENGTH of the **180° bend** in the **Flexible Hose** = 12.5' by 3.00" Hose.

Thus:

The **TOTAL EQUIVALENT LENGTH** of 2.25" I.D. pipe = **210'**

The **TOTAL EQUIVALENT LENGTH** of 3.00" I.D.Hose = 87.5' rounded to **88'**

Operate the User Calculations Function Code 3.8 for both these Data sets to obtain the following results:
(Use a Pipe O.D. = 5.00", and the ID.< C > will equal the ID.< P > value. Ignore the Output Displacement figures).

Pressure Loss in 210 Ft of 2.25" I.D. Pipe = 67.98 p.s.i. (turbulent)
Pressure Loss in 88 Ft of 3.00" I.D. Hose = 7.79 p.s.i. (turbulent)

This gives:

TOTAL PRESSURE LOSS = **76 p.s.i.**

NOTE: At this stage the volume figures for the Pipe System could also be calculated using the Capacities output by Code 3.8 operation for each section but in this case the **actual** Pipe Length figures and **not** the **EQUIVALENT LENGTHS** must be used as the multiplication factor for the Capacity figure.

e.g.
Volume in 2.25" Pipe = 127.5' x 0.00492BBl/Ft = **0.63 BBl**
Volume in 3.00" Hose = 75' x 0.00874BBl/Ft = **0.66 BBl**

Total System volume = **+/- 1·3 BBl**

If we specify the I.D. for the **EQUIVALENT LENGTH** Pipe for the **Entire** system as **3.00"** i.e. the same as for the Hose. Then the **Pressure Loss per FOOT** for 3.00" Pipe, which equals = 7.7926/88p.s.i./ft at 5 BBl/min. will be the **same** for the **System EQUIVALENT LENGTH**.

Hence the **System EQUIVALENT LENGTH** for the example Cementing System will be:

The **Total System Pressure Loss** divided by the **Pressure Loss per Foot** in the Pipe of specified I.D.

$$= 76 \div \left(\frac{7.7926}{88}\right) = 858' \text{ of } 3.00'' \text{ I.D. Pipe.}$$

If the same calculation was done for a specified diameter of 2.25" then the **System EQUIVALENT LENGTH** would be:

$$= 76 \div \left(\frac{67.98}{210}\right) = 235' \text{ of } 2.25'' \text{ I.D. Pipe.}$$

PLANNING BIT HYDRAULICS OPTIMISATION

Code 11 Functions are basically designed to perform Hydraulics Optimisation programmes using **operational data** obtained at the **Wellsite.**

Because of the nature of Bit Hydraulics and its dependance on **System Presssure Losses,** it is stressed that **meaningful optimisations** are **BEST** performed using **Rig Data.** However, it is recognised that Hydraulics is an important aspect of Well Planning, a stage at which Rig Data is not available. In these circumstances the ★OILWELL 1 Module can effectively be used to **Synthesise** sets of Rig Floor Data. These Data Sets can be used as Input Data for the Code 11.0 Function, from which Bit Optimisation results are obtained.

To do this proceed as follows:

1. Decide on the **MUD SPECIFICATIONS** that will be used in the Section of Hole in question.

   RHEOLOGY DATA in the form of:

   a. **FANN DATA**
   or
   b. **n′** and **K′ values**
   or
   c. **PLASTIC VISCOSITY** and **YIELD POINT**

   and **MUD WEIGHT** will be required. These are entered into computer Memory using a suitable Code 13 Function.

2. For the Section of Hole in question decide on the **HOLE** and **DRILL STRING** specifications required and enter these specifications into computer Memory using the Code 9.2 Function (or Code 9.1 if only **PIPE DATA** is to be changed).

   NOTE: Because of the high versatility of the Modules **WELL GEOMETRY DATA** handling routines **exact** Bit Depths at this stage do not need to be a consideration.

3. With the **MUD DATA** and **WELL GEOMETRY DATA** in Memory, perform **either** a Code 3.0 **or** a Code 3.3 Function to calculate the **PIPE** and **ANNULUS PRESSURE LOSSES** for **two** Flow Rates. A value within the expected range of Flow Rates for the Section should be chosen for the first Flow Rate. The second Flow Rate should be chosen from a value of +/− **90%** of the **first.** In selecting the Flow Rates to be used it is important that the **FLOW REGIMES** in each Section of the **PIPE** and **ANNULUS** are the **same** for both Flow Rates. This can be checked, if Code 3.0 is used to obtain results, by checking the Prefix letter on the Pressure Loss Output Data Label "__.PRES. =".
These results will include the **Surface Data** Pressure Loss which is required in the calculation.

At this stage the use of a Record/Data Table may be advantageous. Such as:

SELECT	OBTAIN USING:–CODE 3.0 or 3.3			: CODE 12	FROM PREVIOUS 4 COLUMNS
FLOW RATE VOL/MIN	PIPE PRESSURE LOSS Pp P.S.I.	ANN. PRESSURE LOSS Pa P.S.I.	SURF. PRESSURE LOSS PSURF P.S.I.	BIT PRESSURE LOSS PBIT P.S.I.	SYSTEM PRESSURE LOSS Pp + Pa + PSURF + PBIT P.S.I.

4. Use the **"INTERACTIVE BIT HYDRAULICS" section of the ★OILWELL 1 GENERAL CALCULATIONS** Function (Code 12) to calculate the **BIT PRESSURE LOSS** (ΔP_{bit}) at each of the chosen Flow Rates and then calculate the **synthesised SYSTEM PRESSURE LOSS** for each Flow Rate as the addition of the **PIPE, ANNULUS, SURFACE** and **BIT PRESSURE LOSSES.**

   NOTE: The Nozzle Area can be any value. It is suggested that the use of **GENERAL CALCULATIONS** Function Code 12, Key **'D'** is made to input 3 x 12/32" Nozzles to give the Nozzle Area for the Key 'F' value. The Key **'D'** operation automatically stores the calculated Nozzle Area for **INTERACTIVE BIT HYDRAULICS** use. The **same** Number and Sizes of Nozzles **must** be used for input in response to Code 11.0 Prompts for the details of the Old Bit.

5. Use the same two **FLOW RATES** and their corresponding **synthesised PRESSURE LOSSES** as Input values for the Code 11.0 function. The number and sizes of Nozzles prompted for at the start of the Code 11.0 operation in relation to the 'Old Bit' **must be the same** as those previously used in calculation of the **synthesised SYSTEM PRESSURE LOSSES** for the Flow Rates used.

6. Operation of Code 11.0 will then Output the **OPTIMIZED BIT HYDRAULICS DATA** in the normal way.

The above procedure can be repeated for different Depths and differing Mud Criteria.

GENERAL NOTE

This is one example where the Module can be used in assisting in Well Planning. Many potential uses in Well Planning exist.

With this aim in mind, it may well be advantageous for a User to build/create a **library** of **WELL GEOMETRY DATA CARDS** that cater for the **WELL GEOMETRY** Specifications of all anticipated Well Situations and that can incorporate expected **MUD DATA** for each stage. Such a **library** would greatly facilitate the Input of specific WELL GEOMETRY and RHEOLOGY DATA as required. The idea of having such a library can also be extended to field use, especially when appraisal and/or development drilling is in progress.

Again the significance and power of the Module's DEPTH handling routines, which for any defined section of the well make the WELL GEOMETRY of that section **valid** for **all** DEPTHS, must be stressed.

OTHER POSSIBLE APPLICATION AREAS INCLUDE:

a. Calculation of Specific Pressure Losses/Flow Regimes for particular fluids (e.g. cements) by using the Rheology Data for the fluid Input with a Code 13 Function and performing the Code 3.0 Function for the required Depth.
Of the Data Output **only** those sections that it is known relate to the portion of the Hole that is Cement filled are used.

b. Code 3.8 can be used in many applications where **Pressure Loss** in a PIPE or ANNULUS is needed to be calculated.

c. Performing assessments of the effects of **MUD DATA** specifications on Pressure Losses and on the limitations relating to Formation Breakdown and Kick Analysis.

d. Calculation of volumes for Cement and Displacement calculations.

e. Converting data and calculated Outputs from one set of selected Units to another.
For example: if WELL GEOMETRY DATA etc. are available for a well in one set of Units, then by selecting a Unit set corresponding to these Units, the data may be input. Subsequently, by altering the Current Units set, that data may be Output in the new Current Units set. A useful feature when analysing competitors' well data.

f. Because of the accuracy of String Weight calculations when correct ID.<C> data is used, Module calculations may be beneficially used in helping to determine if and where a string has parted, especially when the original String Weight as per the Weight Indicator is in doubt.

g. By utilization of results from Pressure Loss calculations and Leak Off Test Analysis, Data can be obtained that can be very helpful in determining safe Setting Depths for Casing Strings.

g. Assessing the possible difficulties resulting in running and cementing a casing String in situations where limitations in Formation Strength make Annulus Pressure Losses critical.

FURTHER ANNULUS VOLUME CALCULATIONS WITH THE MODULE

If it is required to know the Annulus Volume **between** two sections of hole the following procedure can be adopted:

1. Use the Code 1.7 Function to determine the **Total Annulus Volume** above a specified **'DEPTH?='** Depth.

2. Use the CODE 1.9 Function to determine the **Annulus Volume** above the specified **'CALC.D?='** Depth for the same Depth as specified in (1.).

3. Deduct the result in (2.) from the result in (1.) to give the **Annulus Volume** from the first Depth to the **'CALC.D'** Depth.

4. Repeat the Code 1.9 Function to determine the **Annulus Volume** above **another 'CALC.D'** Depth for the same initial Depth.

5. Deduct the smaller of the results obtained in (2.) and (4.) from the larger to obtain the **Annular Volume** between the two **'CALC.D'** inputs.

A similar method can be used to determine **Annulus Pressure Losses** in specified sections.

> **NOTE: 'CALC.D'** when used with Standard module Function Codes **only** operates for **Annulus Mode.** It can however be used for **Pipe** (and **Hole**) **Data Modes** if accessed by the User employing Module Catalogue Functions.

An example of ★OILWELL 1 Module usage in this context follows:

EXAMPLE: Casing Cementation Volume Calculations.

1. **★HOLE DATA★**
   Section: – 1. 15,050' (TD) to 10,058' = 4965' x 12.25" Hole
   Section: – 2. 10,085' to 10,050' = 35' x 17.50" Hole
   Section: – 3. 10,050' to 395' (WH) = 9655' x 12.326" I.D. Casing
   Section: – 4. 395' to 360' (Stack) = 35' x 18.75" I.D. Stack
   Section: – 5. 360' to Surface (DF) = 360' x 20" I.D. Riser.

2. **★CASING DATA★**
   Section :'-1. 15.000' (Shoe) to 395' (WH) = 14,605' x 9.625" Casing
   Section: – 2. 395' (DP) to Surface = 395' x 5" D.P.

   Casing ID:< P > = ID.< C >= 8.671"
   D.P.ID:< P >= 4.153"; ID.< C > = 4.226" O.D. = 5.098"

3. **CEMENT REQUIREMENTS**
   Shoe Track 80'
   Tail Slurry 500' above the casing shoe
   Top of Cement at 9000'

4. **MUD DATA**
Mud Weight = 10.5 p.p.g.
Plastic Viscosity = 33 cps
Yield Point = 21 Lbf/100Ft^2

5. **SURFACE SYSTEM and C/KL DATA**
★SURF. DATA★ Length = 123′ x ID.< P >=3″
★C/KL DATA★ Length = 575′ x ID.< P >= 3″

CALCULATE the following:

1. The **WEIGHT** in Mud of the Casing String after **all** the Casing has been picked **but before** running the Landing String. Assume that the Casing is filled with mud.

2. The **VOLUMES** of Lead and Tail Slurries required.

3. The required **DISPLACEMENT FLUID VOLUME.**

Proceed as follows:
(Assumes a Code 0.4 Units Selection).

1. **USE CODE 13.3** to Input the MUD DATA

   NOTE: The use of PV and YP Data as given here is made simply to simplify the Data Input in this example as no Pressure related calculations are involved. Generally PV and YP Data for Input of Rheology are not recommended if better Data are available.

2. **USE CODE 9.2** to Input the WELL GEOMETRY DATA

   NOTE: Had the ★HOLE DATA★ already existed as part of the WELL GEOMETRY DATA as used in the Drilling Phase then the ★PIPE DATA★ only, in respect of the casing, could have been Input using a **CODE 9.1** Function.

3. **USE CODE 1.2** to calculate the STRING WT.

   To the "RHEO.OK?" Prompt respond 'Y' (R/S default)
   To the "Q RATE?=" Prompt respond 0
   To the "DEPTH?=" Prompt respond 14,605′ (Casing length)

   The computer will output:

   CASING WEIGHT in AIR = 680,672 LBf
   CASING WEIGH in MUD = 571,464 LBf

In addition note the Casing CAPACITY of 0.07304 BBl/Ft

4. **USE CODE 1.4** to calculate the HOLE, CASING and ANNULUS summation Data with the Casing landed in the WELLHEAD

To the "RHEO.OK?" Prompt respond 'Y' (R/S Default)
To the "Q.RATE?=" Prompt respond 0 (R/S Default)
To the "DEPTH?=" Prompt respond 15,000' (Casing Shoe)

The computer will output:

TOTAL HOLE CAPACITY = 2303.71 BBl
TOTAL WEIGHT in AIR of the String = 689,247 LBf
TOTAL WEIGHT in MUD of the String = 578,663 LBf
TOTAL STRING DISPLACEMENT = 250.76 BBl
TOTAL STRING CAPACITY = 1073.57 BBl
TOTAL ANNULUS VOLUME = 885.84 BBl

5. **USE CODE 1.9** to calculate the TOTAL ANNULUS VOLUME above the required T.O.C. with the Casing landed in the WELLHEAD

To the "RHEO.OK?=" Prompt respond 'Y' (R/S default)
To the "Q.RATE?=" Prompt respond 0 (R/S default)
To the "DEPTH?=" Prompt respond 15,000' (R/S default)
To the "CALC.D?=" Prompt respond 9000'

The computer will output:

ANNULUS VOLUME above 9000' = 54.93 BBl

6. **USE CODE 1.9** to calculate the TOTAL ANNULUS VOLUME above the required Top of the Tail Slurry

To the "RHEO.OK?=" Prompt respond 'Y' (R/S default)
To the "Q.RATE?=" Prompt respond 0 (R/S default)
To the "DEPTH?=" Prompt respond 15,000' (R/S default)
To the "CALC.D?=" Prompt respond 14,500'

The computer will output:

TOTAL VOLUME ABOVE 14,500' = 857.95 BBl

FROM THESE RESULTS the following Data are obtained:

1. Casing WEIGHT in Mud = 571,464 LBf

2. VOLUME of TAIL SLURRY = 885.84 − 857.95 + (80 x 0.07304)* = 33.7 BBl

   VOLUME OF LEAD SLURRY = 857.95 − 543.93 = 314.0 BBl

3. The required DISPLACEMENT FLUID VOLUME (assuming no stick up above R.T.) = 1073.57 − (80 x 0.07304)* = 1067.7 BBl

* (80 x 0.07304) = The Shoe Track Volume.

In addition the useful output of STRING DISPLACEMENT (i.e. the FLUID VOLUME to be expected as RETURNS from the running of the Casing) of 250.8 BBl should be noted.

This has been a simple example of Module application. When used with **complex strings** the benefits of the Module become more obvious.
Further expansion of usage could have included **PRESSURE LOSS** and **SURGE/SWAB** considerations by using similar CODE 3 operations instead of CODE 1 operations used in the Example.

The Pipe Specification Data given in the tables in this manual are provided specifically to allow accurate calculation of outputs involving Well Geometry Data. Thus, by using appropriate data from the tables when entering Pipe Well Geometry, it is possible to ensure accuracy of volume and weight calculations and improved pressure loss calculations.

The idea behind the tables is to simplify the way in which a calculation can account for the variations in the dimensions of a joint of pipe resulting from tool joints and pipe end preparations.

The tables are for Range II pipe only. However, the following example shows how the ID and OD values can be adjusted to give data for Range III pipe (and, with appropriate modification, for Range I pipe).

Example
It is required to know the weight/ft, capacity, displacement and equivalent ID and OD values for Range III grade X (95) 5 1/2" FH 24.70 lb/ft (nominal wt) DP with tool joint ID = 3 1/2" and OD = 7 1/4".

The average length of the range III pipe = (for example) 41.83 ft. The length of the tool joint = total length of tong space (including hard banding) +3" = 18" +3" = 21" = 1.75'.

The actual wt per/foot of the pipe body (from table) = 22.54 lb

Weight of pipe body/joint = 22.54 x (41.83 − 1.75)	=	903.403 lb
Hence weight of Tool Joint (from Table)	=	207.000 lb
Hence total weight of joint	=	1110.403 lb
Equivalent wt/ft = 1110.403/41.83	=	26.55 lb
Now since steel weighs .2833 lb/cu in	=	3919.531 cu ins/joint
The volume occupied by 1110.403 lb of steel	=	.4040 bbl/joint
Hence the **Displacement/ft** = .4040/41.83	=	**0.00966 bbl/ft**

From the table the capacity of a range II joint can be calculated as = 0.0265 bbl/ft.
Since the table is based on 28.5' of pipe body and length of tool joint as defined above.
The capacity of a range II joint = .62466 bbl/joint
The difference in length of range II from range III = (41.83 − 30.25) = 11.58'.
The capacity of 11.58' of pipe body = (11.58 x 0.021186)= 0.24534 bbl.
Hence the capacity of a joint of range III pipe = .87000 bbl
Hence the **capacity/ft** = .87/41.83 = **0.02080 bbl/ft.**
The equivalent ID/OD values can be obtained from volume/ft data by multiplying by **1029.391** and taking the square root.
i.e.:

Equivalent ID corresponding to joint capacity/foot = $(0.02080 \times 1029.391)^{1/2}$ = **4.627 ins**

Equivalent OD of a joint = $[(0.00966 + 0.02080) \times 1029.391]^{1/2}$ = **5.600 ins**

(Where (0.00966 + 0.02080) = closed end displacement/foot of joint).

EXPLANATION OF PIPE SPECIFICATION TABLE COLUMN DATA – RANGE II PIPE

Column 1 DRILL PIPE NOMINAL SIZE AND WEIGHT

Nominal Size is the outside diameter of the pipe body used in the joint.

Nominal weight is a general term for grouping of certain pipe sizes, it is not the weight per foot of the particular joint in question. (It is based on outdated standards and approximates to the weight per foot including tool joints, of a 20′ joint). This figure should **NOT** be used in string weight calculations.

Column 2 TOOL JOINT SPECS

Type	EU	=	external upset
	IE	=	internal upset
	IEU	=	internal external upset
	OH	=	open hole
	SL – H90	=	slim line H 90
	NC	=	API standards (see table for details)
	H90	=	Hughes 90
	WO	=	Reed wide open
	EH	=	extra hole
	PAC	=	slim hole
	SH	=	slim hole
	FH	=	full hole

OD = outside diameter
ID = inside diameter
Tong space = vertical distance on pin + box, including hard banding, for tong placement.

Column 3 PIPE BODY SPECS

ID inside diameter of pipe body
WT weight/foot of pipe body

where: pipe body = pipe between connections

Column 4 ACTUAL AVERAGE WEIGHT OF A JOINT OF DRILL PIPE LB/FT

This assumes that:

(a) The length of pipe body between tool joints = 28.5′ = average length of minimum and maximum lengths permitted by API for range II pipe.

(b) The tool joint length = the tong space total for pin and box plus 3″.

The average weight/foot of a joint then equals the total weight of the joint divided by the total length. The figure applies to Range II pipe only.

Column 5 WEIGHT OF TOOL JOINT AND DP END PREP GAIN (LBS)

This is obtained from the API adjusted joint weight per foot based on a pipe length of 29.4′ and assuming joint length as defined above.

The DP end prep. gain is the change in weight, compared with normal pipe body weight, caused by the end preparation of the pipe body for welding.

Column 6 EQUIVALENT ID CORRESPONDING TO ACTUAL AVERAGE CAPACITY (INS)

This is the ID of a pipe of uniform ID, of the same length as a joint of DP, required to give the same internal capacity as the joint. It applies to Range II pipe only.

Column 7 EQUIVALENT ID OF A JOINT FOR PRESSURE LOSS CIRCULATIONS (INS)

This is the ID of a pipe of uniform ID, of the same length as a joint of DP, that will result in the same pressure loss as the pressure loss in the joint for the same fluid throughput. Strictly it applies for turbulent flow conditions but can be used in laminar flow calculations. It applies to Range II pipe only.

Column 8 EQUIVALENT OD OF A JOINT FOR VOLUME AND PRESSURE CALCULATIONS (INS)

This is the OD of a pipe of uniform OD, of the same length as a joint, that is required to give the same annular volume in a given hole size as the joint of drill pipe. It may also be used in annulus pressure loss calculations. It applies to Range II pipe only.

Grade:	Pipe Specifications	★OILWELL 1
Light E(75) RII		

	1.		2.					3.		4.	5.	6.	7.	8.
	D.P. NOMINAL		TOOL JOINT SPECIFICATIONS					PIPE SPECS.		ACTUAL JOINT WEIGHT LB/FT	Approx. Tool Joint Weight LBS	Equivalent I.D. CAPACITY INS.	Equivalent I.D. PRESSURE INS.	Equivalent O.D. CAP./PRES. INS.
	SIZE INS.	WEIGHT LB/FT	TYPE		O.D. INS.	I.D. INS.	TONG SPACE INS.	I.D. INS.	WEIGHT LB/FT					
1	2 ⅜	4.85	EU	NC 26	3 ⅜	1 ¾	13	1.995	4.43	5.17	28	1.985	1.979	2.424
2	2 ⅜	4.85	EU	SL H90	3 ¼	1.995	13	1.995	4.43	4.96	22	1.995	1.995	2.416
3	2 ⅜	4.85	EU	OH	3 ⅛	2	13	1.995	4.43	4.885	19	1.995	1.995	2.412
4	2 ⅜	4.85	EU	WO	3 ⅜	2	13	1.995	4.43	5.112	26	1.995	1.995	2.429
5	2 ⅞	6.85	EU	NC 31	4 ⅛	2 ⅛	14	2.441	6.16	7.37	45	2.427	2.419	2.941
6	2 ⅞	6.85	EU	SL H90	3 ⅞	2.441	14	2.441	6.16	7.00	34	2.441	2.441	2.930
7	2 ⅞	6.85	EU	OH	3 ¾	2 7/16	14	2.441	6.16	6.94	32	2.441	2.441	2.925
8	2 ⅞	6.85	EU	WO	3 ⅞	2 7/16	14	2.441	6.16	7.29	42	2.441	2.441	2.948
9	3 ½	9.50	EU	NC 38	4 ¾	2 11/16	16 ½	2.992	8.81	10.44	64	2.976	2.970	3.574
10	3 ½	9.50	EU	SL H90	4 ⅝	2.992	16	2.992	8.81	10.16	55	2.992	2.992	3.573
11	3 ½	9.50	EU	OH	4 ½	3	16 ½	2.992	8.81	9.99	50	2.992	2.992	3.553
12	3 ½	9.50	EU	WO	4 ¾	3	16 ½	2.992	8.81	10.30	59	2.992	2.992	3.580
13	4	11.85	IU	H 90	5 ½	2 13/16	17	3.476	10.46	13.18	99	3.443	3.409	4.096
14	4	11.85	EU	NC 46	5 ¾	3 ¼	17	3.476	10.46	13.22	101	3.464	3.461	4.118
15	4	11.85	EU	OH	5 ¼	3 15/32	17	3.476	10.46	12.22	70	3.503	3.494	4.104
16	4	11.85	EU	WO	5 ¾	3 7/16	17	3.476	10.46	13.12	98	3.474	3.474	4.120
17	4 ½	13.75	IU	H 90	6	3 ¼	17	3.958	12.24	15.34	114	3.922	3.890	4.596
18	4 ½	13.75	EU	NC 50	6 ⅛	3 ¾	17	3.958	12.24	15.07	106	3.974	3.945	4.605
19	4 ½	13.75	EU	OH	5 ¾	3 31/32	17	3.958	12.24	14.16	78	3.959	3.959	4.579
20	4 ½	13.75	EU	WO	6 ⅛	3 ⅞	17	3.958	12.24	14.99	103	3.953	3.953	4.608
21														
22														
23														
24														
25														
26														
27														
28														
29														
30														

★OILWELL 1 Pipe Specifications

Grade: Standard E(75) RII

	1. D.P. NOMINAL		2. TOOL JOINT SPECIFICATIONS					3. PIPE SPECS.		4.	5.	6.	7.	8.
	SIZE INS.	WEIGHT LB/FT	TYPE		O.D. INS.	I.D. INS.	TONG SPACE INS.	I.D. INS.	WEIGHT LB/FT	ACTUAL JOINT WEIGHT LB/FT	Approx. Tool Joint Weight LBS	Equivalent I.D. CAPACITY INS.	Equivalent I.D. PRESSURE INS.	Equivalent O.D. CAP./PRES. INS.
1	2 ⅜	6.65	IU	PAC	2 ⅞	1 ⅜	13	1.815	6.26	6.77	23	1.798	1.771	2.401
2	2 ⅜	6.65	EU	OH	3 ¼	1 ¾	13	1.815	6.26	6.89	27	1.812	1.812	2.422
3	2 ⅜	6.65	EU	NC 26	3 ⅜	1 ¾	13	1.815	6.26	7.03	31	1.812	1.812	2.433
4	2 ⅞	10.40	IU	PAC	3 ⅛	1 ½	14	2.151	9.72	10.31	32	2.125	2.064	2.895
5	2 ⅞	10.40	IU	EH	4 ¼	1 ⅞	14	2.151	9.72	11.25	60	2.139	2.132	2.963
6	2 ⅞	10.40	IU	NC 26	3 ⅜	1 ¾	14	2.151	9.72	10.39	34	2.134	2.117	2.905
7	2 ⅞	10.40	EU	NC 31	4 ⅛	2 ⅛	14	2.151	9.72	10.86	48	2.150	2.150	2.948
8	2 ⅞	10.40	EU	OH	3 ⅞	2 5/32	14	2.151	9.72	10.60	40	2.151	2.151	2.934
9	2 ⅞	10.40	EU	SL H90	3 ⅞	2 5/32	14	2.151	9.72	10.56	39	2.151	2.151	2.930
10	3 ½	13.30	IU	EH	4 ¾	2 7/16	16 ½	2.764	12.31	14.12	74	2.747	2.739	3.583
11	3 ½	13.30	IU	NC 31	4 ⅛	2 ⅛	15	2.764	12.31	13.55	56	2.736	2.696	3.544
12	3 ½	13.30	EU	NC 38	4 ¾	2 11/16	16 ½	2.764	12.31	13.91	68	2.760	2.760	3.581
13	3 ½	13.30	EU	OH	4 ¾	2 11/16	16 ½	2.764	12.31	13.91	68	2.760	2.760	3.581
14	4	14.00	IU	NC 40	5 ¼	2 13/16	17	3.340	12.93	15.20	90	3.313	3.293	4.082
15	4	14.00	IU	SH	4 ⅝	2 9/16	16	3.340	12.93	14.34	63	3.304	3.253	4.035
16	4	14.00	IU	H90	5 ½	2 13/16	17	3.340	12.93	15.59	102	3.313	3.293	4.100
17	4	14.00	EU	NC 46	6	3 ¼	17	3.340	12.93	15.65	103	3.335	3.335	4.121
18	4	14.00	EU	OH	5 ½	3 ¼	17	3.340	12.93	15.14	88	3.335	3.335	4.099
19	4 ½	16.60	IU	NC 46	6	3 ¼	17	3.826	14.98	18.04	117	3.796	3.776	4.600
20	4 ½	16.60	IU	RH	6	3	17	3.826	14.98	17.79	110	3.785	3.735	4.583
21	4 ½	16.60	IU	NC 38	5	2 11/16	16 ½	3.826	14.98	16.72	76	3.775	3.662	4.528
22	4 ½	16.60	IU	H90	6	3 ¼	17	3.826	14.98	18.04	117	3.796	3.776	4.600
23	4 ½	16.60	EU	NC 50	6 ⅜	3 ¾	17	3.826	14.98	17.73	108	3.822	3.822	4.609
24	4 ½	16.60	EU	OH	5 ⅞	3 ¾	17	3.826	14.98	17.29	95	3.822	3.822	4.592
25	5	19.50	IEU	NC 50	6 ⅜	3 ¾	17	4.276	17.93	21.09	125	4.249	4.234	5.094
26	5 ½	21.90	IEU	FH	7	4	18	4.778	19.81	24.08	164	4.736	4.704	5.608
27	6 ⅝	25.20	IU	FH	8	5	24	5.965	22.19	27.30	207	5.900	5.850	6.710
28														
29														
30														

Grade: Heavy E(75) RII	**Pipe Specifications**	★ **OILWELL 1**

	1. D.P. NOMINAL		2. TOOL JOINT SPECIFICATIONS					3. PIPE SPECS.		4.	5.	6.	7.	8.
	SIZE INS.	WEIGHT LB/FT	TYPE		O.D. INS.	I.D. INS.	TONG SPACE INS.	I.D. INS.	WEIGHT LB/FT	ACTUAL JOINT WEIGHT LB/FT	Approx. Tool Joint Weight LBS	Equivalent I.D. CAPACITY INS.	Equivalent I.D. PRESSURE INS.	Equivalent O.D. CAP./PRES. INS.
1	3 ½	15.50	EU	NC 38	5	2 9/16	16 ½	2.602	14.63	16.48	79	2.600	2.600	3.597
2	4	15.70	IU	NC 40	5 ¼	2 11/16	17	3.240	14.69	17.07	96	3.212	3.188	4.087
3	4	15.70	IU	H 90	5 ½	2 13/16	17	3.240	14.69	17.39	106	3.218	3.205	4.108
4	4	15.70	EU	NC 46	6	3 ¼	17	3.240	14.69	17.52	110	3.241	3.241	4.130
5	4 ½	20.00	IEU	NC 46	6	3	17	3.640	18.69	21.83	126	3.608	3.579	4.603
6	4 ½	20.00	IEU	FH	6	3	17	3.640	18.69	21.83	126	3.608	3.579	4.603
7	4 ½	20.00	IEU	H90	6	3	17	3.640	18.69	21.83	126	3.608	3.579	4.603
8	4 ½	20.00	EU	NC 50	6 ⅜	3 ¾	17	3.640	18.69	22.45	145	3.646	3.646	4.658
9	4 ½	22.82	IEU	NC 46	6	3	17	3.500	21.36	24.64	134	3.474	3.457	4.615
10	4 ½	22.82	IEU	FH	6	3	17	3.500	21.36	24.64	134	3.474	3.457	4.615
11	4 ½	22.82	IEU	H 90	6	3	17	3.500	21.36	24.64	134	3.474	3.457	4.615
12	4 ½	22.82	EU	NC 50	6 ⅜	3 ½	17	3.500	21.36	24.65	135	3.500	3.500	4.635
13	5	25.60	IEU	NC 50	6 ⅜	3 ½	17	4.000	24.03	27.24	138	3.974	3.960	5.099
14	5	25.60	IEU	FH	7	3 ½	18	4.000	24.03	28.21	169	3.973	3.958	5.133
15	5 ½	24.70	IEU	FH	7	4	18	4.670	22.54	27.00	175	4.634	4.610	4.620
16														
17														
18														
19														
20														
21														
22														
23														
24														
25														
26														
27														
28														
29														
30														

★OILWELL 1 Pipe Specifications

Grade: X(95) RII

	1.		2.					3.		4.	5.	6.	7.	8.
	D.P. NOMINAL		TOOL JOINT SPECIFICATIONS					PIPE SPECS.		ACTUAL JOINT WEIGHT LB/FT	Approx. Tool Joint Weight LBS	Equivalent I.D. CAPACITY INS.	Equivalent I.D. PRESSURE INS.	Equivalent O.D. CAP./PRES. INS.
	SIZE INS.	WEIGHT LB/FT	TYPE		O.D. INS.	I.D. INS.	TONG SPACE INS.	I.D. INS.	WEIGHT LB/FT					
1	2 ⅞	10.40	EU	NC 31	4 ⅛	2	14	2.151	9.72	9.95	21	2.144	2.142	2.885
2	2 ⅞	10.40	EU	SLH90	3 ⅞	2 5/32	14	2.151	9.72	10.56	39	2.151	2.151	2.929
3	3 ½	13.30	EU	NC 38	5	2 9/16	16 ½	2.764	12.31	14.39	83	2.754	2.751	3.601
4	3 ½	13.30	EU	SL H90	4 ⅝	2 11/16	16	2.764	12.31	13.77	63	2.760	2.760	3.574
5	3 ½	15.50	EU	NC 38	5	2 7/16	16 ½	2.602	14.63	16.60	83	2.593	2.591	3.598
6	4	14.00	IU	NC 40	5 ¼	2 11/16	17	3.340	12.93	15.37	95	3.307	3.273	4.086
7	4	14.00	IU	H 90	5 ½	2 13/16	17	3.340	12.93	15.53	100	3.313	3.293	4.098
8	4	14.00	EU	NC 46	6	3 ¼	17	3.340	12.93	15.65	103	3.335	3.335	4.121
9	4	15.70	IU	NC 40	5 ¼	2 11/16	17	3.240	14.69	17.50	109	3.212	3.188	4.107
10	4	15.70	IU	H 90	5 ½	2 13/16	17	3.240	14.69	17.39	106	3.218	3.205	4.107
11	4 ½	16.60	IU	FH	6	2 ¾	17	3.826	14.98	18.42	129	3.775	3.674	4.599
12	4 ½	16.60	IU	NC 46	6	3	17	3.826	14.98	18.30	125	3.785	3.735	4.602
13	4 ½	16.60	IU	H90	6	3	17	3.826	14.98	18.30	125	3.785	3.735	4.602
14	4 ½	16.60	EU	NC 50	6 ⅜	3 ¾	17	3.826	14.98	18.09	119	3.822	3.822	4.624
15	4 ½	20.00	IEU	FH	6	2 ½	17	3.640	18.69	21.94	125	3.586	3.457	4.585
16	4 ½	20.00	IEU	H 90	6	3	17	3.640	18.69	21.83	126	3.597	3.531	4.599
17	4 ½	20.00	IEU	H 90	6	3	17	3.640	18.69	21.83	126	3.608	3.579	4.603
18	4 ½	20.00	EU	NC 50	6 ⅜	3 ½	17	3.640	18.69	22.22	138	3.632	3.631	4.639
19	4 ½	22.82	IEU	NC 46	6 ¼	2 ¾	17	3.500	21.36	24.71	137	3.463	3.418	4.609
20	4 ½	22.82	IEU	FH	6 ¼	2 ¼	17	3.500	21.36	25.20	152	3.443	3.260	4.614
21	4 ½	22.82	EU	NC 50	6 ⅜	3 ½	17	3.500	21.36	24.66	135	3.500	3.500	4.635
22	5	19.50	IEU	NC 50	6 ⅜	3 ½	17	4.276	17.93	21.45	136	4.237	4.201	5.098
23	5	19.50	IEU	H 90	6 ½	3 ¼	17	4.276	17.93	21.67	143	4.226	4.153	5.096
24	5	25.60	IEU	5½ FH	7	3 ½	18	4.000	24.03	28.77	185	3.973	3.958	5.154
25	5 ½	21.90	IEU	FH	7	3 ¾	18	4.778	19.81	24.39	173	4.725	4.660	5.609
26	5 ½	21.90	IEU	H 90	7	3 ½	18	4.778	19.81	24.51	177	4.714	4.600	5.603
27	5 ½	24.70	IEU	FH	7 ¼	3 ½	18	4.670	22.54	28.07	207	4.610	4.517	5.636
28														
29														
30														

Grade:	Pipe Specifications	★OILWELL 1
G (105) RII		

	1.		2.					3.		4.	5.	6.	7.	8.
	D.P. NOMINAL		TOOL JOINT SPECIFICATIONS					PIPE SPECS.		ACTUAL JOINT WEIGHT LB/FT	Approx. Tool Joint Weight LBS	Equivalent I.D. CAPACITY INS.	Equivalent I.D. PRESSURE INS.	Equivalent O.D. CAP./PRES. INS.
	SIZE INS.	WEIGHT LB/FT	TYPE		O.D. INS.	I.D. INS.	TONG SPACE INS.	I.D. INS.	WEIGHT LB/FT					
1	2 7/8	10.40	EU	NC 31	4 1/8	2	14	2.151	9.72	11.14	56	2.144	2.142	2.961
2	3 ½	13.30	EU	NC 38	5	2 7/16	16 ½	2.764	12.31	14.45	84	2.747	2.739	3.600
3	3 ½	15.50	EU	NC 40	5 ½	2 7/16	17	2.602	14.63	16.95	94	2.593	2.591	3.616
4	4	14.00	IU	NC 40	5 ½	2 7/16	17	3.340	12.93	15.64	103	3.297	3.218	4.089
5	4	14.00	IU	H 90	5 ½	2 13/16	17	3.340	12.93	15.53	100	3.313	3.293	4.098
6	4	14.00	EU	NC 46	6	3 ¼	17	3.340	12.93	15.67	103	3.335	3.335	4.121
7	4 ½	16.60	IU	FH	6	2 ¾	17	3.826	14.98	18.49	131	3.775	3.674	4.601
8	4 ½	16.60	IU	NC 46	6	3	17	3.826	14.98	18.42	129	3.785	3.735	4.607
9	4 ½	16.60	IU	H 90	6	3	17	3.826	14.98	18.30	125	3.785	3.735	4.602
10	4 ½	16.60	EU	NC 50	6 3/8	3 ¾	17	3.826	14.98	18.09	119	3.322	3.822	4.624
11	4 ½	20.00	IEU	NC 46	6 ¼	2 ½	17	3.640	18.69	22.17	136	3.586	3.457	4.601
12	4 ½	20.00	EU	NC 50	6 3/8	3 ½	17	3.640	18.69	22.38	142	3.632	3.631	4.645
13	4 ½	22.82	IEU	NC 46	6 ¼	2 ½	17	3.500	21.36	24.82	140	3.452	3.357	4.606
14	4 ½	22.82	EU	NC 50	6 3/8	3 ¼	17	3.500	21.36	24.82	140	3.487	3.483	4.632
15	5	19.50	IEU	NC 50	6 ½	3 ¼	17	4.276	17.93	21.72	144	4.226	4.153	5.098
16	5	25.60	IEU	5 ½FH	7 ¼	3 ½	18	4.000	24.03	29.15	197	3.973	3.958	5.167
17	5 ½	21.90	IEU	FH	7 ¼	3 ½	18	4.778	19.81	25.15	196	4.714	4.600	5.625
18	5 ½	24.70	IEU	FH	7 ¼	3 ½	18	4.670	22.53	28.07	207	4.610	4.517	5.636
19														
20														
21														
22														
23														
24														
25														
26														
27														
28														
29														
30														

★ OILWELL 1 Pipe Specifications

Grade: S(135) RII

	1.		2.					3.		4.	5.	6.	7.	8.
	D.P. NOMINAL		TOOL JOINT SPECIFICATIONS					PIPE SPECS.		ACTUAL JOINT WEIGHT LB/FT	Approx. Tool Joint Weight LBS	Equivalent I.D. CAPACITY INS.	Equivalent I.D. PRESSURE INS.	Equivalent O.D. CAP./PRES. INS.
	SIZE INS.	WEIGHT LB/FT	TYPE		O.D. INS.	I.D. INS.	TONG SPACE INS.	I.D. INS.	WEIGHT LB/FT					
1	2 ⅞	10.40	EU	3½ EH	4 ¾	2	14	2.151	9.72	11.51	67	2.144	2.142	2.984
2	3 ½	13.30	EU	NC 40	5 ½	2 ¼	17	2.764	12.31	15.04	103	2.738	2.713	3.623
3	4	14.00	EU	NC 46	6	3	17	3.340	12.93	16.28	122	3.322	3.315	4.139
4	4	15.70	EU	NC 46	6	2 ¾	17	3.240	14.69	18.30	133	3.215	3.197	4.146
5	4 ½	16.60	IU	NC 46	6 ¼	2 ¾	17	3.826	14.98	19.05	148	3.775	3.374	4.624
6	4 ½	16.60	EU	NC 50	6 ⅜	3 ½	17	3.826	14.98	18.93	144	3.809	3.803	4.647
7	4 ½	20.00	EU	NC 50	6 ⅝	3	17	3.640	18.69	22.60	149	3.608	3.579	4.634
8	4 ½	22.82	IEU	NC 50	6 ⅝	3	17	3.500	21.36	25.74	168	3.474	3.457	4.660
9	4 ½	22.82	IEU	NC 50	6 ⅝	3	17	3.500	21.36	24.95	144	3.474	3.457	4.627
10	5	19.50	IEU	5½ FH	7 ¼	3 ½	18	4.276	17.93	23.42	197	4.235	4.197	5.168
11	5 ½	21.90	IEU	FH	7 ½	3	18	4.778	19.81	26.06	224	4.694	4.402	5.638
12	5	19.5	IEU	NC 50	6 ½	3 ¼	17	4.276	17.93	21.68	143	4.226	4.153	5.098
13	5	19.5	IEU	NC 50	6 ½	3 ¼	19	4.276	17.93	22.03	157	4.221	4.142	5.106
14	5	25.6	IEU	NC 50	6 ½	3 ¼	19	4.000	24.03	27.75	157	3.959	3.919	5.106
15	5 ½	21.90	IEU	6⅝REG	7 ½	3 ½	18	4.778	19.81	25.85	217	4.174	4.600	5.648
16	5 ½	24.70	IEU	FH	7 ½	3	18	4.670	22.54	29.12	239	4.590	4.337	5.655
17														
18														
19														
20														
21														
22														
23														
24														
25														
26														
27														
28														
29														
30														

Grade:	Pipe Specifications	★OILWELL 1
J55 HEVI-WT DP RII		

	1. D.P. NOMINAL		2. TOOL JOINT SPECIFICATIONS					3. PIPE SPECS.		4.	5.	6.	7.	8.
	SIZE INS.	WEIGHT LB/FT	TYPE		O.D. INS.	I.D. INS.	TONG SPACE INS.	I.D. INS.	WEIGHT LB/FT	ACTUAL JOINT WEIGHT LB/FT	Approx. Tool Joint Weight LBS	Equivalent I.D. CAPACITY INS.	Equivalent I.D. PRESSURE INS.	Equivalent O.D. CAP./PRES. INS.
1	3 ½	26	EU	NC 38	4 ¾	2.1875	53	2.0625	21.35	25.38	222	2.082	2.079	3.720
2	4	28	EU	NC 40	5 ¼	2.6875	53	2.5625	25.19	29.65	253	2.582	2.580	4.216
3	4 ½	42	EU	NC 46	6 ¼	2.875	52	2.75	33.88	41.17	377	2.769	2.767	4.805
4	5	50	EU	NC 50	6 ½	3.125	52	3	42.72	49.38	398	3.019	3.017	5.254
5														
6														
7	TONG SPACE INCLUDES ALLOWANCE FOR CENTRE UPSET													
8	FIGURES BASED ON AN AVERAGE JOINT LENGTH = 30.38 FEET													
9														
10														
11														
12														
13														
14														
15														
16														
17														
18														
19														
20														
21														
22														
23														
24														
25														
26														
27														
28														
29														
30														

DALY DRILLING ENTERPRISES LIMITED

146 Hamilton Place, Aberdeen. AB2 4BB. Scotland