SPREADSHEET ANALYSIS OF LOGS

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ABSTRACT

A method for using electronic spreadsheet software, such as Visicalc, or Lotus 1-2-3 for log analysis is presented. The definition of spreadsheet terms, advantages and limitations of spreadsheets, and some typical examples of spreadsheet analysis are discussed.

Because of the ubiquitous nature of this software, this form of log analysis is expected to become more common in the near future.

Introduction

The tools of the log analysis trade have evolved rapidly over the last 20 years, from charts and nomographs, to slide rules, to programmable calculators, to desktop microcomputers. Each method had or has its drawbacks. Charts are not very accurate or repeatable. Slide rules are difficult for some people to use and don't add or subtract very well. Let's face it, these methods are as obsolete as the ES log.

Programmable calculators are easy to use but not too easy to program. Desktop computers (or terminals to larger computers) may or may not be easy to use, but are almost invariably programmed by others, so custom analysis is difficult.

Another solution has been available for about seven years, but only recently have computers and software been powerful enough, large enough, fast enough and cheap enough to do log analysis. This solution is the electronic spreadsheet on modern microcomputers, typified by products like Visicalc, Supercalc, Context MBA, and Lotus 1-2-3.

Early versions of Visicalc could do log analysis, but memory and speed limitations made it impractical. Today, however, these limitations have been removed with the advent of professional desktop computers like the IBM-PC/XT, the HP 150 and HP 200 series, and many comparable machines.

What Is An Electronic Spreadsheet?

An electronic spreadsheet is a computerized replacement for the pencil and columnar pad so familiar to log analysts who do hand calculations at the well site or in the office. One virtue of the electronic spreadsheet is that it can be much larger than a sheet of paper, often allowing up to 256 columns of data (with up to 72 characters per column) by 2000 rows long. The screen or monitor of the computer is a window on this large array of data.

Each row is assiged a row number and each column is headed by a column letter. The intersection of a row and column is termed a cell. Cells are identified by their row and column designation (e.g. C14).

Movement around the portion of spreadsheet seen on the screen is performed by moving a cursor using the keyboard, lightpen or mouse attached to the computer.

Cells can contain four kinds of data:

1. text or labels
2. numbers (raw data or answers)
3. formulae or algorithms
4. spreadsheet functions

Mathematical formulae in spreadsheets show relationships between cells (e.g. C1=+A1+B1). If the relationship of many cells is similar (e.g. C1=+A1+B1, C2=+A2+B2, etc.) then each individual relationship must be described. There are semi-automatic methods for doing this in most spreadsheets. There are no general purpose array operations such as add column A to column B to get column C.

Spreadsheet functions are shortcuts which help the user perform common mathematical computations, such as SUM, AVERAGE, MINIMUM, MAXIMUM, IF...THEN, and PRESENT VALUE. Some of these are not even available in conventional programming languages but must be coded uniquely each time they are needed.

The act of building a log analysis model with a spreadsheet defines all the mathematical relationships in the model, as well as the raw data and analysis parameters. You can edit formulae, insert rows or columns, fix typographical errors, enter new data, and recompute results without changing a Basic or Fortran program. The spreadsheet is the program!

You can also play "what if?." You could vary the water resistivity, matrix or fluid parameters, or shale values and see the change in the log analysis results in 10 to 30 seconds. Computations can be revised immediately after entering a change, or after entering all changes, as decided by the user.

The original spreadsheet, after testing and debugging, can be used immediately, or saved as a standard analysis package. Standard spreadsheets can be customized to fit individual problems when they are used. Managers or professionals may create spreadsheets for their own use, or for use by other professional or technical staff in other departments.

Spreadsheet software is the most widely used application for microcomputers. Over 500,000 copies of Visicalc have been sold, and there are more than 60 competing products, many with implementations on five or more microcomputers. Table 1 and Table 2 indicate some of these products and their suppliers.

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What To Consider In A Spreadsheet Package

A warning note should be issued. Spreadsheet software is no panacea. It is handy for small jobs needing quick turn around, or those with a lot of "what if?" situations - the same kind of jobs you would do with charts or a calculator. The spreadsheet will not replace dedicated software on microcomputers or mainframes. One of the reasons for this is the difficulty in plotting results in conventional log analysis format (3 track or 4 track presentations).

Many spreadsheet packages do have integrated graphics, and are capable of illustrating most common crossplots (on linear axes) and can do a limited form of depth plot. A few packages have integrated word processing, so final reports can be constructed after the analysis has been completed.

Not all spreadsheets will work on all computers, nor are all computers large enough or fast enough to be useful. The minimum configuration is usually a computer with 256,000 bytes of memory, a dual disc drive with one to five megabyte storage, a CRT with at least 19 lines and 80 characters, an 80 character dot matrix printer, and a plotter (optional). All these components must be supported by the computer's operating system, as well as the spreadsheet software. A digitizer could be added, but custom software, probably in machine language or assembler language, will be required.

The minimum cost for a practical system would be in the order of:

computer	C$ 6,000
dual disc drive	2,000
printer	700
plotter	2,300
	$11,000

Allow for a 45% reduction on these values for US dollar exchange for systems purchased in the USA. The spreadsheet software is often bundled with the hardware, but would cost less than $700 in any case.

Each spreadsheet package utilizes its own syntax (just as the variants of Basic or Fortran do), and interchange of models from one system to another may require some editing. The examples in this article use the language of Lotus 1-2-3, one of the more sophisticated packages. However, the common commands are similar to Visicalc and conversion should be relatively easy.

One important consideration when choosing a spreadsheet package is whether or not the package supports forward referencing. The older packages, or cheaper packages, do not permit calculations of a cell if it refers to a cell not yet calculated. These programs start at the top left corner and work either horizontally or vertically.

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Those that permit forward referencing search the spreadsheet for the key cell and work out from there. This allows the spreadsheet layout to be more flexible and more attractive to the user. Little used columns could be way off screen to allow more valuable columns, such as answers, to be closer to the window. This form of calculation is termed natural computation.

Another necessary feature involves security. There are two forms and both are desireable - hidden cells and protected cells. Hidden cells have a zero width, so formula or data in them cannot be seen. They can still be edited or even made visible, but it is unlikely that an accidental entry to such a cell will be made. Protected cells may be visible or hidden, but cannot be entered by the user to accidentally or erroneously change a key formula, or even lose it permanently. The originator of the spreadsheet can obviously unprotect a cell and modify the contents.

Another area of interest is the ability to use "macros." Macros are miniature programs which can be invoked by a single key stroke. They are stored with the spreadsheet and loaded when the spreadsheet is loaded. They could be used, for example, to print only the desired columns of a larger spreadsheet.

Advantages Of Spreadsheet Analysis

The advantages of spreadsheeet analysis can be stated simply - speed, cost, ease of use, familiarity, and limited programming skills required.

A typical data set of ten depth points and five data curves can be entered in about two minutes by even a poor typist. The calculations take about ten seconds. Three or four crossplots and results can be printed in less than two minutes. Total elapsed time is five minutes. A large data array - say fifty depth points - can be entered, computed and printed in about 20 minutes.

Progressive engineers and geologists familiar with microcomputers and spreadsheets, can learn to use suce a package in less than an hour of practice. Modifying a spreadsheet or creating new ones for specialized analysis should take only one day's practice, and thereafter a few minutes to an hour may be needed to tune the spreadsheet to a particular problem.

The spreadsheet example illustrated later took about 60 hours to write, test and debug, but modifications to this basic structure take only minutes. The user must be familiar with the spreadsheet commands, however.

Because the screen layout, printed results and data structure are one and the same, the spreadsheet contents become familiary quickly. The data sheet is always available for viewing, compared to log analysis packages in which the data structure is invisible to the user.

Other factors, such as built in data management, file storing and retreiving, graphics, simple and friendly keystroke sequences, make spreadsheets more attractive than writing Basic or Fortran programs.

Use of the software is usually free of charge; that is, it is part of an existing microcomputer system already used for other purposes in the work place. Even if it is not, it is a low cost item when compared to stand alone packages priced from $10,000 to $100,000.

Limitations of Spreadsheet Software

The concept of spreadsheet software was developed for business and financial calculations. As a result, scientific use is not perfect. The following lists some of the problems encountered in developing the present program.

A cell can contain only one statement or formula. Therefore, these statements can be extremely complicated and unreadable if they are to be powerful enough to do the task of a multiline subroutine. For example, to select the desired porosity option from the several which may be computed requires a statement over 100 characters long and with 13 closing brackets at the end. Similarly, the statement to find the minimum shale volume (and not crash when no shale data is available) is 205 characters long. Lotus 1-2-3 allows statements to be 240 characters long. Previous programming experience helps, as does the ability to build complicated statements piece by piece, when trying to create one of these monsters.

Cells can be referenced by absolute locations or by relative addresses. Interpretation parameters are logically stored in absolute addresses, so you always know where they are. However, relative locations for log data curves can create unforseen problems. For example, it is tempting to use the editing feature of spreadsheets to move a column of data up or down (depth shifting). However, any references to this data in equations will also be shifted, so that data from two different depths end up being used for a single depth. This can be solved by more absolute addresses in the equations, createing a new problem. Adding lines of data to allow for a larger zone becomes impossible unless one uses named data ranges - but it is starting to get unweildy and complicated at this stage.

Other concepts of editing also fail. For example, re-scaling a curve (for sonde error or a units conversion) is simple. Just copy a formula into each cell and the new value is automatically computed. But if you leave the formula in the cell, it will recompute each time the job is run - not what you wanted. You might consider putting the rescaling equation into a different cell and feed the answer back to the original cell, then delete the rescaling cell. This doesn't work either, since the original cell still contains references to the deleted cell - it never contains the answer you want unless you type the number in yourself.

Arithmetic errors propagate rather badly. If a divide by zero (or similar) error occurs, the term ERR will show in the answer, as well as in every answer that depended on the original error. This is shown by the term ERR appearing in each formula that was affected by the error ~ thus losing the contents of totally innocent formulae. This might happen to 400 or 500 cells due to some very trivial data error. The situation will rectify itself, and all the ERRs will disappear if you fix the originating error. However, since so many equations show ERR, it is not always possible to find the offending equation on the first pass. If you don't, all is lost, and a lot of retyping will ensue.

The graphics programs are general purpose business oriented, and two dimensional, They create reasonable 2-D crossplots, but can not handle Z-plots or 4-D plots. Depth plots can not be made in log analysis format or to a specific depth scale, Even if asked to make a +0.45 to -0.15 scale for density porosity, the program insists on making a -0.20 to +0.50 scale. Depth plots were labelled in scientific notation (2.050E00 for 2050 meters) even when a fixed format was requested. These esthetic problems could not be overcome, and you can't phone your friendly local software supplier for a quick fix over the phone.

Another serious limitation is the inability to use text strings in a formula, or to generate text strings from an equation , or even from a lookup table, It would be nice, for example, to output lithology codes as words or to use the log type or log units in words to switch logic in the program, as Basic and Fortran allow. There is no way to see text on the screen unless you type it there.

Spreadsheet size is also a problem. The examples presented here have the usual shale, porosity, saturation, permeability, and lithology models, as well as six crossplots and a hydrocarbon summary. For ten lines of data, the spreadsheet takes up about 70,000 bytes. A set of fifty data points takes a bit more than 260,000 bytes. Conventional Basic or Fortran data files would take much less space. This results from program "code" being stored with each data file, instead of only once for conventional programs.

The lack of a true DO loop is frustrating and accentuates the space problem. In order to obtain results for three sets of cutoffs, for example, you could run the job three times and print the answers three times. Or all three sets could be coded into the spreadsheet. This takes considerable space, since each cutoff set requires five columns of equations , each the full length of the data set. A DO loop would eliminate the need to code each iteration through the loop. Lotus 1-2-3 does have an iteration mode, but only one variable can be used as the iteration test - not enough to do cutoffs on four or five variables. Indirect addressing would also reduce the problem but there seems to be no way to make a cell address a function of a result.

Examples of Spreadsheet Analysis

The examples shown in the illustrations are from one well in which the Halfway sand was analysed. The Halfway is characterised by anhydrite and dolomite in a shaly sand environment . Analysis requires a complex lithology model. The example was treated first as a hand entry job with eleven lines of data of unequal thickness. A second presentation was made using equally spaced data from a digitizer. Interpretation parameters, raw data, results, net pay, crossplots, and depth plots are illustrated . Little difference in hydrocarbon volume is evident between the two approaches.

The analysis model uses slightly simplified versions of the algorithms used in LOG/MATE. Plots are graphic dumps of the screen contents to the printer. More attractive, but slower, plots can be prepared using the utility programs supplied by Lotus 1-2-3 to drive a pen style colour plotter or colour printer.

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In fact, this spreadsheet program has most of the features of LOG/MATE except for the length of data files, processing speed (five times slower), quality depth plots, 3 and 4-D crossplots, and many of the unique data editing features. Not bad for a $700 program.

Conclusions

Spreadsheet analysis of logs is a viable approach to reducing the burden of quantitative log analysis. It provides sophisticated analysis at low cost, is friendly and easy to use, and can be custom tailored to suit the needs of individual analysts or problems. Sufficient limitatations on existing spreadsheet capabilities exist to suggest that this form of computer aided analysis will not replace stand alone special purpose programs. But spreadsheets are certainly better than nearly all programmable calculator methods at only a modest increase in cost.

Microcomputers and spreadsheet software are becoming ubiquitous in engineering offices, so it is likely that more and more log analysis will be done by this method. The examples presented here should provide a good starting point for any one interested in pursuing this line of analysis.

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3. 1-2-3 For Business
   D.F.Cobb, L.Anderson
   Que Corporation, Indianapolis, IN

4. 1-2-3 Tips, Tricks, and Traps
   D.Anderson
   Que Corporation, Indianapolis, IN

TABLE 3: SPREADSHEET FUNCTIONS AND COMMANDS

VISICALC			ADDITIONAL ITEMS IN LOTUS 1-2-3	
Mathematical				
@SUM	@ROUND		@TODAY	
@ABS	@MOD		@DATE	
@EXP	@DOTPRODUCT		@RAND	
@LN	@LABEL			
@LOG	@LCHOOSE			
@SQRT	@UMDY			
@SIN	@MDY			
@COS	@YEAR			
@TAN	@MONTH			
@ASIN	@DAY			
@ACOS	@HMS			
@ATAN	@SECONDS			
@Y^X				
Statistics and Financial				
@COUNT	@RATE		@STD	
@MIN	@PMT		@VAR	
@MAY	@PV			
@AVE	@FV			
@NPV	@IRR			
Data				
@CHOOSE			@DCOUNT	@SORT
@LOOKUP			@DSUM	
			@DAVG	
			@DMIN	
			@DMAY	
			@DSTD	
			@DVAR	
Logical				
@IF...THEN...ELSE			@GOTO	
@OR	@NOT	@ISERROR	@QUIT	
@AND	@TRUE	@ISNA		
	@FALSE			

TABLE 3: SPREADSHEET FUNCTIONS AND COMMANDS (cont)

VISICALC	ADDITIONAL ITEMS IN LOTUS 1-2-3
Commands	
/A Attribute (Format)	
/B Blank	/RE Erase Range
/C Clear	/WE Erase Worksheet
/D Delete	/WD Delete Worksheet
/E Edit	
/F Format	/RF Format Range
/G Global	/WG Global Worksheet
/I Insert	/WI Insert Worksheet
/M Move	/M Move
/P Print	/P Print
/R Replicate	/C Copy
/S Store	/F File
/T Title	/WT Worksheet Titles
/V Version	
/W Window	/WW Windows
/X Macro	many others

5. Using 1-2-3
D.F.Cobb, G.LeBlond
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TABLE 1: THE TEN MOST POPULAR SPREADSHEET PROGRAMS

Name	Integrated Packages	Supplier
VisiCalc VisiCalc Advanced	VisiFile VisiPlot VisiTerm VisiTrend VisiWord	Visicorp San Jose CA 95134 408-946-9000
SuperCalc SuperCalc 2	SuperChart SuperWriter	Sorcim Corp San Jose CA 95131 408-942-1727
CalcStar	WordStar SpellStar MailMerge	MicroPro Corp San Raphael CA 94903 415-499-1200
Multiplan	Nil	Microsoft Corp Bellevue WA 98004 206-828-8080
PerfectCalc	PerfectFiler PerfectSpeller PerfectWriter	Perfect Software Berkeley CA 94710 415-527-2628
ProCalc	ProGraph ProOp LogiQuest	Software Products San Diego CA 92121 714-450-1526
Context MBA	word processor data comm graphics data base	Context Mgmt Syst Torrance CA 90505 213-378-8277
Lotus 1-2-3	graphics data base	Lotus Corp Cambridge MA 02138 617-492-7171

TABLE 2: SOME OTHER SPREADSHEET SUPPLIERS

Name	Supplier
BudgetPlan	Dangen Corp
Cope-PC	Plenary Systems Inc.
Desktop Plan	Visicorp
Easy Calc	Norell Data Systems
Easy Planner	Information Unlimited Software
Electronic Spreadsheet	American Planning Corp.
Ferox Modeler	Ferox Microsystems
Finar	Finar Research
Graph'n 'Calc	Desktop Computer Software
LogiCalc	Software Products International
Master Planner	Comshare Target Software
Microplan	Chang Laboratories Inc.
MiniModel	Westico Inc.
Plan 80	Business Planning Systems Inc.
Scratch Pad	Super Soft
The Thinker	Texa Soft
Knowledgeman	Micro Data Base Systems
Vision Calc	Visicorp
Graph Plan	Chang Laboratories Inc.
The Planner	Hayden Book Corp.
Peach Colc	Peachtree Software
Super Comp-Twenty	Access Technology, Inc.
Lisa Calc	Apple Computer
Magi Calc	Artsci Inc.
Senior Analyst	Business Solutions Inc.
Basic Plan	Cado Systems
Ultra Calc	CIE Systems
Calc Result	Computer Marketing Service
Planner Calc	Comshare Target Software
Target Planner	Comshare Target Software
Superscreen	Creative Software Concept
Plan Master	Cromemco Inc.
Business Planner	Duosoft Corp.
Execu/Model	Executic Software
Master Calc	Four-M Marketing
Fusion/3-36	Fusion Products
Calc/1	H&A Computer Systems
Horizon	Horizon Software
Novacalc	Hourglass Systems
Colorcalc	Intelligent Systems
Omnicalc	ISA Software
Uni Calc	Lifeboat Associates
Zen Calc	Software Toolworks
Magic Worksheet	Structured Systems Group
T/Maker	T/Maker Co.
TMP/Calc	United Software

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M78: "TOP
N78: "BOTTOM
O78: "Incr
P78: "Vsh
Q78: "PHIe
R78: "Sw
S78: "Perm
T78: "Rwa
U78: "RW@Tf
V78: "Tf
W78: "DENSma
X78: "DELTma
Y78: "Subsea
Z78: "Vshg
AA78: "Clavier
AB78: "Vshs
AC78: "Vshx
AD78: "VSHmin
AE78: "PHIsc
AF78: "PHIdc
AG78: "PHInc
AH78: "PHIxdn
AI78: "PHIxcm
AJ78: "DENSMA
AK78: "PHIxcm
AL78: "PHIxcm
AM78: "PHIbvw
AN78: "PHIbvw
AO78: "PHIbvw
AP78: "PHIbvw
AQ78: "PHImax
AR78: "PHIe
AS78: "SWa
AT78: "SWs
AU78: "SWs
AV78: "SWs
AW78: "SWb
AX78: "SWb
AY78: "SWb
AZ78: "SWb
BA78: "SWb
BB78: "SWp
BC78: "Permw
BD78: "Permt
BE78: "Permp
BF78: "Vsh-h
BG78: "Phi-h
BH78: "Hyd-h
BI78: "Perm-h
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M79: "m
N79: "m
O79: "m
P79: "frac
Q79: "frac
R79: "frac
S79: "md
T79: "ohm-m
U79: "ohm-m
V79: "'C
W79: "kg/m3
X79: "us/m
Y79: "m
Z79: '
AA79: '
AB79: '
AC79: '
AD79: '
AE79: '
AF79: '
AG79: '
AH79: '
AI79: "no gas
AJ79: "for gas
AK79: "for gas
AL79: "final
AM79: "term1
AN79: "term2
AO79: "term3
AP79: "final
AQ79: '
AR79: "selected
AS79: '
AT79: "term1
AU79: "term2
AV79: "final
AW79: "term1
AX79: "term2
AY79: "term3
AZ79: "term4
BA79: "final
BB79: "SWir
BC79: '
BD79: '
BE79: '
BF79: '
BG79: '
BH79: '
BI79: '
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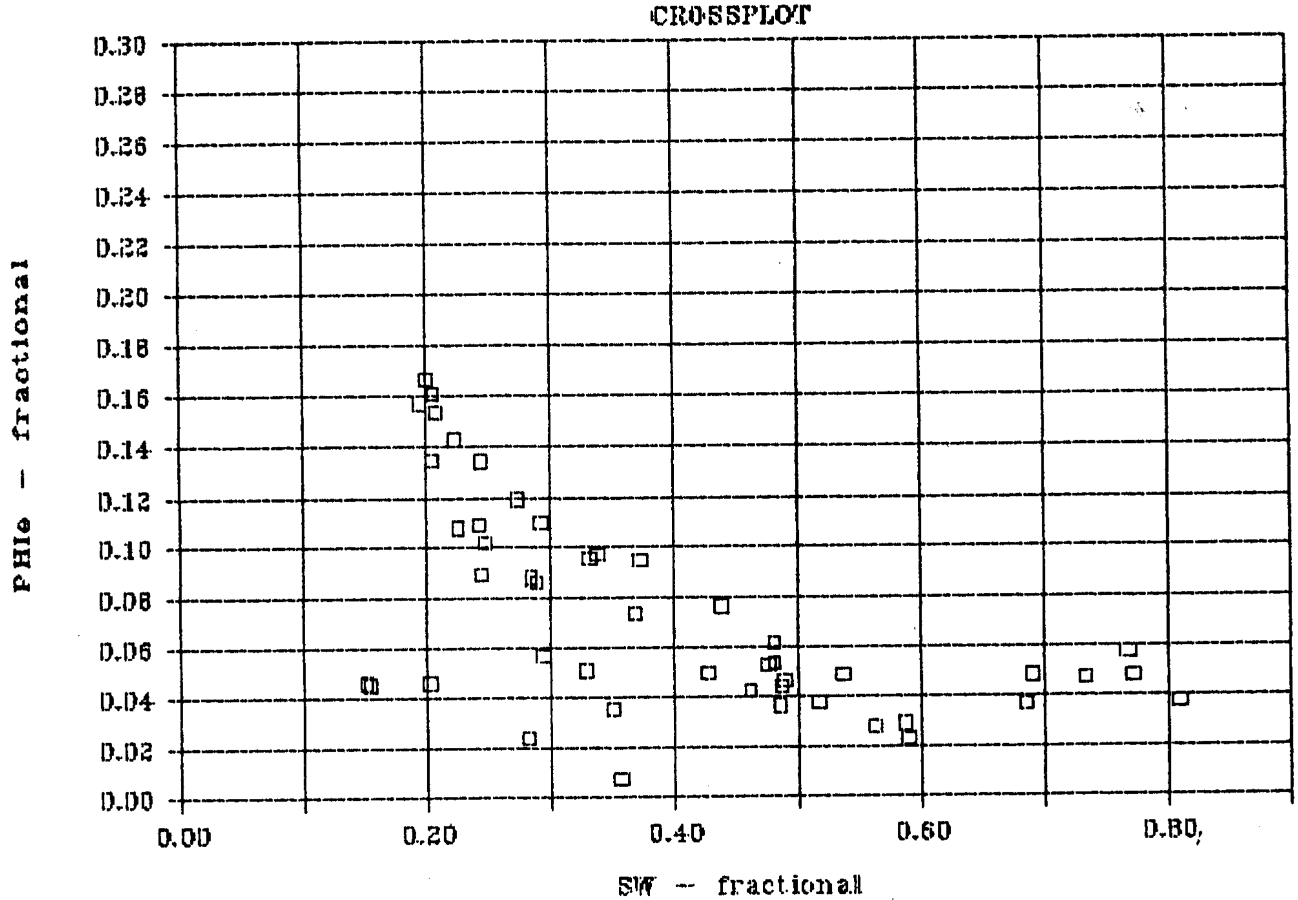
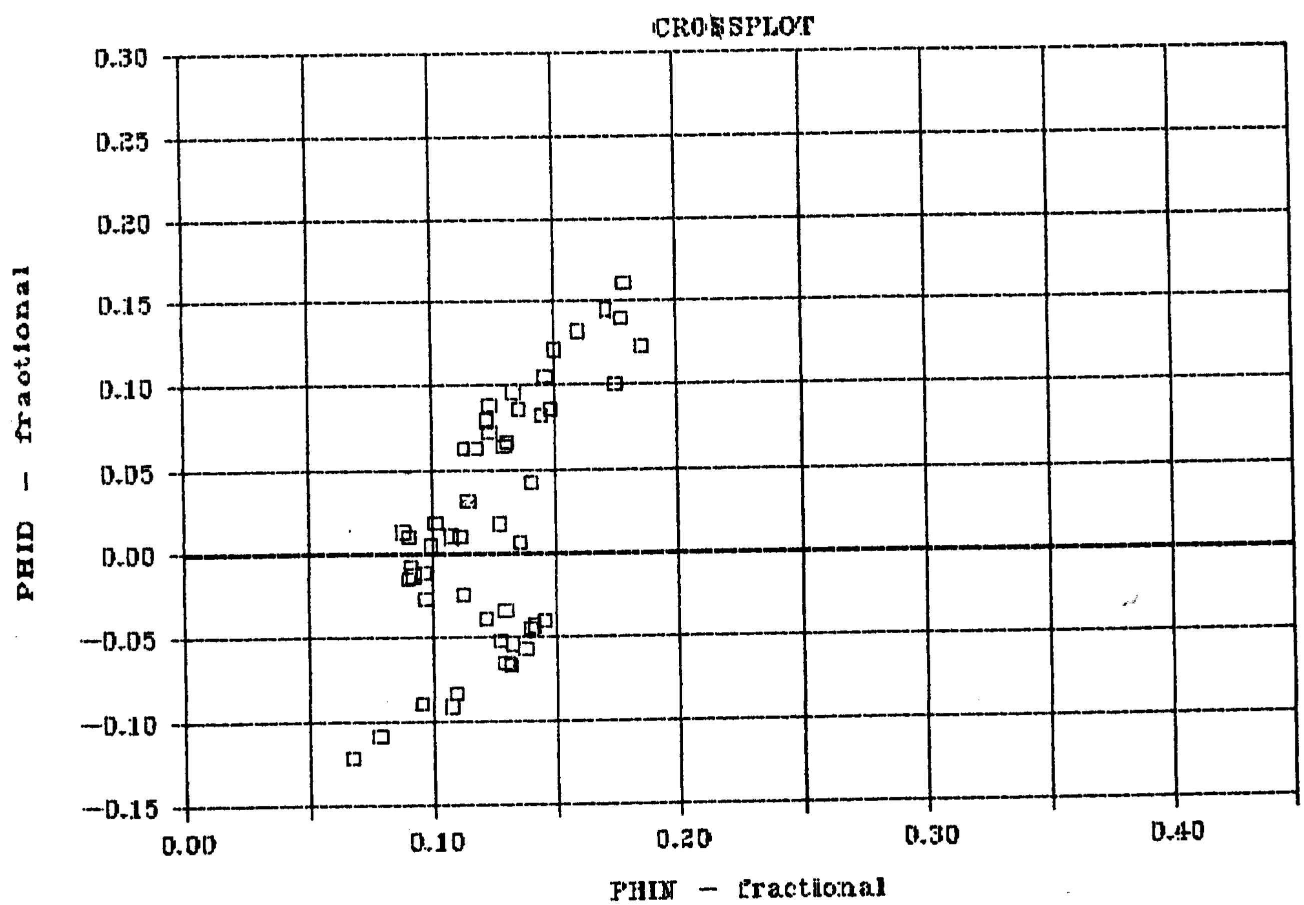
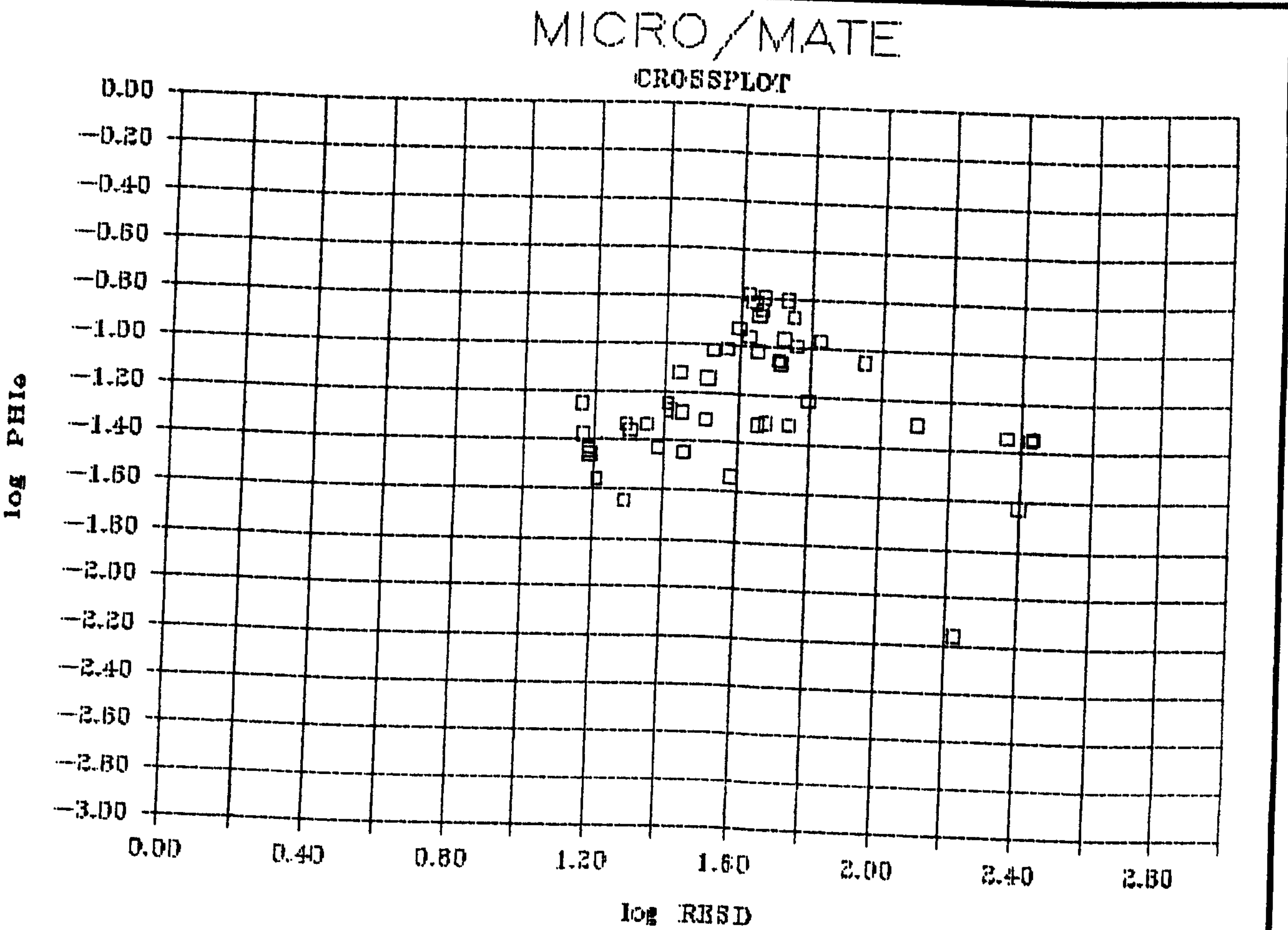
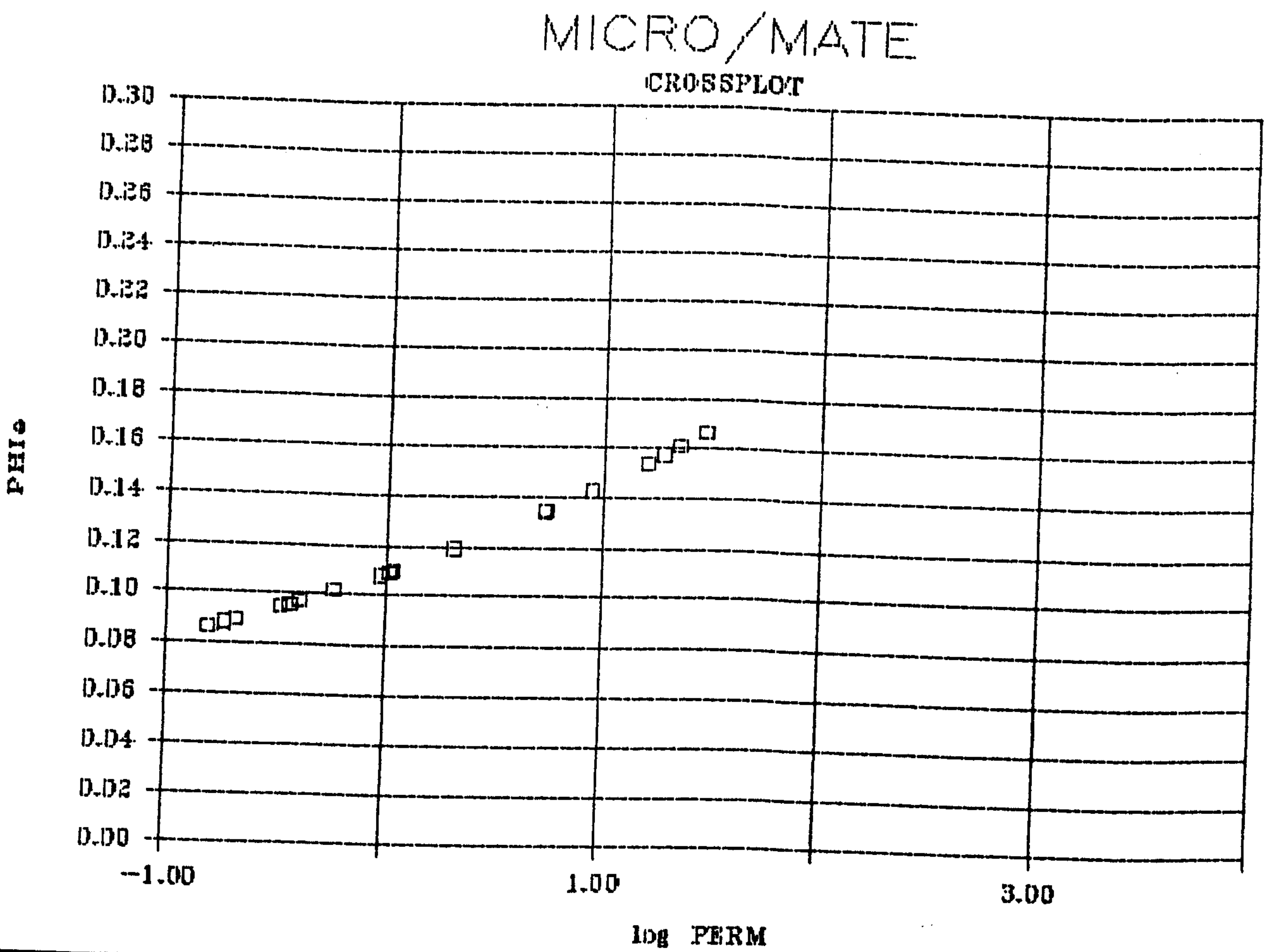
M81: (F1) +A81
N81: (F1) +B81
O81: (F1) +B81-A81
P81: (F2) @IF($A$68,+AD81,(@IF($A$67,+AC81,(@IF($A$66,+AB81,(@IF($A$65,+AA81.(@I
F($A$64,+Z81,@NA))))))))
Q81: (F2) @MAX(0,@MIN(AR81,$G$55*(1-P81)))
R81: (F2) @IF($E$67,+BB81,(@IF($E$66,+BA81,(@IF($E$65,+AV81,(@IF($E$64,+AS81,@NA
)))))))
S81: (F0) @IF($G$66,+BE81,(@IF($G$65,+BD81,(@IF($G$64,+BC81,@NA)))))
T81: (F2) (Q81^$C$49)*C81/$C$46
U81: (F2) +$B$28*($A$55+21.5)/(V81+21.5)
V81: (F0) +$A$46+($A$49-$A$46)/$A$52*A81
W81: (F0) ($K$52-E81*$K$52+E81-Q81)/(1-Q81)
X81: (F0) (F81-Q81*$E$28)/(1-Q81)
Y81: (F1) +$E$55-A81
Z81: (F2) @MIN(1,@MAX(0,@IF($A$64=1,(G81-$F$22)/($F$25-$F$22),@NA)))
AA81: (F2) @MAX(0,@IF($A$65=1,1.7-(3.38-(@MIN(1,@MAX(0,(G81-$F$22)/($F$25-$F$22)
))+0.7)^2)^0.5,@NA))
AB81: (F2) @MIN(1,@MAX(0,@IF($A$66=1,(H81-$G$22)/($G$25-$G$22),@NA)))
AC81: (F2) @MIN(1,@MAX(0,@IF($A$67=1,(ERR-E81)/($C$25-($D$25-$K$52)/(1000-$K$52)
),@NA)))
AD81: (F2) @IF($A$68=0#OR#(@ISNA(Z81)#AND#@ISNA(AA81)#AND#@ISNA(AB81)#AND#@ISNA(
AC81)),@NA,@MIN(@IF(@ISNA(Z81)=0,Z81,1),@IF(@ISNA(AA81)=0,AA81,1),@IF(@ISNA(AB81
)=0,AB81,1),@IF(@ISNA(AC81)=0,AC81,1)))
AE81: (F2) @IF($C$64,@MAX(0,((F81-$E$22)/($E$28-$E$22)-P81*($E$25-$E$22)/($E$28-
$E$22))/$G$49),@NA)
AF81: (F2) @IF($C$65,E81-P81*($D$25-$K$52)/(1000-$K$52),@NA)
AG81: (F2) @IF($C$66,@MAX(0,D81-P81*$C$25),@NA)
AH81: (F2) @IF($C$67,@IF(D81>=E81,(E81*$C$25-D81*($D$25-$K$52)/(1000-$K$52))/($C
$25-($D$25-$K$52)/(1000-$K$52)),((D81^2+E81^2)/2)^0.5),@NA)
AI81: (F2) @IF($C$68,@MAX(0,((4-(3.3+10^(-5*AG81-0.16)))*AF81+0.754*AG81)/((4-(3
.3+10^(-5*AG81-0.16)))+0.754)),@NA)
AJ81: (F0) @IF($C$68,($K$52-E81*$K$52+E81-AI81)/(1-AI81),@NA)
AK81: (F2) @IF($C$68,@IF(AJ81<$D$22,(-AF81/(AG81/0.8-1))*(1/(1+AF81/(0.8-AG81)))
+0.002*(0.3+AI81)*($D$22-2710),0),@NA)
AL81: (F2) @MAX(AI81,AK81)
AM81: (F2) @IF($C$69#OR#$E$66,1-1.15*(1-$C$25)/(1-($D$25-$K$52)/(1000-$K$52)),@N
A)
AN81: (F2) (AM81*($D$25-$K$52)/(1000-$K$52)+0.15*$C$25)/(AM81+0.15)
AO81: (F2) (AM81*E81+0.15*D81)/(AM81+0.15)
AP81: (F2) @MAX(0,AO81-P81*AN81)
AQ81: (F2) @IF($C$70,+$G$55*(1-P81),@NA)
AR81: (F2) @IF($C$70,+AQ81,(@IF($C$69,+AP81,(@IF($C$68,+AL81,(@IF($C$67,+AH81,(@
IF($C$66,+AG81,(@IF($C$65,+AF81,(@IF($C$64,+AE81,@NA)))))))))))))
AS81: (F2) @IF($E$64,@IF(Q81>0.001#AND#P81<1,@MAX(0,@MIN(1,($C$46*U81/(C81*(Q81^
$C$49)))^(1/$C$52))),1),@NA)
AT81: (F2) @IF($E$65,@IF(Q81>0.001#AND#P81<1,+$C$46*U81*(1-P81)/(Q81^$C$49),9999
),@NA)
AU81: (F2) @IF($E$65,+AT81*P81/(2*$B$25),@NA)
AV81: (F2) @IF($E$65,@IF(Q81>0.001#AND#P81<1,@MAX(0,@MIN(1,(((AU81^2)+AT81/C81)^
0.5-AU81)^(2/$C$52))),1),@NA)
AW81: (F2) @IF($E$66,+AN81^2*$B$25,@NA)
AX81: (F2) @IF($E$66,+P81*AN81/AO81,@NA)
AY81: (F2) +$C$46*U81*AW81/(AO81^$C$49)/(AW81+AX81*(U81-AW81))
AZ81: (F2) (AY81/C81)^(1/$C$52)
BA81: (F2) @MAX(0,@MIN(1,(AO81/AP81)*(AZ81-AX81)))
BB81: (F2) @MIN(1,@IF(Q81>0.001,$C$55/Q81,1))
BC81: (F0) @IF($G$64,+$G$52*(Q81^6)/(BB81^2),@NA)
BD81: (F0) @IF($G$65,+$G$52/20*(Q81^4.4)/(BB81^2),@NA)
BE81: (F0) @IF($G$66,@MIN(10000,10^($G$52/2800*Q81-3)),@NA)
BF81: (F2) +O81*P81
BG81: (F2) +Q81*O81
BH81: (F2) +BG81*(1-R81)
BI81: (F0) +S81*O81
```

MICRO/MATE


CROSSPLOT
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
PHIe - fractional
0.00
0.20
0.40
0.60
0.80
SW - fractional


CROSSPLOT
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
PHID - fractional
0.00
0.10
0.20
0.30
0.40
PHIN - fractional


MICRO/MATE
CROSSPLOT
log PHIe
log RESD
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
-1.20
-1.40
-1.60
-1.80
-2.00
-2.20
-2.40
-2.60
-2.80
-3.00
0.00
0.40
0.80
1.20
1.60
2.00
2.40
2.80


MICRO/MATE
CROSSPLOT
PHIe
log PERM
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
-1.00
1.00
3.00