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Stimulation Model for Lenticular Sands

Volume II

Users Manual

E.F. Rybicki
C.T. Luiskutty
J.S. Sutrick
I.D. Palmer
G.H. Shah
L. Tomutsa

July 1987

Work Performed Under Contract No.: DE-AC21-84MC21119

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
The University of Tulsa
Tulsa, Oklahoma

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INTRODUCTION

This User's Manual contains information for four fracture/proppant models. TUPROP1 contains a Geertsma and de Klerk type fracture model. The section of the program utilizing the proppant fracture geometry data from the pseudo three-dimensional highly elongated fracture model is called TUPROPC. The analogous proppant section of the program that was modified to accept fracture shape data from SA3DFRAC is called TUPROPS. TUPROPS also includes fracture closure. Finally there is the penny fracture and its proppant model, PENNPROP.

In the first three chapters, the proppant sections are based on the same theory for determining the proppant distribution but have modifications to support variable height fractures and modifications to accept fracture geometry from three different fracture models. Thus, information about each proppant model in the User's Manual builds on information supplied in the previous chapter.

The exception to the development of combined treatment models is the penny fracture and its proppant model. In this case, a completely new proppant model was developed. A description of how to use the combined treatment model for the penny fracture is contained in Chapter 4.

Equations referred to in this manual are those in the Final Report of Stimulation Model for Lenticular Sands (DOE Contract No. DE-AC21-84MC21119).

CHAPTER I

TUPROP1 CONTAINING CONSTANT HEIGHT FRACTURE MODEL

General Description

The University of Tulsa developed TUPROP1 to model hydraulic fracturing treatments and proppant transport using typical stimulation techniques involving noncross-linked fracturing gels as a transport medium for the proppant material. Non-Newtonian fluid behavior in the program is represented by the power law model. Both variable flow rate schedules and different proppant types can be simulated by TUPROP1. The program is designed to handle 250 elements in both the fracturing and proppant sections. Thus, if 10 foot fracture growth increments are used, the maximum fracture which could be handled would be 2500 ft.

In most well treatments, good proppant carrying capacity is desired. Thus, it is assumed in the program that there is not a need to check equilibrium conditions for fluid velocity and proppant bed height. A situation requiring this check consists of a fracture fluid having a low viscosity trying to carry a large, dense proppant type. These class of stimulations would not result in propped fractures of maximum length. However, since settling and proppant bed formation occur in any treatment, a sophisticated particle tracking procedure has been included in the program to track the particles in the proppant slurry. Thus, a very accurate accounting procedure for the mass of the proppant is contained in the program. To avoid the equilibrium situations, the following program input parameters can be changed; fracture height, fluid viscosity, proppant type, pumping rate, fluid leakoff coefficient and treatment time. Normally, fracture heights between 20 to 200 ft., medium viscosity

fluids, leakoff coefficients between 0 and 0.0044 ft./ $\sqrt{\text{min.}}$, and pumping rates less than 80 bbl/min. will allow proper operation of the program.

Program limitations can be exceeded. If the fracture portion of the program requires more than 250 steps, the program will run through the 250th step, but the treatment time will not be reached. The case where proppant settling is so rapid that the equilibrium flow and equilibrium height of the bed are exceeded, the program will give a Fortran run time error due to negative numbers being introduced. The program also tracks the proppant front and if this front reaches the fracture tip, then a screen out occurs. The proppant front, however, can be devoid of proppant, thus giving a false screen out. Since the original design criterion was to always keep proppant in the slurry, no routine has been implemented to solve this problem. While no error results from the false screen out, the total treatment time will not be reached.

TUPROP1 has five settling models which can be used; however, for non-Newtonian gels, the Sutrick and Rybicki model is recommended. If a Newtonian fracturing fluid is used, the Zigrang and Sylvester settling model should be used. The other three models can be used for comparison. The Daneshy model is purely theoretical and can only be used when the particle Reynold's number is less than 1. The Acharya model could be used to see the effects of very low proppant settling velocities on the fracture but is not recommended for general use. The Clark model is a good approximation for Guar Gum gels, but does not consider wall effects.

The pressure distribution is developed from the following equations:

$$\Delta P = \left(\frac{2 (2n+1) Q}{n H} \right)^n \frac{2 K L}{w_w^{(2n+1)}} \int_{x_1/L}^{x_2/L} \frac{d(x/L)}{w^{(2n+1)}}$$

where ΔP = pressure drop from x_1 to x_2

L = desired fracture length

x = distance from the wellbore

w_w = width at the wellbore

Q = flow rate

H = fracture height

n = behavioral index of the fracturing fluid

K = consistency index of the fracturing fluid

$$W = \frac{(x/L) \ln \left[\frac{1 - \frac{x_0/L}{x/L} \left(\frac{1 - (x/L)^2}{1 - (x_0/L)^2} \right)^{\frac{1}{2}}}{1 + \frac{x_0/L}{x/L} \left(\frac{1 - (x/L)^2}{1 - (x_0/L)^2} \right)^{\frac{1}{2}}} \right] - (x_0/L) \ln \left[\frac{1 - \left(\frac{x/L}{x_0/L} \right)^{\frac{1}{2}}}{1 + \left(\frac{x/L}{x_0/L} \right)^{\frac{1}{2}}} \right]}{x_0/L \ln \frac{(1 - (x_0/L)^2)^{-\frac{1}{2}} + 1}{(1 - (x_0/L)^2)^{-\frac{1}{2}} - 1}}$$

x_0 = maximum distance from the wellbore
which is pressurized

$x_0 < L$ and $x < x_0$

The pressure at the wellbore reacts just as the Geertsma model predicts. As the fracture length increases, the wellbore pressure falls [1].

Input

Input to TUPROP1 comes from two files, COEFFN9999A and DATATUP1. COEFFN9999A is a file containing all the coefficients needed by TUPROP1 so that the wellbore widths can be rapidly calculated without using numerical integration techniques in the program. This file, a copy of which is in Appendix A, is a permanent file requiring no changes.

DATATUP1, in Appendix B, is the input file for changing parameters for different well stimulations. All records in this file use either 10F10.5 or 5I10 formatted input. The file is divided into the following records.

1.	First Record, Format 10F10.5		
	(1) Pipe Flow Consistency Index	KPRIME	lbf.s/ft ²
	(2) Behavior Index	NPRIME	
	(3) Fluid Loss Coefficient	FFC	ft/ $\sqrt{\text{min}}$
	(4) Density of Fracturing Fluid	RHOF	lbm/ft ³
2.	Second Record, Format 10F10.5		
	(1) Treatment Time	TT	min
	(2) Spurt Loss Coefficient	SP	ft ³ /ft ²
	(3) Fraction of Length Pressurized	FLO	
3.	Third Record, Format 5I10		
	(1) Number of Flow Rate Changes	NQ	
4.	Fourth Record, Format 10F10.5		
	(1) Flow Rates, Max 10	Q(I)	bbl/min
5.	Fifth Record, Format 10F10.5		
	(1) Times at which Flow Rate will change, TQ(1)=0.0 and is not put into the record	TQ(I)	min
6.	Sixth Record, Format 5I10		
	(1) Number of Proppant Types, MAX 10	NTP	
7.	Seventh Record, Format 10F10.5		
	(1) Times at which Proppant Type Changes	TP1(I)	min
8.	Eighth Record, Format 10F10.5		
	(1) Initial Concentrations	GC1(I)	lbm/gal
9.	Ninth Record, Format 10F10.5		
	(1) Average Proppant Diameter	DP1(I)	in
10.	Tenth Record, Format 10F10.5		
	(1) Proppant Porosities	PHIP1(I)	
11.	Eleventh Record, Format 10F10.5		
	(1) Proppant Densities	RHOS1(I)	lbm/ft ³
12.	Twelfth Record, 5I10		
	(1) Restart Control	NSTART	
	0 - No Restart		
	1 - Restart		
13.	Thirteenth Record, 10F10.5		
	(1) Poisson's Ratio	NU	
	(2) Young's Modulus	E	psi
	(3) Acceleration of Gravity	G	ft/sec ²
	(4) Fracture Height	HO	ft
	(5) Element Length	DX	ft
14.	Fourteenth Record, 10F10.5		
	(1) Fan Viscometer Outer to Inner Radii	BETA	
	(2) Run Control	CONTROL	
	0.0 - Run Program		
	1.0 - Run Fracture Only		
	No Output		
	2.0 - Run Fracture Only		
	Fracture Output		
	(3) Particle Shear Rate Cut Off Value	GDOTC	sec ⁻¹
	(4) Shear Stress Location Fraction	GDOTF	

15. Fifteenth Record, 5I10
 - (1) Starting Element of Detailed Output NCK1
 - (2) Ending Element of Detailed Output NCK2
 - If NCK1 > NCK2 - No Detailed Output
 - (3) Detailed Output of Last Time Step NCK3
 - 0 - Not Wanted
 - 1 - Output Desired
 - (4) Selection of Settling Model NSETV
 - 1 - Zigrang and Sylvester
 - 2 - Daneshy
 - 3 - Acharya
 - 4 - Clark
 - 5 - Sutrick and Rybicki
 - (5) Selection of Pressure Computation NPRESS
 - 0 - Pressure Not Calculated
 - 1 - Pressure Calculated & Output

Restart Control, listed in the input, causes the same fracture data to be input from the file RESTTUP1. This file is written on when the fracture portion of the program is run. It stores the fracture lengths, wellbore widths, creation times, and fracture width profile. If flow rates, treatment time, leakoff, and fracturing fluid do not change, then this can be used to rapidly check various proppant treatment changes. There is no safety check. If any variable that affects fracturing is changed and restart is employed, the previously stored data in RESTTUP1 will be introduced again. If there is any doubt on the part of the user, zero NSTART and recalculate the fracture data.

Output

In Appendix C, along with the input files and program, is the output corresponding to the input file DATATUP1. The output can be divided into three divisions.

The first division is the echoed input data. This section contains all the input parameters with the exception of control values.

The second section contains the output of the fracture portion of TUPROP1. The first part of this section has the fracture data describing

the time and shape of the fracture with associated pressures if NPRESS was set to 1. The second part of this section is a summary of the fracturing process. The summary includes not only the width and length of the fracture but also the volume calculations of the fracture and fluid lost to the formation.

The last division contains output from the proppant transport portion of TUPROP1. In the first section of this division, a summary of particle tracking is given. If detailed intermediate data were requested ($NCK1 \leq NCK2$), then these statements would be recorded at the correct time step. Next, a summary is given for the propped fracture. Note that the leading edge of the proppant is the slurry front, but if the top particle of the proppant type has reached the bed, the fluid would be clear. For example, the proppant bed in Appendix C extends only 410 feet, while all the leading edges of the proppant types are past this point.

For the sample case, $NCK1$ was greater than $NCK2$, but $NCK3$ was set to one. Therefore, below the name of the settling model is the detailed output for the last time step. The information contained in this section should be self-explanatory. If $NCK3$ were set equal to zero, then following the name of the settling model, a summary of the time steps are printed out along with information describing the disposition of proppant in the final time step. This summation always appears when the proppant section is run. The final portion of this section summarizes the volume of fluid and the mass of proppant injected during the treatment. The injected amounts of fluid and proppant are compared to the amounts obtained from program calculations based on continuity. Thus, the differences given are measures of program effectiveness.

CHAPTER I

APPENDIX A

COEFFN9999A

10100 JAN 23 '86 COEFFN9999A,IMH40820

1 -	-.163627730069872026E+01	.467380160661620600E+00	-.540226867848080450E+01	.339594945743702916E+02	-.12941385151475
2721E+03	.314242863633131927E+03	-.484653385976782088E+03	.477543508148772905E+03	-.266641867100794492E+03	.64773366324268
8178E+02	.246523857597240486E+01	-.233110103496429712E+02	.29596479448159691E+03	-.181359365233007437E+04	.64574864751241
6487E+03	-.164230631211051093E+05	.252148476521716181E+05	-.240872039557524861E+05	.131373160378447410E+05	-.31709301292205
0132E+04	-.216911502773677783E+02	.593862396017360355E+03	-.685910213503293516E+04	.421612582930433753E+05	-.15756873742111
6716E+06	.372033283682780726E+06	-.561674920722766716E+06	.525629310893276140E+06	-.279465910621100042E+06	.65175465947132
7053E+05	.253010391093974551E+03	-.715664591704396633E+04	.816851365724953665E+05	-.500604084779754704E+06	.19557305157569
5705E+07	-.434232850905292130E+07	.647805790996216265E+07	-.597381400753677939E+07	.311714115837578426E+07	-.70897484741751
0262E+06	-.164820355318615496E+04	.964019631939261382E+05	-.527806348696509902E+06	.322688030167994560E+07	-.11906826544468
8662E+08	.277137979540849251E+08	-.410531298329579356E+04	.375231876886901280E+08	-.193530097737194750E+08	.43323431788434
3098E+07	.602575747323758154E+04	-.169969103572949509E+06	.192965387961584384E+07	-.117767559165476316E+08	.43339484135772
8692E+08	-.100560564699958255E+09	.148346531934358629E+09	-.134878595516332673E+09	.640739206090679079E+08	-.15310144240040
9940E+08	-.124824535151735979E+05	.351891278580239935E+06	-.398960487540645433E+07	.243183655086538292E+08	-.89338997498186
6063E+08	.206894631296031773E+09	-.304454905248774720E+09	.275939120624789635E+09	-.140697718205058630E+09	.30989717830581
9143E+08	.136223811870793444E+05	-.383806106554737057E+06	.434660635366313766E+07	-.264678464030878388E+08	.97118432457744
8177E+08	-.224637754199473785E+09	.330070276641720985E+09	-.298584481171076007E+09	.151831516843222285E+09	-.33306586593005
3242E+08	-.608508870053732064E+04	.171338981638721899E+06	-.193846592320142103E+07	.117935816675429673E+08	-.43235234849669
5243E+08	.999259902878668078E+06	-.146692942801939973E+09	.132550319654940354E+09	-.672899918741709468E+08	.14722398735993
3055E+08					

CHAPTER I

APPENDIX B

DATATUP1

16:37 JAN 21 '86 DATATUP1.IND40620

1	-	1.000	0.00100	0.7600	.00220	65.		
2	-	2.000	060.00	0.00000	.99			
3	-	3.000		4				
4	-	4.000	20.0	25.0	30.	35.0		
5	-	5.000	07.5	15.0	25.			
6	-	6.000		3				
7	-	7.000	12.00	20.00	25.00	00.0	00.0	00.0
8	-	8.000	1.000000	1.0	2.0	0.0	0.0	0.0
9	-	9.000	.0450	.0560	.0560	.0	.0	.0
10	-	10.000	30	15	15	00	00	00
11	-	11.000	165.00	165.0	165.0	000.0	000.0	000.0
12	-	12.000		0				
13	-	13.000	25	01777917.	32.2	070.0	10.	
14	-	14.000	1.072836	0.0	60.	0.6667		
15	-	15.000		01	000	1	5	1

CHAPTER I

APPENDIX C

OUTPUT FROM TUPROP1

ILYNX *TUP1 OVER LTUPROP1
 * 3SHARED COMMON:SYS (SHARED LIBRARY) ASSOCIATED.
 * NO LINKING ERRORS.
 * TOTAL PROGRAM SIZE = 25K.
 ILTUPROP1.

INJECTION RATE	=	20.000	25.000	30.000	35.000	RPM
INJECTION RATE TIME	=	.000	7.500	15.000	25.000	MIN
TREATMENT TIME	=	60.000	MIN			
CONSISTENCY INDEX	=	.001000	LB*S**NPRIME/FT**2			
(PIPE FLOW)						
CONSISTENCY INDEX	=	.000960	LB*S**NPRIME/FT**2			
(ASSOLUTE)						
CONSISTENCY INDEX	=	.001035	LB*S**NPRIME/FT**2			
(SLOT FLOW)						
BEHAVIOR INDEX	=	.760				
FLUID DENSITY	=	65.000	LBM/FT**3			
FLUID LOSS COEFFICIENT	=	.220E-02	FT/SQRT(MIN)			
SPURT LOSS	=	.000	FT**3/FT**2			
FRACTURE HEIGHT	=	70.000	FT			
YOUNG MODULUS	=	1777917.0	PSIA			
POISSON RATIO	=	.250				
LENGTH INCREMENT	=	10.00	FT			
PRESSURIZED LENGTH	=	.9900				
PSI	=	1410673				
FAN RADII RATIO	=	1.072836				
ACCEL OF GRAVITY	=	32.200	FT/SEC			
PAD TIME	=	12.000	20.000	25.000	MIN	
INITIAL CONCENTRATION	=	1.000	1.000	2.000	LB/GAL	
PROPPANT DENSITY	=	165.000	165.000	165.000	LBM/FT**3	
PROPPANT DIAMETER	=	.045	.056	.056	IN	
PROPPANT POROSITY	=	.300	.150	.150		

NODE	FILE	TIME MIN	WIDTH FT	LENGTH FT	PRESSURE PSI	WB FT	WB PRES PSI
1	0	.0000	.03213	0.	118.54	.00000	.00
2	1	.0363	.03213	10.	118.35	.00220	246.88
3	2	.1173	.03212	20.	118.16	.00327	276.30
4	3	.2345	.03212	30.	117.96	.00412	274.53
5	4	.3844	.03211	40.	117.77	.00485	265.93
6	5	.5650	.03209	50.	117.58	.00550	256.05
7	6	.7750	.03207	60.	117.39	.00610	246.40
8	7	1.0123	.03205	70.	117.20	.00666	237.44
9	8	1.2790	.03203	80.	117.01	.00719	229.24
10	9	1.5714	.03200	90.	116.81	.00768	221.79
11	10	1.8901	.03197	100.	116.62	.00816	215.00
12	11	2.2345	.03194	110.	116.43	.00861	208.79
13	12	2.6041	.03190	120.	116.23	.00905	203.11
14	13	2.9987	.03186	130.	116.04	.00947	197.88
15	14	3.4178	.03182	140.	115.84	.00988	193.06
16	15	3.8612	.03177	150.	115.65	.01027	188.59
17	16	4.3286	.03172	160.	115.45	.01065	184.44
18	17	4.8198	.03167	170.	115.25	.01103	180.57

19	19	5.3346	.03162	180.	115.06	.01139	176.95
20	19	5.8727	.03156	190.	114.86	.01175	173.55
21	20	6.4339	.03149	200.	114.66	.01209	170.36
22	21	7.0181	.03143	210.	114.45	.01243	198.28
23	22	7.6251	.03136	220.	114.25	.01277	194.31
24	23	8.0767	.03129	230.	114.05	.01311	190.58
25	24	8.5442	.03121	240.	113.84	.01345	187.07
26	25	9.0275	.03113	250.	113.64	.01378	183.75
27	26	9.5263	.03105	260.	113.43	.01410	180.62
28	27	10.0408	.03098	270.	113.22	.01442	177.65
29	28	10.5707	.03087	280.	113.01	.01473	174.83
30	29	11.1160	.03078	290.	112.80	.01504	172.15
31	30	11.6765	.03068	300.	112.58	.01535	169.59
32	31	12.2523	.03058	310.	112.37	.01565	167.16
33	32	12.8432	.03048	320.	112.15	.01595	164.83
34	33	13.4491	.03037	330.	111.93	.01624	162.60
35	34	14.0700	.03026	340.	111.71	.01653	160.46
36	35	14.7059	.03014	350.	111.49	.01681	158.41
37	36	15.3566	.03002	360.	111.26	.01709	156.40
38	37	15.8642	.02990	370.	111.03	.01738	176.96
39	38	16.3829	.02977	380.	110.80	.01767	174.62
40	39	16.9126	.02964	390.	110.57	.01795	172.37
41	40	17.4534	.02950	400.	110.33	.01823	170.21
42	41	18.0050	.02936	410.	110.09	.01851	168.13
43	42	18.5676	.02922	420.	109.85	.01878	166.13
44	43	19.1410	.02907	430.	109.61	.01905	164.20
45	44	19.7253	.02892	440.	109.36	.01932	162.34
46	45	20.3203	.02877	450.	109.11	.01959	160.54
47	46	20.9261	.02860	460.	108.85	.01985	158.80
48	47	21.5425	.02844	470.	108.59	.02011	157.12
49	48	22.1697	.02827	480.	108.33	.02037	155.49
50	49	22.8074	.02810	490.	108.06	.02062	153.92
51	50	23.4558	.02792	500.	107.79	.02088	152.39
52	51	24.1146	.02773	510.	107.52	.02113	150.91
53	52	24.7841	.02754	520.	107.24	.02138	149.46
54	53	25.4640	.02735	530.	106.95	.02162	148.03
55	54	26.1537	.02715	540.	106.66	.02188	146.66
56	55	26.8515	.02695	550.	106.36	.02213	145.33
57	56	27.5576	.02674	560.	106.06	.02238	144.06
58	57	28.2719	.02652	570.	105.75	.02263	142.83
59	58	28.9943	.02630	580.	105.44	.02287	141.64
60	59	29.7248	.02608	590.	105.12	.02312	140.49
61	60	30.4634	.02585	600.	104.79	.02336	139.36
62	61	31.2091	.02561	610.	104.45	.02360	138.22
63	62	31.9619	.02536	620.	104.10	.02384	137.09
64	63	32.7217	.02511	630.	103.75	.02407	135.95
65	64	33.4885	.02486	640.	103.39	.02431	134.83
66	65	34.2613	.02459	650.	103.01	.02454	133.71
67	66	35.0400	.02432	660.	102.63	.02478	132.60
68	67	35.8248	.02404	670.	102.23	.02501	131.50
69	68	36.6144	.02376	680.	101.82	.02524	130.41
70	69	37.4088	.02346	690.	101.40	.02546	129.33
71	70	38.2079	.02316	700.	100.97	.02569	128.26
72	71	39.0116	.02285	710.	100.52	.02592	127.20
73	72	39.8201	.02253	720.	100.05	.02614	126.15
74	73	40.6333	.02220	730.	99.57	.02636	125.11
75	74	41.4512	.02187	740.	99.06	.02658	124.08
76	75	42.2739	.02152	750.	98.54	.02680	123.06
77	76	43.1014	.02116	760.	97.99	.02702	122.05

78	77	40.8792	.02079	770.	97.42	.02724	136.37
79	78	41.6202	.02041	780.	96.82	.02745	135.45
80	79	42.3690	.02002	790.	96.19	.02767	134.56
81	80	43.1254	.01961	800.	95.53	.02788	133.68
82	81	43.8896	.01919	810.	94.83	.02809	132.82
83	82	44.6615	.01876	820.	94.09	.02831	131.97
84	83	45.4411	.01831	830.	93.30	.02852	131.14
85	84	46.2283	.01784	840.	92.45	.02873	130.33
86	85	47.0232	.01735	850.	91.54	.02893	129.53
87	86	47.8257	.01685	860.	90.57	.02914	128.75
88	87	48.6359	.01632	870.	89.51	.02935	127.99
89	88	49.4536	.01577	880.	88.35	.02955	127.23
90	89	50.2790	.01519	890.	87.08	.02976	126.49
91	90	51.1120	.01458	900.	85.66	.02996	125.76
92	91	51.9525	.01394	910.	84.08	.03016	125.05
93	92	52.8006	.01326	920.	82.27	.03036	124.35
94	93	53.6562	.01253	930.	80.18	.03056	123.66
95	94	54.5194	.01175	940.	77.71	.03076	122.98
96	95	55.3902	.01091	950.	74.71	.03096	122.31
97	96	56.2684	.00998	960.	70.93	.03116	121.66
98	97	57.1541	.00895	970.	65.88	.03135	121.01
99	98	58.0474	.00777	980.	58.46	.03155	120.38
100	99	58.9480	.00636	990.	45.31	.03174	119.75
101	100	59.8562	.00451	1000.	.00	.03194	119.14
102	101	60.7719	.00000	1010.	.00	.03213	118.54

WELL BORE WIDTH	=	.38557	IN
AVERAGE WIDTH	=	.30282	IN
FRACTURE LENGTH	=	1010.00	FT
TREATMENT VOLUME	=	5286.83	FT**3
(PAD + SLURRY)			
FRACTURE VOLUME	=	1784.13	FT**3
(ONE WING)			
VOLUME LOST	=	3502.70	FT**3
TREATMENT EFFICIENCY	=	33.75	%
CALCULATED LEAK OFF	=	3318.37	FT**3
FLUID LOSS ERROR	=	5.26	%

WITH	41	ELEMENTS	*****	PROPPANT TYPE	1	---	TOP PARTICLE REACHED PROPPANT BED IN ELEMENT 41
WITH	47	ELEMENTS	*****	PROPPANT TYPE	1	---	ELEMENT CHANGED FROM 41 TO 40
WITH	50	ELEMENTS	*****	PROPPANT TYPE	1	---	ELEMENT CHANGED FROM 40 TO 39
WITH	58	ELEMENTS	*****	PROPPANT TYPE	1	---	ELEMENT CHANGED FROM 39 TO 38
WITH	64	ELEMENTS	*****	PROPPANT TYPE	1	---	ELEMENT CHANGED FROM 38 TO 37
WITH	65	ELEMENTS	*****	PROPPANT TYPE	2	---	TOP PARTICLE REACHED PROPPANT BED IN ELEMENT 25
WITH	67	ELEMENTS	*****	PROPPANT TYPE	2	---	ELEMENT CHANGED FROM 25 TO 24
WITH	68	ELEMENTS	*****	PROPPANT TYPE	1	---	ELEMENT CHANGED FROM 37 TO 36
WITH	73	ELEMENTS	*****	PROPPANT TYPE	2	---	ELEMENT CHANGED FROM 24 TO 23
WITH	74	ELEMENTS	*****	PROPPANT TYPE	1	---	ELEMENT CHANGED FROM 36 TO 35
WITH	74	ELEMENTS	*****	PROPPANT TYPE	1	---	ELEMENT CHANGED FROM 36 TO 34
WITH	80	ELEMENTS	*****	PROPPANT TYPE	3	---	TOP PARTICLE REACHED PROPPANT BED IN ELEMENT 29
WITH	92	ELEMENTS	*****	PROPPANT TYPE	3	---	INTERMEDIATE SETTLING IN ELEMENT 23
WITH	94	ELEMENTS	*****	PROPPANT TYPE	3	---	INTERMEDIATE ELEMENT CHANGED FROM 23 TO 22
WITH	97	ELEMENTS	*****	PROPPANT TYPE	3	---	INTERMEDIATE ELEMENT CHANGED FROM 22 TO 21

FRACTURE LENGTH = 1015.69 FT
 PROPPANT LENGTH = 840.00 FT
 WELLBORE WIDTH = .03224 FT
 = .36688 IN

LEADING EDGE PROPPANT TYPE 1 = 580.00 FT
 LEADING EDGE PROPPANT TYPE 2 = 580.00 FT
 LEADING EDGE PROPPANT TYPE 3 = 570.00 FT

SUTRICK AND RYSICKI SETTLING MODEL

ELEMENT NUMBER	LENGTH FT	TIME SEC	CONC LB/GAL	W(IN) FT	W(OUT) FT	WAVG FT	DM FT	Q(IN) BBL/MIN	Q(OUT) BBL/MIN	ELE VEL FT/SEC	SET VEL FT/SEC	FLUID LOST VEL-FT/SEC
1	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	17.5000	17.5463	.0074	.19812	.4684E-05
2	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	17.1465	17.1918	.0289	.19449	.4684E-05
3	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	17.0359	16.8136	.0550	.19064	.4684E-05
4	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	16.8786	16.7149	.0796	.18659	.4684E-05
5	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	16.7199	16.5497	.1009	.18218	.4684E-05
6	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	16.5587	16.3879	.1160	.17745	.4684E-05
7	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	16.3979	16.2247	.1274	.17262	.4684E-05
8	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	16.2387	16.0621	.1320	.16784	.4684E-05
9	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	16.0701	15.8901	.1331	.16313	.4684E-05
10	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	15.9023	15.7171	.1293	.15846	.4684E-05
11	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	15.7357	15.5488	.1248	.15387	.4684E-05
12	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	15.5688	15.3790	.1198	.14934	.4684E-05
13	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	15.4023	15.2098	.1143	.14487	.4684E-05
14	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	15.2367	15.0408	.1088	.14046	.4684E-05
15	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	15.0701	14.8708	.1033	.13611	.4684E-05
16	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	14.9023	14.7001	.0978	.13181	.4684E-05
17	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	14.7357	14.5308	.0923	.12756	.4684E-05
18	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	14.5688	14.3608	.0868	.12334	.4684E-05
19	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	14.4023	14.1908	.0813	.11916	.4684E-05
20	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	14.2367	14.0208	.0758	.11499	.4684E-05
21	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	14.0701	13.8501	.0703	.11081	.4684E-05
22	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	13.9023	13.6771	.0648	.10664	.4684E-05
23	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	13.7357	13.5058	.0593	.10246	.4684E-05
24	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	13.5688	13.3348	.0538	.09829	.4684E-05
25	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	13.4023	13.1638	.0483	.09411	.4684E-05
26	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	13.2367	12.9888	.0428	.08994	.4684E-05
27	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	13.0701	12.8168	.0373	.08576	.4684E-05
28	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	12.9023	12.6438	.0318	.08159	.4684E-05
29	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	12.7357	12.4708	.0263	.07741	.4684E-05
30	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	12.5688	12.2998	.0208	.07324	.4684E-05
31	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	12.4023	12.1288	.0153	.06906	.4684E-05
32	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	12.2367	11.9588	.0098	.06489	.4684E-05
33	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	12.0701	11.7808	.0043	.06071	.4684E-05
34	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	11.9023	11.6058	.0000	.05654	.4684E-05
35	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	11.7357	11.4268	.0000	.05236	.4684E-05
36	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	11.5688	11.2488	.0000	.04819	.4684E-05
37	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	11.4023	11.0708	.0000	.04401	.4684E-05
38	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	11.2367	10.8938	.0000	.03984	.4684E-05
39	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	11.0701	10.7168	.0000	.03566	.4684E-05
40	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	10.9023	10.5388	.0000	.03149	.4684E-05
41	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	10.7357	10.3608	.0000	.02731	.4684E-05
42	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	10.5688	10.1848	.0000	.02314	.4684E-05
43	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	10.4023	9.9998	.0000	.01896	.4684E-05
44	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	10.2367	9.8208	.0000	.01479	.4684E-05
45	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	10.0701	9.6438	.0000	.01061	.4684E-05
46	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	9.9023	9.4668	.0000	.00644	.4684E-05
47	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	9.7357	9.2208	.0000	.00226	.4684E-05
48	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	9.5688	9.0008	.0000	.00000	.4684E-05
49	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	9.4023	8.7768	.0000	.00000	.4684E-05
50	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	9.2367	8.5488	.0000	.00000	.4684E-05
51	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	9.0701	8.3508	.0000	.00000	.4684E-05
52	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	8.9023	8.1268	.0000	.00000	.4684E-05
53	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	8.7357	7.8938	.0000	.00000	.4684E-05
54	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	8.5688	7.6608	.0000	.00000	.4684E-05
55	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	8.4023	7.4268	.0000	.00000	.4684E-05
56	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	8.2367	7.1488	.0000	.00000	.4684E-05
57	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	8.0701	6.9608	.0000	.00000	.4684E-05
58	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	7.9023	6.7768	.0000	.00000	.4684E-05
59	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	7.7357	6.5888	.0000	.00000	.4684E-05
60	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	7.5688	6.3998	.0000	.00000	.4684E-05
61	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	7.4023	6.2108	.0000	.00000	.4684E-05
62	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	7.2367	6.0208	.0000	.00000	.4684E-05
63	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	7.0701	5.8308	.0000	.00000	.4684E-05
64	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	6.9023	5.6408	.0000	.00000	.4684E-05
65	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	6.7357	5.4508	.0000	.00000	.4684E-05
66	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	6.5688	5.2608	.0000	.00000	.4684E-05
67	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	6.4023	5.0708	.0000	.00000	.4684E-05
68	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	6.2367	4.8808	.0000	.00000	.4684E-05
69	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	6.0701	4.6908	.0000	.00000	.4684E-05
70	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	5.9023	4.5008	.0000	.00000	.4684E-05
71	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	5.7357	4.3108	.0000	.00000	.4684E-05
72	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	5.5688	4.1208	.0000	.00000	.4684E-05
73	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	5.4023	3.9308	.0000	.00000	.4684E-05
74	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	5.2367	3.7408	.0000	.00000	.4684E-05
75	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	5.0701	3.5508	.0000	.00000	.4684E-05
76	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	4.9023	3.3608	.0000	.00000	.4684E-05
77	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	4.7357	3.1708	.0000	.00000	.4684E-05
78	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	4.5688	2.9808	.0000	.00000	.4684E-05
79	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	4.4023	2.7908	.0000	.00000	.4684E-05
80	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	4.2367	2.6008	.0000	.00000	.4684E-05
81	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	4.0701	2.4108	.0000	.00000	.4684E-05
82	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	3.9023	2.2208	.0000	.00000	.4684E-05
83	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	3.7357	2.0308	.0000	.00000	.4684E-05
84	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	3.5688	1.8408	.0000	.00000	.4684E-05
85	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	3.4023	1.6508	.0000	.00000	.4684E-05
86	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	3.2367	1.4608	.0000	.00000	.4684E-05
87	10.00	8.9813	.03326	.03326	.03326	.03326	.03326	3.0701				

41	410.00	18.0181	.0000	.02963	.02950	.02957	.1826E-03	12.1418	12.0275	.5550	.00000000	.5555E-05
42	420.00	18.0182	.0000	.02963	.02950	.02957	.1826E-03	12.0275	12.0275	.5550	.00000000	.5555E-05
43	430.00	18.0183	.0000	.02963	.02950	.02957	.1826E-03	11.9121	11.7459	.5440	.00000000	.5628E-05
44	440.00	18.0184	.0000	.02963	.02950	.02957	.1826E-03	11.7959	11.6787	.5414	.00000000	.5667E-05
45	450.00	18.0185	.0000	.02963	.02950	.02957	.1826E-03	11.6797	11.5606	.5389	.00000000	.5707E-05
46	460.00	18.0186	.0000	.02963	.02950	.02957	.1826E-03	11.5606	11.4415	.5363	.00000000	.5749E-05
47	470.00	18.0187	.0000	.02963	.02950	.02957	.1826E-03	11.4415	11.3215	.5338	.00000000	.5793E-05
48	480.00	18.0188	.0000	.02963	.02950	.02957	.1826E-03	11.3215	11.2003	.5312	.00000000	.5839E-05
49	490.00	18.0189	.0000	.02963	.02950	.02957	.1826E-03	11.2003	11.0781	.5287	.00000000	.5886E-05
50	500.00	18.0190	.0000	.02963	.02950	.02957	.1826E-03	11.0781	10.9547	.5262	.00000000	.5935E-05
51	510.00	18.0191	.0000	.02963	.02950	.02957	.1826E-03	10.9547	10.8301	.5237	.00000000	.5987E-05
52	520.00	18.0192	.0000	.02963	.02950	.02957	.1826E-03	10.8301	10.7043	.5211	.00000000	.6041E-05
53	530.00	18.0193	.0000	.02963	.02950	.02957	.1826E-03	10.7043	10.5772	.5186	.00000000	.6097E-05
54	540.00	18.0194	.0000	.02963	.02950	.02957	.1826E-03	10.5772	10.4489	.5161	.00000000	.6149E-05
55	550.00	18.0195	.0000	.02963	.02950	.02957	.1826E-03	10.4489	10.3194	.5136	.00000000	.6198E-05
56	560.00	18.0196	.0000	.02963	.02950	.02957	.1826E-03	10.3194	10.1886	.5110	.00000000	.6248E-05
57	570.00	18.0197	.0000	.02963	.02950	.02957	.1826E-03	10.1886	10.0569	.5085	.00000000	.6300E-05
58	580.00	18.0198	.0000	.02963	.02950	.02957	.1826E-03	10.0569	9.9240	.5060	.00000000	.6355E-05
59	590.00	18.0199	.0000	.02963	.02950	.02957	.1826E-03	9.9240	9.7881	.5035	.00000000	.6412E-05
60	600.00	18.0200	.0000	.02963	.02950	.02957	.1826E-03	9.7881	9.6518	.5009	.00000000	.6471E-05
61	610.00	18.0201	.0000	.02963	.02950	.02957	.1826E-03	9.6518	9.5140	.4984	.00000000	.6532E-05
62	620.00	18.0202	.0000	.02963	.02950	.02957	.1826E-03	9.5140	9.3745	.4958	.00000000	.6596E-05
63	630.00	18.0203	.0000	.02963	.02950	.02957	.1826E-03	9.3745	9.2334	.4933	.00000000	.6664E-05
64	640.00	18.0204	.0000	.02963	.02950	.02957	.1826E-03	9.2334	9.0905	.4907	.00000000	.6734E-05
65	650.00	18.0205	.0000	.02963	.02950	.02957	.1826E-03	9.0905	8.9459	.4881	.00000000	.6807E-05
66	660.00	18.0206	.0000	.02963	.02950	.02957	.1826E-03	8.9459	8.7993	.4855	.00000000	.6882E-05
67	670.00	18.0207	.0000	.02963	.02950	.02957	.1826E-03	8.7993	8.6507	.4828	.00000000	.6964E-05
68	680.00	18.0208	.0000	.02963	.02950	.02957	.1826E-03	8.6507	8.5001	.4802	.00000000	.7048E-05
69	690.00	18.0209	.0000	.02963	.02950	.02957	.1826E-03	8.5001	8.3473	.4775	.00000000	.7137E-05
70	700.00	18.0210	.0000	.02963	.02950	.02957	.1826E-03	8.3473	8.1926	.4748	.00000000	.7230E-05
71	710.00	18.0211	.0000	.02963	.02950	.02957	.1826E-03	8.1926	8.0387	.4720	.00000000	.7328E-05
72	720.00	18.0212	.0000	.02963	.02950	.02957	.1826E-03	8.0387	7.8787	.4692	.00000000	.7431E-05
73	730.00	18.0213	.0000	.02963	.02950	.02957	.1826E-03	7.8787	7.7119	.4664	.00000000	.7540E-05
74	740.00	18.0214	.0000	.02963	.02950	.02957	.1826E-03	7.7119	7.5464	.4635	.00000000	.7655E-05
75	750.00	18.0215	.0000	.02963	.02950	.02957	.1826E-03	7.5464	7.3779	.4605	.00000000	.7777E-05
76	760.00	18.0216	.0000	.02963	.02950	.02957	.1826E-03	7.3779	7.2062	.4575	.00000000	.7906E-05
77	770.00	18.0217	.0000	.02963	.02950	.02957	.1826E-03	7.2062	7.0311	.4544	.00000000	.8044E-05
78	780.00	18.0218	.0000	.02963	.02950	.02957	.1826E-03	7.0311	6.8525	.4512	.00000000	.8190E-05
79	790.00	18.0219	.0000	.02963	.02950	.02957	.1826E-03	6.8525	6.6700	.4479	.00000000	.8347E-05
80	800.00	18.0220	.0000	.02963	.02950	.02957	.1826E-03	6.6700	6.4835	.4445	.00000000	.8515E-05
81	810.00	18.0221	.0000	.02963	.02950	.02957	.1826E-03	6.4835	6.2926	.4410	.00000000	.8695E-05
82	820.00	18.0222	.0000	.02963	.02950	.02957	.1826E-03	6.2926	6.0969	.4373	.00000000	.8889E-05
83	830.00	18.0223	.0000	.02963	.02950	.02957	.1826E-03	6.0969	5.8962	.4336	.00000000	.9097E-05
84	840.00	18.0224	.0000	.02963	.02950	.02957	.1826E-03	5.8962	5.6899	.4296	.00000000	.9327E-05
85	850.00	18.0225	.0000	.02963	.02950	.02957	.1826E-03	5.6899	5.4777	.4254	.00000000	.9575E-05
86	860.00	18.0226	.0000	.02963	.02950	.02957	.1826E-03	5.4777	5.2580	.4209	.00000000	.9844E-05
87	870.00	18.0227	.0000	.02963	.02950	.02957	.1826E-03	5.2580	5.0327	.4162	.00000000	.1015E-04
88	880.00	18.0228	.0000	.02963	.02950	.02957	.1826E-03	5.0327	4.7986	.4111	.00000000	.1048E-04
89	890.00	18.0229	.0000	.02963	.02950	.02957	.1826E-03	4.7986	4.5556	.4057	.00000000	.1085E-04
90	900.00	18.0230	.0000	.02963	.02950	.02957	.1826E-03	4.5556	4.3025	.3997	.00000000	.1127E-04
91	910.00	18.0231	.0000	.02963	.02950	.02957	.1826E-03	4.3025	4.0379	.3942	.00000000	.1174E-04
92	920.00	18.0232	.0000	.02963	.02950	.02957	.1826E-03	4.0379	3.7603	.3886	.00000000	.1229E-04
93	930.00	18.0233	.0000	.02963	.02950	.02957	.1826E-03	3.7603	3.4674	.3827	.00000000	.1292E-04
94	940.00	18.0234	.0000	.02963	.02950	.02957	.1826E-03	3.4674	3.1563	.3764	.00000000	.1367E-04
95	950.00	18.0235	.0000	.02963	.02950	.02957	.1826E-03	3.1563	2.8233	.3694	.00000000	.1459E-04
96	960.00	18.0236	.0000	.02963	.02950	.02957	.1826E-03	2.8233	2.4628	.3622	.00000000	.1572E-04
97	970.00	18.0237	.0000	.02963	.02950	.02957	.1826E-03	2.4628	2.0667	.3549	.00000000	.1718E-04
98	980.00	18.0238	.0000	.02963	.02950	.02957	.1826E-03	2.0667	1.5890	.3464	.00000000	.1918E-04

ELEMENT NUMBER	ARR VLS CP	RE(FLOW)	SHR RATE PART 1/3	RE(PART)	FRAC HT FT	OP HT FT	BED HT FT	DM BED FT	FALL HT FT	DEM FT	BURR HT FT	NET BURR FT
1		1072.8448	60.0000	5.1968	70.0000	24.5833	45.4167	.9367E+00	.9869	.9869E+00	69.0131	23.5968
2		1087.0236	60.0000	5.1011	70.0000	24.0829	45.9171	.9581E+00	1.0707	.9586E+00	68.0293	22.1122
3		108.1533	60.0000	5.0000	70.0000	23.5392	46.4608	.9720E+00	2.9491	.9277E+00	67.0509	20.5901
4		20.3248	60.0000	4.5941	70.0000	23.0245	46.9755	.9903E+00	3.9234	.8973E+00	66.0766	19.1011
5		18.1874	60.0000	4.7745	70.0000	22.5582	47.4418	1.009E+01	4.8943	.8672E+00	65.1057	17.6680
6		143.8630	60.0000	4.5542	70.0000	22.1672	47.8328	1.029E+01	5.8637	.8386E+00	64.1363	16.3035
7		144.8010	60.0000	4.5277	70.0000	21.9255	48.0745	1.049E+01	6.8412	.8152E+00	63.1588	15.0843
8		140.0847	60.0000	4.5024	70.0000	21.7610	48.2390	1.067E+01	7.8327	.7947E+00	62.1673	13.9283
9		130.1122	60.0000	4.4787	70.0000	21.5264	48.4136	1.084E+01	8.8360	.7720E+00	61.1640	12.8204
10		120.9398	60.0000	4.4568	70.0000	21.3113	48.6687	1.099E+01	9.8519	.7501E+00	60.1481	11.7595
11		112.6474	60.0000	4.4359	70.0000	21.1175	48.8244	1.114E+01	10.8830	.7312E+00	59.1170	10.7426
12		105.7476	60.0000	4.4178	70.0000	20.9451	48.9649	1.127E+01	11.9318	.7144E+00	58.0686	9.7637
13		100.0558	60.0000	4.4028	70.0000	20.7901	49.0998	1.139E+01	13.0000	.6982E+00	57.0020	8.8421
14		97.4488	60.0000	4.3884	70.0000	20.6225	49.2775	1.150E+01	14.0819	.6840E+00	55.9181	7.9406
15		95.8308	60.0000	4.3759	70.0000	20.4807	49.4903	1.160E+01	15.1813	.6695E+00	54.8185	7.0282
16		94.8188	60.0000	4.3638	70.0000	20.3534	49.6866	1.169E+01	16.2923	.6551E+00	53.7077	6.1211
17		94.3188	60.0000	4.3528	70.0000	20.2328	49.8672	1.177E+01	17.4076	.6405E+00	52.5928	5.2252
18		94.3225	60.0000	4.3425	70.0000	20.1111	49.9889	1.184E+01	18.5251	.6269E+00	51.4749	4.3560
19		94.3225	60.0000	4.3325	70.0000	20.0000	49.1039	1.189E+01	19.6536	.6162E+00	50.3464	3.4425
20		94.3225	60.0000	4.3225	70.0000	19.8958	49.1586	1.193E+01	20.8036	.6047E+00	49.1968	2.5378
21		94.3225	60.0000	4.3125	70.0000	19.7943	49.2125	1.196E+01	21.9887	.5941E+00	48.0315	1.6400
22		94.3225	60.0000	4.3025	70.0000	19.6943	49.2755	1.200E+01	23.1639	.5840E+00	46.8755	0.7455
23		94.3225	60.0000	4.2925	70.0000	19.5943	49.3380	1.200E+01	24.3198	.5740E+00	45.7100	0.0000
24		94.3225	60.0000	4.2825	70.0000	19.4943	49.3993	1.200E+01	25.4543	.5640E+00	44.5350	0.0000
25		94.3225	60.0000	4.2725	70.0000	19.3943	49.4593	1.200E+01	26.5673	.5540E+00	43.3500	0.0000
26		94.3225	60.0000	4.2625	70.0000	19.2943	49.5187	1.200E+01	27.6593	.5440E+00	42.1550	0.0000
27		94.3225	60.0000	4.2525	70.0000	19.1943	49.5775	1.200E+01	28.7307	.5340E+00	40.9500	0.0000
28		94.3225	60.0000	4.2425	70.0000	19.0943	49.6359	1.200E+01	29.7810	.5240E+00	39.7350	0.0000
29		94.3225	60.0000	4.2325	70.0000	18.9943	49.6939	1.200E+01	30.8110	.5140E+00	38.5100	0.0000
30		94.3225	60.0000	4.2225	70.0000	18.8943	49.7514	1.200E+01	31.8210	.5040E+00	37.2750	0.0000
31		94.3225	60.0000	4.2125	70.0000	18.7943	49.8084	1.200E+01	32.8110	.4940E+00	36.0300	0.0000
32		94.3225	60.0000	4.2025	70.0000	18.6943	49.8649	1.200E+01	33.7810	.4840E+00	34.7750	0.0000
33		94.3225	60.0000	4.1925	70.0000	18.5943	49.9209	1.200E+01	34.7310	.4740E+00	33.5100	0.0000
34		94.3225	60.0000	4.1825	70.0000	18.4943	49.9764	1.200E+01	35.6610	.4640E+00	32.2350	0.0000
35		94.3225	60.0000	4.1725	70.0000	18.3943	50.0314	1.200E+01	36.5810	.4540E+00	30.9500	0.0000
36		94.3225	60.0000	4.1625	70.0000	18.2943	50.0859	1.200E+01	37.4910	.4440E+00	29.6550	0.0000
37		94.3225	60.0000	4.1525	70.0000	18.1943	50.1399	1.200E+01	38.3910	.4340E+00	28.3500	0.0000
38		94.3225	60.0000	4.1425	70.0000	18.0943	50.1934	1.200E+01	39.2810	.4240E+00	27.0350	0.0000
39		94.3225	60.0000	4.1325	70.0000	17.9943	50.2464	1.200E+01	40.1610	.4140E+00	25.7100	0.0000
40		94.3225	60.0000	4.1225	70.0000	17.8943	50.2989	1.200E+01	41.0310	.4040E+00	24.3750	0.0000
41		94.3225	60.0000	4.1125	70.0000	17.7943	50.3509	1.200E+01	41.8910	.3940E+00	23.0300	0.0000
42		94.3225	60.0000	4.1025	70.0000	17.6943	50.4024	1.200E+01	42.7410	.3840E+00	21.6750	0.0000
43		94.3225	60.0000	4.0925	70.0000	17.5943	50.4534	1.200E+01	43.5810	.3740E+00	20.3100	0.0000
44		94.3225	60.0000	4.0825	70.0000	17.4943	50.5039	1.200E+01	44.4110	.3640E+00	18.9350	0.0000
45		94.3225	60.0000	4.0725	70.0000	17.3943	50.5539	1.200E+01	45.2310	.3540E+00	17.5500	0.0000
46		94.3225	60.0000	4.0625	70.0000	17.2943	50.6034	1.200E+01	46.0410	.3440E+00	16.1550	0.0000
47		94.3225	60.0000	4.0525	70.0000	17.1943	50.6524	1.200E+01	46.8410	.3340E+00	14.7500	0.0000
48		94.3225	60.0000	4.0425	70.0000	17.0943	50.7009	1.200E+01	47.6310	.3240E+00	13.3350	0.0000
49		94.3225	60.0000	4.0325	70.0000	16.9943	50.7489	1.200E+01	48.4110	.3140E+00	11.9100	0.0000
50		94.3225	60.0000	4.0225	70.0000	16.8943	50.7964	1.200E+01	49.1810	.3040E+00	10.4750	0.0000
51		94.3225	60.0000	4.0125	70.0000	16.7943	50.8434	1.200E+01	50.0000	.2940E+00	9.0300	0.0000
52		94.3225	60.0000	4.0025	70.0000	16.6943	50.8899	1.200E+01	50.8110	.2840E+00	7.5750	0.0000
53		94.3225	60.0000	3.9925	70.0000	16.5943	50.9359	1.200E+01	51.6110	.2740E+00	6.1100	0.0000
54		94.3225	60.0000	3.9825	70.0000	16.4943	50.9814	1.200E+01	52.4010	.2640E+00	4.6350	0.0000
55		94.3225	60.0000	3.9725	70.0000	16.3943	51.0264	1.200E+01	53.1810	.2540E+00	3.1500	0.0000
56		94.3225	60.0000	3.9625	70.0000	16.2943	51.0709	1.200E+01	53.9510	.2440E+00	1.6550	0.0000
57		94.3225	60.0000	3.9525	70.0000	16.1943	51.1149	1.200E+01	54.7110	.2340E+00	0.1500	0.0000
58		94.3225	60.0000	3.9425	70.0000	16.0943	51.1584	1.200E+01	55.4610	.2240E+00	0.0000	0.0000
59		94.3225	60.0000	3.9325	70.0000	15.9943	51.2014	1.200E+01	56.2010	.2140E+00	0.0000	0.0000
60		94.3225	60.0000	3.9225	70.0000	15.8943	51.2439	1.200E+01	56.9310	.2040E+00	0.0000	0.0000
61		94.3225	60.0000	3.9125	70.0000	15.7943	51.2859	1.200E+01	57.6510	.1940E+00	0.0000	0.0000
62		94.3225	60.0000	3.9025	70.0000	15.6943	51.3274	1.200E+01	58.3610	.1840E+00	0.0000	0.0000
63		94.3225	60.0000	3.8925	70.0000	15.5943	51.3684	1.200E+01	59.0610	.1740E+00	0.0000	0.0000
64		94.3225	60.0000	3.8825	70.0000	15.4943	51.4089	1.200E+01	59.7510	.1640E+00	0.0000	0.0000
65		94.3225	60.0000	3.8725	70.0000	15.3943	51.4489	1.200E+01	60.4310	.1540E+00	0.0000	0.0000
66		94.3225	60.0000	3.8625	70.0000	15.2943	51.4884	1.200E+01	61.1010	.1440E+00	0.0000	0.0000
67		94.3225	60.0000	3.8525	70.0000	15.1943	51.5274	1.200E+01	61.7610	.1340E+00	0.0000	0.0000
68		94.3225	60.0000	3.8425	70.0000	15.0943	51.5659	1.200E+01	62.4110	.1240E+00	0.0000	0.0000
69		94.3225	60.0000	3.8325	70.0000	14.9943	51.6039	1.200E+01	63.0510	.1140E+00	0.0000	0.0000
70		94.3225	60.0000	3.8225	70.0000	14.8943	51.6414	1.200E+01	63.6810	.1040E+00	0.0000	0.0000
71		94.3225	60.0000	3.8125	70.0000	14.7943	51.6784	1.200E+01	64.3010	.0940E+00	0.0000	0.0000
72		94.3225	60.0000	3.8025	70.0000	14.6943	51.7149	1.200E+01	64.9110	.0840E+00	0.0000	0.0000
73		94.3225	60.0000	3.7925	70.0000	14.5943	51.7509	1.200E+01	65.5110	.0740E+00	0.0000	0.0000
74		94.3225	60.0000	3.7825	70.0000	14.4943	51.7864	1.200E+01	66.1010	.0640E+00	0.0000	0.0000
75		94.3225	60.0000	3.7725	70.0000	14.3943	51.8214	1.200E+01	66.6810	.0540E+00	0.0000	0.0000
76		94.3225	60.0000	3.7625	70.0000	14.2943	51.8559	1.200E+01	67.2510	.0440E+00	0.0000	0.0000
77		94.3225	60.0000	3.7525	70.0000	14.1943	51.8899	1.200E+01	67.8110	.0340E+00	0.0000	0.0000
78		94.3225	60.0000	3.7425	70.0000	14.0943	51.9234	1.200E+01	68.3610	.0240E+00	0.0000	0.0000
79		94.3225	60.0000	3.7325	70.0000	13.9943	51.9564	1.200E+01	68.9010	.0140E+00	0.0000	0.0000
80		94.3225	60.0000	3.7225	70.0000	13.8943	51.9889	1.200E+01	69.4310	.0040E+00	0.0000	0.0000
81		94.3225	60.0000	3.7125	70.0000	13.7943	52.0209	1.200E+01	70.0000	.0000E+00	0.0000	0.0000
82		94.3225	60.0000	3.7025	70.0000	13.6943	52.0524	1.200E+01	70.6110	.0000E+00	0.0000	0.0000
83		94.3225	60.0									

55	1.4	74.8855	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	55.1875	.0000E+00	.0000	.0000
56	1.4	74.8855	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	55.1875	.0000E+00	.0000	.0000
57	1.4	69.4716	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	58.4307	.0000E+00	.0000	.0000
58	1.4	67.4926	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	58.6010	.0000E+00	.0000	.0000
59	1.4	65.7973	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	51.6912	.0000E+00	.0000	.0000
60	1.4	63.8853	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	52.2160	.0000E+00	.0000	.0000
61	1.4	61.5550	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	53.6054	.0000E+00	.0000	.0000
62	1.4	59.4053	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	54.1283	.0000E+00	.0000	.0000
63	1.4	57.2381	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	54.4360	.0000E+00	.0000	.0000
64	1.4	55.0831	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	54.7351	.0000E+00	.0000	.0000
65	1.4	52.9278	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	55.0266	.0000E+00	.0000	.0000
66	1.4	50.7879	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	55.3106	.0000E+00	.0000	.0000
67	1.4	48.6321	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	55.5864	.0000E+00	.0000	.0000
68	1.4	46.4716	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	57.1883	.0000E+00	.0000	.0000
69	1.4	44.3108	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	57.4556	.0000E+00	.0000	.0000
70	1.4	42.1488	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	57.7040	.0000E+00	.0000	.0000
71	1.4	39.9942	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	57.9389	.0000E+00	.0000	.0000
72	1.4	37.8386	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	58.1683	.0000E+00	.0000	.0000
73	1.4	35.6709	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	59.7623	.0000E+00	.0000	.0000
74	1.4	33.5059	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	59.9909	.0000E+00	.0000	.0000
75	1.4	31.3373	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	60.2221	.0000E+00	.0000	.0000
76	1.4	29.1616	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	60.4597	.0000E+00	.0000	.0000
77	1.4	26.9743	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	60.7043	.0000E+00	.0000	.0000
78	1.4	24.7845	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	60.9511	.0000E+00	.0000	.0000
79	1.4	22.5950	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	61.1804	.0000E+00	.0000	.0000
80	1.4	20.4020	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	62.4144	.0000E+00	.0000	.0000
81	1.4	18.2003	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	63.3447	.0000E+00	.0000	.0000
82	1.4	16.0033	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	63.7987	.0000E+00	.0000	.0000
83	1.4	13.8060	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	63.7987	.0000E+00	.0000	.0000
84	1.4	11.6020	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	64.2829	.0000E+00	.0000	.0000
85	1.4	9.4040	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	64.7979	.0000E+00	.0000	.0000
86	1.4	7.2010	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	65.3363	.0000E+00	.0000	.0000
87	1.4	5.0081	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	65.5074	.0000E+00	.0000	.0000
88	1.4	2.8118	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	65.6582	.0000E+00	.0000	.0000
89	1.4	.6144	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	67.4246	.0000E+00	.0000	.0000
90	1.4	.4173	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	67.5548	.0000E+00	.0000	.0000
91	1.4	.2150	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	67.6521	.0000E+00	.0000	.0000
92	1.4	.0119	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	67.7372	.0000E+00	.0000	.0000
93	1.4	.0021	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	69.4318	.0000E+00	.0000	.0000
94	1.4	.0011	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	69.4973	.0000E+00	.0000	.0000
95	1.4	.0006	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	69.5510	.0000E+00	.0000	.0000
96	1.4	.0003	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	69.6126	.0000E+00	.0000	.0000
97	1.4	.0002	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	69.6742	.0000E+00	.0000	.0000
98	1.4	.0001	.0000	.0000	70.0000	70.0000	.0000	.0000E+00	69.8301	.0000E+00	.0000	.0000

ELE / NO	ELE TIME SEC	TOTAL TIME MIN	PROP LEN FT	FRAC LEN FT	CONC LB/GAL	APP VIS CP	ELE VEL FT/SEC	D(IN) FT/SEC	D(OUT) FT/SEC	AVG WIDTH FT	SET VEL FT/S	BED HT FT	OPEN HT FT	SUSP HT FT	FRAC HT FT
1	9.28	12.15	10	108.30	2.0363	12	2.0074	17.5000	17.3863	.03224	.1981	45.4167	22.3433	69.0131	70.0000
2	9.25	12.31	20	111.03	.1128	12	.0280	17.3863	17.1918	.03224	.1945	45.9171	22.0829	69.0293	70.0000
3	9.27	12.48	30	111.78	.0600	12	.0550	17.0359	17.0359	.03223	.1906	46.4608	23.5102	69.0508	70.0000
4	9.27	12.68	40	112.59	.2850	12	.0786	17.0359	17.0359	.03222	.1866	46.9755	23.0245	69.0766	70.0000
5	10.19	12.51	50	112.88	.1863	12	.1009	16.8786	16.8786	.03221	.1822	47.4818	22.7582	69.1097	70.0000
6	10.42	12.99	60	122.34	.4988	12	2.1160	16.7199	16.5597	.03219	.1775	47.4328	22.1672	64.1363	70.0000

66	47.44	74.72	660	663.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
67	47.44	74.72	670	673.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
68	47.44	74.72	680	683.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
69	47.44	74.72	690	693.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
70	47.44	74.72	700	703.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
71	47.44	74.72	710	713.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
72	47.44	74.72	720	723.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
73	47.44	74.72	730	733.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
74	47.44	74.72	740	743.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
75	47.44	74.72	750	753.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
76	47.44	74.72	760	763.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
77	47.44	74.72	770	773.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
78	47.44	74.72	780	783.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
79	47.44	74.72	790	793.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
80	47.44	74.72	800	803.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
81	47.44	74.72	810	813.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
82	47.44	74.72	820	823.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
83	47.44	74.72	830	833.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
84	47.44	74.72	840	843.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
85	47.44	74.72	850	853.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
86	47.44	74.72	860	863.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
87	47.44	74.72	870	873.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
88	47.44	74.72	880	883.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
89	47.44	74.72	890	893.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
90	47.44	74.72	900	903.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
91	47.44	74.72	910	913.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
92	47.44	74.72	920	923.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
93	47.44	74.72	930	933.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
94	47.44	74.72	940	943.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
95	47.44	74.72	950	953.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
96	47.44	74.72	960	963.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
97	47.44	74.72	970	973.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000
98	47.44	74.72	980	983.33	.0000	13.	.4855	8.9459	8.7993	.02464	.0000	.0000	70.0000	.0000	70.0000

TIME OF PROP INJECTION= 49.297
 VOLUME OF INJECTED FLUID = 4241.086
 VOLUME IN FRACTURE= 1405.671
 VOLUME LOST= 2335.374
 DIFFERENCE= 510.036
 ERROR= 12.0268

MASS OF PROP INJECTED= 60711.967
 MASS OF SETTLED PROP= 61314.605
 MASS OF SUSPENDED PROP= 1448.867
 TOTAL MASS= 62763.492
 DIFFERENCE= -2051.524
 ERROR= -3.3798

210P4

CHAPTER II

COMBINED PSEUDO 3-D HIGHLY ELONGATED FRACTURE MODEL AND PROPPANT MODEL TUPROPC

General Description

The University of Tulsa has coupled Oral Roberts University's Highly Elongated Fracture Model, for the symmetric bounding zone case, to The University of Tulsa's Proppant Transport Model (TUPROP1). The modification to TUPROP1, which contained its own fracturing model, was renamed TUPROPC. The combined treatment model will represent hydraulic fracturing treatments and proppant transport using typical stimulation techniques involving noncross-linked fracturing gels as a transport medium for the proppant material. Non-Newtonian fluid behavior in the program is simulated through use of the power law model. Both variable flow rate schedules and different proppant types can be simulated by TUPROPC. The fracturing section can handle any fracture increment but the usual size for massive hydraulic fracture treatments is 100 feet. Fracture lengths are selected in multiples of three; each of which must be a multiple of the fracture increment selected. For example, with a 100 foot increment, the initial selections might be 200, 300, 400. Since TUPROPC is designed to handle 250 elements in the proppant section, if 10 foot increments were used, the maximum fracture that could be handled is 2500 ft. Thus, the effect of element length in the proppant program must be considered when establishing parameters in the fracturing section and vice versa.

Since, in most well stimulations, good proppant carrying capacity is desired, TUPROPC, just as in TUPROP1, has no routine to check for equilibrium conditions for fluid velocity and proppant bed height. The condition of a fracture fluid having a low viscosity trying to carry large, dense proppant would provide a situation requiring this check.

These stimulations would not result in propped fractures of maximum length. However, since settling and proppant bed formation occur in any treatment, a sophisticated particle tracking procedure has been included in the program to track the top particles in the proppant slurry. Thus, a very accurate tracking procedure for the mass of proppant is contained in the program. To avoid the equilibrium situations, the following parameters can be changed; fluid viscosity, proppant type, pumping rate, fluid leakoff coefficient, and treatment time. Normally, a pay zone height between 20 to 200 ft., medium viscosity fluids, leakoff coefficients between 0 and 0.0044 ft./min., and flow rates less than 80 bbl/min. will allow proper operation of the program.

In the fracture section, proper geometric results are maintained if the height to length ratio is at least 1:4. This consideration is important in initializing the program. For example, if the pay zone height is 50 feet and the initial fracture height is taken to be greater than 50 feet say 50.001 feet, the minimum fracture length should not be less than 200 feet.

Program limitations can be exceeded. If the proppant portion of the program requires more than 250 steps, the program will run through the 250th step, but the treatment time will not be reached. The case where proppant settling is so rapid that the equilibrium flow and equilibrium height of the bed are exceeded, the program will give a Fortran run time error due to negative numbers being introduced. The program also tracks the proppant front, and if this front reaches the fracture tip, then a screen out occurs. The proppant front, however, can be devoid of proppant, thus giving a false screen out indication. Since the original design criterion was to always keep proppant in the slurry, no routine has

been implemented to solve this problem. While no actual error results from the false screen out, the same screen out message is printed as if proppant was present and the total treatment time will not be reached. The false screen out condition is not desirable, because proppant was not carried in the fracturing fluid to the end of the fracture. This condition can be rectified by using a more viscous liquid in the treatment, using a smaller proppant or using a less dense proppant.

TUPROPC has five settling models which can be used; however, for Non-Newtonian gels, the Sutrick and Rybicki model is recommended. If a Newtonian fracturing fluid is used, the Zigrang and Sylvester settling model should be used. The other three models can be used for comparison. The Daneshy model is purely theoretical and can only be used when the particle Reynold's number is less than 1. The Acharya model could be used to see the effects of very low proppant settling velocities on the fracture but is not recommended for general use. The Clark model is a good approximation for Guar Gum gels, but does not consider wall effects.

Input

Input in Appendix A for the combined treatment comes from three files. The first file, FLKM is the input file for the fracture section. Secondly, an output file, ORUIN, containing fracture geometry and fracture time is used as input to the proppant section. Data transfer for the second file is done automatically in the format, E26.18, and no direct user input to the file is needed. However, the third file, DATATUPC, is the user input file for the proppant section.

FLKM, the user input file for the fracture section, is a sequential unformatted file. It requires only real or integer inputs. Table 1 is a list of the inputs with units. Note each input is on a separate record.

Table 1. FLKM - Fracture Input

Record No.	Type of Variable	Identification	Variable Name	Units
1	Integer	Number of length groups	NRUN	
2	Integer	Number of flow rates used	NNQ (Limited to 1)	
3	Integer	Flag selected to use the type of calculation	ITQ	
4	Integer	Flag used to select output	IWRITE	
5	Real	Fracture toughness	KCB	Dynes/cm**1.5
6	Real	Pay zone height	HZ	ft
7	Real	Flow rate-one wing	QIN	bbl/min
8	Real	Behavioral index	FLN	
9	Real	Consistency index	FLOWK	Dynes.s ⁿ /cm ²
10	Real	Young's modulus	EMOD	psi
11	Real	Poisson's ratio	RNU	
12	Real	Stress contrast	S2MS1	psi
13	Real	First fracture length	A1	ft
14	Real	Second fracture length	A2	ft
15	Real	Third fracture length	A4	ft
16	Real	Fluid leakoff coefficients	LEAKC	cm/s.5
17	Real	Percent difference in L(T)	DFT	%
18	Integer	Maximum number of iterations	IRUNZ	
19	Integer	Selects option to recompute and list KI's	ICOMP	
20	Real	Percentage for QZ convergence	QPER	%
21	Integer	Number of divisions to split frac	NDIV	
22	Real	XA position at which numerical integration begins	XAZ	
23	Real	Dummy pressure at tip	YZP	psi
24	Integer	Number of segments fracture wing is split into	N	
25	Integer	Flag to increase resolution of tip segment	NRES	
26	Integer	Multiplication factor used to increase resolution of tip segment	MFAC	
27	Integer	Number of steps for numerical integration	NODIV	
28	Integer	Number of width calculations in each vertical fracture section	NUMWID	
29	Real	Fracture height/pay zone height at fracture tip	HSTART	
30	Real	Spurt loss coefficient	SP	cm ³ /cm ²
31	Integer	To determine whether FLOWK varies with x or not	IMU	

DATATUPC is the proppant section input selected by the user. The file is broken down by record in Table 2.

Output

Appendix B contains example output corresponding to the input files. The output can be divided into five divisions.

The first section of output contains the output from the highly elongated fracture model as outlined by Palmer et al. [2].

The second division is the input data from both FLKM and DATATUPC. This section contains all the input parameters for the proppant section with the exception of control values.

The third section contains the equivalent fracture geometry that the proppant model will utilize. The widths given are equivalent widths for a rectangle having the same area as the geometric shape which is "elliptic" in shape.

The fourth division contains output from the proppant transport portion of TUPROP based on equivalent widths. In the first section of this division, a summary of particle tracking is given. If detailed intermediate data were requested ($NCK1 < NCK2$), then these statements would be interspersed at the correct time step. Next, a summary is given for a propped fracture. Note that the leading edge of the proppant is the slurry front, but if the top particle of the proppant type had reached the bed, the fluid would be clear.

For the sample case, $NCK1$ was greater than $NCK2$ but $NCK3$ was set to one. Therefore, below the name of the settling model is the detailed output for the last time step. The information contained in this section should be self-explanatory. If $NCK3$ were set equal to zero, then following the name of the settling model, a summary of the time steps is

Table 2. DATATUPC - Proppant Input

1.	First Record, Format 10F10.5		
	(1) Density of Fracturing Fluid	RHOF	lbm/ft ³
2.	Second Record, Format 5I10		
	(1) Number of Proppant Types, MAX 10	NTP	
3.	Third Record, Format 10F10.5		
	(1) Times at which Proppant Type Changes	TP1(I)	min
4.	Fourth Record, FORMAT 10F10.5		
	(1) Initial Concentrations	CG1(I)	lbm/gal
5.	Fifth Record, Format 10F10.5		
	(1) Average Proppant Diameter	DP1(I)	in
6.	Sixth Record, Format 10F10.5		
	(1) Proppant Porosities	PHIP1(I)	
7.	Seventh Record, Format 10F10.5		
	(1) Proppant Densities	RHOS1(I)	lbm/ft ³
8.	Eighth Record, 5I10		
	(1) Restart Control	NSTART	
	0 - No Restart		
	Always use 0		
9.	Ninth Record, 10F10.5		
	(1) Acceleration of Gravity	G	ft/sec ²
	(2) Element Length	DX	ft
10.	Tenth Record, 10F10.5		
	(1) Fan Viscometer Outer to Inner Radii	BETA	
	(2) Run Control	CONTROL	
	0.0 - Run Program		
	Use 0.0 only		
	(3) Particle Shear Rate Cut Off Value	GDOTC	sec ⁻¹
	(4) Shear Stress Location Fraction	GDOTF	
11.	Eleventh Record, 5I10		
	(1) Starting Element of Detailed Output	NCK1	
	(2) Ending Element of Detailed Output	NCK2	
	If NCK1 > NCK2 - No Detailed Output		
	(3) Detailed Output of Last Time Step	NCK3	
	0 - Not Wanted		
	1 - Output Desired		
	(4) Selection of Settling Model	NSETV	
	1 - Zigrang and Sylvester		
	2 - Daneshy		
	3 - Acharya		
	4 - Clark		
	5 - Sutrick and Rybicki		

printed out along the information describing the disposition of proppant section is run. The final portion of this section summarizes the volume of fluid and the mass of proppant injected during the treatment. The injected amounts of fluid and proppant are compared to the amounts obtained from program calculations based on continuity. Thus, the differences given are measure of program effectiveness.

Following the volume of fluid and proppant, the fracture geometry is output for both the equivalent and the geometric shape of the fracture. The geometrically correct proppant distribution results from redistributing the volumes of the proppant bed and the slurry back into the geometric shape provided by the highly elongated fracture model. In both cases, values are provided for plotting the top of the fracture, the bottom of the fracture, the suspension height, and the bed height at the model intervals specified in DATATUPC as DX.

Coupling of the fracture model with the proppant model is done through Job Control Language (JCL). Proper coupling through JCL allows the combined programs.

CHAPTER II

APPENDIX A

FLKM
DATATUPC
ORUIN

3
1
2
1
0
7
1
1
1
5
1
2
3
4
5
8
1
5
3
1
1
1
5
4
1
1
0
0

30

13:39 SEP 19 '86 DATATOPC.IVD40820

65.0

12.60	20.00	25.00	00.00	00.00	00.00
2.000000	1.00	2.00	0.00	0.00	0.00
.0225	.0500	.0500	.00	.00	.00
30	15	15	.00	.00	.00
165.00	165.0	165.0	000.0	000.0	000.0

32.2	10				
1.072636	0.0	20.	0.3333		

ILIMIT LO=500

CURRENT MAXIMUM FOR LO IS 496

SET 3 ORIGIN

FORTRAN 4-FLK11M OVER *A1 (LS,NOP,SV,ADP)

FORTRAN 77 VERSION C01 SEP 19 '86

13:42 SEP 19 '86 JRU1-1.11040820

[illegible]

.50000000000000000E+02
.20000000000000000E+03
.40000000000000000E+00
20000000000000000E+03
14033004987493121AE+01
125137036048484950E+01
107243308990664914E+01
1219035738533444611E+00
18758719A361328634E+00
72225441377329A704E-01
285614854696727522E+00
241612881525057343E+00
525213309180595673E-01
332127343202433199E+00
2778155147739992995E+00
412855169680646552E-01
369637089616330600E+00
305823865900322524E+00
362908002760155205E-01
401811223560703330E+00
328826322236652222E+00
332556374753352851E-01
430411724102099540E+00
348342720282209229E+00
311118721809163219E-01
456379120575210547E+00
365185148522039356E+00
295271150139606161E-01
480314099695342552E+00
379864089688682866E+00
282880655526543586E-01
5026298409024050323E+00
392720954739618600E+00
272864382054655783E-01
523623377257423292E+00
40399107754113890E+00
26456173239H665723E-01
103082169462158150E+00
7H5697241731693A93E+03
405536313101621768E+03
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.181862644647989525E+04	.303104474496634375E+02	.211563508363020139E+04	.123132535158433748E+02
.150000000000000000E+02	.141273388560283879E+02	.132412773740032064E+02	.797774685548699399E+01
.113361357177236271E+02	.105112932466838269E+02	.920089442323690110E+01	.208577877295390025E+02
.656410713528015463E+01	.473225136560991141E+01	.704176105150404264E+00	.216395460285532545E+02
.199795121607531795E+02	.202934325241561745E+02	.205144205418006934E+02	
.211336702007842110E+02	.213034251283062671E+02	.215685618903995101E+02	
.218177096687397454E+02	.220672525991725169E+02	-.282230948291089632E+27	

ISET F86 DATATUPC,FUN=IV
 ISET F87 URUIN,FUN=IN
 ISET F89 RESTUP1
 IFORTRAN TUPROPC OVER *TUP1(SV,NUP,LS)
 FORTRAN 77 VERSION C01 SEP 19 '86

CHAPTER II

APPENDIX B

OUTPUT FROM TUPROPC

ILYXK *TUP1 OVER LTUPROPC
 LINK C01 HERE
 * SHARED COMMON ISVS (SHARED LIBRARY) ASSOCIATED.
 * NO LINKING ERRORS
 * TOTAL PROGRAM SIZE = 65K.
 ILTUPROPC.

INJECTION RATE = 30.000 HPM
 INJECTION RATE TIME = .000 MIN
 TREATMENT TIME = 30.310 MIN
 CONSISTENCY INDEX = .002089 LR*S**NPRIME/FT**2
 (PIPE FLOW)
 CONSISTENCY INDEX = .002089 LB*S**NPRIME/FT**2
 (ABSOLUTE)
 CONSISTENCY INDEX = .002089 LR*S**NPRIME/FT**2
 (SLOT FLOW)
 BEHAVIOR INDEX = 1.000
 FLUID DENSITY = 65.000 LBM/FT**3
 FLUID LOSS COEFFICIENT = .100E-02 FT/SQRT(MIN)
 SPURT LOSS = .000 FT**3/FT**2
 PAYZONE HEIGHT = 75.000 FT
 YOUNG MODULUS = 5760000.0 PSIA
 POISSON RATIO = .200
 LENGTH INCREMENT = 10.00 FT
 FAV RADII RATIO = 1.072836
 ACCEL OF GRAVITY = 32.200 FT/SEC
 PAD TIME = 12.600 MIN
 MIXING RATIO = 2.000 LB/GAL OF FLUID
 INITIAL CONCENTRATION = 1.834 LB/GAL OF SLURRY
 PROPPANT DENSITY = 165.000 LBM/FT**3
 PROPPANT DIAMETER = .023 IN
 PROPPANT POROSITY = .300

NODE	FLE	TIME MIN	MAX WIDTH FT	EQUIV WIDTH FT	LENGTH FT	HEIGHT FT	MAX WIDTH FT	EQUIV WIDTH FT	WB HT FT
1	0	.0000	.02670	.01325	0.	161.008	.00000	.00000	.000
2	1	2.7565	.02612	.01280	200.	143.213	.01732	.01078	108.023
3	2	4.9223	.02274	.01245	300.	134.724	.01925	.01148	116.433
4	3	7.4674	.02126	.01205	400.	126.449	.02076	.01145	123.827
5	4	10.5036	.01966	.01162	500.	118.373	.02208	.01227	130.962
6	5	13.7923	.01789	.01098	600.	110.384	.02319	.01257	137.394
7	6	17.3448	.01587	.01023	700.	102.424	.02416	.01281	143.467
8	7	21.4945	.01341	.00907	800.	94.254	.02511	.01299	149.681
9	8	25.7760	.00992	.00714	900.	85.350	.02594	.01311	155.472
10	9	30.3104	.00000	.00000	1000.	75.750	.02670	.01325	161.008

FRACTURE LENGTH = 949.10 FT
 PROPPANT LENGTH = 949.10 FT
 WELLBORE WIDTH = .01325 FT
 = .15899 IN

LEADING EDGE PROPPANT TYPE 1 = 990.00 FT

SUTICK AND RYDICKI SETTLING MODEL

FRACTURAL DISTANCE TO WALL = .3333
 SHEAR RATE CUT OFF = 20.0 1/SEC
 FRACTURING FLUID IS HYDROXYPROPYL GUAR

ELEMENT NUMBER	LENGTH FT	TIME SEC	CJNG LB/GAL	W(IN) FT	W(OUT) FT	WAVE FT	DN FT	Q(IN) BBL/MIN	Q(OUT) BBL/MIN	ELE VEL FT/SEC	SET VEL FT/SEC	FLUID LOST VEL-FT/SEC
1	10.00	15.0600	1.6345	.01325	.01323	.01324	.2238E-05	15.0080	14.9418	.6640	.0055473	.3036E-05
2	20.00	15.0060	1.6365	.01323	.01320	.01323	.2238E-05	14.9418	14.8840	.6664	.0055442	.3042E-05
3	30.00	14.9513	1.6388	.01320	.01318	.01318	.2014E-05	14.8840	14.8266	.6688	.0055405	.3047E-05
4	40.00	14.8963	1.6414	.01318	.01315	.01317	.1914E-05	14.8266	14.7695	.6713	.0055363	.3053E-05
5	50.00	14.8410	1.6442	.01315	.01313	.01314	.1823E-05	14.7695	14.7127	.6738	.0055317	.3059E-05
6	60.00	14.7854	1.6473	.01313	.01311	.01312	.1755E-05	14.7127	14.6561	.6763	.0055268	.3065E-05
7	70.00	14.7309	1.6507	.01311	.01308	.01310	.1693E-05	14.6561	14.5995	.6788	.0055218	.3072E-05
8	80.00	14.6764	1.6542	.01308	.01306	.01307	.1643E-05	14.5995	14.5430	.6814	.0055158	.3078E-05
9	90.00	14.6227	1.6579	.01306	.01304	.01305	.1606E-05	14.5430	14.4864	.6839	.0055099	.3084E-05
10	100.00	14.5701	1.6618	.01304	.01302	.01303	.1579E-05	14.4864	14.4296	.6863	.0055037	.3091E-05
11	110.00	14.5184	1.6658	.01302	.01300	.01301	.1559E-05	14.4296	14.3726	.6888	.0054973	.3098E-05
12	120.00	14.4647	1.6700	.01298	.01296	.01299	.1544E-05	14.3726	14.3152	.6911	.0054907	.3105E-05
13	130.00	14.4119	1.6743	.01296	.01294	.01297	.1531E-05	14.3152	14.2572	.6935	.0054839	.3113E-05
14	140.00	14.3717	1.6787	.01294	.01292	.01295	.1515E-05	14.2572	14.1986	.6958	.0054768	.3121E-05
15	150.00	14.3243	1.6833	.01292	.01290	.01293	.1501E-05	14.1986	14.1393	.6981	.0054696	.3129E-05
16	160.00	14.2773	1.6880	.01290	.01288	.01291	.1484E-05	14.1393	14.0791	.7004	.0054622	.3138E-05
17	170.00	14.2305	1.6927	.01288	.01286	.01289	.1468E-05	14.0791	14.0181	.7027	.0054547	.3147E-05
18	180.00	14.1835	1.6976	.01286	.01285	.01288	.1454E-05	14.0181	13.9562	.7050	.0054470	.3156E-05
19	190.00	14.1360	1.7026	.01285	.01283	.01286	.1441E-05	13.9562	13.8934	.7074	.0054391	.3166E-05
20	200.00	14.0876	1.7077	.01283	.01280	.01282	.1428E-05	13.8934	13.8299	.7098	.0054311	.3176E-05
21	210.00	14.0374	1.7129	.01280	.01277	.01279	.1416E-05	13.8299	13.7658	.7124	.0054229	.3187E-05
22	220.00	13.9863	1.7183	.01277	.01274	.01276	.1404E-05	13.7658	13.7009	.7150	.0054145	.3198E-05
23	230.00	13.9337	1.7237	.01274	.01271	.01273	.1392E-05	13.7009	13.6353	.7177	.0054060	.3210E-05
24	240.00	13.8800	1.7293	.01271	.01268	.01269	.1381E-05	13.6353	13.5689	.7205	.0053974	.3223E-05
25	250.00	13.8255	1.7349	.01268	.01264	.01266	.1370E-05	13.5689	13.5020	.7233	.0053885	.3236E-05
26	260.00	13.7701	1.7407	.01264	.01260	.01262	.1359E-05	13.5020	13.4346	.7262	.0053795	.3249E-05
27	270.00	13.7142	1.7467	.01260	.01257	.01259	.1349E-05	13.4346	13.3668	.7292	.0053702	.3263E-05
28	280.00	13.6574	1.7527	.01257	.01253	.01255	.1339E-05	13.3668	13.2988	.7322	.0053608	.3277E-05
29	290.00	13.6011	1.7590	.01253	.01249	.01251	.1330E-05	13.2988	13.2305	.7352	.0053511	.3292E-05
30	300.00	13.5443	1.7654	.01249	.01245	.01247	.1321E-05	13.2305	13.1619	.7383	.0053412	.3307E-05
31	310.00	13.4876	1.7721	.01245	.01241	.01243	.1312E-05	13.1619	13.0932	.7414	.0053309	.3322E-05
32	320.00	13.4312	1.7789	.01241	.01237	.01239	.1303E-05	13.0932	13.0244	.7445	.0053204	.3338E-05
33	330.00	13.3748	1.7858	.01237	.01233	.01235	.1294E-05	13.0244	12.9556	.7477	.0053097	.3355E-05
34	340.00	13.3186	1.7930	.01233	.01229	.01231	.1285E-05	12.9556	12.8868	.7508	.0052987	.3371E-05
35	350.00	13.2626	1.8003	.01229	.01225	.01227	.1276E-05	12.8868	12.8180	.7540	.0052875	.3389E-05
36	360.00	13.2069	1.8074	.01225	.01221	.01223	.1267E-05	12.8180	12.7491	.7572	.0052760	.3406E-05
37	370.00	13.1514	1.8155	.01221	.01217	.01219	.1258E-05	12.7491	12.6800	.7604	.0052643	.3425E-05
38	380.00	13.0954	1.8234	.01217	.01213	.01215	.1250E-05	12.6800	12.6108	.7636	.0052522	.3444E-05
39	390.00	13.0418	1.8315	.01213	.01209	.01211	.1241E-05	12.6108	12.5412	.7668	.0052399	.3464E-05
40	400.00	12.9881	1.8398	.01209	.01205	.01207	.1233E-05	12.5412	12.4712	.7699	.0052273	.3484E-05
41	410.00	12.9351	1.8483	.01205	.01201	.01203	.1224E-05	12.4712	12.4009	.7731	.0052144	.3506E-05
42	420.00	12.8827	1.8570	.01201	.01197	.01199	.1216E-05	12.4009	12.3298	.7762	.0052012	.3528E-05

ELEMENT NUMBER	APP VIS CF	RE (FLOW)	SHR RATE PART 1/S	RE (PART)	FRAC HT FT	OP HT FT	BED HT FT	CH RFD FT	FALL HT FT	DFH FT	SUSP HT FT	NET SUSP FT
100.	17.0392	20.0000	.0101	160.9583	159.3604	.6834	.2943F-02	.4573	.83354	-01	160.0438	159.3604
100.	17.0702	20.0000	.0100	160.0438	158.4530	.6767	.2944F-02	.4114	.83320	-01	159.1296	158.4530
100.	17.1018	20.0000	.0100	159.1296	157.5465	.6700	.2944F-02	.3709	.83284	-01	158.2167	157.5465
100.	17.1341	20.0000	.0100	158.2165	156.6414	.6633	.2944F-02	.3268	.83248	-01	157.3048	156.6414
100.	17.1670	20.0000	.0100	157.3047	155.7382	.6565	.2950F-02	.2818	.83212	-01	156.3947	155.7382
100.	17.2004	20.0000	.0100	156.3947	154.8374	.6497	.2950F-02	.2356	.83176	-01	155.4871	154.8374
100.	17.2339	20.0000	.0100	155.4871	153.9394	.6428	.2950F-02	.1881	.83140	-01	154.5802	153.9394
100.	17.2674	20.0000	.0100	154.5822	153.0447	.6359	.2950F-02	.1389	.83104	-01	153.6806	153.0447
100.	17.3018	20.0000	.0100	153.6806	152.1538	.6289	.2960F-02	.0878	.83068	-01	152.7827	152.1538
100.	17.3354	20.0000	.0100	152.7827	151.2672	.6219	.2960F-02	.0346	.83032	-01	151.8899	151.2672
100.	17.3694	20.0000	.0100	151.8899	150.3851	.6148	.2960F-02	.0000	.83000	-01	150.9999	150.3851
100.	17.4037	20.0000	.0100	150.9999	149.5075	.6076	.2960F-02	.0000	.82968	-01	149.1151	149.5075
100.	17.4381	20.0000	.0099	149.6234	148.6342	.6004	.2970F-02	.0000	.82936	-01	148.2343	148.6342
100.	17.4725	20.0000	.0099	148.7574	147.7681	.5933	.2970F-02	.0000	.82904	-01	147.3574	147.7681
100.	17.5069	20.0000	.0099	147.8840	146.8981	.5861	.2970F-02	.0000	.82872	-01	146.4840	146.8981
100.	17.5413	20.0000	.0099	147.0115	146.0353	.5787	.2970F-02	.0000	.82840	-01	145.6140	146.0353
100.	17.5757	20.0000	.0099	146.1400	145.1755	.5714	.2970F-02	.0000	.82808	-01	144.7469	145.1755
100.	17.6101	20.0000	.0099	145.2669	144.3184	.5642	.2970F-02	.0000	.82776	-01	143.8827	144.3184
100.	17.6445	20.0000	.0099	144.4020	143.4638	.5571	.2970F-02	.0000	.82744	-01	143.0209	143.4638
100.	17.6789	20.0000	.0099	143.5374	142.6117	.5499	.2990F-02	.0000	.82712	-01	142.1616	142.6117
100.	17.7133	20.0000	.0099	142.6716	141.7612	.5428	.3000F-02	.0000	.82680	-01	141.3041	141.7612
100.	17.7477	20.0000	.0099	141.8041	140.9128	.5357	.3000F-02	.0000	.82648	-01	140.4485	140.9128
100.	17.7821	20.0000	.0099	140.9365	140.0662	.5287	.3000F-02	.0000	.82616	-01	139.5950	140.0662
100.	17.8165	20.0000	.0099	140.0688	139.2216	.5217	.3000F-02	.0000	.82584	-01	138.7444	139.2216
100.	17.8509	20.0000	.0099	139.2011	138.3790	.5148	.3010F-02	.0000	.82552	-01	137.8937	138.3790
100.	17.8853	20.0000	.0099	138.3334	137.5382	.5079	.3010F-02	.0000	.82520	-01	137.0446	137.5382
100.	17.9197	20.0000	.0099	137.4657	136.6993	.5011	.3020F-02	.0000	.82488	-01	136.1969	136.6993
100.	17.9541	20.0000	.0099	136.5980	135.8624	.4943	.3020F-02	.0000	.82456	-01	135.3507	135.8624
100.	17.9885	20.0000	.0099	135.7303	135.0274	.4876	.3030F-02	.0000	.82424	-01	134.5050	135.0274
100.	18.0229	20.0000	.0099	134.8626	134.1946	.4808	.3030F-02	.0000	.82392	-01	133.6603	134.1946
100.	18.0573	20.0000	.0099	134.0000	133.3636	.4741	.3040F-02	.0000	.82360	-01	132.8166	133.3636
100.	18.0917	20.0000	.0099	133.1377	132.5347	.4673	.3040F-02	.0000	.82328	-01	131.9749	132.5347
100.	18.1261	20.0000	.0099	132.2750	131.7079	.4604	.3050F-02	.0000	.82296	-01	131.1352	131.7079
100.	18.1605	20.0000	.0099	131.4123	130.8832	.4535	.3050F-02	.0000	.82264	-01	130.2975	130.8832
100.	18.1949	20.0000	.0099	130.5496	130.0608	.4466	.3060F-02	.0000	.82232	-01	129.4618	130.0608
100.	18.2293	20.0000	.0099	129.6869	129.2406	.4397	.3060F-02	.0000	.82200	-01	128.6281	129.2406
100.	18.2637	20.0000	.0099	128.8242	128.4227	.4328	.3070F-02	.0000	.82168	-01	127.7964	128.4227
100.	18.2981	20.0000	.0099	127.9615	127.6071	.4259	.3070F-02	.0000	.82136	-01	126.9667	127.6071
100.	18.3325	20.0000	.0099	127.0988	126.7940	.4190	.3080F-02	.0000	.82104	-01	126.1380	126.7940
100.	18.3669	20.0000	.0099	126.2361	125.9834	.4121	.3080F-02	.0000	.82072	-01	125.3103	125.9834
100.	18.4013	20.0000	.0099	125.3734	125.1751	.4052	.3090F-02	.0000	.82040	-01	124.4836	125.1751
100.	18.4357	20.0000	.0099	124.5107	124.3690	.3983	.3090F-02	.0000	.82008	-01	123.6589	124.3690
100.	18.4701	20.0000	.0099	123.6480	123.5650	.3914	.3100F-02	.0000	.81976	-01	122.8352	123.5650
100.	18.5045	20.0000	.0099	122.7853	122.7628	.3845	.3110F-02	.0000	.81944	-01	122.0125	122.7628
100.	18.5389	20.0000	.0099	121.9226	121.9435	.3776	.3120F-02	.0000	.81912	-01	121.1908	121.9435
100.	18.5733	20.0000	.0099	121.0599	121.1635	.3707	.3120F-02	.0000	.81880	-01	120.3691	121.1635
100.	18.6077	20.0000	.0099	120.1972	120.3658	.3638	.3130F-02	.0000	.81848	-01	119.5474	120.3658
100.	18.6421	20.0000	.0099	119.3345	119.5692	.3569	.3130F-02	.0000	.81816	-01	118.7257	119.5692
100.	18.6765	20.0000	.0099	118.4718	118.7734	.3500	.3140F-02	.0000	.81784	-01	117.9040	118.7734
100.	18.7109	20.0000	.0099	117.6091	117.9787	.3431	.3140F-02	.0000	.81752	-01	117.0823	117.9787
100.	18.7453	20.0000	.0099	116.7464	117.1842	.3362	.3150F-02	.0000	.81720	-01	116.2606	117.1842
100.	18.7797	20.0000	.0099	115.8837	116.3897	.3293	.3150F-02	.0000	.81688	-01	115.4389	116.3897
100.	18.8141	20.0000	.0099	115.0210	115.5967	.3224	.3160F-02	.0000	.81656	-01	114.6172	115.5967
100.	18.8485	20.0000	.0099	114.1583	114.8033	.3155	.3160F-02	.0000	.81624	-01	113.7955	114.8033
100.	18.8829	20.0000	.0099	113.2956	114.0115	.3086	.3170F-02	.0000	.81592	-01	112.9738	114.0115

56	100.	14.0606	20.0000	.0040	114.3144	113.2196	.2959	.3179	-02	23.7214	.6024	-01	113.5155	113.2196
57	100.	14.0304	20.0000	.0040	113.5155	112.4264	.2889	.3186	-02	24.1205	.6097	-01	113.7173	112.4264
58	100.	14.0136	20.0000	.0040	112.7173	111.6337	.2819	.3193	-02	24.5194	.6170	-01	113.9196	111.6337
59	100.	14.0000	20.0000	.0040	111.9196	110.8476	.2748	.3200	-02	24.9180	.6243	-01	114.1224	110.8476
60	100.	17.9950	20.0000	.0089	111.1224	110.0544	.2677	.3206	-02	25.3161	.6316	-01	114.3261	110.0544
61	100.	17.9751	20.0000	.0088	110.3261	109.2695	.2606	.3215	-02	25.7142	.6389	-01	114.5301	109.2695
62	100.	17.9540	20.0000	.0088	109.5301	108.4811	.2533	.3223	-02	26.1120	.6462	-01	114.7344	108.4811
63	100.	17.9312	20.0000	.0087	108.7344	107.6929	.2460	.3230	-02	26.5097	.6535	-01	114.9389	107.6929
64	100.	17.9063	20.0000	.0087	107.9389	106.9048	.2387	.3238	-02	26.9074	.6608	-01	115.1435	106.9048
65	100.	17.8786	20.0000	.0087	107.1435	106.1167	.2313	.3246	-02	27.3052	.6681	-01	115.3479	106.1167
66	100.	17.8477	20.0000	.0086	106.3479	105.3283	.2238	.3254	-02	27.7031	.6754	-01	115.5521	105.3283
67	100.	17.8130	20.0000	.0086	105.5521	104.5394	.2164	.3262	-02	28.1013	.6827	-01	115.7558	104.5394
68	100.	17.7740	20.0000	.0085	104.7558	103.7499	.2090	.3271	-02	28.4997	.6900	-01	115.9589	103.7499
69	100.	17.7300	20.0000	.0085	103.9589	102.9595	.2016	.3279	-02	28.8986	.6973	-01	116.1611	102.9595
70	100.	17.6803	20.0000	.0084	103.1611	102.1686	.1941	.3288	-02	29.2978	.7046	-01	116.3628	102.1686
71	100.	17.6248	20.0000	.0083	102.3628	101.3758	.1870	.3296	-02	29.6978	.7119	-01	116.5628	101.3758
72	100.	17.5631	20.0000	.0083	101.5628	100.5810	.1800	.3305	-02	30.0987	.7192	-01	116.7610	100.5810
73	100.	17.4953	20.0000	.0082	100.7610	99.7834	.1730	.3314	-02	30.4950	.7265	-01	116.9586	99.7834
74	100.	17.4220	20.0000	.0082	99.9564	98.9823	.1662	.3323	-02	30.8905	.7338	-01	117.1555	98.9823
75	100.	17.3437	20.0000	.0081	99.1484	98.1769	.1594	.3332	-02	31.2850	.7411	-01	117.3511	98.1769
76	100.	17.2611	20.0000	.0080	98.3362	97.3665	.1526	.3341	-02	31.6791	.7484	-01	117.5455	97.3665
77	100.	17.1748	20.0000	.0080	97.5191	96.5505	.1458	.3350	-02	32.0728	.7557	-01	117.7386	96.5505
78	100.	17.0857	20.0000	.0079	96.6963	95.7280	.1389	.3359	-02	32.4660	.7630	-01	117.9311	95.7280
79	100.	16.9945	20.0000	.0078	95.8669	94.8984	.1320	.3368	-02	32.8586	.7703	-01	118.1224	94.8984
80	100.	16.9017	20.0000	.0077	95.0304	94.0613	.1250	.3377	-02	33.2507	.7776	-01	118.3128	94.0613
81	100.	16.8083	20.0000	.0076	94.1863	93.2155	.1178	.3386	-02	33.6424	.7849	-01	118.5019	93.2155
82	100.	16.7134	20.0000	.0075	93.3332	92.3611	.1104	.3395	-02	34.0338	.7922	-01	118.6900	92.3611
83	100.	16.6133	20.0000	.0074	92.4715	91.4983	.1029	.3403	-02	34.4249	.7995	-01	118.8773	91.4983
84	100.	16.5032	20.0000	.0073	91.6012	90.6270	.0954	.3412	-02	34.8156	.8068	-01	119.0638	90.6270
85	100.	16.3776	20.0000	.0072	90.7223	89.7472	.0878	.3420	-02	35.2057	.8141	-01	119.2494	89.7472
86	100.	16.2308	20.0000	.0071	89.8349	88.8588	.0802	.3427	-02	35.5950	.8214	-01	119.4341	88.8588
87	100.	16.0562	20.0000	.0070	88.9390	87.9619	.0728	.3433	-02	35.9835	.8287	-01	119.6179	87.9619
88	100.	15.8468	20.0000	.0069	88.0347	87.0565	.0654	.3439	-02	36.3711	.8360	-01	119.8008	87.0565
89	100.	15.5948	20.0000	.0067	87.1219	86.1423	.0583	.3444	-02	36.7578	.8433	-01	119.9828	86.1423
90	100.	15.2914	20.0000	.0066	86.2007	85.2203	.0513	.3447	-02	37.1435	.8506	-01	120.1638	85.2203
91	100.	14.9302	20.0000	.0064	85.2718	84.2897	.0443	.3448	-02	37.5282	.8579	-01	120.3438	84.2897
92	100.	14.5044	20.0000	.0062	84.3342	83.3511	.0380	.3446	-02	37.9119	.8652	-01	120.5228	83.3511
93	100.	14.0078	20.0000	.0060	83.3892	82.4057	.0318	.3441	-02	38.2946	.8725	-01	120.7008	82.4057
94	100.	13.4374	20.0000	.0058	82.4376	81.4543	.0259	.3429	-02	38.6763	.8798	-01	120.8778	81.4543
95	100.	12.7889	20.0000	.0055	81.4802	80.4976	.0203	.3408	-02	39.0570	.8871	-01	121.0538	80.4976
96	100.	12.0560	20.0000	.0051	80.5180	79.5366	.0151	.3371	-02	39.4357	.8944	-01	121.2288	79.5366
97	100.	11.2244	20.0000	.0047	79.5516	78.5718	.0102	.3303	-02	39.8130	.9017	-01	121.4028	78.5718
98	100.	10.2877	20.0000	.0041	78.5820	77.6043	.0057	.3176	-02	40.1888	.9090	-01	121.5758	77.6043
99	100.	9.1764	20.0000	.0035	77.6100	76.6346	.0018	.1821	-02	40.5630	.9163	-01	121.7478	76.6346

ELE NO	ELE TIME SEC	TOTAL TIME MIN	PROP LEN FT	FRAC LEN FT	CONC LB/GAL	APP VIS CP	ELE VEL FT/SEC	Q(IN) FT/SEC	Q(OUT) FT/SEC	AVG WIDTH FT	BET VEL FT/S	BED HT FT	OPEN HT FT	SUSP HT FT	FRAC HT FT
1	11.42	12.40	10	549.73	1.8345	100.	.6640	15.0000	14.9418	.01324	.0055	.6834	159.3604	160.0438	160.9583
2	11.46	13.05	20	575.85	1.8365	100.	.6644	14.9414	14.8840	.01321	.0055	.6767	158.4530	159.2296	160.0438
3	11.46	13.23	30	541.91	1.8388	100.	.6688	14.8840	14.8268	.01319	.0055	.6700	157.5465	158.2163	159.1296
4	11.45	13.40	40	587.97	1.8414	100.	.6713	14.8266	14.7695	.01317	.0055	.6632	156.6414	157.3047	158.2165
5	11.45	13.62	50	594.02	1.8442	100.	.6738	14.7695	14.7127	.01314	.0055	.6565	155.7382	156.3947	157.3047
6	11.44	13.79	60	500.07	1.8473	100.	.6763	14.7127	14.6561	.01312	.0055	.6497	154.8374	155.4871	156.3947

66	10.71	25.23	660	887.14	2.3642	100.	.8684	10.3843	10.2917	.01060	.0047	.2238	105.5283	105.5521	106.3479
67	10.67	25.40	670	891.40	2.3886	100.	.8729	10.3843	10.1918	.01053	.0047	.2164	104.5394	104.7558	105.5521
68	10.60	25.58	680	895.45	2.4089	100.	.8777	10.0833	10.0893	.01045	.0047	.2090	103.7499	103.9589	104.7558
69	10.61	25.76	690	899.58	2.4300	100.	.8828	9.9839	9.9839	.01036	.0047	.2016	102.9595	103.1611	103.9589
70	10.57	25.93	700	903.49	2.4520	100.	.8882	9.8756	9.8756	.01027	.0046	.1941	102.1686	102.3628	103.1611
71	10.53	26.11	710	907.29	2.4750	100.	.8941	9.7641	9.7641	.01017	.0046	.1870	101.3758	101.5628	102.3628
72	10.27	26.28	720	911.06	2.4991	100.	.9004	9.6495	9.6495	.01006	.0046	.1800	100.5810	100.7610	101.5628
73	10.23	26.45	730	914.42	2.5243	100.	.9071	9.5322	9.5322	.00995	.0045	.1730	99.7834	99.9564	100.7610
74	10.19	26.62	740	918.57	2.5507	100.	.9141	9.4125	9.4125	.00983	.0045	.1662	98.9823	99.1484	99.9564
75	10.15	26.79	750	922.30	2.5786	100.	.9213	9.2907	9.2907	.00971	.0045	.1594	98.1769	98.3362	99.1484
76	10.12	26.96	760	926.02	2.6079	100.	.9285	9.1671	9.1671	.00959	.0044	.1526	97.3665	97.5191	98.3362
77	10.09	27.12	770	929.73	2.6388	100.	.9358	9.0423	9.0423	.00947	.0044	.1458	96.5505	96.6963	97.5191
78	10.06	27.29	780	933.42	2.6714	100.	.9430	8.9165	8.9165	.00935	.0043	.1389	95.7280	95.8663	96.6963
79	10.04	27.46	790	937.11	2.7058	100.	.9499	8.7900	8.7900	.00923	.0043	.1320	94.8984	95.0304	95.8663
80	9.96	27.63	800	940.79	2.7423	100.	.9563	8.6634	8.6634	.00912	.0043	.1250	94.0613	94.1863	95.0304
81	9.96	27.79	810	944.45	2.7811	100.	.9623	8.5360	8.5360	.00901	.0042	.1178	93.2155	93.3332	94.1863
82	9.92	27.96	820	948.10	2.8222	100.	.9681	8.4061	8.4061	.00891	.0042	.1104	92.3611	92.4715	93.3332
83	9.87	28.12	830	951.73	2.8659	100.	.9741	8.2714	8.2714	.00880	.0041	.1029	91.4983	91.6012	92.4715
84	9.82	28.29	840	955.33	2.9129	100.	.9800	8.1292	8.1292	.00868	.0041	.0954	90.6270	90.7223	91.6012
85	9.77	28.45	850	958.90	2.9630	100.	.9859	7.9771	7.9771	.00856	.0040	.0878	89.7472	89.8349	90.7223
86	9.72	28.61	860	962.43	3.0169	100.	.9919	7.8121	7.8121	.00843	.0039	.0802	88.8588	88.9340	89.8349
87	9.67	28.77	870	965.92	3.0751	100.	.9978	7.6313	7.6313	.00831	.0039	.0728	87.9619	88.0347	88.9349
88	9.62	28.92	880	969.36	3.1383	100.	1.0033	7.4315	7.4315	.00819	.0038	.0654	87.0565	87.1219	88.0347
89	9.57	29.07	890	972.73	3.2076	100.	1.0089	7.2044	7.2044	.00807	.0037	.0583	86.1425	86.2007	87.1219
90	9.52	29.22	900	976.02	3.2843	100.	1.0142	6.9627	6.9627	.00793	.0036	.0513	85.2205	85.2718	86.2007
91	9.47	29.37	910	979.24	3.3703	100.	1.0193	6.6892	6.6892	.00779	.0035	.0445	84.2897	84.3342	85.2718
92	9.42	29.51	920	982.32	3.4661	100.	1.0242	6.3872	6.3872	.00765	.0034	.0380	83.3511	83.3892	84.3342
93	9.37	29.64	930	985.30	3.5719	100.	1.0289	6.0567	6.0567	.00752	.0033	.0318	82.4037	82.4376	83.3892
94	9.32	29.77	940	988.13	3.7176	100.	1.0334	5.6970	5.6970	.00739	.0032	.0259	81.4543	81.4802	82.4376
95	9.27	29.89	950	990.79	3.8854	100.	1.0378	5.3066	5.3066	.00726	.0030	.0203	80.5076	80.5180	81.4802
96	9.22	30.00	960	993.26	4.1031	100.	1.0421	4.8826	4.8826	.00713	.0028	.0151	79.5516	79.5516	80.5180
97	9.17	30.11	970	995.50	4.4045	100.	1.0463	4.4186	4.4186	.00700	.0026	.0100	78.5718	78.5718	79.5516
98	9.12	30.20	980	997.46	4.8475	100.	1.0504	3.9002	3.9002	.00687	.0023	.0057	77.5820	77.5820	78.5718
99	9.07	30.27	990	999.10	5.3822	100.	1.0544	3.1058	3.1058	.00674	.0019	.0018	76.6346	76.6346	77.5820

TIME OF PROP INJECTION= 17.726
 VOLUME OF INJECTED FLUID = 1364.533
 VOLUME IN FRACTURE= 1188.996
 VOLUME LOST= 304.524
 DIFFERENCE= -128.988
 ERROR= -9.453%

MASS OF PROP INJECTED= 20411.817
 MASS OF SETTLED PROP= 468.872
 MASS OF SUSPENDED PROP= 21246.252
 TOTAL MASS= 21715.123
 DIFFERENCE= -1302.507
 ERROR= -6.381%

EQUIVALENT

FROM CENTER OF PAYZONE

FRACTURE	PROPANT	FRACTURE	SUSP	BED	DISTANCE TO TOP OF	DISTANCE TO BOTTOM OF	DISTANCE TO TOP OF	DISTANCE TO TOP OF
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NODE	LENGTH FT	LENGTH FT	HEIGHT FT	HEIGHT FT	HEIGHT FT	FRACURE FT	OF FRAC FT	SUSP FT	BED FT
1	563.75	0.	160.9583	160.9583	6867	80.4792	-80.4792	80.4792	-79.7925
2	564.79	10.	160.0438	160.0438	6800	80.0219	-80.0219	80.0219	-79.3419
3	575.55	20.	159.1296	159.1296	6733	79.5648	-79.5648	79.5648	-78.8915
4	581.91	30.	158.2165	158.2165	6666	79.1082	-79.1082	79.1082	-78.4416
5	581.97	40.	157.3047	157.3047	6599	78.6523	-78.6523	78.6523	-77.9925
6	590.02	50.	156.3947	156.3947	6531	78.1974	-78.1974	78.1974	-77.5443
7	600.07	60.	155.4871	155.4871	6462	77.7435	-77.7435	77.7435	-77.0973
8	605.59	70.	154.5822	154.5822	6394	77.2911	-77.2911	77.2911	-76.6518
9	611.10	80.	153.6806	153.6806	6324	76.8403	-76.8403	76.8403	-76.2079
10	616.60	90.	152.7827	152.7827	6254	76.3914	-76.3914	76.3914	-75.7659
11	622.10	100.	151.8891	151.8891	6183	75.9446	-75.9446	75.9446	-75.3262
12	627.59	110.	150.9999	150.9999	6112	75.5000	-75.5000	75.5000	-74.8888
13	633.08	120.	150.1151	150.1151	6040	75.0575	-75.0575	75.0575	-74.4535
14	638.56	130.	149.2343	149.2343	5968	74.6171	-74.6171	74.6171	-74.0204
15	644.04	140.	148.3574	148.3574	5895	74.1787	-74.1787	74.1787	-73.5892
16	649.51	150.	147.4840	147.4840	5823	73.7420	-73.7420	73.7420	-73.1597
17	655.98	160.	146.6140	146.6140	5751	73.3070	-73.3070	73.3070	-72.7319
18	661.44	170.	145.7469	145.7469	5678	72.8735	-72.8735	72.8735	-72.3056
19	666.90	180.	144.8827	144.8827	5606	72.4413	-72.4413	72.4413	-71.8807
20	672.36	190.	144.0209	144.0209	5535	72.0104	-72.0104	72.0104	-71.4570
21	677.83	200.	143.1616	143.1616	5464	71.5808	-71.5808	71.5808	-71.0344
22	683.27	210.	142.3041	142.3041	5393	71.1520	-71.1520	71.1520	-70.6128
23	688.72	220.	141.4485	141.4485	5322	70.7243	-70.7243	70.7243	-70.1920
24	694.17	230.	140.5949	140.5949	5252	70.2975	-70.2975	70.2975	-69.7722
25	699.62	240.	139.7434	139.7434	5183	69.8717	-69.8717	69.8717	-69.3534
26	705.07	250.	138.8937	138.8937	5113	69.4469	-69.4469	69.4469	-68.9355
27	710.52	260.	138.0461	138.0461	5045	69.0230	-69.0230	69.0231	-68.5185
28	715.97	270.	137.2004	137.2004	4977	68.6002	-68.6002	68.6002	-68.1025
29	721.42	280.	136.3567	136.3567	4910	68.1784	-68.1784	68.1784	-67.6874
30	726.87	290.	135.5150	135.5150	4842	67.7575	-67.7575	67.7575	-67.2733
31	732.32	300.	134.6755	134.6755	4775	67.3377	-67.3377	67.3377	-66.8603
32	737.77	310.	133.8377	133.8377	4707	66.9189	-66.9189	66.9189	-66.4482
33	743.22	320.	133.0020	133.0020	4639	66.5010	-66.5010	66.5010	-66.0371
34	748.67	330.	132.1683	132.1683	4570	66.0842	-66.0842	66.0842	-65.6272
35	754.12	340.	131.3368	131.3368	4500	65.6684	-65.6684	65.6684	-65.2183
36	759.57	350.	130.5073	130.5073	4431	65.2537	-65.2537	65.2537	-64.8106
37	765.02	360.	129.6801	129.6801	4360	64.8401	-64.8401	64.8401	-64.4040
38	770.47	370.	128.8552	128.8552	4289	64.4276	-64.4276	64.4276	-63.9987
39	775.92	380.	128.0325	128.0325	4218	64.0163	-64.0163	64.0163	-63.5945
40	781.37	390.	127.2122	127.2122	4146	63.6061	-63.6061	63.6061	-63.1915
41	786.82	400.	126.3944	126.3944	4074	63.1972	-63.1972	63.1972	-62.7898
42	792.27	410.	125.5788	125.5788	4001	62.7894	-62.7894	62.7894	-62.3893
43	797.72	420.	124.7655	124.7655	3929	62.3827	-62.3827	62.3827	-61.9899
44	803.17	430.	123.9542	123.9542	3856	61.9771	-61.9771	61.9771	-61.5915
45	808.62	440.	123.1447	123.1447	3782	61.5724	-61.5724	61.5724	-61.1941
46	814.07	450.	122.3370	122.3370	3709	61.1685	-61.1685	61.1685	-60.7976
47	819.52	460.	121.5307	121.5307	3635	60.7653	-60.7653	60.7653	-60.4018
48	824.97	470.	120.7257	120.7257	3562	60.3628	-60.3628	60.3628	-60.0066
49	830.42	480.	119.9218	119.9218	3490	59.9609	-59.9609	59.9609	-59.6119
50	835.87	490.	119.1188	119.1188	3418	59.5594	-59.5594	59.5594	-59.2176
51	841.32	500.	118.3169	118.3169	3346	59.1584	-59.1584	59.1584	-58.8238
52	846.77	510.	117.5152	117.5152	3275	58.7576	-58.7576	58.7576	-58.4301
53	852.22	520.	116.7142	116.7142	3205	58.3571	-58.3571	58.3571	-58.0366
54	857.67	530.	115.9137	115.9137	3134	57.9568	-57.9568	57.9568	-57.6434
55	863.12	540.	115.1137	115.1137	3064	57.5569	-57.5569	57.5569	-57.2505
56	868.57	550.	114.3144	114.3144	2994	57.1572	-57.1572	57.1572	-56.8578

57	344.4A	560.	111.5155	114.5155	.2924	56.757A	-56.757A	56.757A	-56.4654
58	344.1A	570.	112.7173	112.7173	.2854	56.35A6	-56.35A6	56.3586	-56.0732
59	353.42	580.	111.0196	111.0196	.2784	55.959A	-55.959A	55.9598	-55.6814
60	357.67	590.	111.1224	111.1224	.2713	55.5612	-55.5612	55.5612	-55.2899
61	361.92	600.	110.5261	110.5261	.2641	55.1631	-55.1631	55.1631	-54.8989
62	366.15	610.	109.5301	109.5301	.2569	54.7650	-54.7650	54.7650	-54.5081
63	370.37	620.	108.7344	108.7344	.2497	54.3672	-54.3672	54.3672	-54.1175
64	374.5A	630.	107.9389	107.9389	.2425	53.9695	-53.9695	53.9695	-53.7271
65	379.7A	640.	107.1435	107.1435	.2350	53.5717	-53.5717	53.5717	-53.3368
66	382.97	650.	106.3479	106.3479	.2276	53.1740	-53.1740	53.1740	-52.9464
67	387.1A	660.	105.5521	105.5521	.2201	52.7760	-52.7760	52.7760	-52.5559
68	391.30	670.	104.7558	104.7558	.2127	52.3779	-52.3779	52.3779	-52.1652
69	395.45	680.	103.95A9	103.95A9	.2053	51.9794	-51.9794	51.9794	-51.7741
70	399.5A	690.	103.1611	103.1611	.1979	51.5806	-51.5806	51.5806	-51.3827
71	403.49	700.	102.3628	102.3628	.1906	51.1814	-51.1814	51.1814	-50.9908
72	407.29	710.	101.5628	101.5628	.1835	50.7814	-50.7814	50.7814	-50.5979
73	411.06	720.	100.7610	100.7610	.1765	50.3805	-50.3805	50.3805	-50.2040
74	414.52	730.	99.9564	99.9564	.1696	49.9782	-49.9782	49.9782	-49.80A6
75	418.57	740.	99.1484	99.1484	.1628	49.5742	-49.5742	49.5742	-49.4114
76	422.30	750.	98.3362	98.3362	.1560	49.1681	-49.1681	49.1681	-49.0122
77	426.02	760.	97.5191	97.5191	.1492	48.7596	-48.7596	48.7596	-48.6104
78	429.73	770.	96.6963	96.6963	.1424	48.3481	-48.3481	48.3481	-48.2058
79	433.42	780.	95.8669	95.8669	.1355	47.9335	-47.9335	47.9335	-47.7980
80	437.11	790.	95.0304	95.0304	.1285	47.5152	-47.5152	47.5152	-47.3867
81	440.79	800.	94.1863	94.1863	.1214	47.0932	-47.0932	47.0932	-46.9718
82	444.45	810.	93.3332	93.3332	.1141	46.6666	-46.6666	46.6666	-46.5525
83	448.10	820.	92.4715	92.4715	.1067	46.2358	-46.2358	46.2358	-46.1291
84	451.73	830.	91.6012	91.6012	.0991	45.8006	-45.8006	45.8006	-45.7015
85	455.33	840.	90.7223	90.7223	.0916	45.3612	-45.3612	45.3612	-45.2696
86	458.9A	850.	89.8344	89.8344	.0840	44.9175	-44.9175	44.9175	-44.8335
87	462.54	860.	88.9390	88.9390	.0765	44.4695	-44.4695	44.4695	-44.3910
88	466.5.47	870.	88.0347	88.0347	.0691	44.0173	-44.0173	44.0173	-44.3482
89	469.3A	880.	87.1219	87.1219	.0618	43.5609	-43.5609	43.5609	-44.4991
90	472.73	890.	86.2007	86.2007	.0548	43.1004	-43.1004	43.1004	-44.0456
91	476.02	900.	85.2718	85.2718	.0479	42.6359	-42.6359	42.6359	-43.58A0
92	479.23	910.	84.3342	84.3342	.0413	42.1671	-42.1671	42.1671	-43.125A
93	482.32	920.	83.3892	83.3892	.0349	41.6946	-41.6946	41.6946	-42.6597
94	485.30	930.	82.4376	82.4376	.0289	41.2188	-41.2188	41.2188	-42.1899
95	488.13	940.	81.4802	81.4802	.0231	40.7401	-40.7401	40.7401	-41.7170
96	490.79	950.	80.5180	80.5180	.0177	40.2590	-40.2590	40.2590	-41.2413
97	493.26	960.	79.5516	79.5516	.0126	39.7758	-39.7758	39.7758	-40.7632
98	495.50	970.	78.5820	78.5820	.0079	39.2910	-39.2910	39.2910	-40.2831
99	497.44	980.	77.6100	77.6100	.0038	38.8050	-38.8050	38.8050	-40.8012
100	499.1A	990.	76.6364	76.6364	.0009	38.3182	-38.3182	38.3182	-40.3173

GEOMETRIC

NODE	FRACTURE LENGTH FT	PROPPANT LENGTH FT	FRACTURE HEIGHT FT	SUSP HEIGHT FT	BED HEIGHT FT	FROM CENTER OF PAYZONE			
						DISTANCE TO TOP OF FRACTURE FT	DISTANCE TO BOTTOM OF FRAC FT	DISTANCE TO TOP OF SUSP FT	DISTANCE TO TOP OF BED FT
1	563.75	0.	160.9543	160.9583	13.9664	80.4792	-80.4792	80.4792	-66.5126
2	569.79	10.	160.0438	160.0439	13.8450	80.0219	-80.0219	80.0220	-66.1768
3	575.85	20.	159.1296	159.1299	13.7234	79.5648	-79.5648	79.5651	-65.8414

4	581.91	30.	154.2165	154.216H	13.6015	79.1082	-79.1082	79.1086	-65.5067
5	587.97	40.	157.4047	157.4051	13.3799	78.6523	-78.6523	78.6528	-65.1724
6	594.02	50.	156.3953	156.3953	13.3545	78.1974	-78.1974	78.1979	-64.8388
7	600.07	60.	155.4871	155.487A	13.2367	77.7435	-77.7435	77.7442	-64.5068
8	605.59	70.	154.5822	154.5830	13.1152	77.2911	-77.2911	77.2919	-64.1759
9	611.10	80.	153.6806	153.6815	12.9938	76.8403	-76.8403	76.8412	-63.8465
10	616.60	90.	152.7827	152.783A	12.8721	76.3914	-76.3914	76.3924	-63.5193
11	622.16	100.	151.8891	151.8902	12.7501	75.9446	-75.9446	75.9457	-63.1945
12	627.59	110.	150.9999	151.0010	12.6279	75.5000	-75.5000	75.5010	-62.8721
13	633.0A	120.	150.1151	150.1161	12.5062	75.0575	-75.0575	75.0586	-62.5513
14	638.56	130.	149.2343	149.2353	12.3843	74.6171	-74.6171	74.6181	-62.2328
15	644.04	140.	148.3574	148.3583	12.2622	74.1787	-74.1787	74.1796	-61.9145
16	649.51	150.	147.4840	147.4848	12.1403	73.7420	-73.7420	73.7428	-61.6018
17	654.9A	160.	146.6140	146.6147	12.0184	73.3070	-73.3070	73.3077	-61.2886
18	660.44	170.	145.7469	145.7478	11.8960	72.8735	-72.8735	72.8742	-60.9775
19	665.90	180.	144.8827	144.8833	11.7729	72.4413	-72.4413	72.4420	-60.6684
20	671.3A	190.	144.0209	144.0215	11.6496	72.0104	-72.0104	72.0111	-60.3609
21	676.82	200.	143.1616	143.1620	11.5257	71.5808	-71.5808	71.5812	-60.0551
22	682.27	210.	142.3041	142.3045	11.4015	71.1520	-71.1520	71.1525	-59.7505
23	687.72	220.	141.4485	141.4490	11.2771	70.7243	-70.7243	70.7248	-59.4472
24	693.17	230.	140.5949	140.5954	11.1521	70.2975	-70.2975	70.2980	-59.1454
25	698.62	240.	139.7434	139.7439	11.0269	69.8717	-69.8717	69.8722	-58.8448
26	704.07	250.	138.8937	138.8942	10.9019	69.4469	-69.4469	69.4474	-58.5450
27	709.52	260.	138.0461	138.0466	10.7770	69.0230	-69.0230	69.0235	-58.2460
28	714.97	270.	137.2004	137.2009	10.6523	68.6002	-68.6002	68.6007	-57.9479
29	720.42	280.	136.3567	136.3572	10.5279	68.1784	-68.1784	68.1789	-57.6505
30	725.87	290.	135.5150	135.5156	10.4036	67.7575	-67.7575	67.7581	-57.3539
31	731.32	300.	134.6755	134.6759	10.2792	67.3377	-67.3377	67.3382	-57.0585
32	736.77	310.	133.8377	133.8382	10.1550	66.9189	-66.9189	66.9194	-56.7638
33	742.22	320.	133.0020	133.0025	10.0305	66.5010	-66.5010	66.5015	-56.4705
34	747.67	330.	132.1683	132.1688	9.9055	66.0842	-66.0842	66.0847	-56.1787
35	753.12	340.	131.3368	131.3373	9.7804	65.6684	-65.6684	65.6689	-55.8879
36	758.57	350.	130.5073	130.5079	9.6551	65.2537	-65.2537	65.2542	-55.5986
37	764.02	360.	129.6801	129.6807	9.5293	64.8401	-64.8401	64.8406	-55.3107
38	769.47	370.	128.8552	128.8558	9.4030	64.4276	-64.4276	64.4282	-55.0246
39	774.92	380.	128.0323	128.0331	9.2770	64.0163	-64.0163	64.0168	-54.7392
40	780.37	390.	127.2122	127.2128	9.1505	63.6061	-63.6061	63.6067	-54.4556
41	785.82	400.	126.3944	126.3950	9.0231	63.1972	-63.1972	63.1978	-54.1741
42	791.27	410.	125.5788	125.5794	8.8961	62.7894	-62.7894	62.7900	-53.8933
43	796.72	420.	124.7655	124.7660	8.7690	62.3827	-62.3827	62.3833	-53.6138
44	802.17	430.	123.9542	123.9546	8.6416	61.9771	-61.9771	61.9776	-53.3355
45	807.62	440.	123.1447	123.1451	8.5144	61.5724	-61.5724	61.5728	-53.0580
46	813.07	450.	122.3370	122.3373	8.3869	61.1685	-61.1685	61.1688	-52.7815
47	818.52	460.	121.5307	121.5310	8.2597	60.7653	-60.7653	60.7657	-52.5057
48	823.97	470.	120.7257	120.7259	8.1331	60.3628	-60.3628	60.3631	-52.2297
49	829.42	480.	119.9218	119.9220	8.0070	59.9609	-59.9609	59.9611	-51.9539
50	834.87	490.	119.1188	119.1191	7.8813	59.5594	-59.5594	59.5597	-51.6781
51	840.32	500.	118.3169	118.3170	7.7564	59.1584	-59.1584	59.1585	-51.4021
52	845.77	510.	117.5152	117.5154	7.6310	58.7576	-58.7576	58.7578	-51.1266
53	851.22	520.	116.7143	116.7143	7.5049	58.3571	-58.3571	58.3572	-50.8522
54	856.67	530.	115.9137	115.9138	7.3780	57.9568	-57.9568	57.9570	-50.5788
55	862.12	540.	115.1137	115.1139	7.2494	57.5569	-57.5569	57.5570	-50.3074
56	867.57	550.	114.3144	114.3145	7.1182	57.1572	-57.1572	57.1573	-50.0390
57	873.02	560.	113.5155	113.5157	6.9836	56.7578	-56.7578	56.7579	-49.7741
58	878.47	570.	112.7173	112.7174	6.8446	56.3586	-56.3586	56.3588	-49.5140
59	883.92	580.	111.9196	111.9197	6.7002	55.9598	-55.9598	55.9599	-49.2595
60	889.37	590.	111.1224	111.1226	6.5595	55.5612	-55.5612	55.5614	-49.0117
61	894.82	600.	110.3261	110.3262	6.4197	55.1631	-55.1631	55.1631	-48.7714
62	866.15	610.	109.5301	109.5302	6.2276	54.7650	-54.7650	54.7651	-48.5375

63	M70.57	620.	106.7344	107.7344	6.0573	54.3672	-54.3672	54.3672	-48.3099
64	674.51	630.	107.4349	107.4349	5.8435	53.4695	-53.4695	53.4695	-48.0840
65	573.74	640.	107.1445	107.1445	5.7097	53.5717	-53.5717	53.5717	-47.8621
66	M87.97	650.	106.3479	106.3479	5.5380	53.1740	-53.1740	53.1739	-47.6355
67	M87.18	660.	105.5521	105.5520	5.3720	52.7760	-52.7760	52.7759	-47.4040
68	891.30	670.	104.7556	104.7556	5.2139	52.3779	-52.3779	52.3777	-47.1640
69	895.45	680.	103.9589	103.9587	5.0669	51.9794	-51.9794	51.9792	-46.9125
70	899.58	690.	103.1611	103.1610	4.9313	51.5806	-51.5806	51.5804	-46.6493
71	903.49	700.	102.3628	102.3624	4.8102	51.1814	-51.1814	51.1810	-46.3712
72	907.29	710.	101.5628	101.5624	4.7065	50.7814	-50.7814	50.7809	-46.0749
73	911.06	720.	100.7610	100.7603	4.6149	50.3805	-50.3805	50.3798	-45.7656
74	914.82	730.	99.9564	99.9558	4.5284	49.9742	-49.9742	49.9736	-45.4499
75	918.57	740.	99.1484	99.1479	4.4422	49.5742	-49.5742	49.5737	-45.1320
76	922.30	750.	98.3362	98.3356	4.3515	49.1681	-49.1681	49.1675	-44.8167
77	926.02	760.	97.5191	97.5184	4.2495	48.7596	-48.7596	48.7588	-44.5100
78	929.73	770.	96.6963	96.6954	4.1115	48.3481	-48.3481	48.3473	-44.2166
79	933.42	780.	95.8669	95.8656	3.9931	47.9335	-47.9335	47.9321	-43.9408
80	937.11	790.	95.0304	95.0285	3.8824	47.5152	-47.5152	47.5133	-43.6828
81	940.79	800.	94.1863	94.1841	3.7647	47.0932	-47.0932	47.0909	-43.4455
82	944.45	810.	93.3332	93.3311	3.6497	46.6666	-46.6666	46.6645	-43.2269
83	948.10	820.	92.4715	92.4694	3.5284	46.2358	-46.2358	46.2336	-43.0173
84	951.73	830.	91.6012	91.5991	3.4042	45.8006	-45.8006	45.7985	-42.8064
85	955.33	840.	90.7223	90.7202	3.2773	45.3612	-45.3612	45.3590	-42.5980
86	958.90	850.	89.8349	89.8328	3.1512	44.9175	-44.9175	44.9153	-42.3963
87	962.43	860.	88.9390	88.9369	3.0259	44.4695	-44.4695	44.4674	-42.1100
88	965.92	870.	88.0347	88.0326	2.9168	44.0173	-44.0173	44.0152	-41.8491
89	969.36	880.	87.1219	87.1198	2.8089	43.5609	-43.5609	43.5588	-41.5720
90	972.73	890.	86.2007	86.1988	2.7192	43.1008	-43.1008	43.0984	-41.2812
91	976.02	900.	85.2718	85.2696	2.6110	42.6359	-42.6359	42.6337	-40.9749
92	979.24	910.	84.3342	84.3328	2.5120	42.1671	-42.1671	42.1657	-40.6551
93	982.32	920.	83.3892	83.3883	2.4179	41.6946	-41.6946	41.6937	-40.3267
94	985.30	930.	82.4376	82.4368	2.3287	41.2188	-41.2188	41.2180	-39.9901
95	988.13	940.	81.4802	81.4796	2.2481	40.7401	-40.7401	40.7395	-39.6520
96	990.79	950.	80.5180	80.5174	2.1780	40.2590	-40.2590	40.2584	-39.3145
97	993.26	960.	79.5516	79.5512	2.1180	39.7758	-39.7758	39.7754	-38.9878
98	995.50	970.	78.5820	78.5817	2.0629	39.2910	-39.2910	39.2907	-38.6619
99	997.46	980.	77.6100	77.6098	2.0180	38.8050	-38.8050	38.8048	-38.4160
100	999.10	990.	76.6364	76.6364	1.1157	38.3182	-38.3182	38.3182	-38.2025

STOP

CHAPTER III

COMBINED SA3DFRAC AND TUPROPS

SA3DFRAC Model

Program SA3DFRAC is based on semianalytical solution of three-dimensional elliptical fracture using Shah and Kobayashi solutions and two-dimensional fluid flow using Prats and Muskat solutions. This program determines the non-Newtonian effective fluid viscosity, wellbore pressure, net effective pressure at fracture tip, widths $w(x,y)$ as a function of distance from wellbore both in x and y direction, fracture height along the plane of fracture from wellbore to fracture tip, time of growth of a fracture, fluid leakoff volume, and fracture volume.

The program is run interactively. The main program SA3DFRAC and 15 related subroutines and functions are written in Fortran-77, having well documented source code, and have been run on a Honeywell 6600/B3 computer. The program has two output files FRACTURE and PROPIN. The file FRACTURE contains all the results during the computations of the fracture geometry and PROPIN contains just the information needed for the proppant transport model.

The main program SA3DFRAC and 15 related subroutines and function files are linked together through a Job Control Language 'JCL' B-FRACP. The file name of program SA3DFRAC is FRACP.

The file names, subroutines, and function names and their description are:

SR.NO.	FILE NAME	SUBROUTINE/ FUNCTION	DESCRIPTION
1.	SIMQSKP	SIMQSK	This subroutine used by SA3DFRAC solves for x in $[A][X]=[B]$ equation.
2.	SKWIDP	SKWID	This subroutine used by SA3DFRAC and WIDAVG calculates the width of each

segment of various vertical heights of the fracture, using Shah and Kobayashi equation in Part 1, Chapter III, of the Final Report. SKWID also calculates area.

3.	WIDTHAP	WIDAVG	This subroutine calculates the average width of fracture, average of width cubed, leakoff volume, fracture volume, and time of fracture growth. WIDAVG uses area calculations from SKWID. The equation for time and leakoff volume calculations are given in Part 1, Chapter III, of the Final Report.
4.	FALP	FLASEP	This subroutine is used by SA3DFRAC to calculate coefficients used in determining $K_{IA}=K_{CA}$ and $K_{IB}=K_{CB}$ condition.
5.	ELLP	ELLIP	This subroutine is used by SA3DFRAC to calculate elliptic integrals K,E used in determining $K_{IA}=K_{CA}$ and $K_{IB}=K_{CB}$ condition.
6.	SHAH	SHAH	This subroutine is used by SA3DFRAC to calculate Shah and Kobayashi coefficients.
7.	VSCP	VSCITY	This subroutine is used by SA3DFRAC to calculate effective non-Newtonian fluid viscosity, circular fracture radius, Shah and Kobayashi pressure averages, and constant Lamda unit to be used by subroutine DELTA1 for calculating Muskat and Prats average pressures.
8.	RMTP	RMATCH	This subroutine calculates the matching radius for minimum value of discrepancy between the solutions obtained from subroutines PMFNRM and PPFNRM.
9.	PMP	PMFNRM	This subroutine computes the pressure for a line source with an infinite boundary (Muskat solution).
10.	PPP	PPFNRM	This subroutine computes the pressure for a point source with an elliptical boundary (Prats solution). This subroutine uses functions QFUN and RFUN for Newton Raphson method solutions.
11.	QFUNP	QFUN	This function uses Newton Raphson's method to find real roots of equation.

12.	RUNP	RFUN	This function also uses Newton Raphson's method to find real roots of equation.
13.	DELP	DELTA1	This subroutine uses functions RFUN, QFUN, PPFUN, and PMFUN to calculate root mean square value of delta (delta is a measure of optimum half fracture height 'B').
14.	PPFUNP	PPFUN	This subroutine calculates the pressure for a point source with an elliptical boundary using computed pressure differences at fracture tips A and B in PPFNRM and RMATCH.
15.	PMFUNP	PMFUN	This subroutine calculates the pressure for a line source with an infinite boundary using computed pressure at wellbore in subroutine RMATCH.

Input Identification: SA3DFRAC

The input parameters for SA3DFRAC fracture program is introduced interactively and is rather self-explanatory. The record number, identification, variable name, and units for these parameters are:

Record No.	Identification	Variable Name	Units
1.	Number of fracture division along pay zone wing (required for proppant transport model coupling).	NFRAC	
2.	Number of fracturing fluids (required for proppant transport model coupling).	NQ	
3.	Debugging flag. 1 - Debugging required. 0 - No debugging. Use 0 <u>ie</u> no debugging only.	IBUG	
4.	Writing flag. 1 - Write output. 0 - No writing output. Use 1 <u>ie</u> write output.	IWRITE	
5.	Mode I critical stress intensity factor K_{IA} (fracture toughness).	KCA	dynes/cm**1.5
6.	Mode I critical stress intensity factor K_{IB} (fracture toughness).	KCB	dynes/cm**1.5
7.	Pay zone height.	HZ	ft.

8.	Flow rate - both wings.	Q	bbl/min.
9.	Initializing variable. Use RMU = 100	RMU	
10.	Young's modulus.	EMOD	psi
11.	Poisson's ratio.	RNU	
12.	Stress contrast.	S2MS1	psi
13.	Fracture half wing length, along semimajor axis, 'A'.	L	ft.
14.	Percentage accuracy desired in iteration of K_I . Use DIFFAC = 1	DIFFAC	
15.	Perforation height at wellbore.	WELHT	ft.
16.	Flag for viscosity, matching radius, and average pressure calculations. Use IFLAG = 1 for fracture geometry runs. Use IFLAG = 0 for proppant transport model coupling related runs.	IFLAG	
17.	Starting low pressure initializing value. Use POLOW1 = -100	POLOW1	psi
18.	Starting high pressure initializing value. Use POHIG1 = +1000	POHIG1	psi
19.	Half height at wellbore, 'B'. Guess B value for iteration purpose.	B	ft.
20.	Flag for time, leakoff volume, and fracture volume calculations. 1 - Time and volume calculations done. 0 - No time and volume calculations. Use IT = 1 when correct half fracture height B is determined. Use IT = 1 when generating output file "PROPIN" for coupling to proppant transport model TUPROPS. Use IT = 0 when iterating for optimum half fracture height B.	IT	
21.	To calculate width of fracture when $X/A = 0.0$ at 5 different vertical Y/B ratios. Use ICALC = 0.	ICALC	

22. To calculate average width of fracture, average of width cubed, and width at various X/A and Y/B ratios. If IT = 1 areas at various X/A ratios are also calculated. Use ICALL = 0 ICALL
23. Behavioral index. NPRIME
24. Consistency index. KPRIME $\text{lb-ft}^{-2.0}$
25. Number of divisions along the axis. NDIV
Use NDIV = 40.
This NDIV in RMATCH subroutine should not exceed 50.
26. Step of grid or length of an interval. STEP ft.
 $\text{STEP} = L/\text{NDIV}$
Use STEP = 3,5,etc. as required.
27. Initial pressure at wellbore. PO psi
Use PO = 0.
28. Initial pressure difference at A and B. PD psi
Use PD = 0.
29. Flag for printing PMFN pressures. IFLAG
1 - Print all PMFN pressures.
0 - To continue with program.
Use IFLAG = 0.
30. Flag for printing PPFN pressures. IFLAG
1 - Print all PPFN pressures.
0 - To continue with program.
Use IFLAG = 0.
31. Enter range in which matching radius search computation desired. In general use 2 to NDIV for largest range. Matching radius is always between perforation height 'C' and guessed value of half fracture height 'B'. Select RA, RB accordingly. RA, RB ft., ft.
32. Flag to continue matching radius search calculation, aiming for lowest Delta variable value between 'B' and 'C'. IFLAG1
Use 1 to continue matching radius calculations or 0 to continue with program.

33.	Number of divisions along x- and y-axes in DELTA1 subroutine.
Use NDIV = 10.	NDIV	
34.	Stress contrast.
This value should be same as in Record 12.	S2MS1	psi
35.	Flag for printing PROG40 pressure.
1 - To print all PROG40 pressures.
0 - To continue with program.
Use IFLAG = 0.	IFLAG	
36.	Restart control flag.
1 - To rerun with new half wellbore height.
2 - To rerun with new parameters.
3 - To quit.
Use required ICH value.	ICH	
37.	IF IT = 1 fluid leakoff coefficient is required to calculate leakoff volume and fracture growth time.	LEAKC	cm/sec**0.5
38.	Spurt loss coefficient.	SP	cm**3/cm**2
39.	Use ICONV = 1 for automatic convergence of time.	ICONV	
40.	Use TIMP = 1 for percentage convergence of time.	TIMP	
41.	Initializing value of slope.
Use TSLOPE = 0.5	TSLOPE	
42.	IF IT = 1, input behavioral index.	NPRIME	
43.	IF IT = 1, input consistency index.	KPRIME	lbf-s ⁿ /ft**2.0
44.	Restart control flag.
1 - To rerun with new half wellbore height.
2 - To rerun with new parameters.
3 - To quit.
Use required ICH value.	ICH	

Procedure for Running SA3DFRAC Program

SA3DFRAC program should be run interactively in following two ways, to obtain output for fracture geometry alone and/or fracture geometry and input data for coupling it to the proppant transport model.

Procedure for Case 1

Following flow path is selected for running SA3DFRAC program in obtaining optimum fracture half height corresponding to a fixed fracture half length.

Typical Case 1 input parameters are as follows:

Record	Variable	Example Value	Remarks
1.	NFRAC	1	
2.	NQ	1	
3.	IBUG	0	
4.	IWRITE	1	
5.	KCA	1.1E8	
6.	KCB	1.1E8	
7.	HZ	223	
8.	Q	40	
9.	RNU	100	
10.	EMOD	0.75E6	
11.	RNU	0.2	
12.	S2MS1	100	
13.	L	223	
14.	DIFFAC	0.1	
15.	WELHT	90	
16.	IFLAG	1	
17.	POLOW1	-100	
18.	POHIG1	+1000	
19.	B	130	First guess of fracture half height.
20.	IT	0	
21.	ICALC	0	

22.	ICALL	0	
23.	NPRIME	0.482	
24.	KPRIME	0.011	
25.	NDIV	40	Maximum NDIV = 50.
26.	STEP	5	Step = L/NDIV.
27.	P0	0	
28.	PD	0	
29.	IFLAG	0	
30.	IFLAG	0	
31.	RA, RB	20, 40	RA x Step $\geq$ WELHT RB x Step $\leq$ B
32.	IFLAG1	0	
33.	NDIV	10	
34.	S2MS1	100	
35.	IFLAG	0	Note DELTA, root mean square value in output.
36.	ICH	1	Restart SA3DFRAC using next guess of fracture half height.

The variable name DELTA is referred to as a discrepancy factor. With a value for ICH = 1, SA3DFRAC program can be run again from the record number 19 position. Use other values of B = 140 ft., 145 ft., etc., as next guesses of fracture half height and note the values of DELTA, the discrepancy factor, at the end of each run. After plotting DELTA(Δ) versus fracture half height 'B', the value of B which gives a minimum discrepancy value for the graph can be determined; e.g., Figure 1. This is the optimum solution for the half fracture height whose length and other formation and fluid parameters are known (record numbers 1 through 35).

Figure 1. Discrepancy Factor, Δ versus Half Height, B .

The following should be noted by the user of the SA3DFRAC model:

- (1) The user of the SA3DFRAC model should be aware that the computed matching radius is always greater than the half perforated height at the wellbore and less than the guessed value for the half fracture height. Thus, this also indicates that the optimum solution for the half fracture height will always be greater than the half perforated height.
- (2) It is recommended that the use of SA3DFRAC model should start the first guess of the half fracture height using a value which is at least 20-30 feet higher than the half perforated height. The successive guesses should increase in magnitude in an ascending order with intervals of approximate 10 feet or as required. At the end of each run the value of the discrepancy factor, DELTA (Δ), corresponding to each guess of the half fracture height is obtained. The graph of the various guessed fracture heights, B, and the discrepancy factor, DELTA (Δ), are simultaneously plotted at the end of each computer run. A stage will be reached when the decreasing trend of the plot will start to increase again. The value of the fracture half height, B, which gives the minimum discrepancy value for the graph is the final optimum solution for the half fracture height.

Once the optimum half fracture height is determined, use ICH = 1 again at record number 36 and input record numbers 37 through 43 to calculate growth time of fracture, leakoff volume, and fracture volume. The SA3DFRAC program run can now be terminated using ICH = 3 at record number 44. Sample input Case 1 for time, leakoff volume, and fracture volume calculations are given below:

Cont'd. after Record 36

Record	Variable	Example Value	Remarks
37.	LEAKC	0.00787	
38.	SP	0.0	
39.	ICONV	1	
40.	TIMP	1	
41.	TSLOPE	0.5	
42.	NPRIME	0.482	
43.	KPRIME	0.011	

The detailed output file FRACTURE for sample Case 1 run is given in Appendix A.

Procedure for Case 2

A certain flow path is followed for running the SA3DFRAC program for generating two output files, FRACTURE, shown in Appendix B, and PROPIN, shown in Appendix C. PROPIN contains fracture geometry and fracture time details. This output file is used as the fracture geometry input file to the proppant transport model. Data transfer for the second file is done automatically in the format, E26.18, and no direct user input to the file is needed.

PROPIN contains the following records which are automatically transferred to the proppant transport model. Generally 4 to 5 lengths are required to adequately describe the fracture geometry for the proppant transport model.

- 1) Number of lengths.
- 2) Number of flow rates used.

3) For each length following data are required:

- (a) C_{00} , C_{20} , C_{02} empirical constants from published results of Shah and Kobayashi (CGS units).
- (b) Poisson's ratio.
- (c) Half fracture length (cms) (first length should be at least equal to the total pay zone height).
- (d) Half fracture height (cms).
- (e) Maximum wellbore width associated with first half length (cms).
- (f) Leakoff coefficient ($\text{cm}/\text{sec}^{0.5}$).
- (g) Spurt loss ($\text{cm}^{3.0}/\text{cm}^{2.0}$).
- (h) Intermediate growth time for fracture.
- (i) Behavior index.
- (j) Consistency index ($\text{dynes}\cdot\text{s}^n/\text{cm}^{2.0}$).
- (k) Pay zone height (cms).
- (l) Flow rate both wings ($\text{cm}^{3.0}/\text{sec}$).
- (m) Modulus of elasticity ($\text{dynes}/\text{cm}^{2.0}$).
- (n) Stress contrast ($\text{dynes}/\text{cm}^{2.0}$).

Each length group will require input data 3)(a) to (n) to be transferred to the proppant transport model.

SA3DFRAC model is run as many times as the number of length groups, because each run will generate all of the necessary output records pertaining to fracture geometry and growth time. The optimum solution for half fracture heights and growth times corresponding to each half fracture length are computed iteratively first following the procedure described in earlier section "Procedure for Case 1". Once all related λ_{pa} heights and lengths are computed, SA3DFRAC is run again using options $IT = 1$ and $IFLAG = 0$ at record number 16 for each of the length groups followed by time

calculations. At the end of last length group, PROPIN outfile is created and so SA3DFRAC execution can be terminated by entering ICH = 3 at record number 44.

Limitations of SA3DFRAC Model

The sensitivity analysis performed on SA3DFRAC model helped in noting some important observations.

- 1) The program operating range for Young's modulus was between 1×10^5 to 1×10^7 psi.
- 2) The program does not operate for stress contrast values less than 25 psi.
- 3) A limitation of the combined fracture and proppant model is in selecting the initial fracture length. The fracture model SA3DFRAC predicts elliptical fractures along the vertical plane and is appropriate for intermediate length/height ratios in between 1 and 4. For obtaining valid geometry results, the initial half fracture length and the wellbore height must be greater than the total pay zone height. Thus, the model is not capable of supplying information about the early history of fracture. A linear interpolation is done until the valid range of model is arrived at. Any error caused due to this interpolation should not be significant in the final proppant transport distribution profile. Thus, in general initial length is assumed to be equal to the pay zone height. Successive intermediate lengths are selected in ascending order. However, it is recommended to choose more successive intermediate lengths near the initial length to ensure negligible interpolation errors.

Proppant Model

TUPROPC was modified to accept the output fracture parameters of SA3DFRAC. This modification included changing several subroutines to utilize the new geometry that SA3DFRAC provided. Also, a new section was added to the main program to compute the fracture geometry after the fracture closed. The general description for the proppant model remains the same as described for TUPROP1 and TUPROPC. Only the new routines and changes will be described.

The number of geometry sets is determined when the fracture model is run. Usually 3 to 4 geometry sets provide enough initial information. Just as in the highly elongated coupling more detailed geometry is needed for the proppant model to operate. Subroutine INTFL creates intermediate geometry at DX intervals for the equivalent shape. This is accomplished through using another subroutine, ASKP, which calculates the cross-sectional area at any DX interval given the proper constants. The subroutine ASKP was developed from the theory presented in Part 3, Chapter II, of the Final Report for Contract DE-AC21-84MC21119. The equivalent geometry created by INTFL is then used by the proppant model for computing the proppant distribution.

At the end of pumping (treatment time), the rectangular equivalent geometry of the distributed proppant is put back into the elliptical shape by the subroutine GEOM which employs AMATCHP. AMATCHP uses cross-sectional rectangular areas of the proppant bed and suspension height to calculate their geometric heights based on the original elliptically shaped cross-sectional area. In doing the height calculation, AMATCHP uses two subroutines, ASKP and ACHECK. ASKP is used to check if the fracture cross section is filled with either suspended proppant or proppant bed. Then, if the cross-sectional area is between being full and

zero, ACHECK is used to find the geometric height from the bed and suspension area.

The equivalent and geometric shape of the vertical fracture cross section is produced by the subroutine PLOTGEOM. This routine takes the values of fracture height, suspension height, and bed height and references them to a centerline along the fracture.

The coupled version of SA3DFRAC also included closure. The closure section was added in the main program. The closure section utilizes the same subroutines referenced in TUPROP1 and TUPROPC. They are FLDLOS, CONC, SETVEL, SETPROP, and SUSP. The theory for this section is detailed in Part 3, Chapter IV, of the Final Report for Contract DE-AC21-84MC21119. This section produces detailed closure analysis if desired and plotting geometry in an equivalent rectangular cross-sectional shape.

Input

Input of proppant parameters is contained in a file named DATATUPS. A sample input is shown in Appendix D. Following is a description of each record in the file DATATUPS.

Record	Variable	Units	Name and Description
1	RHOF	lbm/ft ³	Density of Fracturing Fluid, 10F10.5
2	NTP		Number of Proppant Types (Max 10), 5I10
3	TP1(I)	min.	Times at which Proppant Type Changes, 10F10.5
4	GC1(I)	lbm/gal.	Initial Mixing Ratio Concentrations, 10F10.5
5	DP1(I)	in.	Average Proppant Diameter, 10F10.5
6	PHIP1(I)		Proppant Porosities, 10F10.5
7	RHOE1(I)	lbm/ft ³	Proppant Densities, 10F10.5
8	G	ft/s ²	Acceleration of Gravity
	DX	ft.	Proppant Element Length, 10F10.5

9	BETA CONTROL GDOTC GDOTF	S-1	Fan Viscometer Outer to Inner Radii Use 0.0 <u>Only</u> Particle Shear Rate Cut Off Value Shear Stress Location Fraction, 10F10.5 HPG:GDOTC=20,GDOTF=.3333 HEC:GDOTC=60,GDOTF=.6667
10	NCK1 NCK2 NCK3 NSETV		Starting Element of Detailed Output Ending Element of Detailed Output NCK1 > NCK2: No Detailed Output Detailed Output of Last Time Step 0: Not Wanted 1: Output Desired Selection of Settling Model, 10F10.5 1: Zigrang and Sylvester 2: Daneshy 3: Acharya 4: Clark 5: Sutrick and Rybicki 6: Contrast Settling Velocity
11	SETVM FLCON	ft./min.	Constant Settling Velocity for Option 6 Variable Stopping Criteria for Particle Diameter 0.0: Automatic Calculation 1.0: One Proppant Diameter 2.0: One Half Proppant Diameter n: One nth Proppant Diameter, 1.0<n<∞ CTINC min. Closure Time Increment, 10F10.5
12	NICT1 NICT2		Increment Number to Print Detailed Closure Analysis Detailed Last Closure Increment 0: Allows NICT1 to Operate and Disables Last Closure Increment 1: Disables NICT1 and Prints Last Detailed Closure Increment

Output

Output is shown in Appendix E. It has the same form as described in the highly elongated coupling part of the user manual. However, the closure output has been added and will be described.

In addition to the five divisions common to both TUPROPC and TUPPOPS, TUPROPS has two additional divisions. The first division contains detailed closure information which can be obtained at each closure interval, the last closure interval only or none at all. The final

division contains a summary of closure information and plotting data referenced from the centerline along the fracture. The data describing the closed fracture is given only for a rectangular cross section since these values are averages and average values are needed in recovery calculations.

The sample output in Appendix E was obtained with NCK1 set greater than NCK2 and NCK3 set to 1. For closure NICT2 was set to 1 which disabled the use of NICT1. To aid in visualizing the output from the fracture and proppant model, Figure II-3 is included from Part 2 of the Final Report for Contract #DE-AC21-84MC21119. The figure was drawn from this output example.

Figure 2. Fracture Geometry at the End of Pumping and After Closure for Case 1.

CHAPTER III

APPENDIX A

16102 JUL 16 '87 FRACTURE.IND40820

```
1 INPUT: NFRAC=NO. OF FRACTURE DIVISION ALONG PAY ZONE WING
2 NO=NO. OF FRACTURING FLUIDS
3
4 NFRAC = 1 NO = 1
5 INPUT 1 IF YOU WANT DEBUG, 0 FOR NO DEBUG
6 DEBUG = 0
7 INPUT: IWRITE, KCA, KCB (BOTH CGS), HZ (PAYZONE WIDTH IN FT), Q (BPM), RMU (CP)
8 IWRITE = 1 KCA, KCB = 1.10E+09 1.10E+09 HZ = 223.0 Q = 40.0 MU = 100.0
9 INPUT: YOUNG'S MOD. (EG. 1.5E6 PSI), POISS. RAT (EG. .1)
10 YOUNG'S MODULUS = 1.50E+06 POISSON'S RATIO = .20
11 INPUT: S2-S1 (PSI), L (FT)
12 S2-S1 = 100.0 L = 223.0
13
14 INPUT: X ACCURACY DESIRED IN ITERATION OF KI
15 ALLOWANCE FOR .10% ERROR
16 NUMWID = 5
17 WELHT: C
18 C = 90.00
19 INPUT 1 IF YOU WANT VISCOSITY, LAMDA, CIRCULAR FRACTURE RADIUS AND AVG. PRESSURES.
20 FLAG = 1
21 INPUT HALF HEIGHT AT WELL BORE, B (FT)
22 B = 130.00
23 INPUT 1 FOR TIME CALC. IN WIDAVG; 0 FOR NO TIME CALC.
24 ITS = 0
25
26 P0 = .313232E+02
27 PA0 = .222487E+02
28 P0B = .801795E+01
29 KI1 = .110000E+09
30 KI2 = .109986E+09
31 KCA = .110000E+09
32 KCB = .110000E+09
33 DIFF1 = .000
34 DIFF2 = .000
35
36 INPUT 0 : TO CALCULATE WIDTH
37 1 : TO START NEW ITERN. TO CALCULATE KI1 & KI2
38 2 : TO STOP
39 IALC = 0
40
41 WIDTHS ARE CALCULATED AT X/A = 0.00000E+00 AND Y/B = 1.00000E+01
42 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
43 YP = .000000E+00 .200000E+00 .400000E+00 .600000E+00 .800000E+00 .100000E+01
44 WID = .440838E+00 .426023E+00 .381929E+00 .309236E+00 .206618E+00 .613355E-04
45 INPUT 0: TO CALCULATE AVERAGE WIDTH OF FRACTURE
46 1: TO CONTINUE WITH PROGRAM
47
48 WIDTHS ARE CALCULATED AT X/A = 9.00000E+00 AND Y/B = 4.35890E+00
49 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
50 YP = .000000E+00 .871780E-01 .174356E+00 .261534E+00 .348712E+00 .435890E+00
51 WID = .170675E+00 .166737E+00 .154595E+00 .132944E+00 .976107E-01 .404357E-04
52
53 AVERAGE WIDTH AT X = .900E+00 THE LENGTH OF A, EQUALS .1204E+00
54
55 WIDTHS ARE CALCULATED AT X/A = 8.00000E+00 AND Y/B = 6.00000E+00
56 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
```

```

59 YP= .000000E+00 .120000E+00 .240000E+00 .360000E+00 .480000E+00 .600000E+00
60 WID= .241139E+00 .234991E+00 .216232E+00 .183534E+00 .132180E+00 .432757E-04
61
62 AVERAGE WIDTH AT X = .800E+00 THE LENGTH OF A, EQUALS .1680E+00
63
64 WIDTHS ARE CALCULATED AT X/A= 700000E+00 AND Y/B= 714143E+00
65 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
66 YP= .000000E+00 .142829E+00 .285657E+00 .428486E+00 .571314E+00 .714143E+00
67 WID= .293530E+00 .285448E+00 .260974E+00 .219012E+00 .155036E+00 .629908E-04
68
69 AVERAGE WIDTH AT X = .700E+00 THE LENGTH OF A, EQUALS .2023E+00
70
71 WIDTHS ARE CALCULATED AT X/A= 600000E+00 AND Y/B= 800000E+00
72 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
73 YP= .000000E+00 .160000E+00 .320000E+00 .480000E+00 .640000E+00 .800000E+00
74 WID= .335147E+00 .325351E+00 .295850E+00 .245890E+00 .171451E+00 .551077E-04
75
76 AVERAGE WIDTH AT X = .600E+00 THE LENGTH OF A, EQUALS .2290E+00
77
78 WIDTHS ARE CALCULATED AT X/A= 500000E+00 AND Y/B= 866025E+00
79 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
80 YP= .000000E+00 .173205E+00 .346410E+00 .519615E+00 .692820E+00 .866025E+00
81 WID= .368604E+00 .357319E+00 .323473E+00 .266685E+00 .183565E+00 .623788E-04
82
83 AVERAGE WIDTH AT X = .500E+00 THE LENGTH OF A, EQUALS .2500E+00
84
85 WIDTHS ARE CALCULATED AT X/A= 400000E+00 AND Y/B= 916515E+00
86 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
87 YP= .000000E+00 .183303E+00 .366606E+00 .549909E+00 .733212E+00 .916515E+00
88 WID= .395112E+00 .382581E+00 .345108E+00 .282667E+00 .192503E+00 .605413E-04
89
90 AVERAGE WIDTH AT X = .400E+00 THE LENGTH OF A, EQUALS .2663E+00
91
92 WIDTHS ARE CALCULATED AT X/A= 300000E+00 AND Y/B= 953939E+00
93 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
94 YP= .000000E+00 .190788E+00 .381576E+00 .572364E+00 .763151E+00 .953939E+00
95 WID= .415309E+00 .401789E+00 .361448E+00 .294560E+00 .198936E+00 .668602E-04
96
97 AVERAGE WIDTH AT X = .300E+00 THE LENGTH OF A, EQUALS .2787E+00
98
99 WIDTHS ARE CALCULATED AT X/A= 200000E+00 AND Y/B= 979796E+00
100 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
101 YP= .000000E+00 .195459E+00 .391918E+00 .587878E+00 .783837E+00 .979796E+00
102 WID= .429547E+00 .415311E+00 .372844E+00 .302802E+00 .203281E+00 .642256E-04
103
104 AVERAGE WIDTH AT X = .200E+00 THE LENGTH OF A, EQUALS .2873E+00
105
106 WIDTHS ARE CALCULATED AT X/A= 100000E+00 AND Y/B= 994987E+00
107 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
108 YP= .000000E+00 .198497E+00 .397995E+00 .596992E+00 .795990E+00 .994987E+00
109 WID= .438023E+00 .423353E+00 .379680E+00 .307654E+00 .205795E+00 .647332E-04
110
111 AVERAGE WIDTH AT X = .100E+00 THE LENGTH OF A, EQUALS .2924E+00
112
113 WIDTHS ARE CALCULATED AT X/A= 149012E-07 AND Y/B= 100000E+01
114 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
115 YP= .000000E+00 .280000E+00 .400000E+00 .600000E+00 .800000E+00 .100000E+01
116 WID= .440838E+00 .426023E+00 .381929E+00 .309256E+00 .206618E+00 .559914E-04
117
118 AVERAGE WIDTH AT X = .149E-07 THE LENGTH OF A, EQUALS .2941E+00

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110 AVERAGE WIDTH OF FRACTURE = .2389E+00
120 AVERAGE OF WIDTH CUBE = .2616E+01
130
140 Q= 40.0
150 RMUS 100.0
160 HE 223.0
170 BS 130.0
180 AS 223.0
190 PO=P-S1 31.3
200
210 INPUT NON-NEWTONIAN FLUID PARAMETERS N & K(BU )
220 N = .482 K = .01100
230
240 CIRCULAR FRACTURE RADIUS, R (CGS) = .537972E+04
250 CIRCULAR FRACTURE RADIUS, R (BU) = .176500E+03
260
270 EFFECTIVE NON-NEWTONIAN FLUID VISCOSITY, MUEFF(CGS)= .454716E+00
280 EFFECTIVE NON-NEWTONIAN FLUID VISCOSITY, MUEFF(BU)= .949693E-03
290
300 AVERAGE OF THE PRESSURE OVER THE WHOLE SURFACE, PXYSKA(CGS)= .160136E+07
310 AVERAGE OF THE PRESSURE OVER THE WHOLE SURFACE, PXYSKA(BU)= .232283E+02
320
330 AVERAGE OF THE PRESSURE ALONG X, OR MAJOR AXIS, PXSKA(CGS)= .195089E+07
340 AVERAGE OF THE PRESSURE ALONG X, OR MAJOR AXIS, PXSKA(BU)= .282984E+02
350
360 AVERAGE OF THE PRESSURE ALONG Y, OR MINOR AXIS, PYSKA(CGS)= .162387E+07
370 AVERAGE OF THE PRESSURE ALONG Y, OR MINOR AXIS, PYSKA(BU)= .235548E+02
380
390 LAMDA(BU )= .508550E+02
400
410 OUTPUT RESULTS OF SUBROUTINE RMATCH1
420 .....
430 INPUT NDIV (# OF DIVISIONS)
440
450 NDIV= 40
460 AS= 223.000 BS= 130.000 CS= 90.000
470
480 INPUT STEP OF GRID, I.E STEPSA/NDIV,ETC
490
500 STEPS= 5.000
510
520 INPUT PD = THE PRESSURE AT WELLBORE
530
540 PD= .0000
550
560 ENTER PRESS.DIFF.PD = PB -PA
570
580 PB = PA = .000
590
600 *HIT 1 TO PRINT ALL PMFN PRESSURES .
610 0 TO CONTINUE WITH PROGRAM.

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179 0
180 *HIT 1 TO PRINT ALL PPFN PRESSURES.
181 0 TO CONTINUE WITH PROGRAM.
182
183 Q# 0
184 Q# .247330E-01 Q1# .694091E-01K# .173004E+01K1# .203734E+01
185 IDEBUG = 0
186
187 -----
188 RESULTS: NITER K M1(IN) M1(OUT) : 10 .1730E+01 .1000E-04 .6730E+00
189 -----
190 M# .327638E+00 M1# .672362E+00
191 Q# .247330E-01 Q1# .694091E-01K# .173004E+01K1# .203734E+01
192 IDEBUG = 0
193
194 -----
195 RESULTS: NITER K M1(IN) M1(OUT) : 10 .1730E+01 .1000E-04 .6730E+00
196 -----
197 M# .327638E+00 M1# .672362E+00
198 ENTER RANGE IN WHICH DEL(L) CALCULATION SHOULD BE DONE
199 RANGE FROM - TO 20- 40
200
201 STEP NO. RMATCH,% DIFF IN P4FNRM & PPFNRM PRESS.
202 0 55.00 72.2982
203 1 100.00 62.8405
204 2 105.00 64.3630
205 3 110.00 75.3138
206 4 115.00 97.0009
207 5 120.00 108.3409
208 6 125.00 108.0078
209 7 130.00 100.0000
210 8 135.00 100.0000
211 9 140.00 100.0000
212 10 145.00 100.0000
213 11 150.00 100.0000
214 12 155.00 100.0000
215 13 160.00 100.0000
216 14 165.00 100.0000
217 15 170.00 100.0000
218 16 175.00 100.0000
219 17 180.00 100.0000
220 18 185.00 100.0000
221 19 190.00 100.0000
222 20 195.00 100.0000
223
224 DO YOU NEED TO CONTINUE DEL(L) CALCULATION! INPUT 0 FOR NO OR 1 FOR YES
225
226 IFLAG1 = 0
227 STEP NO. MATCHING RADIUS(FT.), MIN.% DIFF.
228 21 100.00 628405E+02
229 PCOR# 712474E+00 PDD# .104155E+01
230 OUTPUT RESULTS OF DELTA1 SUBROUTINE
231 -----
232 INPUT: NDIV (# OF DIVISIONS)
233 NDIV# 10
234 A# 223.000 B# 130.000 C# 90.000
235 P(0)# 1.0415 PDE .0000
236
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239 RM= 100.0000
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RM= 100.0000
 INPUT: S2-S1 (PSI)
 S2-S1= 100.0HZ# 223.0LAMDA = .508550E+02
 PXYSKA= .232283E+02 PXSKA= .282984E+02 PYSKA = .235548E+02
 HIT 1 TO PRINT ALL PROG40 PRESSURES
 0 TO CONTINUE WITH PROGRAM.
 IDEBUG = 0

RESULTS: NITER K M1(IN) M1(OUT) : 10 .1730E+01 .1000E-04 .6730E+00
 AVERAGE FLUID PRESSURE OVER WHOLE SURFACE PFXYP = .2666E+00
 AVERAGE PRESSURE OVER Y - AXIS, PFYMP = .755246E+00
 AVERAGE PRESSURE OVER X-AXIS, PFXMP = .308380E+00

TOTAL NO. OF POINTS IN THE QUADRANT = 90.0000
 TOTAL NO. OF POINTS IN THE HIGHER STRESS REGION= 5.6745

AVG. MP PRESS. OVER WHOLE SURFACE-PXYMPA= .1266E+02
 EFFECTIVE AVG. SK PRESS. OVER WHOLE SURFACE-PXYSKA= .2323E+02
 DIFFERENCE OF (PXYSKA-PXYMPA)=DPXY = .105659E+02
 AVERAGE MP PRESSURE ALONG X AXIS-PXMPA = .262486E+02
 EFFECTIVE AVERAGE SK PRESSURE ALONG X AXIS-PXSKA = .282984E+02
 AVERAGE MP PRESSURE ALONG Y AXIS-PYMPA = .469488E+02
 EFFECTIVE AVERAGE SK PRESSURE ALONG Y AXIS-PYSKA = .235548E+02
 DIFFERENCE OF (PXSKA-PXMPA)=DELX = .204985E+01
 DIFFERENCE OF (PYSKA-PYMPA)=DELY = .233939E+02
 R.M.S VALUE DEL OF DELX AND DELY--DEL = .166054E+02

HIT 1 TO RERUN WITH NEW HALF WELLBORE HGT.
 2 TO RERUN WITH NEW PARAMETERS
 3 TO QUIT

INPUT HALF HEIGHT AT WELL BORE, B (FT)
 B = 140.00
 INPUT 1 FOR TIME CALCN. IN WIDAVG/ 0 FOR NO TIME CALC.
 IT = 0

P0 = .552246E+02

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PA0 = .124584E+02
POB = -.789872E+01
KI1 = .110000E+09
KI2 = .110000E+09
KCA = .110000E+09
KCB = .110000E+09
DIFF1 = .000
DIFF2 = .000

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INPUT 0 : TO CALCULATE WIDTH
        : TO START NEW ITERN. TO CALCULATE KI1 & KI2
        : TO STOP
ICALC = 0

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WIDTHS ARE CALCULATED AT X/A= .000000E+00 AND Y/B= .100000E+01
YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
YP= .000000E+00 .200000E+00 .400000E+00 .600000E+00 .800000E+00 .100000E+01
WID= .730142E+00 .698577E+00 .606278E+00 .460566E+00 .273355E+00 .636740E-04
INPUT 0 : TO CALCULATE AVERAGE WIDTH OF FRACTURE
        : TO CONTINUE WITH PROGRAM

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WIDTHS ARE CALCULATED AT X/A= .000000E+00 AND Y/B= .435890E+00
YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
YP= .000000E+00 .071780E-01 .174356E+00 .261534E+00 .348712E+00 .435890E+00
WID= .194634E+00 .189310E+00 .173175E+00 .145475E+00 .103138E+00 .406699E-04

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AVERAGE WIDTH AT X = .900E+00 THE LENGTH OF A, EQUALS .1343E+00

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WIDTHS ARE CALCULATED AT X/A= .000000E+00 AND Y/B= .600000E+00
YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
YP= .000000E+00 .120000E+00 .240000E+00 .360000E+00 .480000E+00 .600000E+00
WID= .303628E+00 .293862E+00 .264692E+00 .216216E+00 .146595E+00 .437714E-04

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AVERAGE WIDTH AT X = .800E+00 THE LENGTH OF A, EQUALS .2042E+00

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WIDTHS ARE CALCULATED AT X/A= .000000E+00 AND Y/B= .714143E+00
YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
YP= .000000E+00 .142329E+00 .285657E+00 .428486E+00 .571314E+00 .714143E+00
WID= .398898E+00 .384715E+00 .342685E+00 .274121E+00 .179342E+00 .640541E-04

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AVERAGE WIDTH AT X = .700E+00 THE LENGTH OF A, EQUALS .2633E+00

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WIDTHS ARE CALCULATED AT X/A= .000000E+00 AND Y/B= .800000E+00
YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
YP= .000000E+00 .160000E+00 .320000E+00 .480000E+00 .640000E+00 .800000E+00
WID= .483271E+00 .464899E+00 .410716E+00 .323360E+00 .205620E+00 .563175E-04

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AVERAGE WIDTH AT X = .600E+00 THE LENGTH OF A, EQUALS .3147E+00

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WIDTHS ARE CALCULATED AT X/A= .000000E+00 AND Y/B= .866025E+00
YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
YP= .000000E+00 .173205E+00 .346410E+00 .519615E+00 .692820E+00 .866025E+00
WID= .556512E+00 .534348E+00 .469192E+00 .364963E+00 .226912E+00 .640343E-04

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AVERAGE WIDTH AT X = .500E+00 THE LENGTH OF A, EQUALS .3587E+00

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WIDTHS ARE CALCULATED AT X/A= .000000E+00 AND Y/B= .916515E+00
YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
YP= .000000E+00 .183303E+00 .366606E+00 .549909E+00 .733212E+00 .916515E+00

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359 . WID= .617839E+00 .592413E+00 .517828E+00 .399155E+00 .243882E+00 .623886E-04
360 .
361 . AVERAGE WIDTH AT X = .400E+00 THE LENGTH OF A, EQUALS .3952E+00
362 .
363 . WIDTHS ARE CALCULATED AT X/A= 300000E+00 AND Y/B= .953939E+00
364 . YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
365 . YP= .000000E+00 .190788E+00 .381576E+00 .572364E+00 .763151E+00 .953939E+00
366 . WID= .666449E+00 .638389E+00 .556202E+00 .425909E+00 .256869E+00 .691171E-04
367 .
368 . AVERAGE WIDTH AT X = .300E+00 THE LENGTH OF A, EQUALS .4240E+00
369 .
370 . WIDTHS ARE CALCULATED AT X/A= 200000E+00 AND Y/B= .979796E+00
371 . YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
372 . YP= .000000E+00 .195959E+00 .391918E+00 .587878E+00 .783837E+00 .979796E+00
373 . WID= .701667E+00 .671676E+00 .583917E+00 .445124E+00 .266054E+00 .665476E-04
374 .
375 . AVERAGE WIDTH AT X = .200E+00 THE LENGTH OF A, EQUALS .4448E+00
376 .
377 . WIDTHS ARE CALCULATED AT X/A= 100000E+00 AND Y/B= .994987E+00
378 . YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
379 . YP= .000000E+00 .198997E+00 .397995E+00 .596992E+00 .795990E+00 .994987E+00
380 . WID= .722998E+00 .691829E+00 .600672E+00 .456699E+00 .271533E+00 .671691E-04
381 .
382 . AVERAGE WIDTH AT X = .100E+00 THE LENGTH OF A, EQUALS .4573E+00
383 .
384 . WIDTHS ARE CALCULATED AT X/A= .149012E-07 AND Y/B= .100000E+01
385 . YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
386 . YP= .000000E+00 .200000E+00 .400000E+00 .600000E+00 .800000E+00 .100000E+01
387 . WID= .730142E+00 .698577E+00 .606278E+00 .460566E+00 .273355E+00 .581262E-04
388 .
389 . AVERAGE WIDTH AT X = .149E-07 THE LENGTH OF A, EQUALS .4615E+00
390 .
391 . AVERAGE WIDTH OF FRACTURE = .3458E+00
392 .
393 . AVERAGE OF WIDTH CUBE = .9432E-01
394 .
395 .
396 . Q= 40.0
397 . RMU= 100.0
398 . H= 223.0
399 . B= 140.0
400 . A= 223.0
401 . POMP-S1 55.2
402 .
403 . INPUT NON-NEWTONIAN FLUID PARAMETERS N & K(BU)
404 . N = .482 K = .01100
405 .
406 . CIRCULAR FRACTURE RADIUS, R (CGS) = .553212E+04
407 . CIRCULAR FRACTURE RADIUS, R (BU) = .181500E+03
408 .
409 . EFFECTIVE NON-NEWTONIAN FLUID VISCOSITY, MUEFF(CGS) = .778110E+00
410 . EFFECTIVE NON-NEWTONIAN FLUID VISCOSITY, MUEFF(BU) = .162512E+02
411 .
412 . AVERAGE OF THE PRESSURE OVER THE WHOLE SURFACE, PXYSKA(CGS) = .198218E+07
413 . AVERAGE OF THE PRESSURE OVER THE WHOLE SURFACE, PXYSKA(BU) = .287522E+02
414 .
415 . AVERAGE OF THE PRESSURE ALONG X, OR MAJOR AXIS, PXSKA(CGS) = .282442E+07
416 .
417 .
418 .

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419      AVERAGE OF THE PRESSURE ALONG X,OR MAJOR AXIS,PXS(A,BU)= ,409692E+02
420
421      AVERAGE OF THE PRESSURE ALONG Y,OR MINOR AXIS,PYS(A,BU)= ,235661E+07
422
423      AVERAGE OF THE PRESSURE ALONG Y,OR MINOR AXIS,PYS(A,BU)= ,341835E+02
424
425      LAMDA(BU )= ,241336E+02
426
427
428      OUTPUT RESULTS OF SUBROUTINE RMATCH1
429      -----
430
431      INPUT NDIV (# OF DIVISIONS)
432
433      NDIV= 40
434      AS= 223.000 BS= 140.000 CS= 90.000
435
436      INPUT STEP OF GRID, I.E STEP=A/NDIV.ETC
437
438      STEP= 5.000
439
440      INPUT PO = THE PRESSURE AT WELLBORE
441
442      PO= .0000
443
444      ENTER PRESS.DIFF,PD = PB -PA
445
446      PB - PA = .000
447
448      -HIT 1 TO PRINT ALL PMFN PRESSURES .
449      0 TO CONTINUE WITH PROGRAM.
450
451      -HIT 1 TO PRINT ALL PPFN PRESSURES .
452      0 TO CONTINUE WITH PROGRAM.
453
454      Q= .352830E-01 Q1= .522809E-01K= .180032E+01K1= .191651E+01
455      IOEBUG = 0
456
457      -----
458      RESULTS: NITER K M1(IN) M1(OUT) : 10 .1800E+01 .1000E-04 .5681E+00
459      -----
460      M= .432338E+00 M1= .567662E+00
461      Q= .352830E-01 Q1= .522809E-01K= .180032E+01K1= .191651E+01
462      IOEBUG = 0
463
464      -----
465      RESULTS: NITER K M1(IN) M1(OUT) : 10 .1800E+01 .1000E-04 .5681E+00
466      -----
467      M= .432338E+00 M1= .567662E+00
468      ENTER RANGE IN WHICH DEL(L) CALCULATION SHOULD BE DONE
469      RANGE FROM = TO 20= 35
470
471      STEP NO. RMATCH,X DIFF IN PMFNRM & PPFNRM PRESS.
472      20 45.00 70.5003
473      21 100.00 57.1733
474      22 105.00 54.3819
475      23 110.00 59.2465
476      24 115.00 71.9330
477      25 120.00 95.0111
478      26 125.00 136.1568

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27	130.00	219.2386
28	135.00	455.8831
29	140.00	200.0000
30	145.00	200.0000
31	150.00	200.0000
32	155.00	200.0000
33	160.00	200.0000
34	165.00	200.0000
35	170.00	200.0000

DO YOU NEED TO CONTINUE DEL(L) CALCULATION! INPUT 0 FOR NO OR 1 FOR YES

IFLAG1 = 0
STEP NO., MATCHING RADIUS(FT.), MIN. X DIFF.
22 105.00 543819E+02
PCOR = 782038E+00 POD = .108176E+01
OUTPUT RESULTS OF DELTA1 SUBROUTINE

INPUT: NDIV (# OF DIVISIONS)
NDIV = 10
A = 223.000 B = 140.000 C = 90.000
P(0) = 1.0818 PDF = .0000
RM = 105.0000

INPUT: S2-S1 (PSI)
S2-S1 = 100.0HZ = 223.0LAMDA = .241336E+02
PXYSKA = .287522E+02 PXSKA = .409692E+02 PYSKA = .341835E+02

HIT 1 TO PRINT ALL PROG40 PRESSURES
0 TO CONTINUE WITH PROGRAM.
0
IDEBUG = 0

RESULTS: NITER K M1(IN) M1(OUT) : 10 .1800E+01 .1000E-04 .5681E+00

AVERAGE FLUID PRESSURE OVER WHOLE SURFACE PFXYP = .2561E+00
AVERAGE PRESSURE OVER Y = AXIS , PFYMP = .747672E+00
AVERAGE PRESSURE OVER X=AXIS, PFXMP = .314692E+00

TOTAL NO. OF POINTS IN THE QUADRANT = 90.0000
TOTAL NO. OF POINTS IN THE HIGHER STRESS REGION = 9.6144

AVG. MP PRESS. OVER WHOLE SURFACE - PXYMPA = .4007E+01
EFFECTIVE AVG. SK PRESS. OVER WHOLE SURFACE - PXYSKA = .2875E+02
DIFFERENCE OF (PXYSKA-PXYMPA) = DPXY = .247456E+02

AVERAGE MP PRESSURE ALONG X AXIS-PXMPA = .323402E+02
 EFFECTIVE AVERAGE SK PRESSURE ALONG X AXIS-PXSKA = .409692E+02
 AVERAGE MP PRESSURE ALONG Y AXIS-PYMPA = .386455E+02
 EFFECTIVE AVERAGE SK PRESSURE ALONG Y AXIS-PYSKA = .341835E+02
 DIFFERENCE OF (PXSKA-PXMPA)=DELX = .862898E+01
 DIFFERENCE OF (PYSKA-PYMPA)=DELY = -.446198E+01
 R.M.S VALUE DEL OF DELX AND DELY--DEL = .686908E+01

*HIT 1 TO RERUN WITH NEW HALF WELLBORE HGT.
 2 TO RERUN WITH NEW PARAMETERS
 3 TO QUIT

INPUT HALF HEIGHT AT WELL BORE,B(FT)

B = 145.00

INPUT 1 FOR TIME CALCN. IN WIDAVG; 0 FOR NO TIME CALC.

IT = 0

P0 = .686523E+02
 PA0 = .670443E+01
 POB = -.163990E+02
 KI1 = .110000E+09
 KI2 = .109957E+09
 KCA = .110000E+09
 KCB = .110000E+09
 DIFF1 = .000
 DIFF2 = .000

INPUT 0 : TO CALCULATE WIDTH

1 : TO START NEW ITERN. TO CALCULATE KI1 & KI2

2 : TO STOP

ICALC = 0

WIDTHS ARE CALCULATED AT X/A = 0.000000E+00 AND Y/B = 1.000000E+01

YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A

YP = .000000E+00 .200000E+00 .400000E+00 .600000E+00 .800000E+00 .100000E+01
 WID = .900734E+00 .859239E+00 .738366E+00 .549388E+00 .312175E+00 .647602E-04

INPUT 0 : TO CALCULATE AVERAGE WIDTH OF FRACTURE

1 : TO CONTINUE WITH PROGRAM

WIDTHS ARE CALCULATED AT X/A = 9.000000E+00 AND Y/B = 4.35890E+00

YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A

YP = .000000E+00 .871780E-01 .174356E+00 .261534E+00 .348712E+00 .435890E+00
 WID = .208763E+00 .202615E+00 .184115E+00 .152832E+00 .106353E+00 .407786E-04

AVERAGE WIDTH AT X = .900E+00 THE LENGTH OF A, EQUALS .1425E+00

WIDTHS ARE CALCULATED AT X/A = 8.000000E+00 AND Y/B = 6.000000E+00

YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A

YP = .000000E+00 .120000E+00 .240000E+00 .360000E+00 .480000E+00 .600000E+00
 WID = .340476E+00 .328565E+00 .293223E+00 .235402E+00 .154980E+00 .440017E-04

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599 AVERAGE WIDTH AT X = .800E+00 THE LENGTH OF A, EQUALS .2254E+00
600
601 WIDTHS ARE CALCULATED AT X/A = 700000E+00 AND Y/B = 714143E+00
602 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
603 YP = .000000E+00 .142829E+00 .285657E+00 .428486E+00 .571314E+00 .714143E+00
604 WID = .461030E+00 .443230E+00 .390793E+00 .306471E+00 .193481E+00 .645481E-04
605
606 AVERAGE WIDTH AT X = .700E+00 THE LENGTH OF A, EQUALS .2992E+00
607
608 WIDTHS ARE CALCULATED AT X/A = 600000E+00 AND Y/B = 800000E+00
609 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
610 YP = .000000E+00 .160000E+00 .320000E+00 .480000E+00 .640000E+00 .800000E+00
611 WID = .570614E+00 .547157E+00 .478345E+00 .368837E+00 .225497E+00 .568794E-04
612
613 AVERAGE WIDTH AT X = .600E+00 THE LENGTH OF A, EQUALS .3651E+00
614
615 WIDTHS ARE CALCULATED AT X/A = 500000E+00 AND Y/B = 866025E+00
616 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
617 YP = .000000E+00 .173205E+00 .346410E+00 .519615E+00 .692820E+00 .866025E+00
618 WID = .667315E+00 .638701E+00 .554986E+00 .422655E+00 .252126E+00 .648032E-04
619
620 AVERAGE WIDTH AT X = .500E+00 THE LENGTH OF A, EQUALS .4226E+00
621
622 WIDTHS ARE CALCULATED AT X/A = 400000E+00 AND Y/B = 916515E+00
623 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
624 YP = .000000E+00 .183303E+00 .366606E+00 .549909E+00 .733212E+00 .916515E+00
625 WID = .749174E+00 .716102E+00 .619519E+00 .467538E+00 .273769E+00 .632466E-04
626
627 AVERAGE WIDTH AT X = .400E+00 THE LENGTH OF A, EQUALS .4710E+00
628
629 WIDTHS ARE CALCULATED AT X/A = 300000E+00 AND Y/B = 953939E+00
630 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
631 YP = .000000E+00 .190788E+00 .381576E+00 .572364E+00 .763151E+00 .953939E+00
632 WID = .814538E+00 .777857E+00 .670865E+00 .503015E+00 .290569E+00 .701653E-04
633
634 AVERAGE WIDTH AT X = .300E+00 THE LENGTH OF A, EQUALS .5095E+00
635
636 WIDTHS ARE CALCULATED AT X/A = 200000E+00 AND Y/B = 979796E+00
637 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
638 YP = .000000E+00 .195459E+00 .391918E+00 .587878E+00 .783837E+00 .979796E+00
639 WID = .862127E+00 .822795E+00 .708160E+00 .528671E+00 .302569E+00 .676261E-04
640
641 AVERAGE WIDTH AT X = .200E+00 THE LENGTH OF A, EQUALS .5374E+00
642
643 WIDTHS ARE CALCULATED AT X/A = 100000E+00 AND Y/B = 994987E+00
644 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
645 YP = .000000E+00 .198997E+00 .397995E+00 .596992E+00 .795990E+00 .994987E+00
646 WID = .891038E+00 .850087E+00 .730784E+00 .544193E+00 .309773E+00 .683005E-04
647
648 AVERAGE WIDTH AT X = .100E+00 THE LENGTH OF A, EQUALS .5543E+00
649
650 WIDTHS ARE CALCULATED AT X/A = 149012E-07 AND Y/B = 100000E+01
651 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
652 YP = .000000E+00 .200000E+00 .400000E+00 .600000E+00 .800000E+00 .100000E+01
653 WID = .900734E+00 .859238E+00 .738366E+00 .549388E+00 .312175E+00 .591177E-04
654
655 AVERAGE WIDTH AT X = .149E-07 THE LENGTH OF A, EQUALS .5600E+00
656
657 AVERAGE WIDTH OF FRACTURE = .4087E+00
658

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659 AVERAGE OF WIDTH CUBE = .1663E+00
660
661 Q= 40.0
662 RMU= 100.0
663 H= 223.0
664 B= 145.0
665 A= 223.0
666 PO=P-S1 68.7
667
668 INPUT NON-NEWTONIAN FLUID PARAMETERS N & K(BU )
669 N = .482 K = .01100
670
671 CIRCULAR FRACTURE RADIUS, R (CGS) = .560832E+04
672
673 CIRCULAR FRACTURE RADIUS, R (BU) = .18400CE+03
674
675 EFFECTIVE NON-NEWTONIAN FLUID VISCOSITY, MUEFF(CGS)= .974072E+00
676
677 EFFECTIVE NON-NEWTONIAN FLUID VISCOSITY, MUEFF(BU)= .203439E+02
678
679 AVERAGE OF THE PRESSURE OVER THE WHOLE SURFACE, PXYSKA(CGS)= .219936E+07
680
681 AVERAGE OF THE PRESSURE OVER THE WHOLE SURFACE, PXYSKA(BU)= .319025E+02
682
683 AVERAGE OF THE PRESSURE ALONG X, OR MAJOR AXIS, PXSKA(CGS)= .330933E+07
684
685 AVERAGE OF THE PRESSURE ALONG X, OR MAJOR AXIS, PXSKA(BU)= .480030E+02
686
687 AVERAGE OF THE PRESSURE ALONG Y, OR MINOR AXIS, PYSKA(CGS)= .277841E+07
688
689 AVERAGE OF THE PRESSURE ALONG Y, OR MINOR AXIS, PYSKA(BU)= .403019E+02
690
691 LAMDA(BU )= .171401E+02
692
693
694 OUTPUT RESULTS OF SUBROUTINE RMATCH1
695 -----
696
697 INPUT NDIV (# OF DIVISIONS)
698
699 NDIV= 40
700 A= 223.000 B= 145.000 C= 90.000
701
702 INPUT STEP OF GRID, I.E STEP=A/NDIV, ETC
703
704 STEP= 5.000
705
706 INPUT PO = THE PRESSURE AT WELLBORE
707
708 PO= .0000
709
710 ENTER PRESS.DIFF.PO = PB -PA
711
712 PB - PA = .000
713
714 -HIT 1 TO PRINT ALL PMFN PRESSURES .
715 0 TO CONTINUE WITH PROGRAM.
716
717 -HIT 1 TO PRINT ALL PPFN PRESSURES .
718 0 TO CONTINUE WITH PROGRAM.

```

```

719 0
720 Q= .415473E-01 Q1= .449256E-01K= .184271E+01K1= .186578E+01
721 IDEBUG = 0
722
723 -----
724 RESULTS: #ITER K M1(IN) M1(OUT) : 10 .1843E+01 .1000E-04 .5136E+00
725 -----
726 M= .486726E+00 M1= .513274E+00
727 Q= .415473E-01 Q1= .449256E-01K= .184271E+01K1= .186578E+01
728 IDEBUG = 0
729
730 -----
731 RESULTS: #ITER K M1(IN) M1(OUT) : 10 .1843E+01 .1000E-04 .5136E+00
732 -----
733 M= .486726E+00 M1= .513274E+00
734 ENTER RANGE IN WHICH DEL(L) CALCULATION SHOULD BE DONE
735 RANGE FROM - TO 20- 35
736
737 STEP NO. RMATCH, % DIFF IN PMFNRM & PPFNRM PRESS.
738 20 95.00 69.6501
739 21 100.00 55.4389
740 22 105.00 51.2843
741 23 110.00 54.2470
742 24 115.00 64.3306
743 25 120.00 63.5218
744 26 125.00 117.8453
745 27 130.00 1185.5890
746 28 135.00 365.2196
747 29 140.00 1996.4076
748 30 145.00 2000.0000
749 31 150.00 2000.0000
750 32 155.00 2000.0000
751 33 160.00 2000.0000
752 34 165.00 2000.0000
753 35 170.00 2000.0000
754 DO YOU NEED TO CONTINUE DEL(L) CALCULATION? INPUT 0 FOR NO OR 1 FOR YES
755
756 IFLAG1 = 0
757 STEP NO. MATCHING RADIUS(FT.), MIN, % DIFF.
758 22 105.00 512843E+02
759 PCOR = .782038E+00 POD = .108518E+01
760 OUTPUT RESULTS OF DELTA1 SUBROUTINE
761 -----
762
763 INPUT: NDIV (# OF DIVISIONS)
764 NDIV= 10
765
766 A= 223.000 B= 145.000 C= 90.000
767
768 P(0)= 1.0852 PD= .0000
769
770 RM= 105.0000
771
772
773
774 INPUT: S2-S1 (PSI)
775
776 S2-S1= 100.0HZ= 223.0LAMDA = .171401E+02
777
778 PXYSKA= .319025E+02PXSKA= .480030E+02PYSKA = .403019E+02

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779 *
780 * -HIT 1 TO PRINT ALL PROG40 PRESSURES.
781 *   0 TO CONTINUE WITH PROGRAM.
782 *
783 *   0
784 *   IDEBUG = 0
785 *
786 * -----
787 * RESULTS: #ITER  K  M1(IN)  M1(OUT)  I 10  .1843E+01  .1000E-04  .5136E+00
788 * -----
789 *           AVERAGE FLUID PRESSURE OVER WHOLE SURFACE  PFXMP =  .2423E+00
790 *
791 *           AVERAGE PRESSURE OVER Y - AXIS ,PFYMP =  .735460E+00
792 *
793 *           AVERAGE PRESSURE OVER X-AXIS,PFXMP =  .307798E+00
794 *
795 * -----
796 *
797 * TOTAL NO. OF POINTS IN THE QUADRANT      =  90.0000
798 *
799 * TOTAL NO. OF POINTS IN THE HIGHER STRESS REGION=  11.5728
800 * -----
801 *
802 *   AVG. MP PRESS. OVER WHOLE SURFACE-PXYMPA= .1182E+01
803 *   EFFECTIVE AVG. SK PRESS. OVER WHOLE SURFACE-PXYSKA= .3190E+02
804 *
805 *   DIFFERENCE OF (PXYSKA-PXYMPA)=DPXY =  .307201E+02
806 *
807 *   AVERAGE MP PRESSURE ALONG X AXIS-PXMPA =  .359958E+02
808 *
809 *   EFFECTIVE AVERAGE SK PRESSURE ALONG X AXIS-PXSKA =  .480030E+02
810 *
811 *   AVERAGE MP PRESSURE ALONG Y AXIS-PYMPA =  .379882E+02
812 *
813 *   EFFECTIVE AVERAGE SK PRESSURE ALONG Y AXIS-PYSKA =  .403019E+02
814 *
815 *   DIFFERENCE OF (PXSKA-PXMPA)=DELX =  .129073E+02
816 *
817 *   DIFFERENCE OF (PYSKA-PYMPA)=DELY =  .231365E+01
818 *
819 *   R.M.S VALUE DEL OF DELX AND DELY--DEL =  .864660E+01
820 *
821 * -HIT 1 TO RERUN WITH NEW HALF WELLBORE HGT.
822 *   2 TO RERUN WITH NEW PARAMETERS
823 *   3 TO QUIT
824 *
825 *   1
826 *   INPUT HALF HEIGHT AT WELL BORE,B(FT)
827 *   B = 140.00
828 *   INPUT 1 FOR TIME CALCN. IN WIDAVG; 0 FOR NO TIME CALC.
829 *   IT= 1
830 *
831 *   P0 = .552246E+02
832 *   PA0 = .124584E+02
833 *   P0B = -.789872E+01
834 *   KI1 = .110000E+09
835 *   KI2 = .110026E+09
836 *   KCA = .110000E+09
837 *   KCB = .110000E+09
838 *   DIFF1 = .000
839 *   DIFF2 = .000

```

```

839
840
841 INPUT 0 : TO CALCULATE WIDTH
842 1 : TO START NEW ITERN. TO CALCULATE KI1 & KI2
843 2 : TO STOP
844 IALC = 0
845
846 WIDTHS ARE CALCULATED AT X/A= 000000E+00 AND Y/B= 100000E+01
847 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
848 YP= .000000E+00 .200000E+00 .400000E+00 .600000E+00 .800000E+00 .100000E+01
849 WID= .730142E+00 .698577E+00 .606278E+00 .460566E+00 .273355E+00 .636740E-04
850 AREA OF THE VERTICAL SECTION (IN CM**2): 410313E+04
851 INPUT 0: TO CALCULATE AVERAGE WIDTH OF FRACTURE
852 1: TO CONTINUE WITH PROGRAM
853
854 WIDTHS ARE CALCULATED AT X/A= 900000E+00 AND Y/B= 435890E+00
855 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
856 YP= .000000E+00 .871780E+01 .174356E+00 .261534E+00 .348712E+00 .435890E+00
857 WID= .194634E+00 .189310E+00 .173175E+00 .145475E+00 .103138E+00 .406699E-04
858 AREA OF THE VERTICAL SECTION (IN CM**2): .527084E+03
859
860 AVERAGE WIDTH AT X = .900E+00 THE LENGTH OF A, EQUALS .1343E+00
861
862 WIDTHS ARE CALCULATED AT X/A= 800000E+00 AND Y/B= 600000E+00
863 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
864 YP= .000000E+00 .120000E+00 .240000E+00 .360000E+00 .480000E+00 .600000E+00
865 WID= .303628E+00 .293862E+00 .264692E+00 .216216E+00 .146595E+00 .437714E-04
866 AREA OF THE VERTICAL SECTION (IN CM**2): .109910E+04
867
868 AVERAGE WIDTH AT X = .800E+00 THE LENGTH OF A, EQUALS .2042E+00
869
870 WIDTHS ARE CALCULATED AT X/A= 700000E+00 AND Y/B= 714143E+00
871 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
872 YP= .000000E+00 .142829E+00 .285657E+00 .428486E+00 .571314E+00 .714143E+00
873 WID= .398898E+00 .384715E+00 .342685E+00 .274121E+00 .179342E+00 .640541E-04
874 AREA OF THE VERTICAL SECTION (IN CM**2): .168258E+04
875
876 AVERAGE WIDTH AT X = .700E+00 THE LENGTH OF A, EQUALS .2633E+00
877
878 WIDTHS ARE CALCULATED AT X/A= 600000E+00 AND Y/B= 800000E+00
879 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
880 YP= .000000E+00 .160000E+00 .320000E+00 .480000E+00 .640000E+00 .800000E+00
881 WID= .483271E+00 .464899E+00 .410716E+00 .323360E+00 .205620E+00 .563175E-04
882 AREA OF THE VERTICAL SECTION (IN CM**2): .224797E+04
883
884 AVERAGE WIDTH AT X = .600E+00 THE LENGTH OF A, EQUALS .3147E+00
885
886 WIDTHS ARE CALCULATED AT X/A= 500000E+00 AND Y/B= 866025E+00
887 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
888 YP= .000000E+00 .173205E+00 .346410E+00 .519615E+00 .692820E+00 .866025E+00
889 WID= .556512E+00 .534348E+00 .469192E+00 .364963E+00 .226912E+00 .640343E-04
890 AREA OF THE VERTICAL SECTION (IN CM**2): .276971E+04
891
892 AVERAGE WIDTH AT X = .500E+00 THE LENGTH OF A, EQUALS .3587E+00
893
894 WIDTHS ARE CALCULATED AT X/A= 400000E+00 AND Y/B= 916515E+00
895 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
896 YP= .000000E+00 .183303E+00 .366606E+00 .549909E+00 .733212E+00 .916515E+00
897 WID= .617839E+00 .592413E+00 .517828E+00 .399155E+00 .243882E+00 .623886E-04
898 AREA OF THE VERTICAL SECTION (IN CM**2): .322611E+04

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899 -
900 - AVERAGE WIDTH AT X = .400E+00 THE LENGTH OF A, EQUALS .3952E+00
901 -
902 - WIDTHS ARE CALCULATED AT X/A = 300000E+00 AND Y/B = .953939E+00
903 - YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
904 - YP = .000000E+00 .190788E+00 .381576E+00 .572364E+00 .763151E+00 .953939E+00
905 - WID = .666449E+00 .638389E+00 .556202E+00 .425909E+00 .256869E+00 .691171E-04
906 - AREA OF THE VERTICAL SECTION (IN CM**2) : .354948E+04
907 -
908 - AVERAGE WIDTH AT X = .300E+00 THE LENGTH OF A, EQUALS .4240E+00
909 -
910 - WIDTHS ARE CALCULATED AT X/A = 200000E+00 AND Y/B = .979796E+00
911 - YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
912 - YP = .000000E+00 .195959E+00 .391918E+00 .587878E+00 .783837E+00 .979796E+00
913 - WID = .701667E+00 .671676E+00 .583917E+00 .445124E+00 .266054E+00 .665476E-04
914 - AREA OF THE VERTICAL SECTION (IN CM**2) : .387600E+04
915 -
916 - AVERAGE WIDTH AT X = .200E+00 THE LENGTH OF A, EQUALS .4448E+00
917 -
918 - WIDTHS ARE CALCULATED AT X/A = 100000E+00 AND Y/B = .994987E+00
919 - YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
920 - YP = .000000E+00 .198997E+00 .397995E+00 .596992E+00 .795990E+00 .994987E+00
921 - WID = .722998E+00 .691829E+00 .600672E+00 .456699E+00 .271533E+00 .671691E-04
922 - AREA OF THE VERTICAL SECTION (IN CM**2) : .404586E+04
923 -
924 - AVERAGE WIDTH AT X = .100E+00 THE LENGTH OF A, EQUALS .4573E+00
925 -
926 - WIDTHS ARE CALCULATED AT X/A = .149012E-07 AND Y/B = 100000E+01
927 - YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
928 - YP = .000000E+00 .200000E+00 .400000E+00 .600000E+00 .800000E+00 .100000E+01
929 - WID = .730142E+00 .698577E+00 .606278E+00 .460566E+00 .273355E+00 .581262E-04
930 - AREA OF THE VERTICAL SECTION (IN CM**2) : .410313E+04
931 -
932 - AVERAGE WIDTH AT X = -.149E-07 THE LENGTH OF A, EQUALS .4615E+00
933 -
934 - AVERAGE WIDTH OF FRACTURE = .3458E+00
935 -
936 - AVERAGE OF WIDTH CUBE = .9432E+01
937 - INPUT: LEAKC(CGS), SP(CGS), ICONV (=1 FOR AUTOMATIC CONVERGENCE OF TIME)
938 - AND TIMP (I.E. PERCENTAGE FOR TIME CONVERGENCE)
939 - LEAKC = .787000E-02 SP = .000000E+00 ICONV = 1 TIMP(X) = 1.00000
940 - INPUT INITIAL VALUE OF TSLOPE, TCEPT=TSLOPE
941 - INITIAL VALUE OF TSLOPE = TCEPT = .50000
942 - VOLUME OF EACH SEGMENT:
943 - .17913E+06 .55266E+06 .94536E+06 .13358E+07 .17093E+07
944 -
945 - .20377E+07 .23197E+07 .25406E+07 .26923E+07 .27694E+07
946 -
947 -
948 - A AMZ ALEAK B
949 - .67970E+04 .41104E+04 .59868E+04 .42672E+04
950 -
951 - AFT AMZFT ALKFT BFT
952 - .22300E+03 .13486E+03 .19642E+03 .14000E+03
953 -
954 - TIME FROM A-T EQN: .49729E+04 SEC .82882E+02 MIN
955 - TIME FROM V/D: .16922E+04 SEC .28203E+02 MIN
956 - PERCENT DIFF. IN TIME = -193.87871 TSLOPE = .50000
957 -
958 - TIME FROM A-T EQN: .13523E+03 SEC .22538E+01 MIN

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959 • TIME FROM V/Q: .52863E+03 SEC .88105E+01 MIN
960 • PERCENT DIFF. IN TIME = 74.41891 TSLOPE = .75000
961 •
962 • TIME FROM A-T EQN: .57186E+03 SEC .95310E+01 MIN
963 • TIME FROM V/Q: .76549E+03 SEC .12758E+02 MIN
964 • PERCENT DIFF. IN TIME = 25.29488 TSLOPE = .62500
965 •
966 • TIME FROM A-T EQN: .14954E+04 SEC .24924E+02 MIN
967 • TIME FROM V/Q: .10557E+04 SEC .17595E+02 MIN
968 • PERCENT DIFF. IN TIME = -41.65134 TSLOPE = .56250
969 •
970 • TIME FROM A-T EQN: .90165E+03 SEC .15028E+02 MIN
971 • TIME FROM V/Q: .68519E+03 SEC .14753E+02 MIN
972 • PERCENT DIFF. IN TIME = -1.85977 TSLOPE = .59375
973 •
974 • TIME FROM A-T EQN: .71389E+03 SEC .11898E+02 MIN
975 • TIME FROM V/Q: .82030E+03 SEC .13672E+02 MIN
976 • PERCENT DIFF. IN TIME = 12.97221 TSLOPE = .60938
977 •
978 • TIME FROM A-T EQN: .80108E+03 SEC .13351E+02 MIN
979 • TIME FROM V/Q: .85134E+03 SEC .14189E+02 MIN
980 • PERCENT DIFF. IN TIME = 5.90425 TSLOPE = .60156
981 •
982 • TIME FROM A-T EQN: .84955E+03 SEC .14159E+02 MIN
983 • TIME FROM V/Q: .86790E+03 SEC .14465E+02 MIN
984 • PERCENT DIFF. IN TIME = 2.11404 TSLOPE = .59766
985 •
986 • TIME FROM A-T EQN: .87513E+03 SEC .14585E+02 MIN
987 • TIME FROM V/Q: .87645E+03 SEC .14608E+02 MIN
988 • PERCENT DIFF. IN TIME = .15072 TSLOPE = .59570
989 •
990 •
991 • VOLUME OF ONE WING:
992 • FRAC VOL(CGS): .17078E+08 LEAK VOL(CGS): .29199E+08
993 • TOTVOL(CGS): .46277E+08 TOTVOL(BRL): .29215E+03
994 • TOTVOL(GAL): .12226E+05
995 •
996 • Q= 40.0
997 • RMU= 100.0
998 • H= 223.0
999 • B= 140.0
1000 • A= 223.0
1001 • P0=P-81 55.2
1002 •
1003 • INPUT NPRIME,KPRIME(BU)
1004 • NPRIME = .482000001000000000E+00
1005 • KPRIME = .109999999000000000E-01
1006 •
1007 • *HIT 1 TO RERUN WITH NEW HALF WELLBORE HGT.
1008 • 2 TO RERUN WITH NEW PARAMETERS
1009 • 3 TO QUIT
1010 •

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CHAPTER III

APPENDIX B

16130 JUL 16 '87 FRACTURE.IN040820

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1 INPUT: NFRAC=NO. OF FRACTURE DIVISION ALONG PAY ZONE WING
2 NO=NO. OF FRACTURING FLUIDS
3
4 NFRAC = 4 NO = 1
5 INPUT 1 IF YOU WANT DEBUG, 0 FOR NO DEBUG
6 IBUG = 0
7 INPUT: IWRITE, KCA, KCB (80TH CGS), HZ (PAYZONE WIDTH IN FT), Q (BPM), RMU (CP)
8 IWRITE = 1 KCA, KCB = .110E+09 .110E+09 HZ = 223.0 Q = 40.0 MU = 100.0
9 INPUT: YOUNG'S MOD. (EG. 1.5E6 PSI), POISS. RAT (EG. .1)
10 YOUNG'S MODULUS = 1.50E+06 POISSON'S RATIO = .20
11 INPUT: S2-S1 (PSI), L (FT)
12 S2-S1 = 100.0 L = 223.0
13
14 INPUT: XACCURACY DESIRED IN ITERATION OF KI
15 ALLOWANCE FOR 1.00% ERROR
16 NUMWID = 5
17 WELHTIC:
18 C = 90.00
19 INPUT 1 IF YOU WANT VISCOSITY, LAMDA, CIRCULAR FRACTURE RADIUS AND AVG. PRESSURES,
20 IFLAG = 0
21 INPUT HALF HEIGHT AT WELL BORE, B (FT)
22 B = 140.00
23 INPUT 1 FOR TIME CALC. IN WIDAVG; 0 FOR NO TIME CALC.
24 IT = 1
25
26 P0 = .546875E+02
27 PA0 = .126518E+02
28 POB = -.770538E+01
29 KI1 = .110000E+09
30 KI2 = .109470E+09
31 KCA = .110000E+09
32 KCB = .110000E+09
33 DIFF1 = .000
34 DIFF2 = .003
35
36 INPUT 0 : TO CALCULATE WIDTH
37 1 : TO START NEW ITER. TO CALCULATE KI1 & KI2
38 2 : TO STOP
39 IALC = 0
40
41 WIDTHS ARE CALCULATED AT X/A = .000000E+00 AND Y/B = .100000E+01
42 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
43 YP = .000000E+00 .200000E+00 .400000E+00 .600000E+00 .800000E+00 .100000E+01
44 WID = .723763E+00 .692517E+00 .601144E+00 .456861E+00 .271393E+00 .633524E-04
45 AREA OF THE VERTICAL SECTION (IN CM**2): .406891E+04
46 INPUT 0: TO CALCULATE AVERAGE WIDTH OF FRACTURE
47 1: TO CONTINUE WITH PROGRAM
48
49 WIDTHS ARE CALCULATED AT X/A = .900000E+00 AND Y/B = .435890E+00
50 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
51 YP = .000000E+00 .871780E-01 .174356E+00 .261534E+00 .348712E+00 .435890E+00
52 WID = .194106E+00 .188808E+00 .172750E+00 .145169E+00 .102975E+00 .406377E-04
53 AREA OF THE VERTICAL SECTION (IN CM**2): .525849E+03
54
55 AVERAGE WIDTH AT X = .900E+00 THE LENGTH OF A, EQUALS .1340E+00
56
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59 * WIDTHS ARE CALCULATED AT X/A= .800000E+00 AND Y/B= .600000E+00
60 * YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
61 * YP= .000000E+00 .120000E+00 .240000E+00 .360000E+00 .480000E+00 .600000E+00
62 * WID= .302250E+00 .292553E+00 .263583E+00 .215416E+00 .146171E+00 .437033E-04
63 * AREA OF THE VERTICAL SECTION (IN CM**2): .109466E+04
64 *
65 * AVERAGE WIDTH AT X = .800E+00 THE LENGTH OF A, EQUALS .2033E+00
66 *
67 * WIDTHS ARE CALCULATED AT X/A= .700000E+00 AND Y/B= .714143E+00
68 * YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
69 * YP= .000000E+00 .142829E+00 .285657E+00 .428486E+00 .571314E+00 .714143E+00
70 * WID= .396575E+00 .382508E+00 .340815E+00 .272772E+00 .178627E+00 .639079E-04
71 * AREA OF THE VERTICAL SECTION (IN CM**2): .167368E+04
72 *
73 * AVERAGE WIDTH AT X = .700E+00 THE LENGTH OF A, EQUALS .2619E+00
74 *
75 * WIDTHS ARE CALCULATED AT X/A= .600000E+00 AND Y/B= .800000E+00
76 * YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
77 * YP= .000000E+00 .160000E+00 .320000E+00 .480000E+00 .640000E+00 .800000E+00
78 * WID= .480005E+00 .461796E+00 .408088E+00 .321464E+00 .204616E+00 .561511E-04
79 * AREA OF THE VERTICAL SECTION (IN CM**2): .223396E+04
80 *
81 * AVERAGE WIDTH AT X = .600E+00 THE LENGTH OF A, EQUALS .3127E+00
82 *
83 * WIDTHS ARE CALCULATED AT X/A= .500000E+00 AND Y/B= .866025E+00
84 * YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
85 * YP= .000000E+00 .173205E+00 .346410E+00 .519615E+00 .692820E+00 .866025E+00
86 * WID= .552369E+00 .530412E+00 .465857E+00 .362557E+00 .225637E+00 .638066E-04
87 * AREA OF THE VERTICAL SECTION (IN CM**2): .275046E+04
88 *
89 * AVERAGE WIDTH AT X = .500E+00 THE LENGTH OF A, EQUALS .3561E+00
90 *
91 * WIDTHS ARE CALCULATED AT X/A= .400000E+00 AND Y/B= .916515E+00
92 * YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
93 * YP= .000000E+00 .183303E+00 .366606E+00 .549909E+00 .733212E+00 .916515E+00
94 * WID= .612928E+00 .587748E+00 .513876E+00 .396304E+00 .242372E+00 .621345E-04
95 * AREA OF THE VERTICAL SECTION (IN CM**2): .320197E+04
96 *
97 * AVERAGE WIDTH AT X = .400E+00 THE LENGTH OF A, EQUALS .3922E+00
98 *
99 * WIDTHS ARE CALCULATED AT X/A= .300000E+00 AND Y/B= .953939E+00
100 * YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
101 * YP= .000000E+00 .190788E+00 .381576E+00 .572364E+00 .763151E+00 .953939E+00
102 * WID= .660912E+00 .633129E+00 .551745E+00 .422694E+00 .255166E+00 .688067E-04
103 * AREA OF THE VERTICAL SECTION (IN CM**2): .357114E+04
104 *
105 * AVERAGE WIDTH AT X = .300E+00 THE LENGTH OF A, EQUALS .4206E+00
106 *
107 * WIDTHS ARE CALCULATED AT X/A= .200000E+00 AND Y/B= .979796E+00
108 * YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
109 * YP= .000000E+00 .195959E+00 .391918E+00 .587878E+00 .783837E+00 .979796E+00
110 * WID= .695667E+00 .665977E+00 .579088E+00 .441640E+00 .264209E+00 .662883E-04
111 * AREA OF THE VERTICAL SECTION (IN CM**2): .384446E+04
112 *
113 * AVERAGE WIDTH AT X = .200E+00 THE LENGTH OF A, EQUALS .4411E+00
114 *
115 * WIDTHS ARE CALCULATED AT X/A= .100000E+00 AND Y/B= .994987E+00
116 * YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
117 * YP= .000000E+00 .198997E+00 .397995E+00 .596992E+00 .795990E+00 .994987E+00
118 * WID= .716714E+00 .685860E+00 .595615E+00 .453050E+00 .269600E+00 .668341E-04

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119 AREA OF THE VERTICAL SECTION (IN CM**2): .401232E+04
120
121 AVERAGE WIDTH AT X = .100E+00 THE LENGTH OF A, EQUALS .4535E+00
122
123 WIDTHS ARE CALCULATED AT X/A= -.149012E-07 AND Y/B= .100000E+01
124 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
125 YP= .000000E+00 .200000E+00 .400000E+00 .600000E+00 .800000E+00 .100000E+01
126 WID= .723763E+00 .692517E+00 .601144E+00 .456861E+00 .271393E+00 .578326E-04
127 AREA OF THE VERTICAL SECTION (IN CM**2): .406890E+04
128
129 AVERAGE WIDTH AT X = -.149E-07 THE LENGTH OF A, EQUALS .4576E+00
130
131 AVERAGE WIDTH OF FRACTURE = .3433E+00
132
133 AVERAGE OF WIDTH CUBE = .9209E-01
134 INPUT: LEAKC(CGS), SP(CGS), ICONV (=1 FOR AUTOMATIC CONVERGENCE OF TIME)
135 AND TIMP (T/E PERCENTAGE FOR TIME CONVERGENCE)
136 LEAKC = .787000E-02 SP= .000000E+00 ICONV= 1 TIMP(X)= 1.00000
137 INPUT INITIAL VALUE OF TSLOPE; TCEPT=TSLOPE
138 INITIAL VALUE OF TSLOPE = TCEPT = .50000
139 VOLUME OF EACH SEGMENT:
140 .17871E+06 .59073E+06 .94083E+06 .13280E+07 .16940E+07
141 .20229E+07 .23019E+07 .25202E+07 .26701E+07 .27464E+07
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	A	AHZ	ALEAK	B
	.67970E+04	.41104E+04	.59868E+04	.42672E+04
	AFT	AHZFT	ALKFT	BFT
	.22300E+03	.13486E+03	.19642E+03	.14000E+03
TIME FROM A-T EQN:	.49729E+04 SEC			.82882E+02 MIN
TIME FROM V/Q:	.16898E+04 SEC			.28164E+02 MIN
PERCENT DIFF. IN TIME	-194.28734	TSLOPE =		.50000
TIME FROM A-T EQN:	.13523E+03 SEC			.22538E+01 MIN
TIME FROM V/Q:	.52628E+03 SEC			.87714E+01 MIN
PERCENT DIFF. IN TIME	74.30470	TSLOPE =		.75000
TIME FROM A-T EQN:	.57186E+03 SEC			.95310E+01 MIN
TIME FROM V/Q:	.76314E+03 SEC			.12719E+02 MIN
PERCENT DIFF. IN TIME	25.06488	TSLOPE =		.62500
TIME FROM A-T EQN:	.14954E+04 SEC			.24924E+02 MIN
TIME FROM V/Q:	.10534E+04 SEC			.17556E+02 MIN
PERCENT DIFF. IN TIME	-41.96730	TSLOPE =		.56250
TIME FROM A-T EQN:	.90165E+03 SEC			.15028E+02 MIN
TIME FROM V/Q:	.88284E+03 SEC			.14714E+02 MIN
PERCENT DIFF. IN TIME	-2.13086	TSLOPE =		.59375
TIME FROM A-T EQN:	.71389E+03 SEC			.11898E+02 MIN
TIME FROM V/Q:	.81795E+03 SEC			.13632E+02 MIN
PERCENT DIFF. IN TIME	12.72222	TSLOPE =		.60938
TIME FROM A-T EQN:	.80108E+03 SEC			.13351E+02 MIN
TIME FROM V/Q:	.84900E+03 SEC			.14150E+02 MIN
PERCENT DIFF. IN TIME	5.64384	TSLOPE =		.60156

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179 TIME FROM A-T EQN: .84955E+03 SEC .14159E+02 MIN
180 TIME FROM V/Q: .86555E+03 SEC .14426E+02 MIN
181 PERCENT DIFF. IN TIME = 1.84833 TSLOPE = .59766
182
183 TIME FROM A-T EQN: .87513E+03 SEC .14585E+02 MIN
184 TIME FROM V/Q: .87410E+03 SEC .14568E+02 MIN
185 PERCENT DIFF. IN TIME = -.11768 TSLOPE = .59570
186
187
188 VOLUME OF ONE WING:
189 FRAC VOL(CGS): .16954E+08 LEAK VOL(CGS): .29199E+08
190 TOTVOL(CGS): .46153E+08 TOTVOL(BRL): .29137E+03
191 TOTVOL(GAL): .12194E+05
192
193 Q= 40.0
194 RMU= 100.0
195 H= 223.0
196 B= 140.0
197 A= 223.0
198 P0=P-81 54.7
199
200 INPUT NPRIME,KPRIME(BU)
201 NPRIME = .482000001000000000E+00
202 KPRIME = .109999999000000000E-01
203
204 -HIT 1 TO RERUN WITH NEW HALF WELLBORE HGT.
205 2 TO RERUN WITH NEW PARAMETERS
206 3 TO QUIT
207
208 INPUT 1 IF YOU WANT DEBUG, 0 FOR NO DEBUG
209 IBUG= 0
210 INPUT: IWRITE,KCA,KCB(BOTH CGS), HZ(PAYZONE WIDTH IN FT), Q(BPM),RMU(CP)
211 IWRITE= 1 KCA,KCB= .110E+09 .110E+09 HZ= 223.0 Q= 40.0 RMU= 100.0
212 INPUT: YOUNG'S MOD.(EG. 1 SE6 PSI), POISS,RAT(EG. .1)
213 YOUNG'S MODULUS = 150E+06 POISSON'S RATIO = .20
214 INPUT: S2-S1(Psi), L(FT)
215 S2-S1= 100.0 L= 300.0
216
217 INPUT: XACCURACY DESIRED IN ITERATION OF KI
218 ALLOWANCE FOR 1.00% ERROR
219 NUMAID = 5
220 WELHTIC:
221 C = 90.00
222 INPUT 1 IF YOU WANT VISCOSITY,LAMDA,CIRCULAR FRACTURE RADIUS AND AVG.PRESSURES.
223 IFLAG = 0
224 INPUT HALF HEIGHT AT WELL BORE,B(FT)
225 B = 155.00
226 INPUT 1 FOR TIME CALCN. IN WIDAVG? 0 FOR NO TIME CALC.
227 IT= 1
228
229 P0 = .557617E+02
230 PA0 = .141487E+02
231 P0B = -.139158E+02
232 KI1 = .110000E+09
233 KI2 = .110184E+09
234 KCA = .110000E+09
235 KCB = .110000E+09
236 DIFF1 = .000
237 DIFF2 = .002
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INPUT 0 : TO CALCULATE WIDTH
1 : TO START NEW ITERN. TO CALCULATE KI1 & KI2
2 : TO STOP
ICALC = 0

WIDTHS ARE CALCULATED AT X/A= 000000E+00 AND Y/B= 100000E+01
YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
YP= .000000E+00 .200000E+00 .400000E+00 .600000E+00 .800000E+00 .100000E+01
WID= .852955E+00 .814730E+00 .703202E+00 .528105E+00 .306094E+00 .670944E-04
AREA OF THE VERTICAL SECTION (IN CM**2): 525097E+04
INPUT 0: TO CALCULATE AVERAGE WIDTH OF FRACTURE
1: TO CONTINUE WITH PROGRAM

WIDTHS ARE CALCULATED AT X/A= 900000E+00 AND Y/B= 435890E+00
YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
YP= .000000E+00 .871780E-01 .174356E+00 .261534E+00 .348712E+00 .435890E+00
WID= .226254E+00 .219944E+00 .200860E+00 .168228E+00 .118718E+00 .464949E-04
AREA OF THE VERTICAL SECTION (IN CM**2): .676199E+03

AVERAGE WIDTH AT X = .900E+00 THE LENGTH OF A, EQUALS .1557E+00

WIDTHS ARE CALCULATED AT X/A= 800000E+00 AND Y/B= 600000E+00
YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
YP= .000000E+00 .120000E+00 .240000E+00 .360000E+00 .480000E+00 .600000E+00
WID= .353483E+00 .341807E+00 .307007E+00 .249467E+00 .167663E+00 .493364E-04
AREA OF THE VERTICAL SECTION (IN CM**2): .140906E+04

AVERAGE WIDTH AT X = .800E+00 THE LENGTH OF A, EQUALS .2366E+00

WIDTHS ARE CALCULATED AT X/A= 700000E+00 AND Y/B= 714143E+00
YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
YP= .000000E+00 .142829E+00 .285657E+00 .428486E+00 .571314E+00 .714143E+00
WID= .464886E+00 .447848E+00 .397468E+00 .315726E+00 .204021E+00 .712209E-04
AREA OF THE VERTICAL SECTION (IN CM**2): .215598E+04

AVERAGE WIDTH AT X = .700E+00 THE LENGTH OF A, EQUALS .3050E+00

WIDTHS ARE CALCULATED AT X/A= 600000E+00 AND Y/B= 800000E+00
YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
YP= .000000E+00 .160000E+00 .320000E+00 .480000E+00 .640000E+00 .800000E+00
WID= .563647E+00 .541511E+00 .476376E+00 .371937E+00 .232881E+00 .618243E-04
AREA OF THE VERTICAL SECTION (IN CM**2): .287933E+04

AVERAGE WIDTH AT X = .600E+00 THE LENGTH OF A, EQUALS .3644E+00

WIDTHS ARE CALCULATED AT X/A= 500000E+00 AND Y/B= 866025E+00
YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
YP= .000000E+00 .173205E+00 .346410E+00 .519615E+00 .692820E+00 .866025E+00
WID= .649434E+00 .622678E+00 .544200E+00 .419353E+00 .256068E+00 .694865E-04
AREA OF THE VERTICAL SECTION (IN CM**2): .354655E+04

AVERAGE WIDTH AT X = .500E+00 THE LENGTH OF A, EQUALS .4153E+00

WIDTHS ARE CALCULATED AT X/A= 400000E+00 AND Y/B= 916515E+00
YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
YP= .000000E+00 .183303E+00 .366606E+00 .549909E+00 .733212E+00 .916515E+00
WID= .721299E+00 .690564E+00 .600611E+00 .458279E+00 .274435E+00 .670232E-04
AREA OF THE VERTICAL SECTION (IN CM**2): .413006E+04

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299
300 AVERAGE WIDTH AT X = .400E+00 THE LENGTH OF A, EQUALS .4575E+00
301
302 WIDTHS ARE CALCULATED AT X/A= 300000E+00 AND Y/B= .953939E+00
303 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
304 YP= .000005E+00 .190788E+00 .381576E+00 .572364E+00 .763151E+00 .953939E+00
305 WID= .778277E+00 .744330E+00 .645119E+00 .488712E+00 .288420E+00 .736438E-04
306 AREA OF THE VERTICAL SECTION (IN CM**2): .460730E+04
307
308 AVERAGE WIDTH AT X = .300E+00 THE LENGTH OF A, EQUALS .4908E+00
309
310 WIDTHS ARE CALCULATED AT X/A= 200000E+00 AND Y/B= .979796E+00
311 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
312 YP= .000000E+00 .195959E+00 .391918E+00 .587878E+00 .783837E+00 .979796E+00
313 WID= .819567E+00 .783263E+00 .677266E+00 .510557E+00 .298278E+00 .704752E-04
314 AREA OF THE VERTICAL SECTION (IN CM**2): .496072E+04
315
316 AVERAGE WIDTH AT X = .200E+00 THE LENGTH OF A, EQUALS .5148E+00
317
318 WIDTHS ARE CALCULATED AT X/A= 100000E+00 AND Y/B= .994987E+00
319 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
320 YP= .000000E+00 .198997E+00 .397995E+00 .596992E+00 .795990E+00 .994987E+00
321 WID= .844578E+00 .806837E+00 .696699E+00 .523712E+00 .304146E+00 .708670E-04
322 AREA OF THE VERTICAL SECTION (IN CM**2): .517778E+04
323
324 AVERAGE WIDTH AT X = .100E+00 THE LENGTH OF A, EQUALS .5293E+00
325
326 WIDTHS ARE CALCULATED AT X/A= .149012E-07 AND Y/B= .100000E+01
327 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
328 YP= .000000E+00 .200000E+00 .400000E+00 .600000E+00 .800000E+00 .100000E+01
329 WID= .852955E+00 .814730E+00 .703202E+00 .528105E+00 .306094E+00 .612485E-04
330 AREA OF THE VERTICAL SECTION (IN CM**2): .525096E+04
331
332 AVERAGE WIDTH AT X = -.149E-07 THE LENGTH OF A, EQUALS .9342E+00
333
334 AVERAGE WIDTH OF FRACTURE = .4004E+00
335
336 AVERAGE OF WIDTH CUBE = .1483E+00
337 INPUT: LEAKC(CGS), SP(CGS), ICONV (=1 FOR AUTOMATIC CONVERGENCE OF TIME)
338 AND TIMP (I.E. PERCENTAGE FOR TIME CONVERGENCE)
339 LEAKC = .787000E-02 SP= .000000E+00 ICONV= 1 TIMP(%)= 1.00000
340 INPUT INITIAL VALUE OF TSLOPE: TCEPT=TSLOPE
341 INITIAL VALUE OF TSLOPE & TCEPT = .50000
342 VOLUME OF EACH SEGMENT:
343 .30916E+06 .95338E+06 .16299E+07 .23021E+07 .29379E+07
344 .35097E+07 .39947E+07 .43745E+07 .46353E+07 .47680E+07
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A	AHZ	ALEAK	B
.91440E+04	.63518E+04	.82787E+04	.47244E+04
APT	AHZFT	ALKFT	BFT
.30000E+03	.20839E+03	.27161E+03	.15500E+03
TIME FROM A-T EQN: .90000E+04 SEC	.15000E+03 MIN		
TIME FROM V/B: .31033E+04 SEC	.51722E+02 MIN		
PERCENT DIFF. IN TIME = 190.01271	TSLOPE = .50000		
TIME FROM A-T EQN: .20083E+03 SEC	.33472E+01 MIN		

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359 TIME FROM V/Q: .90287E+03 SEC .15048E+02 MIN
360 PERCENT DIFF. IN TIME = 77.75663 TSLOPE = .75000
361
362 TIME FROM A-T EQN: .91917E+03 SEC .15319E+02 MIN
363 TIME FROM V/Q: .13321E+04 SEC .22201E+02 MIN
364 PERCENT DIFF. IN TIME = 30.99679 TSLOPE = .62500
365
366 TIME FROM A-T EQN: .25338E+04 SEC .42230E+02 MIN
367 TIME FROM V/Q: .18752E+04 SEC .31253E+02 MIN
368 PERCENT DIFF. IN TIME = -35.12411 TSLOPE = .56250
369
370 TIME FROM A-T EQN: .14859E+04 SEC .24765E+02 MIN
371 TIME FROM V/Q: .15543E+04 SEC .25905E+02 MIN
372 PERCENT DIFF. IN TIME = 4.39976 TSLOPE = .59375
373
374 TIME FROM A-T EQN: .19264E+04 SEC .32107E+02 MIN
375 TIME FROM V/Q: .16994E+04 SEC .28324E+02 MIN
376 PERCENT DIFF. IN TIME = -13.35790 TSLOPE = .57813
377
378 TIME FROM A-T EQN: .16890E+04 SEC .28149E+02 MIN
379 TIME FROM V/Q: .16235E+04 SEC .27058E+02 MIN
380 PERCENT DIFF. IN TIME = -4.03457 TSLOPE = .58594
381
382 TIME FROM A-T EQN: .15835E+04 SEC .26392E+02 MIN
383 TIME FROM V/Q: .15881E+04 SEC .26468E+02 MIN
384 PERCENT DIFF. IN TIME = .28742 TSLOPE = .58984
385
386
387 VOLUME OF ONE WING:
388 FRAC VOL(CGS): .29415E+08 LEAK VOL(CGS): .54436E+08
389 TOTVOL(CGS): .83851E+08 TOTVOL(BRL): .52936E+03
390 TOTVOL(GAL): .22153E+05
391
392 Q= 40.0
393 RMU= 100.0
394 H= 223.0
395 B= 155.0
396 A= 300.0
397 P0=P-31 55.8
398
399 INPUT NPRIME,KPRIME(BU)
400 NPRIME = .482000001000000000E+00
401 KPRIME = .109999999000000000E-01
402
403 *HIT 1 TO RERUN WITH NEW HALF WELLBORE HGT.
404 2 TO RERUN WITH NEW PARAMETERS
405 3 TO QUIT
406
407 INPUT 1 IF YOU WANT DEBUG, 0 FOR NO DEBUG
408 IBUG= 0
409 INPUT: IWRITE,KCA,KCB(BOTH CGS), HZ(PAYZONE WIDTH IN FT), Q(BPM), RMU(CP)
410 IWRITE= 1 KCA,KCB= .110E+09 .110E+09 HZ= 223.0 Q= 40.0 RMU= 100.0
411 INPUT: YOUNG'S MODULUS (EG, 1.5E6 PSI), POISSON'S RATIO (EG, .1)
412 YOUNG'S MODULUS = 750E+06 POISSON'S RATIO = .20
413 INPUT: S2-S1(PST), L(FT)
414 S2-S1= 100.0 L= 340.0
415
416
417 INPUT: %ACCURACY DESIRED IN ITERATION OF KI
418 ALLOWANCE FOR 1.00% ERROR

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419 NUMWID = 5
420 WELHT:C:
421 C = 90.00
422 INPUT 1 IF YOU WANT VISCOSITY, LAMDA, CIRCULAR FRACTURE RADIUS AND AVG. PRESSURES.
423 IFLAG = 0
424 INPUT HALF HEIGHT AT WELL BORE, B (FT)
425 B = 165.00
426 INPUT 1 FOR TIME CALCN. IN WIDAVG/ 0 FOR NO TIME CALC.
427 IT = 1
428
429 PO = .600586E+02
430 PAO = .132493E+02
431 POB = -.191749E+02
432 KI1 = .110000E+09
433 KI2 = .110201E+09
434 KCA = .110000E+09
435 KCB = .110000E+09
436 DIFF1 = .0001
437 DIFF2 = .0002
438
439
440 INPUT 0 : TO CALCULATE WIDTH
441 1 : TO START NEW ITERN. TO CALCULATE KI1 & KI2
442 2 : TO STOP
443 IALC = 0
444
445 WIDTHS ARE CALCULATED AT X/A = .000000E+00 AND Y/B = .100000E+01
446 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
447 YP = .000000E+00 .200000E+00 .400000E+00 .600000E+00 .800000E+00 .100000E+01
448 WID = .978868E+00 .933561E+00 .801624E+00 .595489E+00 .337181E+00 .692358E-04
449 AREA OF THE VERTICAL SECTION (IN CM**2): .635152E+04
450 INPUT 0: TO CALCULATE AVERAGE WIDTH OF FRACTURE
451 1: TO CONTINUE WITH PROGRAM
452
453 WIDTHS ARE CALCULATED AT X/A = .900000E+00 AND Y/B = .435890E+00
454 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
455 YP = .000000E+00 .871780E-01 .174356E+00 .261534E+00 .348712E+00 .435890E+00
456 WID = .246732E+00 .239633E+00 .218222E+00 .181848E+00 .127323E+00 .492782E-04
457 AREA OF THE VERTICAL SECTION (IN CM**2): .780780E+03
458
459 AVERAGE WIDTH AT X = .900E+00 THE LENGTH OF A, EQUALS .1690E+00
460
461 WIDTHS ARE CALCULATED AT X/A = .800000E+00 AND Y/B = .600000E+00
462 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
463 YP = .000000E+00 .120000E+00 .240000E+00 .360000E+00 .480000E+00 .600000E+00
464 WID = .391611E+00 .378184E+00 .338284E+00 .272766E+00 .180936E+00 .520580E-04
465 AREA OF THE VERTICAL SECTION (IN CM**2): .164877E+04
466
467 AVERAGE WIDTH AT X = .800E+00 THE LENGTH OF A, EQUALS .2603E+00
468
469 WIDTHS ARE CALCULATED AT X/A = .700000E+00 AND Y/B = .714143E+00
470 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
471 YP = .000000E+00 .142829E+00 .285657E+00 .428486E+00 .571314E+00 .714143E+00
472 WID = .520706E+00 .500887E+00 .442444E+00 .348236E+00 .221319E+00 .748238E-04
473 AREA OF THE VERTICAL SECTION (IN CM**2): .254754E+04
474
475 AVERAGE WIDTH AT X = .700E+00 THE LENGTH OF A, EQUALS .3389E+00
476
477 WIDTHS ARE CALCULATED AT X/A = .600000E+00 AND Y/B = .800000E+00
478 YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A

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479  YP= .000000E+00 .160000E+00 .320000E+00 .480000E+00 .640000E+00 .800000E+00
480  WID= .636312E+00 .610384E+00 .534281E+00 .412996E+00 .253715E+00 .646832E-04
481  AREA OF THE VERTICAL SECTION (IN CM**2): .342720E+04
482
483  AVERAGE WIDTH AT X = .600E+00 THE LENGTH OF A, EQUALS .4080E+00
484
485  WIDTHS ARE CALCULATED AT X/A= 500000E+00 AND Y/B= .866025E+00
486  YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
487  YP= .000000E+00 .173205E+00 .346410E+00 .519615E+00 .692820E+00 .866025E+00
488  WID= .737380E+00 .705899E+00 .613775E+00 .468031E+00 .279957E+00 .724225E-04
489  AREA OF THE VERTICAL SECTION (IN CM**2): .424463E+04
490
491  AVERAGE WIDTH AT X = .500E+00 THE LENGTH OF A, EQUALS .4675E+00
492
493  WIDTHS ARE CALCULATED AT X/A= 400000E+00 AND Y/B= .916515E+00
494  YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
495  YP= .000000E+00 .183303E+00 .366606E+00 .549909E+00 .733212E+00 .916515E+00
496  WID= .822409E+00 .786139E+00 .680209E+00 .513495E+00 .300869E+00 .696203E-04
497  AREA OF THE VERTICAL SECTION (IN CM**2): .496325E+04
498
499  AVERAGE WIDTH AT X = .400E+00 THE LENGTH OF A, EQUALS .5172E+00
500
501  WIDTHS ARE CALCULATED AT X/A= 300000E+00 AND Y/B= .953939E+00
502  YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
503  YP= .000000E+00 .190788E+00 .381576E+00 .572364E+00 .763151E+00 .953939E+00
504  WID= .890024E+00 .849880E+00 .732798E+00 .549162E+00 .316871E+00 .762847E-04
505  AREA OF THE VERTICAL SECTION (IN CM**2): .555318E+04
506
507  AVERAGE WIDTH AT X = .300E+00 THE LENGTH OF A, EQUALS .5565E+00
508
509  WIDTHS ARE CALCULATED AT X/A= 200000E+00 AND Y/B= .979796E+00
510  YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
511  YP= .000000E+00 .195959E+00 .391918E+00 .587878E+00 .783837E+00 .979796E+00
512  WID= .939116E+00 .896129E+00 .770864E+00 .574831E+00 .328187E+00 .728504E-04
513  AREA OF THE VERTICAL SECTION (IN CM**2): .594117E+04
514
515  AVERAGE WIDTH AT X = .200E+00 THE LENGTH OF A, EQUALS .5849E+00
516
517  WIDTHS ARE CALCULATED AT X/A= 100000E+00 AND Y/B= .994987E+00
518  YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
519  YP= .000000E+00 .198997E+00 .397995E+00 .596992E+00 .795990E+00 .994987E+00
520  WID= .968890E+00 .924167E+00 .793908E+00 .590314E+00 .334937E+00 .731607E-04
521  AREA OF THE VERTICAL SECTION (IN CM**2): .626061E+04
522
523  AVERAGE WIDTH AT X = .100E+00 THE LENGTH OF A, EQUALS .6020E+00
524
525  WIDTHS ARE CALCULATED AT X/A= .149012E-07 AND Y/B= 1.00000E+01
526  YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
527  YP= .000000E+00 .200000E+00 .400000E+00 .600000E+00 .800000E+00 .100000E+01
528  WID= .978868E+00 .933561E+00 .801624E+00 .593489E+00 .337181E+00 .632033E-04
529  AREA OF THE VERTICAL SECTION (IN CM**2): .635152E+04
530
531  AVERAGE WIDTH AT X = .149E-07 THE LENGTH OF A, EQUALS .6078E+00
532
533  AVERAGE WIDTH OF FRACTURE = .4512E+00
534
535  AVERAGE OF WIDTH CUBE = .2181E+00
536  INPUT: LEAKC(CGS), SP(CGS), ICONV (=1 FOR AUTOMATIC CONVERGENCE OF TIME)
537  AND TIMP (I.E PERCENTAGE FOR TIME CONVERGENCE)
538  LEAKC = .787000E-02 SP= .000000E+00 ICONV= 1 TIMP(%)= 1.00000

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539 INPUT INITIAL VALUE OF TSLOPE; TCEPT=TSLOPE;
540 INITIAL VALUE OF TSLOPE = TCEPT = .50000
541 VOLUME OF EACH SEGMENT:
542 .40457E+06 .12589E+07 .21744E+07 .30959E+07 .39752E+07
543
544 .47712E+07 .54492E+07 .59818E+07 .63484E+07 .65351E+07
545
546
547 A AHZ ALEAK B
548 .10353E+05 .76390E+04 .95089E+04 .50292E+04
549
550 AFT AHZFT ALKFT BFT
551 .34000E+03 .25062E+03 .31197E+03 .16500E+03
552
553 TIME FROM A-T EQN: .11560E+05 SEC .19267E+03 MIN
554 TIME FROM V/Q: .40720E+04 SEC .67867E+02 MIN
555 PERCENT DIFF. IN TIME = -183.83980 TSLOPE = .50000
556
557 TIME FROM A-T EQN: .23730E+03 SEC .39551E+01 MIN
558 TIME FROM V/Q: .11892E+04 SEC .19820E+02 MIN
559 PERCENT DIFF. IN TIME = 80.08496 TSLOPE = .75000
560
561 TIME FROM A-T EQN: .11230E+04 SEC .18716E+02 MIN
562 TIME FROM V/Q: .17413E+04 SEC .29022E+02 MIN
563 PERCENT DIFF. IN TIME = 35.51149 TSLOPE = .62500
564
565 TIME FROM A-T EQN: .31652E+04 SEC .52754E+02 MIN
566 TIME FROM V/Q: .24496E+04 SEC .40826E+02 MIN
567 PERCENT DIFF. IN TIME = -29.21675 TSLOPE = .56250
568
569 TIME FROM A-T EQN: .18346E+04 SEC .30577E+02 MIN
570 TIME FROM V/Q: .20302E+04 SEC .33836E+02 MIN
571 PERCENT DIFF. IN TIME = 9.63299 TSLOPE = .59375
572
573 TIME FROM A-T EQN: .23921E+04 SEC .39868E+02 MIN
574 TIME FROM V/Q: .22195E+04 SEC .36992E+02 MIN
575 PERCENT DIFF. IN TIME = -7.77350 TSLOPE = .57813
576
577 TIME FROM A-T EQN: .20912E+04 SEC .34853E+02 MIN
578 TIME FROM V/Q: .21204E+04 SEC .35339E+02 MIN
579 PERCENT DIFF. IN TIME = 1.37644 TSLOPE = .58594
580
581 TIME FROM A-T EQN: .22356E+04 SEC .37259E+02 MIN
582 TIME FROM V/Q: .21688E+04 SEC .36146E+02 MIN
583 PERCENT DIFF. IN TIME = -3.08021 TSLOPE = .58203
584
585 TIME FROM A-T EQN: .21619E+04 SEC .36032E+02 MIN
586 TIME FROM V/Q: .21443E+04 SEC .35738E+02 MIN
587 PERCENT DIFF. IN TIME = -.82320 TSLOPE = .58398
588
589
590 VOLUME OF ONE WING:
591 FRAC VOL (CGS): .39995E+08 LEAK VOL (CGS): .73223E+08
592 TOTVOL (CGS): .11322E+09 TOTVOL (BRL): .71476E+03
593 TOTVOL (GAL): .29912E+05
594
595 Q= 40.0
596 R4U= 100.0
597 H= 223.0
598 B= 165.0

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599      A= 340.0
600      P0=P-S1 60.1
601
602      INPUT NPRIME,KPRIME(BU)
603      NPRIME = .482000001000000000E+00
604      KPRIME = .109999999000000000E-01
605
606      -HIT 1 TO RERUN WITH NEW HALF WELLBORE HGT.
607      2 TO RERUN WITH NEW PARAMETERS
608      3 TO QUIT
609
610      INPUT 1 IF YOU WANT DEBUG, 0 FOR NO DEBUG
611      DEBUG= 0
612      INPUT: IWRITE,KCA,KCB(BOTH CGS), HZ(PAYZONE WIDTH IN FT), Q(BPM), RMU(CP)
613      IWRITE= 1 KCA,KCB= .110E+09 .110E+09 HZ= 223.0 Q= 40.0 RMU= 100.0
614      INPUT: YOUNG'S MOD.(EG. 1 SE6 PSI), POISSON'S RAT(EG. .1)
615      YOUNG'S MODULUS = 150E+06 POISSON'S RATIO = .20
616      INPUT: S2-S1(PSI), L(FT)
617      S2-S1= 100.0 L= 378.0
618
619
620      INPUT: XACCURACY DESIRED IN ITERATION OF KI
621      ALLOWANCE FOR 1.00% ERROR
622      NUMNID = 5
623      WELHTIC:
624      C = 90.00
625      INPUT 1 IF YOU WANT VISCOSITY,LAMDA,CIRCULAR FRACTURE RADIUS AND AVG.PRESSURES.
626      IFLAG = 0
627      INPUT HALF HEIGHT AT WELL BORE,B(FT)
628      B = 170.00
629      INPUT 1 FOR TIME CALC. IN WIDAVG; 0 FOR NO TIME CALC.
630      IT = 1
631
632      P0 = .579102E+02
633      PA0 = .147340E+02
634      P0B = -.196778E+02
635      KI1 = .110000E+09
636      KI2 = .109058E+09
637      KCA = .110000E+09
638      KCB = .110000E+09
639      DIFF1 = .000
640      DIFF2 = .009
641
642
643      INPUT 0 : TO CALCULATE WIDTH
644      1 : TO START NEW ITER. TO CALCULATE KI1 & KI2
645      2 : TO STOP
646      ICALC = 0
647
648      WIDTHS ARE CALCULATED AT X/A= 000000E+00 AND Y/B= 100000E+01
649      YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
650      YP= .000000E+00 .200000E+00 .400000E+00 .600000E+00 .800000E+00 .100000E+01
651      WID= .990337E+00 .944407E+00 .810670E+00 .601787E+00 .340225E+00 .695477E-04
652      AREA OF THE VERTICAL SECTION (IN CM**2): .661647E+04
653      INPUT 0: TO CALCULATE AVERAGE WIDTH OF FRACTURE
654      1: TO CONTINUE WITH PROGRAM
655
656      WIDTHS ARE CALCULATED AT X/A= 900000E+00 AND Y/B= 435890E+00
657      YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
658      YP= .000000E+00 .871780E-01 .174356E+00 .261534E+00 .348712E+00 .435890E+00

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659 * WID= .256694E+00 .249361E+00 .227232E+00 .189580E+00 .132982E+00 .516131E-04
660 * AREA OF THE VERTICAL SECTION (IN CM**2): .837963E+03
661 *
662 * AVERAGE WIDTH AT X = .900E+00 THE LENGTH OF A, EQUALS .1760E+00
663 *
664 * WIDTHS ARE CALCULATED AT X/A= .000000E+00 AND Y/B= .600000E+00
665 * YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
666 * YP= .000000E+00 .120000E+00 .240000E+00 .360000E+00 .480000E+00 .600000E+00
667 * WID= .403890E+00 .390131E+00 .349222E+00 .281968E+00 .187475E+00 .541579E-04
668 * AREA OF THE VERTICAL SECTION (IN CM**2): .175441E+04
669 *
670 * AVERAGE WIDTH AT X = .800E+00 THE LENGTH OF A, EQUALS .2688E+00
671 *
672 * WIDTHS ARE CALCULATED AT X/A= .700000E+00 AND Y/B= .714143E+00
673 * YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
674 * YP= .000000E+00 .142829E+00 .285657E+00 .428486E+00 .571314E+00 .714143E+00
675 * WID= .533815E+00 .513589E+00 .453925E+00 .357676E+00 .227787E+00 .773235E-04
676 * AREA OF THE VERTICAL SECTION (IN CM**2): .269378E+04
677 *
678 * AVERAGE WIDTH AT X = .700E+00 THE LENGTH OF A, EQUALS .3478E+00
679 *
680 * WIDTHS ARE CALCULATED AT X/A= .600000E+00 AND Y/B= .800000E+00
681 * YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
682 * YP= .000000E+00 .150000E+00 .320000E+00 .480000E+00 .640000E+00 .800000E+00
683 * WID= .649536E+00 .623141E+00 .545651E+00 .422101E+00 .259685E+00 .664151E-04
684 * AREA OF THE VERTICAL SECTION (IN CM**2): .360702E+04
685 *
686 * AVERAGE WIDTH AT X = .600E+00 THE LENGTH OF A, EQUALS .4167E+00
687 *
688 * WIDTHS ARE CALCULATED AT X/A= .500000E+00 AND Y/B= .866025E+00
689 * YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
690 * YP= .000000E+00 .173205E+00 .346410E+00 .519615E+00 .692820E+00 .866025E+00
691 * WID= .750356E+00 .718359E+00 .624716E+00 .476562E+00 .285250E+00 .739169E-04
692 * AREA OF THE VERTICAL SECTION (IN CM**2): .445168E+04
693 *
694 * AVERAGE WIDTH AT X = .500E+00 THE LENGTH OF A, EQUALS .4759E+00
695 *
696 * WIDTHS ARE CALCULATED AT X/A= .400000E+00 AND Y/B= .916515E+00
697 * YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
698 * YP= .000000E+00 .183303E+00 .366606E+00 .549909E+00 .733212E+00 .916515E+00
699 * WID= .834982E+00 .798156E+00 .690605E+00 .521338E+00 .303459E+00 .706788E-04
700 * AREA OF THE VERTICAL SECTION (IN CM**2): .519178E+04
701 *
702 * AVERAGE WIDTH AT X = .400E+00 THE LENGTH OF A, EQUALS .5251E+00
703 *
704 * WIDTHS ARE CALCULATED AT X/A= .300000E+00 AND Y/B= .953939E+00
705 * YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
706 * YP= .000000E+00 .190788E+00 .381576E+00 .572364E+00 .763151E+00 .953939E+00
707 * WID= .902172E+00 .861442E+00 .742659E+00 .556382E+00 .320829E+00 .771009E-04
708 * AREA OF THE VERTICAL SECTION (IN CM**2): .579793E+04
709 *
710 * AVERAGE WIDTH AT X = .300E+00 THE LENGTH OF A, EQUALS .5639E+00
711 *
712 * WIDTHS ARE CALCULATED AT X/A= .200000E+00 AND Y/B= .979796E+00
713 * YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
714 * YP= .000000E+00 .195959E+00 .391918E+00 .587878E+00 .783837E+00 .979796E+00
715 * WID= .950905E+00 .907311E+00 .780290E+00 .581554E+00 .331650E+00 .733834E-04
716 * AREA OF THE VERTICAL SECTION (IN CM**2): .624723E+04
717 *
718 * AVERAGE WIDTH AT X = .200E+00 THE LENGTH OF A, EQUALS .5920E+00

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719 *
720 * WIDTHS ARE CALCULATED AT X/A= .100000E+00 AND Y/B= .994987E+00
721 * YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
722 * YP= .000000E+00 .198997E+00 .397995E+00 .596992E+00 .795990E+00 .994987E+00
723 * WID= .980442E+00 .935099E+00 .803052E+00 .596720E+00 .338087E+00 .735425E-04
724 * AREA OF THE VERTICAL SECTION (IN CM**2): .652335E+04
725 *
726 * AVERAGE WIDTH AT X = .100E+00 THE LENGTH OF A, EQUALS .6089E+00
727 *
728 * WIDTHS ARE CALCULATED AT X/A= -.149012E-07 AND Y/B= .100000E+01
729 * YP ARE Y/B VALUES AT VARIOUS VERTICAL POINTS FOR A FIXED X/A
730 * YP= .000000E+00 .200000E+00 .400000E+00 .600000E+00 .800000E+00 .100000E+01
731 * WID= .990337E+00 .944407E+00 .810670E+00 .601787E+00 .340225E+00 .634881E-04
732 * AREA OF THE VERTICAL SECTION (IN CM**2): .661646E+04
733 *
734 * AVERAGE WIDTH AT X = -.149E-07 THE LENGTH OF A, EQUALS .6146E+00
735 *
736 * AVERAGE WIDTH OF FRACTURE = .4590E+00
737 *
738 * AVERAGE OF WIDTH CUBE = .2276E+00
739 * INPUT: LEAKC(CGS), SP(CGS), ICONV (=1 FOR AUTOMATIC CONVERGENCE OF TIME)
740 * AND TIMP (I.E. PERCENTAGE FOR TIME CONVERGENCE)
741 * LEAKC = .787000E-02 SP= .000000E+00 ICONV= 1 TIMP(X)= 1.00000
742 * INPUT INITIAL VALUE OF TSLOPE; TCEPT=TSLOPE
743 * INITIAL VALUE OF TSLOPE * TCEPT = .50000
744 * VOLUME OF EACH SEGMENT:
745 * .48273E+06 .14934E+07 .25625E+07 .36297E+07 .46424E+07
746 *
747 * .55553E+07 .63309E+07 .69389E+07 .73568E+07 .75695E+07
748 *
749 *
750 * A AHZ ALEAK B
751 * .11521E+05 .86971E+04 .10632E+05 .51816E+04
752 *
753 * AFT AHZFT ALKFT BFT
754 * .37800E+03 .28534E+03 .34881E+03 .17000E+03
755 *
756 * TIME FROM A-T EQN: .14288E+05 SEC .23814E+03 MIN
757 * TIME FROM V/Q: .50019E+04 SEC .83365E+02 MIN
758 * PERCENT DIFF. IN TIME = -185.66022 TSLOPE = .50000
759 *
760 * TIME FROM A-T EQN: .27331E+03 SEC .45552E+01 MIN
761 * TIME FROM V/Q: .13999E+04 SEC .23331E+02 MIN
762 * PERCENT DIFF. IN TIME = 80.47608 TSLOPE = .75000
763 *
764 * TIME FROM A-T EQN: .13304E+04 SEC .22174E+02 MIN
765 * TIME FROM V/Q: .20792E+04 SEC .34653E+02 MIN
766 * PERCENT DIFF. IN TIME = 36.01267 TSLOPE = .62500
767 *
768 * TIME FROM A-T EQN: .38213E+04 SEC .63688E+02 MIN
769 * TIME FROM V/Q: .29605E+04 SEC .49342E+02 MIN
770 * PERCENT DIFF. IN TIME = -29.07331 TSLOPE = .56250
771 *
772 * TIME FROM A-T EQN: .21930E+04 SEC .36550E+02 MIN
773 * TIME FROM V/Q: .24376E+04 SEC .40627E+02 MIN
774 * PERCENT DIFF. IN TIME = 10.03470 TSLOPE = .59375
775 *
776 * TIME FROM A-T EQN: .28732E+04 SEC .47886E+02 MIN
777 * TIME FROM V/Q: .26734E+04 SEC .44557E+02 MIN
778 * PERCENT DIFF. IN TIME = -7.47330 TSLOPE = .57813

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779 *
780 * TIME FROM A-T EQN: .25056E+04 SEC .41761E+02 MIN
781 * TIME FROM V/Q: .25498E+04 SEC .42497E+02 MIN
782 * PERCENT DIFF. IN TIME = 1.73309 TSLOPE = .58594
783 *
784 * TIME FROM A-T EQN: .26819E+04 SEC .44698E+02 MIN
785 * TIME FROM V/Q: .26101E+04 SEC .43502E+02 MIN
786 * PERCENT DIFF. IN TIME = -2.75023 TSLOPE = .58203
787 *
788 * TIME FROM A-T EQN: .25920E+04 SEC .43200E+02 MIN
789 * TIME FROM V/Q: .25796E+04 SEC .42993E+02 MIN
790 * PERCENT DIFF. IN TIME = -.47951 TSLOPE = .58398
791 *
792 *
793 * VOLUME OF ONE WING:
794 * FRAC VOL (CGS): .46562E+08 LEAK VOL (CGS): .89641E+08
795 * TOTVOL (CGS): .13620E+09 TOTVOL (BRL): .85987E+03
796 * TOTVOL (GAL): .35985E+05
797 *
798 * D= 40.0
799 * RMU= 100.0
800 * H= 223.0
801 * B= 170.0
802 * A= 378.0
803 * PO=P-31 57.9
804 *
805 * INPUT NPRIME,KPRIME(BU)
806 * NPRIME = .4820000010000000000E+00
807 * KPRIME = .1099999990000000000E-01
808 *
809 * -HIT 1 TO RERUN WITH NEW HALF WELLBORE HGT.
810 * 2 TO RERUN WITH NEW PARAMETERS
811 * 3 TO QUIT
812 *

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CHAPTER III

APPENDIX C

[illegible]

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4      1
1297014620000000000E+07
.6797039550000000000E+04
7869998600000000000E-02
.8741005860000000000E+00
.4820000001000000000E+00
.6797039550000000000E+04
.2238931120000000000E+07
.9143999510900000000E+04
7869998600000000000E-02
.1588008142000000000E+04
.4820000001000000000E+00
.6797039550000000000E+04
.3040201620000000000E+07
1036319970900000000E+05
7869998600000000000E-02
.2142270630900000000E+04
.4820000001000000000E+00
.6797039550000000000E+04
.3539695750900000000E+07
.1152143950800000000E-05
7869998609000000000E-02
.2579608860900000000E+04
.4820000001000000000E+00
.6797039550900000000E+04

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.49775901400000000000E+13
.42671997100000000000E+04
.00000000000000000000E+00

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```

.109999990000000000E+01
.105600000000000000E+06
.157072513000000000E+14
.472439990000000000E+04
.000000000000000000E+00

```

```

* 109999990000000000E=01
* 105600000000000000E+06
* 303314030000000000E+14
* 502919971000000000E+04
* 000000000000000000E+00

```

```

010999999000000000E-01
010560000000000000E+06
040893449000000000E+14
051815996100000000E+04
000000000000000000E+00

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*10999999900000000000E=01
*10560000000000000000E+06

```

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.2790769690000000000E+13
.1237620180000000000E+00

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.5170499990000000000E+11
.6517054770000000000E+13
.8529553190000000000E+00

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.51704999900000000000E+11
.10792816300000000000E+14
.97886810500000000000E+00

```

```

.51704999900000000000E+11
.13461592500000000000E+14
.99033743900000000000E+00

```

.517049999000000000E+11

.2000000030000000000E+00

```

.689400000000000000E+07
.20000000030000000000E+00

```

.689400000000000000E+07
 .20000000030000000000E+00

:689400000000000000E+07
 :200000003000000000E+00

.689400000000000000E+07

CHAPTER III

APPENDIX D

09:49 JUL 28 '87 DATATUPS.IND40820

1	1.0000	65.0					
2	2.0000		1				
3	3.0000	024.500	87.00	133.88	150.00	00.0	00.0
4	4.0000	02.000000	1.0	5.0	0.00001	0.0	0.0
5	5.0000	.0560	.037	.037	.037	.0	.0
6	6.0000	.30	.3	.3	.30	.00	.00
7	7.0000	165.00	165.0	165.0	165.0	000.0	000.0
8	8.0000	32.2	10				
9	9.0000	1.072836	0.0	20.	0.3333		
10	10.0000		01	000	1	5	
11	11.0000	1.25	0000.	10.			
12	12.0000		0000				
13	13.0000						

IFORTRAN TUPROPS OVER *TUP1(SV,NOP,LS)
 FORTRAN 77 VERSION 000 JUL 28 '87

CHAPTER III

APPENDIX E

ILYNN *TUP1 OVER LTUPROPS

LINK C01 HERE

* 1 SHARED COMMON SYS (SHARED LIBRARY) ASSOCIATED.

* NO LINKING ERRORS

* TOTAL PROGRAM SIZE = 41K.

ILTUPROPS.

INJECTION RATE	=	40.000	BPM
INJECTION RATE TIME	=	.000	MIN
TREATMENT TIME	=	43.095	MIN
CONSISTENCY INDEX (PIPE FLOW)	=	.011000	LB*9**NPRIME/FT**2
CONSISTENCY INDEX (ABSOLUTE)	=	.010150	LB*9**NPRIME/FT**2
CONSISTENCY INDEX (SLOT FLOW)	=	.011774	LB*9**NPRIME/FT**2
BEHAVIOR INDEX	=	.482	
FLUID DENSITY	=	65.000	LB/FT**3
FLUID LOSS COEFFICIENT	=	.200E-02	FT/3QRT(MIN)
SPURT LOSS	=	.000	FT**3/FT**2
PAVZONE HEIGHT	=	223.000	FT
YOUNG MODULUS	=	749917.4	PSIA
POISSON RATIO	=	.200	
LENGTH INCREMENT	=	10.00	FT
FAN RADII RATIO	=	1.072836	
ACCEL OF GRAVITY	=	32.200	FT/SEC
PAD TIME	=	24.500	MIN
MIXING RATIO	=	2.000	LB/GAL OF FLUID
INITIAL CONCENTRATION	=	1.834	LB/GAL OF SLURRY
PROPPANT DENSITY	=	165.000	LB/FT**3
PROPPANT DIAMETER	=	.056	IN
PROPPANT POROSITY	=	.300	

NODE	ELE	TIME MIN	MAX WIDTH FT	EQUIV WIDTH FT	LENGTH FT	HEIGHT FT	MAX WB WIDTH FT	EQUIV WB WIDTH FT	WB HT FT
1	0	.0000	.03275	.02143	0	340.000	.00000	.00000	.000
2	1	14.6075	.02180	.01486	223	274.530	.02395	.01605	280.000
3	2	26.4501	.01359	.00971	300	206.847	.02792	.01849	310.000
4	3	35.7141	.00847	.00629	340	148.573	.03205	.02098	330.000
5	4	43.0948	.00000	.00000	378	.000	.03275	.02143	340.000

FRACTURE LENGTH	=	377.38	FT
PROPPANT LENGTH	=	360.00	FT
WELLBORE WIDTH	=	.02142	FT
	=	.25706	IN

LEADING EDGE PROPPANT TYPE 1 = 360.00 FT

SUTRICK AND RYBICKI SETTLING MODEL

FRACTIONAL DISTANCE TO WALL = .3333
 SHEAR RATE CUT OFF = 20.0 1/SEC
 FRACTURING FLUID IS HYDROXYPROPYL GUAR

ELEMENT NUMBER	LENGTH FT	TIME SEC	CONC LB/GAL	W(IN) FT	W(OUT) FT	WAVG FT	DW FT	Q(IN) BBL/MIN	Q(OUT) BBL/MIN	ELE VEL FT/SEC	SET VEL FT/SEC	FLUID LOSS VEL-FT/SEC
1	10.00	38.4593	.8370	.02142	.02141	.02141	.7294E-03	20.0000	19.7273	.2600	.0249621	.5098E-05
2	20.00	38.9249	.8484	.02141	.02137	.02139	.7449E-03	19.7273	19.4529	.2569	.0247832	.5123E-05
3	30.00	39.3286	.8534	.02137	.02130	.02133	.7757E-03	19.4529	19.1763	.2543	.0246229	.5150E-05
4	40.00	39.6888	.8639	.02130	.02120	.02125	.8220E-03	19.1763	18.8971	.2521	.0244854	.5177E-05
5	50.00	39.9444	.8757	.02120	.02108	.02114	.8835E-03	18.8971	18.6146	.2503	.0243706	.5206E-05
6	60.00	40.1553	.8890	.02108	.02093	.02101	.9601E-03	18.6146	18.3285	.2490	.0242744	.5235E-05
7	70.00	40.3303	.9036	.02093	.02076	.02084	.1052E-04	18.3285	18.0382	.2481	.0242086	.5267E-05
8	80.00	40.4787	.9197	.02076	.02055	.02065	.1158E-04	18.0382	17.7432	.2477	.0241662	.5299E-05
9	90.00	40.5977	.9373	.02055	.02032	.02044	.1279E-04	17.7432	17.4430	.2476	.0241401	.5334E-05
10	100.00	40.6932	.9564	.02032	.02007	.02020	.1415E-04	17.4430	17.1372	.2479	.0241366	.5372E-05
11	110.00	40.7676	.9771	.02007	.01979	.01993	.1564E-04	17.1372	16.8254	.2487	.0241566	.5412E-05
12	120.00	40.8213	.9995	.01979	.01948	.01963	.1728E-04	16.8254	16.5070	.2497	.0242010	.5454E-05
13	130.00	40.8595	.0238	.01948	.01914	.01931	.1905E-04	16.5070	16.1815	.2516	.0242773	.5501E-05
14	140.00	40.8856	.0000	.01914	.01878	.01896	.0966E-04	16.1815	15.8487	.2537	.0243735	.5551E-05
15	150.00	40.9095	.0783	.01878	.01840	.01859	.2299E-04	15.8487	15.5081	.2563	.0245005	.5603E-05
16	160.00	40.9225	.1432	.01840	.01799	.01819	.3155E-04	15.5081	15.1592	.2593	.0246553	.5663E-05
17	170.00	40.9255	.1811	.01799	.01755	.01777	.3743E-04	15.1592	14.8018	.2633	.0248307	.5729E-05
18	180.00	40.9188	.2224	.01755	.01709	.01732	.4283E-04	14.8018	14.4354	.2677	.0250331	.5801E-05
19	190.00	40.9022	.2660	.01709	.01661	.01685	.4783E-04	14.4354	14.0598	.2728	.0252680	.5879E-05
20	200.00	40.8756	.3116	.01661	.01610	.01635	.5248E-04	14.0598	13.6744	.2787	.0255390	.5966E-05
21	210.00	40.8399	.3599	.01610	.01556	.01583	.5674E-04	13.6744	13.2791	.2855	.0258497	.6066E-05
22	220.00	40.7953	.3705	.01556	.01501	.01529	.6056E-04	13.2791	12.8734	.2933	.0262031	.6167E-05
23	230.00	40.7426	.4299	.01501	.01443	.01472	.6351E-04	12.8734	12.4570	.3023	.0266030	.6288E-05
24	240.00	40.6826	.4958	.01443	.01382	.01412	.6571E-04	12.4570	12.0294	.3128	.0270534	.6419E-05
25	250.00	40.6154	.5692	.01382	.01319	.01351	.6744E-04	12.0294	11.5902	.3249	.0276316	.6572E-05
26	260.00	40.5460	.6518	.01319	.01254	.01287	.6833E-04	11.5902	11.1387	.3390	.0282882	.6752E-05
27	270.00	40.4751	.7455	.01254	.01186	.01220	.6846E-04	11.1387	10.6737	.3558	.0289751	.6966E-05
28	280.00	40.4010	.8533	.01186	.01116	.01151	.6804E-04	10.6737	10.1936	.3757	.0297779	.7222E-05
29	290.00	40.3250	.9701	.01116	.01043	.01079	.6381E-04	10.1936	9.6951	.3999	.0307765	.7551E-05
30	300.00	40.2474	.1290	.01043	.00967	.01005	.6381E-04	9.6951	9.1776	.4296	.0319228	.7966E-05
31	310.00	40.1594	.1228	.00967	.00887	.00927	.7120E-04	9.1776	8.6353	.4670	.0332661	.8512E-05
32	320.00	40.0615	.1105	.00887	.00804	.00846	.7710E-04	8.6353	8.0538	.5152	.0348193	.9242E-05
33	330.00	39.9535	.0855	.00804	.00717	.00761	.8282E-04	8.0538	7.4297	.5799	.0366042	.1023E-04
34	340.00	39.8352	.0555	.00717	.00624	.00670	.8945E-04	7.4297	6.7427	.6719	.0387192	.1158E-04
35	350.00	39.7039	.0333	.00624	.00522	.00573	.9788E-04	6.7427	5.9676	.8147	.0422668	.1352E-04
36	360.00	39.5665	.0066	.00522	.00406	.00464	.1159E-03	5.9676	5.0221	1.0519	.0485793	.1665E-04

ELEMENT NUMBER	APP VIS CP	RE(FLOW)	SHR RATE PART 1/3	RE(PART)	FRACTION FT	OP HT FT	BED HT FT	OH BED FT	FALL HT FT	DFH FT	SUSP HT FT	NET SUSP FT
1	52.	20.6888	11.4508	.0818	339.8381	336.3644	3.3543	.3410E+01	.9600	.9600E+00	338.8184	335.4641
2	52.	20.3018	11.3402	.0809	339.7188	336.1044	3.2561	.3399E+01	1.9240	.9647E+00	337.6743	335.4192
3	53.	19.9619	11.2554	.0800	339.3605	335.6030	3.1566	.3393E+01	2.8905	.9684E+00	336.2802	335.1206
4	53.	19.6662	11.1995	.0794	338.7626	334.8577	3.0660	.3394E+01	3.8584	.9713E+00	334.7346	333.6649
5	53.	19.4125	11.1721	.0789	337.9237	333.8650	2.9771	.3399E+01	4.8266	.9735E+00	333.0421	330.0650

TIME OF PROP INJECTION= 18.614
 VOLUME OF INJECTED FLUID = 1902.315
 VOLUME IN FRACTURE= 1506.247
 VOLUME LOST= 395.811
 DIFFERENCE= -109.333
 ERROR= -5.748%

MASS OF PROP INJECTED= 28456.487
 MASS OF SETTLED PROP= 1328.715
 MASS OF SUSPENDED PROP= 27186.246
 TOTAL MASS= 28474.960
 DIFFERENCE= -18.553
 ERROR= -.065%

EQUIVALENT

NODE	FRACTURE LENGTH FT	PROPPANT LENGTH FT	FRACTURE HEIGHT FT	SUSP HEIGHT FT	BED HEIGHT FT	FROM CENTER OF PAYZONE			
						DISTANCE TO TOP OF FRACTURE FT	DISTANCE TO BOTTOM OF FRACTURE FT	DISTANCE TO TOP OF SUSP FT	DISTANCE TO TOP OF BED FT
1	287.32	0.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
2	287.32	10.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
3	287.32	20.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
4	287.32	30.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
5	287.32	40.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
6	287.32	50.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
7	287.32	60.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
8	287.32	70.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
9	287.32	80.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
10	287.32	90.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
11	287.32	100.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
12	287.32	110.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
13	287.32	120.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
14	287.32	130.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
15	287.32	140.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
16	287.32	150.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
17	287.32	160.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
18	287.32	170.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
19	287.32	180.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
20	287.32	190.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
21	287.32	200.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
22	287.32	210.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
23	287.32	220.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
24	287.32	230.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
25	287.32	240.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
26	287.32	250.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
27	287.32	260.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
28	287.32	270.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
29	287.32	280.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
30	287.32	290.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156
31	287.32	300.	339.8380	339.8380	3.4034	169.9190	-169.9190	169.9190	-166.5156

32	370.51	310.	193.8067	193.8067	.4009	96.9033	-96.9033	96.9033	-96.5025
33	372.53	310.	180.1451	180.1451	.3048	90.0726	-90.0726	90.0726	-89.7678
34	373.80	310.	164.8676	164.8676	.2160	82.4338	-82.4338	82.4338	-82.2178
35	375.20	310.	147.4727	147.4727	.1362	73.7363	-73.7363	73.7363	-73.6002
36	376.40	310.	127.0940	127.0940	.0678	63.5470	-63.5470	63.5470	-63.4792
37	377.58	360.	101.9578	101.9578	.0185	50.9789	-50.9789	50.9789	-50.9604

GEOMETRIC

NODE	FRACTURE LENGTH FT	PROPPANT LENGTH FT	FRACTURE HEIGHT FT	SUSP HEIGHT FT	BED HEIGHT FT	FROM CENTER OF PAYZONE			
						DISTANCE TO TOP OF FRACTURE FT	DISTANCE TO BOTTOM OF FRAC FT	DISTANCE TO TOP OF SUSP FT	DISTANCE TO TOP OF BED FT
1	287.32	0.	339.8380	339.8380	17.9032	169.9190	-169.9190	169.9190	-152.0159
2	290.53	0.	339.7187	339.8402	17.5783	169.8594	-169.8594	169.7808	-152.2851
3	293.87	0.	339.3605	339.7326	17.2411	169.6803	-169.6803	169.6461	-152.4391
4	297.25	0.	338.7925	338.7561	16.8967	169.3813	-169.3813	169.3748	-152.4826
5	300.86	0.	337.9237	337.5694	16.5528	168.9619	-168.9619	168.6046	-152.8094
6	305.28	0.	336.8842	336.8673	16.1933	168.4211	-168.4211	168.2463	-152.2668
7	307.83	0.	335.5114	335.9588	15.8198	167.7577	-167.7577	167.2011	-151.9419
8	310.42	0.	333.9407	333.3828	15.4253	166.9704	-166.9704	166.4124	-151.5451
9	313.07	0.	332.0325	330.9044	15.0226	166.0573	-166.0573	165.8472	-151.0346
10	315.76	0.	330.0325	307.5002	14.6077	165.0163	-165.0163	164.8848	-150.4846
11	318.48	100.	327.6900	305.1598	14.1817	163.8450	-163.8450	163.3148	-149.6633
12	321.23	100.	325.0813	302.8815	13.7446	162.5406	-162.5406	161.3408	-148.7960
13	323.99	120.	322.1999	300.6711	13.2976	161.0999	-161.0999	159.5712	-147.8023
14	326.77	140.	319.0388	298.5455	12.8407	159.5192	-159.5192	157.9263	-146.6785
15	329.54	150.	315.5883	296.5330	12.3737	157.7942	-157.7942	156.7388	-145.4205
16	332.31	150.	311.8402	294.6923	11.8967	155.9201	-155.9201	154.7722	-144.0234
17	335.06	150.	307.7811	293.1350	11.4121	153.8916	-153.8916	152.2454	-142.4794
18	337.79	170.	303.4048	292.1007	10.9213	151.7024	-151.7024	150.3983	-140.7812
19	340.58	170.	298.6909	290.4034	10.4255	149.3455	-149.3455	148.0579	-138.9249
20	343.35	170.	293.6234	289.4780	9.9287	146.8127	-146.8127	145.1633	-136.9143
21	346.17	200.	288.1697	288.2881	9.3787	144.0949	-144.0949	141.9932	-134.7162
22	348.93	200.	282.3625	286.2588	8.8791	141.1813	-141.1813	139.0776	-132.3022
23	351.71	200.	276.1188	283.0128	8.3678	138.0594	-138.0594	135.9533	-129.6916
24	354.54	200.	269.4300	279.3208	7.8061	134.7150	-134.7150	132.6058	-126.9089
25	357.34	200.	262.5737	275.1488	7.1690	131.1309	-131.1309	129.0179	-123.9619
26	359.86	200.	254.5717	269.4561	6.4938	127.2868	-127.2868	125.1693	-120.7930
27	362.23	200.	246.3171	262.5436	5.7229	123.1585	-123.1585	123.0351	-117.3357
28	364.49	200.	237.8426	254.7017	4.8632	118.7163	-118.7163	118.5854	-113.5531
29	366.63	200.	227.8469	246.7062	3.9235	113.9235	-113.9235	113.7827	-109.4032
30	368.63	200.	217.4673	237.3135	2.8921	108.7336	-108.7336	108.5799	-104.8414
31	370.51	300.	206.1737	206.3023	1.8869	103.0869	-103.0869	102.9154	-99.8000
32	372.53	310.	193.8067	193.8102	2.7026	96.9033	-96.9033	96.7068	-94.2008
33	373.80	320.	180.1451	179.9115	2.1800	90.0726	-90.0726	89.8390	-87.9326
34	375.20	330.	164.8676	164.5754	1.6053	82.4338	-82.4338	82.1416	-80.8285
35	376.40	340.	147.4727	146.150	1.0999	73.7363	-73.7363	72.8786	-72.6364
36	377.58	350.	127.0940	124.5589	.6317	63.5470	-63.5470	61.0120	-62.3153
37	377.58	360.	101.9578	100.1135	.2030	50.9789	-50.9789	49.1346	-50.7759

CLOSURE INC = 7 TIME OF CLOSURE = 70. MIN TOTAL TIME = 113.11 MIN

ELEM NO	FLAG	CT MIN	TOTAL CT MIN	CONC LB/GAL	WCAVG FT	AVG SUBP HT FT	AVG BED HT FT	AVG NET SUB HT	VOL RED INC CUFT	VOL IN SUB CUFT	VOL FLD LOST CUFT	VOL FLD TO LOSE	
1	1	70	112	9753	8.5780	.00467	198.9521	6.6895	315.1862	.7142	8.5661	70.1996	63.4781
1	1	70	112	9753	8.5796	.00467	198.4561	7.3121	311.7373	.8679	8.5646	70.4010	63.3577
1	1	70	112	9753	8.5845	.00467	197.7598	7.2182	308.3629	.8658	8.5548	70.6062	63.1033
1	1	70	112	9753	8.5935	.00467	196.8495	7.1235	307.0668	.8623	8.5347	70.8167	62.7164
1	1	60	102	9753	8.1275	.00467	195.7541	6.6596	306.6767	.7786	8.5058	62.5528	62.1966
1	1	60	102	9753	8.1348	.00467	194.4411	6.5479	305.8728	.7694	8.4878	62.7802	61.5469
1	1	60	102	9753	8.1966	.00467	192.9238	6.4226	304.4110	.7563	8.4207	62.9968	60.7683
1	1	60	102	9753	8.2548	.00467	191.2011	6.2944	302.8772	.7416	8.3642	63.2240	59.8631
1	1	60	102	9753	8.3231	.00467	189.2726	6.1550	301.2762	.7237	8.2984	63.4633	58.8336
1	1	60	102	9753	8.4053	.00467	187.1384	6.0071	299.6142	.7032	8.2231	63.7165	57.6428
1	1	60	102	9753	8.5013	.00467	184.1991	5.8523	297.8694	.6806	8.1384	63.9834	56.4136
1	1	60	92	9753	8.1220	.00467	182.2562	5.7257	297.0082	.6845	8.0443	63.2376	55.0295
1	1	60	92	9753	8.2336	.00467	179.5112	5.6175	295.6247	.6630	7.9407	63.5145	53.5343
1	1	60	92	9753	8.3619	.00467	176.5664	5.5017	293.4909	.6395	7.8278	63.8113	51.9320
1	1	60	92	9753	8.5095	.00467	173.4247	5.3850	291.2633	.6142	7.7055	64.1302	50.2271
1	1	60	92	9753	8.6755	.00467	170.0680	5.2674	288.9394	.5869	7.5745	64.4736	48.4234
1	1	60	82	9753	8.2750	.00467	166.6415	5.1544	287.3627	.5696	7.4371	64.81107	46.5250
1	1	60	82	9753	8.4860	.00467	163.0589	5.0493	285.2621	.5522	7.2936	65.14630	44.5360
1	1	60	82	9753	8.6755	.00467	159.4986	4.9434	282.4695	.5386	7.1413	65.48448	42.4654
1	1	60	82	9753	8.9290	.00467	155.4986	4.8375	278.9535	.5197	6.9649	65.82594	40.3355
1	1	60	72	9753	8.2297	.00467	150.1377	4.7348	274.4425	.5010	6.7600	66.17104	38.1545
1	1	60	72	9753	8.7024	.00467	144.9579	4.6318	270.0357	.4829	6.5395	66.51416	35.9183
1	1	60	72	9753	8.9415	.00467	139.4978	4.5274	264.8637	.4651	6.3061	66.85436	33.6321
1	1	60	72	9753	9.1435	.00467	133.7275	4.4251	258.8599	.4475	6.0601	67.18421	31.3052
1	1	60	62	9753	8.8933	.00467	127.6538	4.3296	252.4079	.4307	5.8017	67.50994	28.9451
1	1	60	62	9753	9.0543	.00467	121.3309	4.2396	245.7737	.4135	5.5303	67.83524	26.5577
1	1	60	62	9753	9.5433	.00467	114.7707	4.1502	238.2494	.3955	5.2460	68.15145	24.1511
1	1	60	62	9753	9.1737	.00467	107.9775	4.0626	229.7760	.3781	4.9490	68.45726	21.7343
1	1	60	52	9753	8.0046	.00467	100.9568	3.9735	220.5453	.3605	4.6394	68.75332	19.3161
1	1	60	52	9753	8.3046	.00467	93.7154	3.8883	210.5586	.3427	4.3175	69.04590	16.9062
1	1	60	52	9753	8.7041	.00467	86.2617	3.8049	199.2739	.3248	3.9838	69.33644	14.5139
1	1	60	52	9753	9.0984	.00467	78.6154	3.7222	186.5036	.3070	3.6390	69.62559	12.1487
1	1	60	52	9753	9.7102	.00467	70.8174	3.6408	172.1955	.2890	3.2852	69.91536	9.8189
1	1	60	52	9753	10.3827	.00467	62.8679	3.5678	155.9823	.2710	2.9222	70.207470	7.5350
1	1	60	52	9753	10.2826	.00467	54.2107	3.4955	137.1828	.2530	2.5524	70.49957	5.3323
1	1	60	52	9753	10.7893	.00467	42.8393	3.4270	114.4889	.2350	2.1961	70.79149	3.3481

ELEM NO	FLD LOST VEL FT/S	SET VEL FT/SEC	SHR RATE PART 1/S	RE (PART)	FALL HT FT	DFH FT	CL AREA SQ FT
1	3137E+00	.0020807	.4537E+00	.1281E-02	17.4323	.1248E+01	.9284E+00
1	3443E+00	.0020611	.4659E+00	.1258E-02	23.3463	.1237E+01	.9261E+00
1	3499E+00	.0020480	.4817E+00	.1244E-02	24.2614	.1229E+01	.9229E+00
1	3555E+00	.0020358	.4989E+00	.1232E-02	25.1217	.1222E+01	.9186E+00
1	3611E+00	.0020236	.5179E+00	.1221E-02	24.6673	.1213E+01	.9135E+00
1	3667E+00	.0020114	.5385E+00	.1210E-02	25.3589	.1204E+01	.9074E+00
1	3723E+00	.0020000	.5617E+00	.1199E-02	25.9575	.1195E+01	.9003E+00
1	3779E+00	.0020000	.5874E+00	.1188E-02	26.5086	.1185E+01	.8923E+00
1	3835E+00	.0020000	.6150E+00	.1177E-02	26.9733	.1174E+01	.8833E+00
1	3891E+00	.0020000	.6447E+00	.1166E-02	27.3707	.1163E+01	.8733E+00
1	3947E+00	.0020000	.6764E+00	.1155E-02	27.7147	.1151E+01	.8624E+00

1	3564	05	0027471	5940E+00	1945E+02	26	7929	1648E+01	8505E+00
2	3577	05	0025564	5553E+00	1754E+02	27	1279	1539E+01	8377E+00
3	3590	05	0023703	5140E+00	1557E+02	27	4075	1422E+01	8240E+00
4	4605	05	0021642	4701E+00	1358E+02	27	6304	1299E+01	8093E+00
5	4620	05	0019481	4241E+00	1158E+02	27	7955	1169E+01	7938E+00
6	4875	05	0025112	5461E+00	102E+02	26	8638	1507E+01	7777E+00
7	4884	05	0022408	4885E+00	11434E+02	27	8388	1344E+01	7604E+00
8	4920	05	0019617	4288E+00	1177E+02	27	8388	1177E+01	7433E+00
9	4946	05	0016767	3679E+00	9262E+02	28	9551	1006E+01	7233E+00
10	4973	05	0013908	3064E+00	6887E+02	29	8185	8342E+00	7006E+00
11	4322	05	0019140	4154E+00	5226E+02	30	8289	1148E+01	6765E+00
12	4356	05	0015855	3445E+00	3529E+02	32	9957	9513E+00	6510E+00
13	4411	05	0012456	2768E+00	338E+02	34	7222	7474E+00	6241E+00
14	4466	05	0009223	2068E+00	338E+02	37	1007	5534E+00	5957E+00
15	4396	05	0015382	3355E+00	8101E+02	39	4438	9229E+00	5662E+00
16	5081	05	0011295	2475E+00	5082E+02	42	6548	6777E+00	5356E+00
17	5179	05	0007776	1762E+00	2934E+02	46	2463	4665E+00	5039E+00
18	5294	05	0004579	1062E+00	1329E+02	50	2586	2747E+00	4711E+00
19	6337	05	0013205	2900E+00	448E+02	54	6618	1923E+00	4373E+00
20	6601	05	0008271	1833E+00	3184E+02	60	2431	1496E+00	4026E+00
21	6923	05	0004388	1034E+00	1256E+02	66	2484	2633E+00	3669E+00
22	7507	05	0001546	3875E+00	6622E+02	73	2676	9277E+00	3305E+00
23	7557	05	0000321	1175E+00	3975E+02	81	1795	1625E+00	2934E+00
24	8255	05	0000000	6869E+00	181E+02	90	1777	1675E+00	2530E+00
25	8625	05	0000000	5981E+00	1087E+02	102	2664	1575E+00	1962E+00

PROPPED GEOMETRY

FROM CENTER OF PAYZONE

ELEM NO	FLAG	CT MIN	TOTAL CT MIN	CL FRAC HT FT	NCAVG FT	NODE NO	LENGTH FT	PROP CL FRAC HT FT	DISTANCE TO TOP OF FRACTURE FT	DISTANCE TO BOTTOM OF FRACTURE FT	DISTANCE TO TOP OF PROP FRACTURE FT	AVERAGE FRACTURE WIDTH FT	CL AREA SQ FT
1	1	70	112.9753	198.9521	.00467	1	0	199.0118	169.9190	-169.9190	29.0928	.00467	.9287E+00
2	1	70	112.9753	198.4551	.00467	2	10	198.7041	169.8594	-169.8594	28.8447	.00467	.9273E+00
3	1	70	112.9753	197.7498	.00467	3	20	198.1079	169.8803	-169.8803	28.6427	.00467	.9245E+00
4	1	60	108.9753	196.8495	.00467	4	30	197.3047	169.8813	-169.8813	27.9234	.00467	.9208E+00
5	1	60	108.9753	195.7541	.00467	5	40	196.3018	168.4619	-168.4619	27.3400	.00467	.9161E+00
6	1	60	108.9753	194.8411	.00467	6	50	195.0976	168.4211	-168.4211	26.6766	.00467	.9105E+00
7	1	60	108.9753	192.9238	.00467	7	60	193.6825	167.7577	-167.7577	26.0228	.00467	.9039E+00
8	1	60	108.9753	191.2011	.00467	8	70	192.0625	167.9704	-166.9704	25.3677	.00467	.8963E+00
9	1	60	108.9753	189.7266	.00467	9	80	190.2369	166.0573	-166.0573	24.7196	.00467	.8878E+00
10	1	60	108.9753	187.1384	.00467	10	90	188.2055	165.0163	-165.0163	24.0922	.00467	.8783E+00
11	1	60	108.9753	184.7991	.00467	11	100	185.9667	163.8450	-163.8450	23.4837	.00467	.8679E+00
12	1	50	92.9753	182.2562	.00467	12	110	183.5277	162.5406	-162.5406	22.8970	.00467	.8565E+00
13	1	50	92.9753	179.5112	.00467	13	120	180.8837	161.0999	-161.0999	22.3358	.00467	.8444E+00
14	1	50	92.9753	176.8247	.00467	14	130	178.0368	159.5192	-159.5192	21.7917	.00467	.8308E+00
15	1	50	92.9753	173.8247	.00467	15	140	174.9956	157.7942	-157.7942	21.2814	.00467	.8166E+00
16	1	50	92.9753	170.0080	.00467	16	150	171.7613	155.9201	-155.9201	20.8412	.00467	.8016E+00
17	1	40	82.9753	166.6415	.00467	17	160	168.3697	153.8916	-153.8916	20.4782	.00467	.7857E+00
18	1	40	82.9753	163.0589	.00467	18	170	164.8502	151.7024	-151.7024	20.1478	.00467	.7683E+00
19	1	40	82.9753	159.2889	.00467	19	180	161.1739	149.3455	-149.3455	19.8284	.00467	.7521E+00
20	1	40	82.9753	154.9946	.00467	20	190	157.1417	146.8127	-146.8127	19.5290	.00467	.7333E+00
21	1	40	82.9753	150.1177	.00467	21	200	152.5661	144.0949	-144.0949	19.2471	.00467	.7120E+00
22	1	30	72.9753	144.9579	.00467	22	210	147.5478	141.1813	-141.1813	18.9365	.00467	.6886E+00

23	1	30	72.9753	139.4978	.00467
24	1	30	72.9753	133.7275	.00467
25	1	30	72.9753	127.5538	.00467
26	1	20	62.9753	121.3309	.00467
27	1	20	62.9753	114.7707	.00467
28	1	20	62.9753	107.9775	.00467
29	1	20	62.9753	100.9568	.00467
30	1	10	52.9753	93.7134	.00467
31	1	10	52.9753	86.2617	.00467
32	1	10	52.9753	78.6134	.00467
33	1	10	52.9753	70.8174	.00467
34	1	10	52.9753	62.8679	.00467
35	2	10	52.9753	54.2107	.00467
36	2	10	52.9753	42.8393	.00467

SEVUL = 1678.823
 SSUSC = 235.0325
 SBFO = 11.50409
 SPT = 1432.5286
 SDC = 925.3388
 SBCC = 246.5365
 STOP

23	220	142.2279	138.0594	-138.0594	4.1684	.00467	.6637E+00
24	230	136.6126	134.7150	-134.7150	1.8976	.00467	.6375E+00
25	240	130.6906	131.1309	-131.1309	2.4403	.00467	.6099E+00
26	250	124.4923	127.2868	-127.2868	2.7949	.00467	.5810E+00
27	260	118.0508	123.1585	-123.1585	5.1077	.00467	.5509E+00
28	270	111.3741	118.7163	-118.7163	7.3422	.00467	.5197E+00
29	280	104.4671	113.9235	-113.9235	9.4563	.00467	.4875E+00
30	290	97.3361	108.7336	-108.7336	11.3976	.00467	.4542E+00
31	300	89.4885	103.0869	-103.0869	13.0983	.00467	.4199E+00
32	310	82.4386	96.9033	-96.9033	14.4648	.00467	.3847E+00
33	320	74.7164	90.0726	-90.0726	15.3562	.00467	.3487E+00
34	330	66.8427	82.4338	-82.4338	15.5911	.00467	.3119E+00
35	340	58.5393	73.7363	-73.7363	15.1970	.00467	.2732E+00
36	350	48.1250	63.5470	-63.5470	14.4220	.00467	.2246E+00
37	360	.0000	50.9789	-50.9789	50.9789	.00000	.0000E+00

CHAPTER IV

COMBINED PENNY FRACTURE PROPPANT MODEL

The penny shaped fracture proppant model (PFP) consists of the PENNYC6 fracture model and the two-dimensional particle tracking proppant model. These programs can be run independently or linked through JCL statements where execution is done under one file name.

Pennyfrac Model

Program PENNYC6 determines the wellbore pressure, average pressure, wellbore width, and time of growth of a fracture of given radius. The program is run interactively.

The main program is M-PENNYC6 and the subroutine called LEAKOFF is used for time calculation. The program in Appendix A is written in Fortran and has been run on a Honeywell 6600/B3 and an IBM-PC.

The input parameters for MPEN.FOR in Appendix A are listed following this paragraph. The record number indicates each statement requiring input. Some statements require more than one piece of data. As an example, record 4 requires two pieces of data, consistency index, and behavior index for the fluid. Record 7 must be repeatedly guessed until LHS and RHS of Equation IV-2 in Part 1 of the Final Report Contract #DE-AC21-84MC21119 agrees within 1%. The difference is always given as positive so the LHS value must be compared to the RHS value so the value of R1RAT is not unknowingly exceeded. Then 7, 8, and 9 must be repeated setting R1RAT equal to 1.0 until record 10 appears. Remember, R1RAT is set equal to 1.0 after the first iterative value, which was less than one. Other records are entered in order until record 13. After a guessed value for ARI, record 14 is entered. If the guess for record 13 was good then a range of ARI values are established and record 15 is entered. If this

range is not established then a new ARI guess will be required until a range is found. Assuming record 13 was a good guess, the record order proceeds until number 17. If the value of Y at the bottom of the screen cannot be matched to a value of Z, which is the output of the 20 increments selected in record 16, then a one must be placed in record 17 and record 13 appears again. The process must be repeated until $Z \approx Y$. Once $Z \approx Y$ then proceed to the end, record 19.

Input Parameters

Record	Parameter	Example Value To Be Entered	Remark
1	RRZAT	100	Dimensionless radius R/R_0 where R is the final radius of the frac and R_0 is the radius of the wellbore.
2	IABE	0	If 1, value of K_C' and Q_D defined by Abe' et al. should be given; if not 1, other parameters should be input to calculate K_C' and Q_D .
3	KP	1.3877	$\bar{K}$, flow consistency index, in $\text{dyne-s}^n/\text{cm}^2$
	NP	0.615	n, flow behavior index
4	NU	0.22	ν , Poisson's ratio
	QZ	15	Pump rate, BPM
5	S	6800	In situ stress, psi
	E	4.8×10^6	Young's modulus, psi
	KC	1.32×10^8	Fracture toughness, $\text{dynes/cm}^{3/2}$
6	RZ	0.75	Radius of the wellbore, ft.
	KCP	--}	Values of K_C' and Q_D as defined by Abe' et al. (if IABE = 1)
	QD	--}	

7	R1RAT	0.999997472	R_1/R value. For small fractures ($R/R_0 < 100$), this value needs to be iterated until the LHS and RHS of Equation IV-2 in Part 1 agrees within 1%. For large fractures, it can be given as 1.0.
8	IQRL	1	Calculates $Q(r)/Q(o)$
9	IASSY	1	Asymptotic values (i.e., for $R_1/R \approx 1$) of frac B results calculated.
10	LHART	1	Time calculated using the leakoff coefficient.
11	Q	15	Pump rate, BPM
	LEAKC	0.0025	Leakoff coefficient, $\text{cm}/\sqrt{s}$
	SP	0.0	Spurt coefficient, cm
	RO	0.75	Radius of well, ft.
12	RRAT	100	R/R_0
13	ARI	0.91	Value of α in Equation IV-22 in Part 1; guess or value of α^{-2} /of α .
14	ERF1	0.8018828034	Value of the error function [or $\alpha e^{\alpha^2} \text{erfc}(\alpha)$]
15	ERF2	0.7969081998	Error function corresponding to $ARI + 0.01$ or $\alpha e^{\alpha^2} \text{erfc}(\alpha)$ corresponding to $ARI + 0.005$.
16	INC	20	No. of increments between old and new ARI values.
17	ITL	0	If one value of $Z \neq Y$, input 1 so that the calculation will be repeated using new α .

18	TT	0.01355503	Total treatment time, HRS, obtained from the program such that $Z=Y$; to be used in the proppant model.
19	ICHECK	0	Input 1 if the program is to be run with new R/R_0 .

The program has two output files. One is MPEN.OUT, described in Appendix B, which contains all the results during the computations. The other is MPEN.IN, described in Appendix C, which contains just the information needed for the proppant transport model.

The output file MPEN.IN (in Appendix C) contains 24 records. These records supply necessary fracture information to the proppant section. Output, from PENNYC6 to MPEN.IN, is made in free format. The variables by record are:

Record	Variable	Units	Name
1	RRZAT		Dimensionless Radius
2	KP, NP	dyne-s ⁿ /cm ² ,	Consistency Index
			Behavior Index
3	QZ	bpm	Pumping Rate
4	RZ	ft.	Wellbore Radius
5-22	RLRAT, QRLZ		
23	WIDTHB	cm	Wellbore Width
24	TT	sec.	Total Treatment Time

Procedure for Running the Program

The program is run interactively, and is rather self-explanatory. However, the following items should be borne in mind when running the program.

1. R1RAT, the ratio R_1/R . R_1 is the radius of the pressurized zone. For small values of R/R_0 , R1RAT is obtained by iteration such that Equation IV-2 in Part 1 of the Final Report for Contract DE-AC21-84MC21119 is satisfied. Then the wellbore

pressure is obtained from Equation IV-3 in Part 1 of the Final Report for Contract DE-AC21-84MC21119. It has been observed that for $R/R_0 > 100$, the unwetted region is of negligible extent (i.e., $R_1/R=1$) and the asymptotic value of $P(o)$ can be obtained from Equation IV-5.

2. The program is coded that it will run first with effective viscosity, $\bar{\mu}$ = the consistency index, k , of the fluid. The width obtained here is used to calculate new $\bar{\mu}$ value from Equation IV-13. An iteration on width is continued each time using $\bar{\mu}$ calculated using the previous width.
3. The QRLZ values given are $q(r)/q(o)$ defined by Equation IV-9.
4. The leakoff coefficient is used only in the time calculation. The time is solved from Equations IV-22 and IV-23 in Part 1 of the Final Report for Contract DE-AC21-84MC21119. For this equation IV-23 is rewritten as

$$\frac{6 \pi^2 c^2 R^2}{Q(o)} \frac{1}{W_{we} + 3 Sp} = \frac{2\alpha}{\sqrt{\pi}} - 1 + e^{\alpha} \operatorname{erfc}(\alpha)$$

The left hand side is set equal to Y . A value of α is guessed and the right hand side is evaluated as Z . Tables are used for obtaining error functions (erf) or complementary error functions (erfc). A table is given in Appendix H. By trial and error method the correct value of α is determined so that $Z=Y$. Then t is calculated from (IV-22). Sometimes interpolation may be needed. It is seen that if $Y < 1.512154034$, the error function table should be used. Otherwise, the table of complementary error functions should be used.

Two-Dimensional Fluid Flow Proppant Transport Model

Since the penny shaped fracture had radial fluid flow characteristics, a new proppant model using two-dimensional fluid flow was developed. The theory and development is given in the Final Report for Contract DE-AC21-84MC21119. Therefore, only the input parameters and output will be discussed further.

The proppant model in Appendix D is named PENNPROP. It contains 11 subroutines. All of these routines are included under the main program name PENNPROP. They are:

1. KUTTA This routine solved the 4th order Runge Kutta equation in Part 3, Chapter 3, Appendix A, of the Final Report utilizing 3 function subroutines.
2. FX This function subroutine is used by KUTTA to find the position of the particle in x.
3. FY This function subroutine is also used by KUTTA to solve for the y position of the particle.
4. CD This function subroutine is used by FX and FY to find the coefficient of drag on the particle.
5. FLOWFD This subroutine is used by the main program to find the fluid velocity on the particle at its new location calculated by the Runge Kutta numerical method.
6. NATCUS This is a subroutine used to establish piece-wise-cubic spline coefficients for the non-dimensionalized radius and flow data from PENNYC6.
7. CUBVAL This subroutine is used in FLOWFD to find the flow rate at a particular radial position. It uses the coefficients produced by NATCUS.

8. BEDHT This subroutine calculates the position of the top of the proppant bed in cartesian and polar coordinates for small angle increments.
9. BEDEQ This subroutine calculates the position of the top of the proppant bed in cartesian and polar coordinates when the entire range of angular increments is summed.
10. BEDEQ1 This subroutine calculates the position of the top of the proppant bed in cartesian and polar coordinates when intermediate summing occurs.
11. BEQSM This subroutine is used to evaluate the coordinates associated with top of the bed to ensure the volume of proppant was distributed properly.

Input

The proppant input file for PENNPROP is called PPDAT.IN. This file contains proppant parameters, numerical controls and printing controls for the output. The input file is unformatted with the exception of the initial vector angles for the radial stream lines. The input data are:

Record	Variable	Units	Name
1	NTHETA		Number of Angles, Integer
2	THETA0	degrees	Vector Angle, Real, 11F5.1
3	"		
4	"		
5	RHO	lbm/cu.ft.	Density of Proppant, Real
6	RHOF	lbm/cu.ft.	Density of Fluid, Real
7	DT	sec.	Time Step, Real
8	IPRINT		Print Control, Integer
9	T0	sec.	Initial Time, Real
10	W0	bpm	Initial Particle Velocity, Real
11	D	in.	Particle Diameter, Real
12	GR	ft./s ²	Acceleration of Gravity, Real
13	PDT	sec.	Pad Time, Real
14	CON	lb./gal. of slurry	Concentration of Slurry, Real
15	PHI		Proppant Porosity, Real
16	NPRT1		Output, Control, Integer
17	SF		Starting Factor, Real

An input sample is shown in Appendix E. The values given for THETA0 represent a realistic distribution of initial vectors. These angles seemed to give the best results during computation. Fewer angles are not recommended and more angles will increase computation time significantly.

Time steps, DT, greater than 0.1 sec. will generally not allow the fourth order Runge-Kutta routine to operate. Should this occur the following message will appear on the screen, "you must decrease the time increment." The amount of particle tracking data written to the output file is controlled by the print control, IPRINT. The time increments between 0 and the final particle time is given by

$$\text{Printing Time Step} = \text{DT} \times \text{IPRINT}.$$

Thus, input from Appendix E will give a printing time step of 5 sec. DT and IPRINT must be changed together to maintain a desired time step should DT need to be decreased. Small decreases in DT will require much more computer time. Thus, as large a value of DT as possible should be used.

The particle velocity is given in non standard units of bpm to simplify establishing the initial velocity of the particle. Using these units of flow, the particle speed may be adjusted relative to the fluid flow speed without computation of the fluid velocity in ft./sec. Thus, consider the flow units of the particle are artificially imposed and do not consider particle density when the speed of the particle is calculated.

Since only so much proppant volume is allowed due to theory, the pad time, PDT, and concentration, CON, become the primary control. The porosity will also be a minor controlling factor. Should the pad time be insufficient for the maximum volume, then the following message is displayed, "you must decrease concentration and/or increase pad time." If

a particle treatment were done, but an intermediate summation fails, then the message will read, "proppant calculation partially complete but you must decrease concentration and/or increase pad time."

The Output Control is used to suppress particle tracking output. If a zero is entered only the input information is written to the output file. If a one is entered then particle tracking information is written to the output file at the interval established by DT and IPRINT. Suppression of particle tracking will decrease total program run time. This is especially true for very small printing time steps.

Setting the starting factor at 1.0 references all starting values for the proppant section to the wellbore radius, RZ. During program evaluation, much more reasonable starting velocities were found around a distance 10 times that of the wellbore diameter. Thus, a factor of 10.0 for an RZ of .75 feet proved to be reasonable for fracture radii from 75 feet out to 500 feet. For radii below 75 feet, the starting factor may be reduced toward a value of 1.0. The starting factor should never be set less than 1.

Two other error messages can appear on the screen. One is "put in a proppant diameter less than W_w " where W_w is the value of the wellbore width. This message is an indication that the proppant diameter, D, selected is greater than the wellbore width. Thus, no proppant can enter the fracture. The other is "you must increase the print control number or increase the time step if possible." This message indicates that printing time steps are too small. The current cut-off for the number of printed values is set at 200. This insures that array sizes for suspension height coordinates will not be exceeded.

Output

Output from the proppant section, shown in Appendix E, is contained in two files. The first file is called PPDAT.OUT. An example of this file is shown in Appendix F. The second file is PPDAT.PLT. Appendix G contains an example of PPDAT.PLT.

PPDAT.OUT has two parts. The second part may be suppressed as discussed previously. The first part is an output of input data from MPEN.IN and PPDAT.IN. Not all input data is output. The second part is particle tracking information at each initial vector angle. At each angle, time is output at the printing time interval giving particle position, particle velocity, and fluid velocity by cartesian coordinates in feet.

PPDAT.PLT has no column description, so this data can be used directly as input data for plotting software. Column headings would be as follows:

Fracture Geometry
at .99 of Radius, ft.

x	y
.	.
.	.
.	.

One Particle Diameter
Geometry, ft.

x	y
.	.
.	.
.	.

Top of Suspension, ft.

x	y
.	.
.	.
.	.

Top of Bed, ft.

x	y
.	.
.	.
.	.

The examples of output data were obtained from input data shown in the examples in the appendices. Both programs were compiled and run on an

IBM PC AT using IBM Professional Fortran Version 1.0. Any IBM or IBM compatible machine which can support a Fortran compiler should be able to run these programs once they have been properly compiled and linked using the correct job control language for the hardware and software. The Fortran language used is Fortran 77. If the input parameters are correct, the proppant section should run requiring no other inputs. The proppant section is not interactive as is the fracture program.

CHAPTER IV

APPENDIX A

MPEN.FOR (PENNYC6)
LEAKOFF.FOR (LEAKOFF)

```

C *****
C
C M-PENNYC6B: SIMILAR TO PENNYC5 WITH SOME MODIFN TO INCLUDE 129
C (070186) DIFFERENT LEAKOFF FACTOR THEN ROBERT HART'S FACTOR
C AND ADDITION TO INCLUDE NON-NEWTONIAN FLUID FLOW
C IN CALCULATING MUBAR.
C R.H.'S DEF: WZ = WIDTH OR WIDTHHUP Q = QZ
C RO = RZ
C MUBAR --> NON-NEWTONIAN FLOW (2 CONST : K" & N")
C LINK: PENNYC6 LEAKOFF DASHIN FORT.LB
C FACTOR=(WZ + 3.*SP)/3. INSTEAD OF ROBERT HART'S LEAKOFF FACTOR.
C =(8.*WZ + 27.*SP)/27.
C *****
      REAL KC,NU,KP,NP,MUBAR
      REAL QZ,E
      DOUBLE PRECISION R1RAT,F,G,PBS,LHS,H1,H2,H,EZ,RHS,
C          RRZAT,RZ,KCP,QD,PZS,WD,QRLZ,R,RL,P,PBUL,PZUL,
C          WDUL,S,RLRAT

      INTEGER IABE
      COMMON/XBLOC/PI,RRZAT,RZ,WIDTH,QZ

      OPEN (UNIT=1, FILE='MPEN.OUT')
      OPEN (UNIT=4, FILE='MPEN.IN')
      OPEN (UNIT=5, FILE='CON')

1000      IWT=0
          PI=3.141592654
          IQ=0.
          WRITE(5,20)
20          FORMAT(' INPUT: R/R(0) ')
          READ *, RRZAT
          WRITE(5,30) RRZAT
          WRITE(1,30) RRZAT
          WRITE(4,*) RRZAT
30          FORMAT(' R/R(0)= ',F13.6)
C
          WRITE(5,40)
40          FORMAT('/ HIT 1 IF YOU WANT TO USE ABE'S KC" & QD ')
          READ *, IABE
          WRITE(5,1) IABE
          WRITE(1,1) IABE
1          FORMAT(' IABE = ',I5)
          IF(IABE.EQ.1.) GOTO 2400
C
C      INPUT PARAM TO CALC KC" AND QD **
          WRITE(5,48)
48          FORMAT(' INPUT PARAMETERS TO CALC KC" & Q(D): ')
          WRITE(5,49)
49          FORMAT(' INPUT: K" AND N" TO CALC NON-NEWTONIAN FLOW ')
          READ *, KP,NP
          WRITE(5,50) KP,NP
          WRITE(1,50) KP,NP
          WRITE(4,*) KP,NP
50          FORMAT(' K"= ',E13.6,' N"= ',E13.6)

C      FOR NEWTONIAN FLOW, SET N"= 1.
C
C      INITIALIZE MUBAR TO K" FOR THE FIRST CALCN OF WIDTH (W(0))
          MUBAR = KP
C
          WRITE(5,51)

```



```

51 C FORMAT(/' NU(POISSON'S CONST), QZ(FLOW RATE AT WELLBORE',
    C ' IN BPM) ')
    READ *, NU,QZ
    WRITE(5,52) NU,QZ
    WRITE(1,52) NU,QZ
    WRITE(4,*) QZ
52 FORMAT(' NU= ',F5.2,' QZ= ',F5.2)

C INPUT ABE'S VALUE FOR KC* AND Q(D) **
    WRITE(5,53)
53 C FORMAT(/' S(STRESS CONST IN PSI), E(YOUNG'S MOD IN PSI),',
    C ' KC(FRACTURE TOUGHNESS IN CGS) ')
    READ *, S,E,KC
    WRITE(5,54) S,E,KC
    WRITE(1,54) S,E,KC
54 C FORMAT(' S= ',E13.6,' E= ',E13.6,' KC= ',E13.6)
    WRITE(5,55)
55 C FORMAT(/' RZ(THE RADIUS AT WELLBORE IN FEET) ')
    READ *, RZ
    WRITE(5,56) RZ
    WRITE(1,56) RZ
    WRITE(4,*) RZ
56 C FORMAT(' RZ= ',F8.2)

C
C CONVERSION OF INPUT TO CGS UNITS **
    QZ = QZ * 2640.
    S = S * 68940.
    E = E * 68940.
    RZ = RZ * 30.48
C SET ICOUNT TO 1; ICOUNT CHECKS IF THIS IS THE FIRST TIME CALCN
    ICOUNT = 1.
C
C TO CALC KC* & Q(D) **
    KCP = PI*KC / (S*DSQRT(2.*RZ))
2300 CP = S**4*RZ**3*PI / (6.*MUBAR*QZ) * (8.*(1.- NU**2)/(PI*E))**3
    QD = 1./CP
C RESET I CALC TO 0.
    I CALC = 0.
    GOTO 2450
C
C TO INPUT ABE'S KC* & QD **
2400 C WRITE(5,120)
120 C FORMAT(' INPUT ABE'S VALUE OF : KC*, Q(D) ')
    READ *, KCP,QD
2450 C WRITE(5,130) KCP,QD
    WRITE(1,130) KCP,QD
130 C FORMAT(' KC*= ',E13.6,' Q(D)= ',E13.6)

C
C GUESS VALUE FOR R1/R (R1RAT) **
2500 C WRITE(5,140)
140 C FORMAT(' GUESS: R1/R ')
    READ *, R1RAT
    WRITE(5,150) R1RAT
    WRITE(1,150) R1RAT
150 C FORMAT(' R1/R= ',E16.9)

C
C IF R1/R HAS MORE THAN TEN 9S THEN USE ASYMPTOTIC CALCNS **
    IF(R1RAT.GE.0.9999999999) GOTO 5000
C
C TO COMPUTE PBAR/S, DR/DT, LHS, RHS OF EGNS **

```

```

2600 F = DSQRT(1.- R1RAT**2)
      G = DSQRT(1./R1RAT**2 - 1.)
      PBS = (KCP*DSQRT(1./RRZAT) + 1.)/(1.- F)
      IF (IQ.EQ.1.) GOTO 2700
      LHS = PBS*(PBS - 1.)**3
2700 H1 = 3.*(PBS - 1.)*(1.- F)
      H2 = R1RAT*PBS*(1.-R1RAT)/F
      H = (1.- F)/(H1 - H2 - KCP/2.*DSQRT(1./RRZAT))
      EZ = (1.+R1RAT)*DLOG(1.+R1RAT)-(1.-R1RAT)*DLOG(1.-R1RAT)
      IF (IQ.EQ.1.) GOTO 2800
      RHS = QD/RRZAT**3 *(1.+ 3.*H*(PBS - 1.)*(EZ/(2.*R1RAT) - 1.
C      - DLOG(R1RAT*G)))
C
C ARE THEY EQUAL?
      DIF = ABS(LHS-RHS)/LHS*100.
      WRITE(5,160) LHS,RHS,DIF
      WRITE(1,160) LHS,RHS,DIF
160  FORMAT(// LHS= ',E13.6,' RHS= ',E13.6,' DIF= ',F13.6)
      IF(DIF.GT.0.01) GOTO 2500
C
C TO COMPUTE P(0)/S & WD(1) WITH THE BEST R1/R VALUE **
      PZS = PBS + QD/(PBS - 1.)**3 *1./RRZAT**3 *(DLOG(R1RAT*RRZAT) -
C      1. + 3.*H*(PBS - 1.)*(1.- EZ/(2.*R1RAT)))
      WD = (PBS - 1.)*RRZAT
C
C WIDTH = WELLBORE WIDTH IN CM **
      WIDTH = WD * 8.*(1.- NU**2)*RZ*S / (PI*E)
      WRITE(5,161) WIDTH
      WRITE(1,161) WIDTH
161  FORMAT(// WELLBORE WIDTH(CM) = ',F13.6)
C
C TO CALC FLOW RATE, Q(RL)/Q(0) **
C QRLZ = Q(RL)/Q(0) QZ IS NOT EQUAL TO Q(0)
C QZ = 2.*PI*RZ*Q(0) / DENSITY
      WRITE(5,165)
165  FORMAT(// HIT 1 IF YOU WANT TO CALC Q(RL)/Q(0) '
C      // WITH RL/R = .1 TO .9 & .91 TO .99 ')
      READ *, IQRL
      WRITE(5,2) IQRL
      WRITE(1,2) IQRL
2    FORMAT(' IQRL = ',I5)
      IF (IQRL.NE.1.) GOTO 4500
C
2800 R = RRZAT * RZ
      RLRAT = 0.1
C DO-LOOP TO CALC Q(RL)/Q(0) FROM RL/R= .1 TO .9 **
      DO 4300 I=1,9,1
        RL = RLRAT * R
        P = R**2 - RL**2
        QRLZ = RZ/RL *( 1.- 3.*H/R*(PBS - 1.)*(R - DSQRT(P))
C        - 1./R**3*(1.- 3.*H*(PBS - 1.))
C        *(R**3 - DSQRT(P**3)) )
C      TO CALC ALPHA USING Q(RL) **
      ALPHA = DLOG(1.- QRLZ) / DLOG(RLRAT)
C
      WRITE(5,166) RLRAT,QRLZ,ALPHA
      WRITE(1,166) RLRAT,QRLZ,ALPHA
      IF (R1RAT.GE..999999999900.AND.IWT.EQ.0)
C      WRITE(4,*) RLRAT,QRLZ

```

```

166 C      FORMAT(' RL/R= ',F6.4,' Q(RL)/Q(0)= ',
C          ,E13.6,' ALPHA= ',F13.6)
4300 RLRAT = RLRAT + 0.1
C
C      RLRAT = .91
C      DO-LOOP TO CALC Q(RL)/Q(0) FROM RL/R= .91 TO .99 **
C
C      DO 4400 J=1,9,1
C      RL = RLRAT * R
C      P = R**2 - RL**2
C      QRLZ = RZ/RL *( 1.- 3.*H/R*(PBS - 1.)
C          *(R - DSQRT(P))- 1./R**3*(1.- 3.*
C          H*(PBS - 1.))*R**3 - DSQRT(P**3)) )
C      TO CALC ALPHA USING Q(RL) **
C      ALPHA = DLOG(1.- QRLZ) / DLOG(RLRAT)
C
C      WRITE(5,167)RLRAT,QRLZ,ALPHA
C      WRITE(1,167) RLRAT,QRLZ,ALPHA
C      IF (R1RAT.GE..9999999999D0.AND.IWT.EQ.0)
C          WRITE(4,*) RLRAT,QRLZ
167 C      FORMAT(' RL/R= ',F6.4,' Q(RL)/Q(0)= ',
C          ,E13.6,' ALPHA= ',F13.6)
4400 RLRAT = RLRAT + 0.01
C      IF (R1RAT.GE..9999999999D0) IWT=1
C
C      IF (IQ.EQ.1.) GOTO 5100
C
C      WRITE OUT RESULTS **
C
4500 WRITE(5,170)
C      WRITE(1,170)
170 C      FORMAT('/' -----',
C          , '-----')
C      WRITE(5,180) RRZAT,R1RAT,PBS,PZS,WD,WIDHUL
C      WRITE(1,180) RRZAT,R1RAT,PBS,PZS,WD,WIDHUL
180 C      FORMAT(' R/R0= ',F13.6/' R1/R= ',E15.9/' P-BAR/S= ',F13.6/
C          , ' P(0)/S= ',F13.6/' WD(1)= ',F13.6/
C          , ' WELLBORE WIDTH(CM) = ',F13.6)
C
C      WRITE(5,181)
181 C      FORMAT('/' HIT 1 IF YOU WANT ASSYMPTOTE VALUE OF PBAR/S, P(0)/S
C          READ *, IASSY
C          IF (IASSY.NE.1.) GOTO 5010
C
C      5000 CONTINUE
C
C      TO CALC THE ASSYMPTOTE VALUES OF P-BAR/S & P(0)/S (I.E. AT R1=R)
C
C      PBUL = KCP*DSQRT(1./RRZAT) + 1.
C      PZUL = PBUL + QD/(PBUL - 1.)*3 *(1./RRZAT)**3*(DLOG(RRZAT)
C          - 1. + .3682)
C      WDUL = (PBUL - 1.)*RRZAT
C      WIDHUL = WELLBORE WIDTH(UPPER LIMIT) IN CM **
C
C      WIDHUL = WDUL * 8.*(1.- NU**2)*RZ*S / (PI*E)
C      IF (R1RAT.GE.0.9999999999) WIDTH=WIDHUL
C
C      WRITE(5,182) PBUL,PZUL,WDUL,WIDHUL
C      WRITE(1,182) PBUL,PZUL,WDUL,WIDHUL
182 C      FORMAT('/' ( P-BAR/S )QS = ',F13.6/' ( P(0)/S )UL = ',F13.6/
C          , ' ( WD(1) )UL = ',F13.6/' ( WELLBORE WIDTH(CM) )UL = ',
C          , F13.6)
C
C      ASSIGN PBUL TO PBS FOR ITERATION PURPOSES **

```

```

                    PBS = PBUL
5010                WRITE(5,190)
                    WRITE(1,190)
190                FORMAT('-----',
C                    '-----')
C
                    IF (RIRAT.LT.0.9999999999) GOTO 5100
                    WRITE(5,195)
                    WRITE(1,195)
195                FORMAT('/' HIT 1 IF YOU WANT TO CALC Q(RL)/Q(0) ')
                    READ *, IQ
                    WRITE(5,3) IQ
                    WRITE(1,3) IQ
3                    FORMAT(' IQ = ',I5)
                    IF (IQ.NE.1.) GOTO 5100
                    RIRAT = 0.999999999999D0
                    GOTO 2600
C
5100                CONTINUE
C
C -----
C CALC MUBAR AND COMPARE WITH INITIALISATION OF MUBAR=K*
C
C      C1 = 2.*PI*KP/(3.*(3.-NP))*((2.+ 1./NP)/PI)**NP
C      * 1./((QZ)**(1.- NP))
C      R = RRZAT * RZ
C      MUBAR = C1 * (R*WIDTH**2)**(1.-NP)
C      WRITE(5,196) MUBAR
C      WRITE(1,196) MUBAR
196                FORMAT(' MUBAR= ',E13.6)
C
C      TO CALC ANOTHER WIDTH
C
C      IF (ICALC.EQ.1.) GOTO 2300
C      IF(ICOUNT.NE.1.) GOTO 197
C      WIDTHA = WIDTH
C      ICOUNT = ICOUNT + 1.
C      TO CALC WIDTHB USING THE NEW MUBAR **
C      GOTO 198
197                WIDTHB = WIDTH
C      WIDIF = ABS(WIDTHB - WIDTHA)/WIDTHA * 100.
C      WRITE(5,1971) WIDTHA,WIDTHB,WIDIF
C      WRITE(1,1971) WIDTHA,WIDTHB,WIDIF
1971               FORMAT('/' WIDTHA= ',F13.6,' WIDTHB= ',F13.6,' WIDIF= ',F13.6)
C      IF (WIDIF.GT.0.01) GOTO 199
C      GOTO 5110
198                GOTO 2300
C
199                CONTINUE
C
C      IF WIDTHS DIFFER THEN SET ICALC=1 TO GENERATE ANOTHER WIDTH
C      ICALC = 1.
C      WIDTH DIFFERENCE IS GREAT SO ASSIGN WIDTHB TO WIDTHA **
C      WIDTHA = WIDTHB
C      WRITE WIDTH VALUES TO CHECK
C      WRITE(5,1991) WIDTH,WIDTHA,WIDTHB
C      WRITE(1,1991) WIDTH,WIDTHA,WIDTHB
1991               FORMAT('/' WIDTH= ',F13.6,' WIDTHA= ',F13.6,' WIDTHB= ',F13.6)
C      RETURN TO MUBAR CALCN
C      GOTO 2300
C
C
C      ELSE IF THEY DIFFER BY < 0.01  CALC TIME FROM LEAKOFF SUBR
C      -----

```

134

```

5110  WRITE(5,200)
      WRITE(1,200)
      WRITE(4,*) WIDTHB
200   FORMAT(/' HIT 1 IF YOU WANT ROB.HART'S LEAKOFF CALCNS ')
      READ *, LHART
      WRITE(1,4) LHART
      WRITE(5,4) LHART
4     FORMAT(' LHART =',I5)
      IF(LHART.NE.1.) GOTO 5200
      IF (RIRAT.GT.0.9999999999) WIDTH = WIDHUL
      CALL LKOFF1(WIDTH,QZ)
C
5200  CONTINUE
      WRITE(5,210)
      WRITE(1,210)
210   FORMAT(/' HIT 1 IF YOU WANT TO RUN PROGRAM AGAIN ')
      READ *, ICHECK
      WRITE(1,5) ICHECK
      WRITE(5,5) ICHECK
5     FORMAT(' ICHECK =',I5)
      IF(ICHECK.EQ.1.) GOTO 1000
C
      CLOSE (UNIT=1)
      CLOSE (UNIT=4)
      CLOSE (UNIT=5)
      END

```

```

SUBROUTINE LKOFF1 (WZ,Q)
C*****
C THIS IS SUBROUTINE S-LEAKOFF LINKED TO M-PENNYC6B-- 135
C INPUT- Q , SP , C , AND RO
C OUTPUT-CALCULATES THE TIME FOR THE FRACTURE W/O LEAKOFF.
C*****
REAL LEAKC
PI = 3.141592654

C
WRITE(5,31)
31 FORMAT(' INPUT Q(BPM), LEAKC(CGS), SP(CGS), AND RO(FT) ')
READ *,Q,LEAKC,SP,RO
WRITE(5,32)Q,LEAKC,SP,RO
WRITE(1,32)Q,LEAKC,SP,RO
32 FORMAT(' Q(BPM) =',F5.1,2X,' LEAKC(CGS) =',F8.6,
C 2X,' SP(CGS)= ',F8.6,2X,' RO(FT)= ',F8.6)
Q=Q*2640.
C=LEAKC
RO=RO*30.48
C INPUT THE R/RO RATIO FOR THE FRACTURE
WRITE(5,10)
10 FORMAT(' INPUT VALUE FOR R/RO ')
READ *, RRAT
WRITE(5,20) RRAT
WRITE(1,20) RRAT
20 FORMAT(' R/RO =',F6.0)
C R CAN BE CALCULATED BY LETTING RO EQUAL .75' OR 22.86CM
R = RRAT * RO

C
C
C Y IS THE QUANTITY OF THE EQUATION:
C
C 
$$R^{**2} = \frac{Q}{2 * (PI^{**2}) * (C^{**2})} * \left( \frac{WOE}{3} + \frac{3 * SP}{3} \right)$$

C
C THEREBY ISOLATING  $(2*ALPHA/SQRT(PI))-1 + e^{**}(ALPHA^{**2})*ERFC\ ALPHA$ 
C
C 
$$Y = 6 * (PI * C * R)^{**2} / (Q * (WZ + 3 * SP))$$

WRITE(5,42) Y
42 FORMAT(' Y=',F18.12)
C
C IF Y IS LESS THAN 1.275469274 THEN THE TABLE TITLED: " ERROR FUNCTION
C & ITS DERIVATIVE " IS TO BE UTILIZED, CONVERSELY IF Y IS GREATER
C THAN 1.275469274 THEN THE TABLE TITLED " COMPLEMENTARY ERROR
C FUNCTION " IS TO BE USED
C44 IF ( Y.GT.1.275469274 ) GOTO 200
C
C 8/29/86 IT SEEMS THAT IF Y > 1.512154034
C (NOT 1.275469274) COMPLIMENTARY ERF SHOULD BE USED.
C
44 IF (Y.GT.1.512154034) GO TO 200
WRITE(5,45)
45 FORMAT(' INPUT DATA FROM TABLE TITLED : ',
& 'ERROR FUNCT. & ITS DERIVATIVE')
47 WRITE(5,50)
50 FORMAT(' GUESS ALPHA ')
READ *, ARI
WRITE(5,60) ARI
WRITE(1,60) ARI
60 FORMAT(' ALPHA1 =',F6.2)
C
WRITE(5,70)ARI
70 FORMAT(' INPUT ERF(X) FOR ',F6.2 )

```

```

      READ *, ERF1
      WRITE(5,80) ARI,ERF1
      WRITE(1,80) ARI,ERF1
80    FORMAT(' ERF1 FOR ',F6.2,' IS ',F15.10 )
C
C    ACCORDING TO THE TABLE ERFC = 1 - ERF
      VALI = 1.- ERF1
      WRITE(5,81)VALI
      WRITE(1,81)VALI
81    FORMAT(' VALI   = ',F12.6)
      ERFCI1 = (EXP(ARI**2))* VALI
      Z = (2.* ARI)/(SQRT(PI)) - 1. + ERFCI1
C
      WRITE(5,810)Z,Y
      WRITE(1,810)Z,Y
810   FORMAT(' Z= ',F18.12,5X,' Y= ',F18.12)
C
      IF (Z.GT.Y) GOTO 811
      WRITE(5,812)
812   FORMAT(' Z<Y; NEW Z TO BE CALCULATED ')
      GO TO 47
811   ARJ = ARI - 0.01
C
      WRITE(5,82) ARJ,ARI
82    FORMAT(' THE VALUE OF ALPHA(R) LIES BETWEEN',F6.2,' &',F6.2)
C
      WRITE(5,85) ARJ
85    FORMAT(' ALPHA2 =',F6.2)
      WRITE(5,90) ARJ
90    FORMAT(' INPUT ERF(X) FOR ',F6.2 )
      READ *, ERF2
      WRITE(5,100) ARJ,ERF2
      WRITE(1,100) ARJ,ERF2
100   FORMAT(' ERF2 FOR ',F6.2,' = ',F15.10 )
C
      VALJ = 1.- ERF2
      ERFCJ2 = (EXP(ARJ**2))* VALJ
      E = VALI - VALJ
C
C    THE TIME FOR THE FRACTURE WITH LEAKOFF IS PRINTED WITH EACH VALUE
C    ALPHA. THE ACTUAL TIME WILL BE FOUND BY COMPAIRING THE Z VALUE WI
C    CALCULATED Y VALUE
C
      WRITE(5,110)
110   FORMAT(' INPUT THE NUMBER OF ITERATIONS DESIRED,USUALLY 20')
      READ *, INC
      RINC = 0.01 / FLOAT(INC)
      ARK = ARJ
      DO 116 I = 1,20
        ARK = ARK + RINC
        B = ARK - ARJ
        VALU = B * E / 0.01
        VALK = VALJ + VALU
        ERFCCK = (EXP(ARK**2))*VALK
        Z = ((2.* ARK)/(SQRT(PI))) - 1. + ERFCCK
        TSQRT = ( ARK * ( WZ + 3.*SP))/( 3.*C*(SQRT(PI)))
        TSEC = TSQRT **2
        THRS = TSEC / 3600.
        WRITE(5,115)Z,ARK,THRS
        WRITE(1,115)Z,ARK,THRS
115   FORMAT(' Z =',F12.10,3X,' ALPHA =',F7.4,3X,' THRS =',F12.8)
116   CONTINUE

```

```

C          GOTO 2000
C
C
C
C
C
190      WRITE(5,191)
191      FORMAT(' INPUT THE NEXT GUESS OF ALPHA ')
      GOTO 221
C
200      WRITE(5,210)
210      FORMAT(' INPUT DATA FROM TABLE TITLED: ',
      &      ' COMPLEMENTARY ERROR FUNCTION')
      WRITE(5,220)
220      FORMAT(' INPUT (X)**-2 ')
221      READ *, ARI
      WRITE(5,230) ARI
      WRITE(1,230) ARI
230      FORMAT(' ALPHA ** -2 =',F6.4)
C
      ALPHA3 = ARI **(-0.5)
      WRITE(5,231) ALPHA3
      WRITE(1,231) ALPHA3
231      FORMAT(' ALPHA3=',F15.12)
C
      WRITE(5,240)
240      FORMAT(' INPUT COMPLEMENTARY ERROR FUNCTION VALUE ')
      READ *, ERROR3
      WRITE(5,250) ERROR3
      WRITE(1,250) ERROR3
250      FORMAT(' ERROR FUNCTION =',F9.7)
      XERFC3 = ERROR3 / ALPHA3
C
      Z3 = (2.*ALPHA3)/(SQRT(PI))-1.+ XERFC3
      WRITE(5,251)Z3,Y
      WRITE(1,251)Z3,Y
251      FORMAT(' Z3= ',F18.12,5X,' Y =',F18.12)
      IF (Z3.GT.Y) GOTO 252
      WRITE(5,253)
253      FORMAT(' Z3 < Y; NEW Z3 TO BE CALCULATED ')
      GO TO 190
252      ARJ = ARI + 0.005
      ALPHA4 = ARJ **(-0.5)
      WRITE(5,255) ARI,ARJ
255      FORMAT(' THE VALUE LIES BETWEEN ',F5.3,' AND ',F5.3)
      WRITE(5,260) ARJ
      WRITE(1,260) ARJ
260      FORMAT(' INPUT COMPLEMENTARY ERROR FUNCTION FOR ',F5.3)
      READ *, ERROR4
      WRITE(5,280)ERROR4
      WRITE(1,280)ERROR4
280      FORMAT(' ERROR FUNCTION = ',F9.7)
C
      XERFC4= ERROR4 / ALPHA4
      Z4 = (2*ALPHA4)/(SQRT(PI))-1. + XERFC4
C
      E = ERROR4 - ERROR3
      WRITE(5,283)E
283      FORMAT(' E =',F15.12)
      ARK = ARI
      WRITE(5,285)
285      FORMAT(' INPUT THE NUMBER OF ITERATIONS, USUALLY 20')
      READ *, INC
      RINC = 0.005 / FLOAT(INC)

```


CHAPTER IV

APPENDIX B

MPEN.OUT

R/R(0)= 100.000000
 IABE = 0
 K*= 0.138770E+01 N*= 0.615000E+00
 NU= 0.22 QZ= 15.00
 S= 0.680000E+04 E= 0.480000E+07 KC= 0.132000E+09
 RZ= 0.75
 KC*= 0.130825E+00 Q(D)= 0.463230E+00
 R1/R= 0.999997472E+00

LHS= 0.368359E-05 RHS= 0.368355E-05 DIF= 0.000860

WELLBORE WIDTH(CM) = 0.120583
 IQRL = 1
 RL/R= 0.1000 Q(RL)/Q(0)= 0.996983E-01 ALPHA= 0.045612
 RL/R= 0.2000 Q(RL)/Q(0)= 0.493828E-01 ALPHA= 0.031467
 RL/R= 0.3000 Q(RL)/Q(0)= 0.323719E-01 ALPHA= 0.027332
 RL/R= 0.4000 Q(RL)/Q(0)= 0.236481E-01 ALPHA= 0.026119
 RL/R= 0.5000 Q(RL)/Q(0)= 0.181889E-01 ALPHA= 0.026483
 RL/R= 0.6000 Q(RL)/Q(0)= 0.142959E-01 ALPHA= 0.028188
 RL/R= 0.7000 Q(RL)/Q(0)= 0.112045E-01 ALPHA= 0.031591
 RL/R= 0.8000 Q(RL)/Q(0)= 0.846260E-02 ALPHA= 0.038086
 RL/R= 0.9000 Q(RL)/Q(0)= 0.562995E-02 ALPHA= 0.053586
 RL/R= 0.9100 Q(RL)/Q(0)= 0.531276E-02 ALPHA= 0.056483
 RL/R= 0.9200 Q(RL)/Q(0)= 0.498306E-02 ALPHA= 0.059912
 RL/R= 0.9300 Q(RL)/Q(0)= 0.463776E-02 ALPHA= 0.064055
 RL/R= 0.9400 Q(RL)/Q(0)= 0.427266E-02 ALPHA= 0.069201
 RL/R= 0.9500 Q(RL)/Q(0)= 0.388172E-02 ALPHA= 0.075024
 RL/R= 0.9600 Q(RL)/Q(0)= 0.345572E-02 ALPHA= 0.084800
 RL/R= 0.9700 Q(RL)/Q(0)= 0.297913E-02 ALPHA= 0.097953
 RL/R= 0.9800 Q(RL)/Q(0)= 0.242168E-02 ALPHA= 0.120014
 RL/R= 0.9900 Q(RL)/Q(0)= 0.170499E-02 ALPHA= 0.169790

 R/R0= 100.000000
 R1/R= 0.999997472E+00
 P-BAR/S= 1.015366
 P(0)/S= 1.522737
 WD(1)= 1.536560
 WELLBORE WIDTH(CM) = 0.120583

(P-BAR/S)QS = 1.013082
 (P(0)/S)UL = 1.835106
 (WD(1))UL = 1.308249
 (WELLBORE WIDTH(CM))UL = 0.120583

 MUBAR= 0.870746E-01
 KC*= 0.130825E+00 Q(D)= 0.290665E-01
 R1/R= 0.100000000E+01

(P-BAR/S)QS = 1.013082
 (P(0)/S)UL = 1.064662
 (WD(1))UL = 1.308249
 (WELLBORE WIDTH(CM))UL = 0.102667

 HIT 1 IF YOU WANT TO CALC Q(RL)/Q(0)
 IQ = 1

RL/R= 0.1000 Q(RL)/Q(0)= 0.996977E-01 ALPHA= 0.045612
 RL/R= 0.2000 Q(RL)/Q(0)= 0.493817E-01 ALPHA= 0.031466
 RL/R= 0.3000 Q(RL)/Q(0)= 0.323703E-01 ALPHA= 0.027331
 RL/R= 0.4000 Q(RL)/Q(0)= 0.236461E-01 ALPHA= 0.026116
 RL/R= 0.5000 Q(RL)/Q(0)= 0.181865E-01 ALPHA= 0.026479
 RL/R= 0.6000 Q(RL)/Q(0)= 0.142933E-01 ALPHA= 0.028183

RL/R= 0.7000 Q(RL)/Q(0)= 0.112018E-01 ALPHA= 0.031584
 RL/R= 0.8000 Q(RL)/Q(0)= 0.846000E-02 ALPHA= 0.038074
 RL/R= 0.9000 Q(RL)/Q(0)= 0.562783E-02 ALPHA= 0.053566
 RL/R= 0.9100 Q(RL)/Q(0)= 0.531072E-02 ALPHA= 0.056461
 RL/R= 0.9200 Q(RL)/Q(0)= 0.498111E-02 ALPHA= 0.059888
 RL/R= 0.9300 Q(RL)/Q(0)= 0.463592E-02 ALPHA= 0.064030
 RL/R= 0.9400 Q(RL)/Q(0)= 0.427093E-02 ALPHA= 0.069172
 RL/R= 0.9500 Q(RL)/Q(0)= 0.388012E-02 ALPHA= 0.075793
 RL/R= 0.9600 Q(RL)/Q(0)= 0.345427E-02 ALPHA= 0.084764
 RL/R= 0.9700 Q(RL)/Q(0)= 0.297786E-02 ALPHA= 0.097911
 RL/R= 0.9800 Q(RL)/Q(0)= 0.242062E-02 ALPHA= 0.119962
 RL/R= 0.9900 Q(RL)/Q(0)= 0.170424E-02 ALPHA= 0.169715
 MUBAR= 0.769307E-01

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WIDTHA= 0.120583 WIDTHB= 0.102667 WIDIF= 14.858546

WIDTH= 0.102667 WIDTHA= 0.102667 WIDTHB= 0.102667

KC= 0.130825E+00 Q(D)= 0.256804E-01

R1/R= 0.100000000E+01

(P-BAR/S)QS = 1.013082

(P(0)/S)UL = 1.058653

(WD(1))UL = 1.308249

(WELLBORE WIDTH(CM))UL = 0.102667

HIT 1 IF YOU WANT TO CALC Q(RL)/Q(0)

IQ = 0

MUBAR= 0.769307E-01

WIDTHA= 0.102667 WIDTHB= 0.102667 WIDIF= 0.000000

HIT 1 IF YOU WANT ROB.HART'S LEAKOFF CALCNS

LHART = 1

Q(BPM) = 15.0 LEAKC(CGS) = 0.002500 SP(CGS) = 0.000000 RO(FT) = 0.750000

R/RO = 100.

ALPHA1 = 0.82

ERF1 FOR 0.82 IS 0.7538107634

VALI = 0.246189

Z= 0.407539129257 Y= 0.475728720427

ALPHA1 = 0.91

ERF1 FOR 0.91 IS 0.8018828034

VALI = 0.198117

Z= 0.480308532715 Y= 0.475728720427

ERF2 FOR 0.90 = 0.7969081998

Z = 0.4724887311 ALPHA = 0.9005 THRS = 0.01343540

Z = 0.4729040361 ALPHA = 0.9010 THRS = 0.01345032

Z = 0.4733190238 ALPHA = 0.9015 THRS = 0.01346525

Z = 0.4737335742 ALPHA = 0.9020 THRS = 0.01348019

Z = 0.4741477072 ALPHA = 0.9025 THRS = 0.01349514

Z = 0.4745613933 ALPHA = 0.9030 THRS = 0.01351010

Z = 0.4749746621 ALPHA = 0.9035 THRS = 0.01352507

Z = 0.4753875434 ALPHA = 0.9040 THRS = 0.01354004

Z = 0.4758000076 ALPHA = 0.9045 THRS = 0.01355503

Z = 0.4762120247 ALPHA = 0.9050 THRS = 0.01357002

Z = 0.4766236246 ALPHA = 0.9055 THRS = 0.01358502

Z = 0.4770347774 ALPHA = 0.9060 THRS = 0.01360002

Z = 0.4774456024 ALPHA = 0.9065 THRS = 0.01361504

Z = 0.47785559208 ALPHA = 0.9070 THRS = 0.01363006

Z = 0.4782658219 ALPHA = 0.9075 THRS = 0.01364510

Z = 0.4786752760 ALPHA = 0.9080 THRS = 0.01366014

Z = 0.4790843725 ALPHA = 0.9085 THRS = 0.01367519

Z = 0.4794929922 ALPHA = 0.9090 THRS = 0.01369024

Z = 0.4799011648 ALPHA = 0.9095 THRS = 0.01370531
Z = 0.4803089201 ALPHA = 0.9100 THRS = 0.01372038
THE TIME FOR THE FRACTURE W/O LEAKOFF 0.0079 HOURS
TOTAL TREATMENT TIME = 0.01355503 HRS

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HIT 1 IF YOU WANT TO RUN PROGRAM AGAIN
ICHECK = 0

CHAPTER IV

APPENDIX C

MPEN.IN

```
100.000000000000000000
 1.38769996      0.61500001
15.00000000
 0.750000000000000000
 0.10000000149011612 9.96977407713340036E-02
 0.20000000298023224 4.93817145629499091E-02
 0.30000000447034836 3.23703394600533129E-02
 0.40000000596046448 2.36460941232046890E-02
 0.50000000745058060 1.81865377915540194E-02
 0.60000000894069672 1.42933381810794770E-02
 0.70000001043081284 1.12018456602202068E-02
 0.80000001192092895 8.46000483036135793E-03
 0.90000001341104507 5.62782665086232654E-03
 0.91000002622604370 5.31072481811824520E-03
 0.92000002600252628 4.98111493584575075E-03
 0.93000002577900886 4.63591635333190574E-03
 0.94000002555549145 4.27092577321842946E-03
 0.95000002533197403 3.88011801596790853E-03
 0.96000002510845661 3.45426842750603093E-03
 0.97000002488493919 2.97786104239963767E-03
 0.98000002466142178 2.42062225623476592E-03
 0.99000002443790436 1.70423559737134566E-03
 0.10266654
1.35550303E-02
```

CHAPTER IV
APPENDIX D
PENNPROP.FOR


```

C TWO DIMENSIONAL SPHERICAL PARTICLE TRACKING
  DIMENSION RLDRO(40),QRDQW0(40),RLDR(40),QRDQW(40)
  + ,BC(40),CC(40),DC(40),THETA0(25),THETAP(25)
  + ,BHX(40),BHY(40),SHX(200),SHY(200)
  EXTERNAL FX,FY
  REAL NPRIME,KPRIME,MDOOTD
  COMMON /A1/ B,C,UF,VF
  COMMON /A2/ RHOF,D,NPRIME,KPRIME,W,GR
  COMMON /A3/ RLDRO,QRDQW0,BC,CC,DC
  OPEN (UNIT=7, FILE='PARTDAT.IN')
  OPEN (UNIT=2, FILE='PARTDAT.OUT')
  OPEN (UNIT=3, FILE='PARTDAT.PLT')
  OPEN (UNIT=4, FILE='MPEN.IN')
  READ (7,*) NTHETA
  READ (7,1008) (THETA0(I), I=1,NTHETA)
  READ (4,*) RRZAT,KPRIME,NPRIME,QW,RZ
  R=RZ*RRZAT
  KPRIME=KPRIME/478.803
  RLDRO(1)=RZ/R
  QRDQW0(1)=1.0
  DO 30 I=2,19
    READ (4,*) RLDRO(I),QRDQW0(I)
    QRDQW0(I)=QRDQW0(I)*RLDRO(I)*RRZAT
30 CONTINUE
  READ (4,*) WW,TT
  TT=TT*60.*60.
  WW=WW/12./2.54
  CALL NATCUS (19,RLDRO,QRDQW0,BC,CC,DC)
  READ (7,*) RHO,RHOF,DT,IPRINT,T0,W0,D,GR
  + ,PDT,CON,PHI
  READ (7,*) NPRT1,SF
  QW=QW*9.36E-2
  W0=W0*9.36E-2
  PI=3.14159
  RHOBAR=RHO/RHOF
  A=RHOBAR+0.5
  B=-GR*((RHOBAR-1.0)/A)
  C=3./(4.*D*A)
  IF(D/12..GE,WW) THEN
    WRITE (6,2000) WW*12.
    STOP
  ENDIF
  RDP=.99*R*SQRT(1.-(D/12./WW)**2)
  R0=R*0.99
  VS=0.0
  VSS=0.0
  NCT1=1
  NCT2=1
  NFLAG1=0
  NVS=1
  BHX1=0.0
  BHY1=0.0
  NJ=1
  * F3=1./SQRT(((R0**2-.75**2)**3)-((R0**2-RDP**2)**3))
  F3=1./SQRT(((R0**2-.75**2)**3)-SQRT((R0**2-RDP**2)**3))
  VSC=30./180.*PI*WW/3./R0/F3
C PRINT *,VSC
  DO 40 J=1,NTHETA
    IF (J.EQ.1) THEN
      DTHETA=0.0
    ELSE
      DTHETA=ABS(THETA0(J)-THETA0(J-1))/180.*PI
    ENDIF

```

```

MDOTD=QW*CON*7.481/(2.*PI)*DTHETA
IF (SF.EQ.1.0) THEN
W=WW
ELSE
W=WW*SQRT(1.-(RZ*SF/R)**2)
ENDIF
THETA=THETA0(J)
FC=COS(THETA*PI/180.)
FS=SIN(THETA*PI/180.)
X0=FC*RZ*SF
Y0=FS*RZ*SF
T=T0
X=X0
Y=Y0
XTEMP=X0
YTEMP=Y0
FVEL=QW/(W*2.*PI*(RZ*SF))
PVEL=W0/(W*2.*PI*(RZ*SF))
UF=FVEL*FC
VF=FVEL*FS
U=PVEL*FC
V=PVEL*FS
CX=.99*R*FC
CY=.99*R*FS
PX=RDP*FC
PY=RDP*FS
I=0
IF (J.EQ.1) THEN
WRITE (2,1011)
WRITE (2,1012)
DO 12 JJ=1,19
    WRITE (2,1013) RLDRO(JJ),GRDQWO(JJ)
12 CONTINUE
WRITE (2,1010)
WRITE (2,1014) WW
WRITE (2,1034) WW*12.
WRITE (2,1015) R
WRITE (2,1016) TT
WRITE (2,1017) DT
WRITE (2,1018) IPRINT
WRITE (2,1019) T0
WRITE (2,1020) GR
WRITE (2,1036) SF,RZ
WRITE (2,1010)
WRITE (2,1021) QW/9.36E-2
WRITE (2,1022) QW
WRITE (2,1023) FVEL
WRITE (2,1033) RHOF
WRITE (2,1025) NPRIME
WRITE (2,1026) KPRIME
WRITE (2,1010)
WRITE (2,1024) PVEL
WRITE (2,1027) PDT
WRITE (2,1028) PHI
WRITE (2,1030) CON
WRITE (2,1031) RHO
WRITE (2,1029) D
WRITE (2,1035) D/12.
WRITE (2,1009)
ENDIF
IF (NPRT1.EQ.1) WRITE (2,1032) THETA
10 IF (NPRT1.EQ.1) WRITE (2,1000)
11 IF (NPRT1.EQ.1) WRITE (2,1001) T,X,Y,U,V,UF,VF

```

```

20 CALL KUTTA (X,Y,U,V,T,DT,FX,FY)
   CALL FLOWFD (X,Y,UF,VF,R,GW,PI,W,WW)
   IF (J.EQ.1) THEN
     IF (YTEMP.LT.Y) THEN
       YTEMP=Y
       XTEMP=X
     ELSE IF (NCT1.EQ.1) THEN
       SHY(1)=YTEMP
       SHX(1)=0.0
       SHY(2)=YTEMP
       SHX(2)=XTEMP
       NCT1=NCT1+1
     ELSE IF (I.EQ.(IPRINT-1)) THEN
       NCT1=NCT1+1
       IF (NCT1.EQ.200) THEN
         WRITE (6,1050)
         STOP
       ENDIF
       SHY(NCT1)=Y
       SHX(NCT1)=X
     ENDIF
   ENDIF
   RCK=SQRT(X**2 +Y**2 )
   IF (RCK.GE.RDP.OR.T.GE.(TT-PDT)) THEN
     THETAP(J)=ATAN(Y/X)
     IF (NPRT1.EQ.1) THEN
       WRITE (2,1001) T,X,Y,U,V,UF,VF
       WRITE (2,1009)
     ENDIF
     IF (J.EQ.1) THEN
       IF (T.GE.(TT-PDT).AND.NCT1.EQ.1) THEN
         SHY(NCT1)=Y
         SHX(NCT1)=0.0
       ENDIF
       NCT1=NCT1+1
       SHY(NCT1)=Y
       SHX(NCT1)=X
     ENDIF
     IF (RCK.GE.RDP.AND.J.NE.1) THEN
       CALL BEDHT (PHI,MDOTD,PDT,TT,T,RDP,WW,THETAP,RHO,
+         R,J,PI,BHX1,BHY1,VS,NVS,NJ,VSC,VSS,F3,
+         D1THET)
       IF (NFLAG1.EQ.0.AND.NCT2.EQ.1) THEN
         NCT1=NCT1+1
         SHY(NCT1)=Y
         SHX(NCT1)=X
         BHY(1)=Y
         BHX(1)=X
       ENDIF
       IF (BHY1.NE.0.0) THEN
         NCT2=NCT2+1
         BHY(NCT2)=BHY1
         BHX(NCT2)=BHX1
       ENDIF
     ELSE IF (T.LT.(TT-PDT)) THEN
       NFLAG1=1
       BHY(1)=Y
       BHX(1)=X
     ELSE IF (J.NE.1.AND.T.GE.(TT-PDT)) THEN
       NCT1=NCT1+1
       SHY(NCT1)=Y
       SHX(NCT1)=X
     ENDIF

```

WRITE (3,1001) CX,CY,PX,PY
GOTO 40

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ENDIF

I=I+1

IF (I.EQ.IPRINT) THEN

I=0

GOTO 11

ENDIF

GOTO 20

40 CONTINUE

IF (NVS.EQ.NTHETA) THEN

CALL BEDEQ (VS,R,RDP,WV,PI,BHX,BHY,SHX,SHY,NCT1,NCT2
+ ,F3)

ENDIF

IF (NJ.NE.1.AND.NVS.NE.NTHETA.AND.NVS.NE.1) THEN

CALL BEDEQ1 (VS,R,RDP,WV,PI,BHX,BHY,SHX,SHY,NCT1,NCT2
+ ,NJ,THETAP,F3)

ENDIF

WRITE (3,1010)

DIFFCK=BHX(2)-BHX(1)

DO 55 I=3,NCT2

DIFF=BHX(I)-BHX(I-1)

IF (DIFFCK.LT.0.0.AND.DIFF.GT.0.0) THEN

CALL BEDSM(VSS,R,RDP,WV,PI,BHX,BHY,SHX,SHY,NCT1
+ ,NCT2,F3)

GOTO 56

ENDIF

55 CONTINUE

56 DO 50 I=1,NCT1

WRITE (3,1001) SHX(I),SHY(I)

50 CONTINUE

WRITE (3,1010)

DO 60 I=1,NCT2

WRITE (3,1001) BHX(I),BHY(I)

60 CONTINUE

1000 FORMAT (6X,'TIME',7X,'X',9X,'Y',5X,'PART U X',2X,
+ 'PART U Y',3X,'FLD U X',3X,'FLD U Y',/)

1001 FORMAT (1X,F10.3,6F10.3)

1002 FORMAT (2F10.3)

1008 FORMAT (11F5.1)

1009 FORMAT (1X,'-----',
+ '-----',/)

1010 FORMAT (/)

1011 FORMAT (5X,'PROPPANT PLACEMENT -- PENNEY FRACTURE',/)

1012 FORMAT (12X,'RL/R',4X,'Q(RL)/Q(0)',/)

1013 FORMAT (6X,F10.2,F12.6)

1014 FORMAT (5X,'MAXIMUM WELLBORE WIDTH = ',F10.6,' FT')

1015 FORMAT (5X,'FRACTURE RADIUS = ',F10.3,' FT')

1016 FORMAT (5X,'TREATMENT TIME = ',F10.3,' SEC')

1017 FORMAT (5X,'TIME INCREMENT = ',F10.3,' SEC')

1018 FORMAT (5X,'PRINTING CONTROL = ',I10)

1019 FORMAT (5X,'INITIAL TIME = ',F10.3,' SEC')

1020 FORMAT (5X,'GRAVITATIONAL CONSTANT = ',F10.3,' FT/SEC**2')

1021 FORMAT (5X,'PUMPING RATE = ',F10.3,' BBL/MIN')

1022 FORMAT (5X,' = ',F10.3,' CU FT/SEC')

1023 FORMAT (5X,'INITIAL FLUID VELOCITY = ',F10.3,' FT/SEC')

1024 FORMAT (5X,'INITIAL PARTICLE VEL = ',F10.3,' FT/SEC')

1025 FORMAT (5X,'BEHAVIOR INDEX = ',F10.6)

1026 FORMAT (5X,'CONSISTENCY INDEX = ',F10.6,' LBM*SEC**N',
+ '/SQ FT')

1027 FORMAT (5X,'PAD TIME = ',F10.3,' SEC')

1028 FORMAT (5X,'PROPPANT POROSITY = ',F10.3)

1029 FORMAT (5X,'PROPPANT DIAMETER = ',F10.5,' IN')

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1030 FORMAT (5X,'PROPPANT CONCENTRATION' = ',F10.3,' LBM/GAL')
1031 FORMAT (5X,'PROPPANT DENSITY' = ',F10.3,' LBM/CU FT')
1032 FORMAT (5X,'INITIAL FLOW ANGLE' = ',F10.1,' DEGREES',
+ ' FROM X AXIS',/)
1033 FORMAT (5X,'FLUID DENSITY' = ',F10.3,' LBM/CU FT')
1034 FORMAT (5X,' = ',F10.5,' IN')
1035 FORMAT (5X,' = ',F10.6,' FT')
1036 FORMAT (5X,'SCALING FACTOR' = ',F10.3,' X ',F5.3)
1050 FORMAT (/ ,1X,'YOU MUST INCREASE THE PRINT CONTROL NUMBER'
+ ',/ ,1X,'OR INCREASE THE TIME STEP IF POSSIBLE')
2000 FORMAT (/ ,1X,'PARTICLE DIAMETER EXCEEDS WELLBORE WIDTH',/,
+ ' 1X,'PUT IN A PROPPANT DIAMETER LESS THAN ',F10.6)
2001 FORMAT (1X,15,10F10.5)
CLOSE (UNIT=7)
CLOSE (UNIT=2)
CLOSE (UNIT=3)
CLOSE (UNIT=4)
END

```

C

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SUBROUTINE KUTTA (X,Y,U,V,T,H,F1,F2)
D1X=H*U
D1Y=H*V
D1U=H*F1(X,Y,U,V,T)
D1V=H*F2(X,Y,U,V,T)
D2X=H*(U+D1U/2.)
D2Y=H*(V+D1V/2.)
D2U=H*F1(X+D1X/2.,Y+D1Y/2.,U+D1U/2.,V+D1V/2.,T+H/2.)
D2V=H*F2(X+D1X/2.,Y+D1Y/2.,U+D1U/2.,V+D1V/2.,T+H/2.)
D3X=H*(U+D2U/2.)
D3Y=H*(V+D2V/2.)
D3U=H*F1(X+D2X/2.,Y+D2Y/2.,U+D2U/2.,V+D2V/2.,T+H/2.)
D3V=H*F2(X+D2X/2.,Y+D2Y/2.,U+D2U/2.,V+D2V/2.,T+H/2.)
D4X=H*(U+D3U)
D4Y=H*(V+D3V)
D4U=H*F1(X+D3X,Y+D3Y,U+D3U,V+D3V,T+H)
D4V=H*F2(X+D3X,Y+D3Y,U+D3U,V+D3V,T+H)
T=T+H
X=X+(D1X+2.*D2X+2.*D3X+D4X)/6.
Y=Y+(D1Y+2.*D2Y+2.*D3Y+D4Y)/6.
U=U+(D1U+2.*D2U+2.*D3U+D4U)/6.
V=V+(D1V+2.*D2V+2.*D3V+D4V)/6.
RETURN
END

```

C

```

SUBROUTINE FLOWFD (X,Y,UF,VF,R0,QW,PI,WR,WJ)
DIMENSION RLDR0(40),QRDQW0(40),BC(40),CC(40),DC(40)
COMMON /A3/ RLDR0,QRDQW0,BC,CC,DC
R=SQRT(X**2 +Y**2 )
RLDR=R/R0
IF (RLDR.GT.1.0) THEN
WRITE (6,1036)
STOP
ENDIF
CALL CUBVAL (1,RLDR0,RLDR,QRDQW,QRDQW0,BC,CC,DC)
WR=SQRT(1.-RLDR**2)*WJ
QR=QW*QRDQW
WF=QR/(WR*PI*2.*R)
UF=X/R*WF
VF=Y/R*WF
RETURN

```

```

1036 FORMAT (/ ,1X,'YOU MUST DECREASE THE TIME INCREMENT')
END

```

C

```

SUBROUTINE NATCUS (M,X,A,B,C,D)
DIMENSION X(100),A(40),B(40),C(40),D(40),H(40),
+ T(40),U(40),Z(40),ALPHA(40)
DO 10 I=1,M-1
    H(I)=X(I+1)-X(I)
10 CONTINUE
DO 20 I=2,M-1
    ALPHA(I)=3.*(A(I+1)*H(I-1)-A(I)*(X(I+1)-X(I-1))+
+ A(I-1)*H(I))/(H(I-1)*H(I))
20 CONTINUE
T(1)=1.0
U(1)=0.0
Z(1)=0.0
DO 30 I=2,M
    T(I)=2.*(X(I+1)-X(I-1))-H(I-1)*U(I-1)
    U(I)=H(I)/T(I)
    Z(I)=(ALPHA(I)-H(I-1)*Z(I-1))/T(I)
30 CONTINUE
T(M)=1.0
Z(M)=0.0
C(M)=Z(M)
DO 40 J=M-1,1,-1
    C(J)=Z(J)-U(J)*C(J+1)
    B(J)=(A(J+1)-A(J))/H(J)-H(J)*(C(J+1)+2.*C(J))/3.
    D(J)=(C(J+1)-C(J))/(3.*H(J))
40 CONTINUE
C DO 50 J=1,M
C IF (J.NE.M) THEN
C WRITE (2,1000) J,X(J),A(J),B(J),C(J),D(J)
C ELSE
C WRITE (2,1000) J,X(J),A(J)
C ENDIF
C 50 CONTINUE
C PRINT *
1000 FORMAT (1X,12,5E18.6)
C RETURN
C END

SUBROUTINE CUBVAL (NV,X,XVAL,VAL,A,B,C,D)
DIMENSION XVAL(255),VAL(255),A(40),B(40),C(40),
+ D(40),X(40)
J=1
DO 10 I=1,NV
    VAL(I)=0.0
30 IF (XVAL(I).GT.X(J+1)) THEN
    J=J+1
    GOTO 30
ENDIF
DELX=XVAL(I)-X(J)
VAL(I)=A(J)+B(J)*DELX+C(J)*DELX**2+D(J)*DELX**3
10 CONTINUE
C DO 20 I=1,NV
C WRITE (2,1000) I,XVAL(I),VAL(I)
C 20 CONTINUE
1000 FORMAT (1X,13,2E18.6)
C RETURN
C END

SUBROUTINE BEDEQ1 (VS,R,RDP,WJ,PI,BHX,BHY,SHX,SHY
+ ,NCT1,NCT2,NJ,THETAP,F3)
DIMENSION BHX(40),BHY(40),SHX(200),SHY(200),THETAP(25)
NCT1T=0
RO=.99*R

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DTHETA=VS*3.*R0*F3/WW
CTHETA=30.*PI/180.
C1THET=ABS(-PI/2.-THETAP(NJ))
C2THET=ABS(-PI/2.-THETAP(NJ+1))
IF (DTHETA.GT.CTHETA) THEN
  WRITE (6,1000)
  STOP
ELSE IF (DTHETA.GT.C1THET) THEN
  WRITE (6,1001)
  STOP
ELSE
  F1=3.*R0*VS/(C1THET*WW)
  F2=SQRT((R0**2-RDP**2)**3)
  BHR=(R0**2-((F1+F2)**(2./3.)))*0.5
  NCT2=NCT2+1
  BHX(NCT2)=BHR*COS(-PI/2.+C2THET)
  BHY(NCT2)=BHR*SIN(-PI/2.+C2THET)
  NCT2=NCT2+1
  BHX(NCT2)=0.0
  BHY(NCT2)=-BHR
  DO 20 I=1,NCT1
    BRS=SQRT(SHY(I)**2+SHX(I)**2)
    STHETA=ATAN(SHY(I)/SHX(I))
    IF (STHETA.LT.(-PI/2.+C1THET).AND.BRS.GE.BHR) THEN
      SHX(I)=0.0
      SHY(I)=0.0
    ELSE
      NCT1T=NCT1T+1
    ENDIF
  20 CONTINUE
  NCT1=NCT1T
ENDIF
RETURN
1000 FORMAT (/,1X,'YOU MUST DECREASE CONCENTRATION AND/OR'
+           ', INCREASE PAD TIME.')
1001 FORMAT (/,1X,'PROPPANT CALCULATION PARTIALLY COMPLETE',/
+           ',1X,'BUT YOU MUST DECREASE CONCENTRAION AND/OR'
+           ', INCREASE PAD TIME.')
END

C
SUBROUTINE BEDEQ (VS,R,RDP,WW,PI,BHX,BHY,SHX,SHY,NCT1,NCT2
+               ,F3,D1THET)
DIMENSION BHX(40),BHY(40),SHX(200),SHY(200)
NCT1T=0
R0=.99*R
DTHETA=VS*3.*R0*F3/WW
CTHETA=30.*PI/180.
IF (D1THET.GT.CTHETA) CTHETA=D1THET
IF (DTHETA.GT.CTHETA) THEN
  WRITE (6,1000)
  STOP
ELSE
  F1=3.*R0*VS/(CTHETA*WW)
  F2=SQRT((R0**2-RDP**2)**3)
  BHR=(R0**2-((F1+F2)**(2./3.)))*0.5
  FAC=(RDP-BHR)/5.
  DO 10 I=3,7
    RB=(1-2)*FAC+BHR
    BHX(I)=RB*COS(-PI/2.+CTHETA)
    BHY(I)=RB*SIN(-PI/2.+CTHETA)
  10 CONTINUE
  NCT2=7
  BHX(1)=0.0

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      BHY(1)=-BHR
      BHX(2)=BHR*COS(-PI/2.+CTHETA)
      BHY(2)=BHR*SIN(-PI/2.+CTHETA)
      DO 20 I=1,NCT1
        BRS=SQRT(SHY(I)**2+SHX(I)**2)
        STHETA=ATAN(SHY(I)/SHX(I))
        IF (STHETA.LT.(-PI/2.+CTHETA).AND.BRS.GE.BHR) THEN
          SHX(I)=0.0
          SHY(I)=0.0
        ELSE
          NCT1T=NCT1T+1
        ENDIF
      ENDIF
20    CONTINUE
      NCT1=NCT1T
    ENDIF
    RETURN
1000 FORMAT (/,1X,'YOU MUST DECREASE CONCENTRATION AND/OR'
+           , ' INCREASE PAD TIME.')
    END

C
    SUBROUTINE BEDSM (VS,R,RDP,UW,PI,BHX,BHY,SHX,SHY,NCT1,NCT2
+                   ,F3)
    DIMENSION BHX(40),BHY(40),SHX(200),SHY(200)
    NCT1T=0
    R0=.99*R
    CTHETA=PI/2.+ATAN(BHY(1)/BHX(1))
    F1=3.*R0*VS/(CTHETA*UW)
    F2=SQRT((R0**2-RDP**2)**3)
    BHR=(R0**2-((F1+F2)**(2./3.)))*0.5
    FAC=(RDP-BHR)/5.
    DO 10 I=3,7
      RB=(I-2)*FAC+BHR
      BHX(I)=RB*COS(-PI/2.+CTHETA)
      BHY(I)=RB*SIN(-PI/2.+CTHETA)
10    CONTINUE
      NCT2=7
      BHX(1)=0.0
      BHY(1)=-BHR
      BHX(2)=BHR*COS(-PI/2.+CTHETA)
      BHY(2)=BHR*SIN(-PI/2.+CTHETA)
      DO 20 I=1,NCT1
        BRS=SQRT(SHY(I)**2+SHX(I)**2)
        STHETA=ATAN(SHY(I)/SHX(I))
        IF (STHETA.LT.(-PI/2.+CTHETA).AND.BRS.GE.BHR) THEN
          SHX(I)=0.0
          SHY(I)=0.0
        ELSE
          NCT1T=NCT1T+1
        ENDIF
      ENDIF
20    CONTINUE
      NCT1=NCT1T
    RETURN
    END

C
    SUBROUTINE BEDHT (PHI,MDO TD,PDT,TT,T,RDP,UW,THETAP,RHO,
+                   R,J,PI,BHX,BHY,VS,NVS,NJ,USC,VSS,F4,
+                   DTHETA)
    DIMENSION THETAP(25)
    REAL MDO TD
    R0=.99*R
    IF (VS.EQ.0.0) THEN
      DTHETA=ABS(THETAP(J)-THETAP(J-1))
      IF ((PI/2.+THETAP(J-1)).GT.30.*PI/180.) THEN

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      VSC=(PI/2.+THETAP(J-1))*WW/3./R0/F4
    ELSE
      VSC=30./180.*PI*WW/3./R0/F4
    ENDIF
  ELSE
    DTHETA=ABS(THETAP(J)-THETAP(NJ))
    IF ((PI/2.+THETAP(NJ)).GT.30.*PI/180.) THEN
      VSC=(PI/2.+THETAP(NJ))*WW/3./R0/F4
    ELSE
      VSC=30./180.*PI*WW/3./R0/F4
    ENDIF
  ENDIF
  TTS=TT-PDT-T
  VS=VS+(MDOTD*TTS/(RHO*(1.-PHI)))
  VSS=VSS+(MDOTD*TTS/(RHO*(1.-PHI)))
  F1=3.*R0*VS/(DTHETA*WW)
  F2=SQRT((R0**2-RDP**2)**3)
  F3=R0**2-((F1+F2)**(2./3.))
  IF (VS.GT.VSC) THEN
    WRITE (4,1000) VSC
    STOP
  ENDIF
  IF (F0.GE.0.5425) THEN
    VS=0.0
    BHR=(R0**2-((F1+F2)**(2./3.)))*0.5
    BHX=BHR*COS(THETAP(J))
    BHY=BHR*SIN(THETAP(J))
    NVS=1
  ELSE
    IF (NVS.EQ.1) NJ=J-1
    NVS=NVS+1
    BHX=0.0
    BHY=0.0
  ENDIF
C   PRINT *,VSC,DTHETA,VS,F1,F2,F3,BHR,BHX,BHY,J,NJ,NVS
  RETURN
1000 FORMAT (/,'YOU MUST DECREASE CONCENTRATION AND/OR'
+           ', INCREASE PAD TIME.',/,',1X, 'MAXIMUM VOLUME'
+           ', OF PROPPANT IS ',F10.4,' CU FT')
  END
C
  FUNCTION FX(X,Y,U,V,T)
  COMMON /A1/ B,C,UF,VF
C   PRINT *, (UF-U)**2+(VF-V)**2
  WR=SQRT((UF-U)**2+(VF-V)**2)
  FX=C*CD(WR)*(UF-U)*WR
  RETURN
  END
C
  FUNCTION FY(X,Y,U,V,T)
  COMMON /A1/ B,C,UF,VF
  WR=SQRT((UF-U)**2+(VF-V)**2)
  FY=B+C*CD(WR)*(VF-V)*WR
  RETURN
  END
C
  FUNCTION CD(U)
  COMMON /A2/ RHOF,D,NPRIME,KPRIME,W,GR
  REAL NPRIME,KPRIME
  GDOT=2.*(2.*NPRIME+1.)/NPRIME*ABS(U)/W
  AMU=KPRIME/GDOT*(1.-NPRIME)
  RE=RHOF*D*ABS(U)/(AMU*GR)
  IF (RE.EQ.0.0) CD=0.0

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```
IF (RE.GT.0.0.AND.RE.LE.1.) CD=24./RE
IF (RE.GT.1.0.AND.RE.LE.400.) CD=24./RE**0.646
IF (RE.GT.400.0.AND.RE.LE.3.E+5) CD=0.5
IF (RE.GT.3.E+5.AND.RE.LE.2.E+6) CD=3.66E-4*RE**.4275
IF (RE.GT.2.E+6) CD=.18
RETURN
END
```

CHAPTER IV

APPENDIX E

PPDAT.IN

24

89.9 89.0 88.0 87.0 85.0 83.0 80.0 70.0 60.0 50.0 40.0
30.0 20.0 10.0 00.0-10.0-20.0-30.0-40.0-50.0-60.0-70.0
-80.0-89.0

165.0

65.0

0.1

50

0.0

15.0

.025

32.174

09.0

1.83

0.3

1

10.

CHAPTER IV

APPENDIX F

PPDAT.OUT

PROPPANT PLACEMENT -- PENNEY FRACTURE

RL/R	Q(RL)/Q(0)
0.01	1.000000
0.10	0.996977
0.20	0.987634
0.30	0.971110
0.40	0.945844
0.50	0.909327
0.60	0.857600
0.70	0.784129
0.80	0.676800
0.90	0.506504
0.91	0.483276
0.92	0.458263
0.93	0.431140
0.94	0.401467
0.95	0.368611
0.96	0.331610
0.97	0.288853
0.98	0.237221
0.99	0.168719

MAXIMUM WELLBORE WIDTH = 0.003368 FT
 = 0.04042 IN
 FRACTURE RADIUS = 75.000 FT
 TREATMENT TIME = 48.798 SEC
 TIME INCREMENT = 0.100 SEC
 PRINTING CONTROL = 50
 INITIAL TIME = 0.000 SEC
 GRAVITATIONAL CONSTANT = 32.174 FT/SEC**2
 SCALING FACTOR = 10.000 X 0.750

PUMPING RATE = 15.000 BBL/MIN
 = 1.404 CU FT/SEC
 INITIAL FLUID VELOCITY = 8.890 FT/SEC
 FLUID DENSITY = 65.000 LBM/CU FT
 BEHAVIOR INDEX = 0.615000
 CONSISTENCY INDEX = 0.002898 LBM*SEC**N/SQ FT

INITIAL PARTICLE VEL = 8.890 FT/SEC
 PAD TIME = 9.000 SEC
 PROPPANT POROSITY = 0.300
 PROPPANT CONCENTRATION = 1.830 LBM/GAL
 PROPPANT DENSITY = 165.000 LBM/CU FT
 PROPPANT DIAMETER = 0.02500 IN
 = 0.002083 FT

INITIAL FLOW ANGLE = 89.9 DEGREES FROM X AXIS

TIME	X	Y	PART V X	PART V Y	FLD V X	FLD V Y
0.000	0.013	7.500	0.016	8.890	0.016	8.890

5.000	0.066	21.220	0.010	1.388	0.010	3.176 ¹⁶⁰
10.000	0.119	26.342	0.012	0.774	0.012	2.581
15.000	0.183	29.470	0.014	0.509	0.014	2.321
20.000	0.263	31.607	0.018	0.360	0.018	2.173
25.000	0.364	33.150	0.023	0.265	0.023	2.079
30.000	0.492	34.299	0.029	0.200	0.029	2.015
35.000	0.654	35.173	0.036	0.153	0.037	1.968
39.800	0.850	35.822	0.046	0.120	0.046	1.935

INITIAL FLOW ANGLE = 89.0 DEGREES FROM X AXIS

TIME	X	Y	PART V X	PART V Y	FLD V X	FLD V Y
0.000	0.131	7.499	0.155	8.889	0.155	8.889
5.000	0.658	21.212	0.098	1.387	0.098	3.175
10.000	1.186	26.322	0.115	0.771	0.116	2.577
15.000	1.828	29.428	0.143	0.504	0.144	2.315
20.000	2.628	31.530	0.179	0.351	0.180	2.164
25.000	3.635	33.011	0.225	0.249	0.227	2.063
30.000	4.904	34.059	0.284	0.174	0.286	1.989
35.000	6.501	34.766	0.357	0.111	0.360	1.926
39.800	8.418	35.157	0.444	0.053	0.447	1.868

INITIAL FLOW ANGLE = 88.0 DEGREES FROM X AXIS

TIME	X	Y	PART V X	PART V Y	FLD V X	FLD V Y
0.000	0.262	7.495	0.310	8.884	0.310	8.884
5.000	1.315	21.187	0.196	1.381	0.197	3.169
10.000	2.370	26.261	0.230	0.762	0.232	2.568
15.000	3.648	29.304	0.284	0.487	0.286	2.298
20.000	5.239	31.297	0.355	0.323	0.358	2.136
25.000	7.228	32.597	0.444	0.203	0.447	2.017
30.000	9.712	33.346	0.553	0.099	0.557	1.913
35.000	12.795	33.573	0.683	-0.009	0.688	1.805
39.800	16.410	33.246	0.825	-0.130	0.831	1.683

INITIAL FLOW ANGLE = 87.0 DEGREES FROM X AXIS

TIME	X	Y	PART V X	PART V Y	FLD V X	FLD V Y
0.000	0.393	7.490	0.465	8.878	0.465	8.878
5.000	1.970	21.146	0.293	1.372	0.294	3.160
10.000	3.549	26.160	0.344	0.746	0.346	2.552
15.000	5.456	29.099	0.423	0.461	0.426	2.271
20.000	7.816	30.914	0.525	0.278	0.528	2.090
25.000	10.741	31.921	0.649	0.130	0.654	1.942
30.000	14.342	32.202	0.794	-0.017	0.799	1.795
35.000	18.711	31.704	0.954	-0.185	0.960	1.627
39.800	23.670	30.358	1.110	-0.380	1.115	1.431

INITIAL FLOW ANGLE = 85.0 DEGREES FROM X AXIS

TIME	X	Y	PART V X	PART V Y	FLD V X	FLD V Y
0.000	0.654	7.471	0.775	8.856	0.775	8.856
5.000	3.276	21.015	0.487	1.344	0.488	3.131
10.000	5.885	25.839	0.566	0.697	0.570	2.502
15.000	9.007	28.451	0.688	0.377	0.692	2.186

20.000	12.808	29.726	0.836	0.142	0.841	1.752
25.000	17.397	29.874	1.001	-0.081	1.007	1.729
30.000	22.822	28.858	1.167	-0.327	1.172	1.482
35.000	29.030	26.528	1.310	-0.608	1.314	1.201
39.800	35.557	22.896	1.401	-0.904	1.403	0.903

INITIAL FLOW ANGLE = 83.0 DEGREES FROM X AXIS

TIME	X	Y	PART U X	PART U Y	FLD U X	FLD U Y
0.000	0.914	7.444	1.083	8.824	1.083	8.824
5.000	4.571	20.820	0.676	1.302	0.678	3.089
10.000	8.178	25.365	0.779	0.625	0.783	2.429
15.000	12.436	27.509	0.929	0.259	0.935	2.067
20.000	17.502	28.041	1.098	-0.040	1.104	1.769
25.000	23.411	27.085	1.262	-0.342	1.267	1.466
30.000	30.065	24.559	1.391	-0.668	1.394	1.139
35.000	37.219	20.356	1.459	-1.009	1.460	0.798
39.800	44.239	14.738	1.455	-1.323	1.454	0.484

INITIAL FLOW ANGLE = 80.0 DEGREES FROM X AXIS

TIME	X	Y	PART U X	PART U Y	FLD U X	FLD U Y
0.000	1.302	7.386	1.544	8.755	1.544	8.755
5.000	6.483	20.411	0.951	1.215	0.953	3.001
10.000	11.505	24.385	1.072	0.481	1.077	2.283
15.000	17.270	25.615	1.236	0.036	1.241	1.841
20.000	23.844	24.793	1.389	-0.357	1.393	1.449
25.000	31.075	22.019	1.492	-0.747	1.495	1.059
30.000	38.642	17.317	1.521	-1.125	1.521	0.682
35.000	46.158	10.813	1.474	-1.463	1.471	0.345
39.800	53.014	3.117	1.376	-1.729	1.372	0.081

INITIAL FLOW ANGLE = 70.0 DEGREES FROM X AXIS

TIME	X	Y	PART U X	PART U Y	FLD U X	FLD U Y
0.000	2.565	7.048	3.041	8.354	3.041	8.354
5.000	12.441	18.113	1.740	0.751	1.739	2.531
10.000	21.177	19.248	1.764	-0.172	1.765	1.605
15.000	30.029	16.614	1.764	-0.826	1.762	0.975
20.000	38.669	11.179	1.679	-1.320	1.674	0.484
25.000	46.704	3.587	1.528	-1.691	1.522	0.117
30.000	53.903	-5.565	1.351	-1.950	1.345	-0.139
32.700	57.421	-10.974	1.256	-2.051	1.250	-0.239

INITIAL FLOW ANGLE = 60.0 DEGREES FROM X AXIS

TIME	X	Y	PART U X	PART U Y	FLD U X	FLD U Y
0.000	3.750	6.495	4.445	7.699	4.445	7.699
5.000	17.491	14.660	2.280	0.125	2.269	1.902
10.000	28.264	12.410	2.042	-0.902	2.034	0.893
15.000	37.886	6.250	1.803	-1.507	1.794	0.296
20.000	46.259	-2.322	1.548	-1.886	1.540	-0.077
25.000	53.396	-12.379	1.312	-2.114	1.305	-0.303
27.000	55.934	-16.674	1.228	-2.177	1.221	-0.364

INITIAL FLOW ANGLE = 50.0 DEGREES FROM X AXIS

TIME	X	Y	PART U X	PART U Y	FLD U X	FLD U Y
0.000	4.821	5.745	5.714	6.810	5.714	6.810
5.000	21.456	10.449	2.572	-0.535	2.550	1.242
10.000	32.944	5.054	2.060	-1.485	2.045	0.314
15.000	42.233	-3.682	1.670	-1.952	1.659	-0.145
20.000	49.775	-14.123	1.360	-2.195	1.351	-0.383
23.500	54.219	-21.991	1.186	-2.291	1.178	-0.478

INITIAL FLOW ANGLE = 40.0 DEGREES FROM X AXIS

TIME	X	Y	PART U X	PART U Y	FLD U X	FLD U Y
0.000	5.745	4.821	6.810	5.714	6.810	5.714
5.000	24.321	5.829	2.670	-1.150	2.637	0.632
10.000	35.705	-2.188	1.954	-1.922	1.935	-0.119
15.000	44.267	-12.708	1.502	-2.238	1.489	-0.427
20.000	50.946	-24.299	1.190	-2.377	1.181	-0.563
21.000	52.110	-26.686	1.139	-2.394	1.131	-0.579

INITIAL FLOW ANGLE = 30.0 DEGREES FROM X AXIS

TIME	X	Y	PART U X	PART U Y	FLD U X	FLD U Y
0.000	6.495	3.750	7.699	4.445	7.699	4.445
5.000	26.164	1.056	2.634	-1.685	2.593	0.105
10.000	36.994	-9.052	1.799	-2.244	1.779	-0.435
15.000	44.734	-20.822	1.337	-2.430	1.324	-0.616
19.100	49.673	-30.922	1.088	-2.487	1.080	-0.672

INITIAL FLOW ANGLE = 20.0 DEGREES FROM X AXIS

TIME	X	Y	PART U X	PART U Y	FLD U X	FLD U Y
0.000	7.048	2.565	8.354	3.041	8.354	3.041
5.000	27.089	-3.699	2.514	-2.135	2.468	-0.337
10.000	37.140	-15.456	1.630	-2.482	1.610	-0.670
15.000	44.069	-28.127	1.185	-2.565	1.174	-0.749
17.600	46.940	-34.811	1.031	-2.575	1.022	-0.758

INITIAL FLOW ANGLE = 10.0 DEGREES FROM X AXIS

TIME	X	Y	PART U X	PART U Y	FLD U X	FLD U Y
0.000	7.386	1.302	8.755	1.544	8.755	1.544
5.000	27.200	-8.323	2.341	-2.507	2.294	-0.702
10.000	36.365	-21.385	1.460	-2.663	1.441	-0.848
15.000	42.523	-34.725	1.046	-2.663	1.036	-0.846
16.400	43.930	-38.449	0.967	-2.656	0.959	-0.839

INITIAL FLOW ANGLE = 0.0 DEGREES FROM X AXIS

TIME	X	Y	PART U X	PART U Y	FLD U X	FLD U Y
0.000	7.500	0.000	8.890	0.000	8.890	0.000

5.000	26.583	-12.735	2.139	-2.817	2.092	-1.002
10.000	34.819	-26.837	1.295	-2.803	1.277	-0.985
15.000	40.250	-40.689	0.919	-2.738	0.910	-0.920
15.500	40.703	-42.056	0.893	-2.732	0.884	-0.914

INITIAL FLOW ANGLE = -10.0 DEGREES FROM X AXIS

TIME	X	Y	PART V X	PART V Y	FLD V X	FLD V Y
0.000	7.386	-1.302	8.755	-1.544	8.755	-1.544
5.000	25.315	-16.869	1.919	-3.070	1.874	-1.249
10.000	32.610	-31.804	1.135	-2.912	1.120	-1.092
14.700	37.111	-45.216	0.815	-2.802	0.807	-0.983

INITIAL FLOW ANGLE = -20.0 DEGREES FROM X AXIS

TIME	X	Y	PART V X	PART V Y	FLD V X	FLD V Y
0.000	7.048	-2.565	8.354	-3.041	8.354	-3.041
5.000	23.466	-20.668	1.688	-3.279	1.647	-1.451
10.000	29.821	-36.272	0.982	-2.999	0.968	-1.177
14.000	33.200	-47.985	0.733	-2.868	0.725	-1.048

INITIAL FLOW ANGLE = -30.0 DEGREES FROM X AXIS

TIME	X	Y	PART V X	PART V Y	FLD V X	FLD V Y
0.000	6.495	-3.750	7.699	-4.445	7.699	-4.445
5.000	21.102	-24.078	1.452	-3.448	1.415	-1.615
10.000	26.524	-40.220	0.833	-3.068	0.821	-1.244
13.500	29.072	-50.686	0.640	-2.925	0.633	-1.104

INITIAL FLOW ANGLE = -40.0 DEGREES FROM X AXIS

TIME	X	Y	PART V X	PART V Y	FLD V X	FLD V Y
0.000	5.745	-4.821	6.810	-5.714	6.810	-5.714
5.000	18.290	-27.052	1.212	-3.584	1.181	-1.747
10.000	22.791	-43.621	0.688	-3.122	0.678	-1.298
13.100	24.679	-53.051	0.543	-2.975	0.536	-1.153

INITIAL FLOW ANGLE = -50.0 DEGREES FROM X AXIS

TIME	X	Y	PART V X	PART V Y	FLD V X	FLD V Y
0.000	4.821	-5.745	5.714	-6.810	5.714	-6.810
5.000	15.100	-29.547	0.971	-3.691	0.945	-1.850
10.000	18.688	-46.449	0.547	-3.164	0.539	-1.339
12.800	20.057	-55.082	0.440	-3.016	0.434	-1.193

INITIAL FLOW ANGLE = -60.0 DEGREES FROM X AXIS

TIME	X	Y	PART V X	PART V Y	FLD V X	FLD V Y
0.000	3.750	-6.495	4.445	-7.699	4.445	-7.699
5.000	11.600	-31.528	0.728	-3.771	0.709	-1.928
10.000	14.284	-48.679	0.408	-3.196	0.402	-1.370

12.500	15.205	-56.472	0.335	-3.052	0.331	-1.228
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INITIAL FLOW ANGLE = -70.0 DEGREES FROM X AXIS

TIME	X	Y	PART U X	PART U Y	FLD U X	FLD U Y
0.000	2.565	-7.048	3.041	-8.354	3.041	-8.354
5.000	7.865	-32.965	0.486	-3.827	0.473	-1.982
10.000	9.651	-50.289	0.271	-3.218	0.267	-1.391
12.300	10.218	-57.514	0.225	-3.077	0.223	-1.254

INITIAL FLOW ANGLE = -80.0 DEGREES FROM X AXIS

TIME	X	Y	PART U X	PART U Y	FLD U X	FLD U Y
0.000	1.302	-7.386	1.544	-8.755	1.544	-8.755
5.000	3.973	-33.836	0.243	-3.860	0.236	-2.014
10.000	4.864	-51.262	0.135	-3.230	0.133	-1.404
12.200	5.136	-58.203	0.113	-3.092	0.112	-1.268

INITIAL FLOW ANGLE = -89.0 DEGREES FROM X AXIS

TIME	X	Y	PART U X	PART U Y	FLD U X	FLD U Y
0.000	0.131	-7.499	0.155	-8.889	0.155	-8.889
5.000	0.399	-34.125	0.024	-3.871	0.024	-2.024
10.000	0.488	-51.584	0.014	-3.235	0.013	-1.408
12.200	0.515	-58.534	0.011	-3.095	0.011	-1.271

CHAPTER IV

APPENDIX G

PPDAT.PLT

0.130	74.250	0.102	58.344
1.296	74.239	1.018	58.335
2.591	74.205	2.036	58.309
3.886	74.148	3.054	58.264
6.471	73.967	5.085	58.122
9.049	73.697	7.110	57.909
12.893	73.122	10.131	57.458
25.395	69.772	19.955	54.826
37.125	64.302	29.172	50.527
47.727	56.879	37.503	44.694
56.879	47.727	44.694	37.503
64.302	37.125	50.527	29.172
69.772	25.395	54.826	19.955
73.122	12.893	57.458	10.131
74.250	0.000	58.344	0.000
73.122	-12.893	57.458	-10.131
69.772	-25.395	54.826	-19.955
64.302	-37.125	50.527	-29.172
56.879	-47.727	44.694	-37.503
47.727	-56.879	37.503	-44.694
37.125	-64.302	29.172	-50.527
25.395	-69.772	19.955	-54.826
12.893	-73.122	10.131	-57.458
1.296	-74.239	1.018	-58.335

0.000	35.822
0.850	35.822
8.418	35.157
16.410	33.246
23.670	30.358
35.557	22.896
44.239	14.738
53.014	3.117
57.421	-10.974

57.421	-10.974
56.242	-10.749
51.368	-15.313
48.177	-19.540
44.851	-22.968
41.702	-25.959
38.699	-28.699
35.794	-31.327
32.973	-34.070
29.759	-36.258
26.524	-38.336
23.257	-40.548
19.690	-42.326
15.968	-43.855
12.099	-44.934
8.149	-45.867
4.099	-46.448
0.410	-46.654

CHAPTER IV
APPENDIX H
ERROR FUNCTIONS
COMPLEMENTARY ERROR FUNCTIONS

TABLE OF ERROR FUNCTIONS

<u>X</u>	<u>ERF X</u>	<u>X</u>	<u>ERF X</u>
0.00	0.00000 00000	0.40	0.42839 23550
0.01	0.01128 34156	0.41	0.43796 90902
0.02	0.02256 45747	0.42	0.44746 76184
0.03	0.03384 12223	0.43	0.45688 66945
0.04	0.04511 11061	0.44	0.46622 51153
0.05	0.05637 19778	0.45	0.47548 17198
0.06	0.06762 15944	0.46	0.48465 53900
0.07	0.07885 77198	0.47	0.49374 50509
0.08	0.09007 81258	0.48	0.50274 96707
0.09	0.10128 05939	0.49	0.51166 82612
0.10	0.11246 29160	0.50	0.52049 98778
0.11	0.12362 28962	0.51	0.52924 36198
0.12	0.13475 83518	0.52	0.53789 86305
0.13	0.14586 71148	0.53	0.54646 40969
0.14	0.15694 70331	0.54	0.55493 92505
0.15	0.16799 59714	0.55	0.56332 33663
0.16	0.17901 18132	0.56	0.57161 57638
0.17	0.18999 24612	0.57	0.57981 58062
0.18	0.20093 58390	0.58	0.58792 29004
0.19	0.21183 98922	0.59	0.59593 64972
0.20	0.22270 25892	0.60	0.60385 60908
0.21	0.23352 19230	0.61	0.61168 12189
0.22	0.24429 59116	0.62	0.61941 14619
0.23	0.25502 25996	0.63	0.62704 64433
0.24	0.26570 00590	0.64	0.63458 58291
0.25	0.27632 63902	0.65	0.64202 93274
0.26	0.28689 97232	0.66	0.64937 66880
0.27	0.29741 82185	0.67	0.65662 77023
0.28	0.30788 00680	0.68	0.66378 22027
0.29	0.31828 34959	0.69	0.67084 00622
0.30	0.32862 67595	0.70	0.67780 11938
0.31	0.33890 81503	0.71	0.68466 55502
0.32	0.34912 59948	0.72	0.69143 31231
0.33	0.35927 86550	0.73	0.69810 39429
0.34	0.36936 45293	0.74	0.70467 80779
0.35	0.37938 20536	0.75	0.71115 56337
0.36	0.38932 97011	0.76	0.71753 67528
0.37	0.39920 59840	0.77	0.72382 16140
0.38	0.40900 94524	0.78	0.73001 04313
0.39	0.41873 87001	0.79	0.73610 34538

TABLE OF ERROR FUNCTIONS

<u>X</u>	<u>ERF X</u>	<u>X</u>	<u>ERF X</u>
0.80	0.74210 09647	1.20	0.91031 39782
0.81	0.74800 32806	1.21	0.91295 55080
0.82	0.75381 07509	1.22	0.91553 38810
0.83	0.75952 37569	1.23	0.91805 01041
0.84	0.76514 27115	1.24	0.92050 51843
0.85	0.77066 80576	1.25	0.92290 01283
0.86	0.77610 02683	1.26	0.92523 59418
0.87	0.78143 98455	1.27	0.92751 36293
0.88	0.78668 73192	1.28	0.92973 41930
0.89	0.79184 32468	1.29	0.93189 86327
0.90	0.79690 82124	1.30	0.93400 79449
0.91	0.80188 28258	1.31	0.93606 31228
0.92	0.80676 77215	1.32	0.93806 51551
0.93	0.81156 35586	1.33	0.94001 50262
0.94	0.81627 10190	1.34	0.94191 37153
0.95	0.82089 08073	1.35	0.94376 21961
0.96	0.82542 36496	1.36	0.94556 14366
0.97	0.82987 02930	1.37	0.94731 23980
0.98	0.83423 15043	1.38	0.94901 60353
0.99	0.83850 80696	1.39	0.95067 32958
1.00	0.84270 07929	1.40	0.95228 51198
1.01	0.84681 04962	1.41	0.95385 24394
1.02	0.85083 80177	1.42	0.95537 61786
1.03	0.85478 42115	1.43	0.95685 72531
1.04	0.85864 99465	1.44	0.95829 65696
1.05	0.86243 61061	1.45	0.95969 50256
1.06	0.86614 35866	1.46	0.96105 35095
1.07	0.86977 32972	1.47	0.96237 28999
1.08	0.87332 61584	1.48	0.96365 40654
1.09	0.87680 31019	1.49	0.96489 78648
1.10	0.88020 50696	1.50	0.96610 51465
1.11	0.88353 30124	1.51	0.96727 67481
1.12	0.88678 78902	1.52	0.96841 34969
1.13	0.88997 06704	1.53	0.96951 62091
1.14	0.89308 23276	1.54	0.97058 56899
1.15	0.89612 38429	1.55	0.97162 27333
1.16	0.89909 62029	1.56	0.97262 81220
1.17	0.90200 03990	1.57	0.97360 26275
1.18	0.90483 74269	1.58	0.97454 70093
1.19	0.90760 82860	1.59	0.97546 20158

TABLE OF ERROR FUNCTIONS

<u>X</u>	<u>ERF X</u>	<u>X</u>	<u>ERF X</u>
1.60	0.97634 83833	1.80	0.98909 05016
1.61	0.97720 68366	1.81	0.98952 45446
1.62	0.97803 80884	1.82	0.98994 31565
1.63	0.97884 28397	1.83	0.99034 68051
1.64	0.97962 17795	1.84	0.99073 59476
1.65	0.98037 55850	1.85	0.99111 10301
1.66	0.98110 49213	1.86	0.99147 24883
1.67	0.98181 04416	1.87	0.99182 07476
1.68	0.98249 27870	1.88	0.99215 62228
1.69	0.98315 25869	1.89	0.99247 93184
1.70	0.98379 04586	1.90	0.99279 04292
1.71	0.98440 70075	1.91	0.99308 99398
1.72	0.98500 28274	1.92	0.99337 82251
1.73	0.98557 84998	1.93	0.99365 56502
1.74	0.98613 45950	1.94	0.99392 25709
1.75	0.98667 16712	1.95	0.99417 93336
1.76	0.98719 02752	1.96	0.99442 62755
1.77	0.98769 09422	1.97	0.99466 37246
1.78	0.98817 41959	1.98	0.99489 20004
1.79	0.98864 05487	1.99	0.99511 14132
		2.00	0.99532 22650

COMPLEMENTARY ERROR FUNCTION

x^{-2}	$x e^{x^2} \text{ERFC } x$	x^{-2}	$x e^{x^2} \text{ERFC } x$
0.250	0.51079 14	0.125	0.53406 72
0.245	0.51163 07	0.120	0.53511 47
0.240	0.51247 67	0.115	0.53617 29
0.235	0.51332 94	0.110	0.53724 20
0.230	0.51418 90	0.105	0.53832 23
0.225	0.51505 55	0.100	0.53941 41
0.220	0.51592 92	0.095	0.54051 76
0.215	0.51681 01	0.090	0.54163 32
0.210	0.51769 83	0.085	0.54276 11
0.205	0.51859 40	0.080	0.54390 16
0.200	0.51949 74	0.075	0.54505 51
0.195	0.52040 85	0.070	0.54622 19
0.190	0.52132 75	0.065	0.54740 24
0.185	0.52225 45	0.060	0.54859 69
0.180	0.52318 98	0.055	0.54980 58
0.175	0.52413 33	0.050	0.55102 95
0.170	0.52508 55	0.045	0.55226 85
0.165	0.52604 63	0.040	0.55352 32
0.160	0.52701 59	0.035	0.55479 41
0.155	0.52799 46	0.030	0.55608 17
0.150	0.52898 25	0.025	0.55738 65
0.145	0.52997 98	0.020	0.55870 90
0.140	0.53098 67	0.015	0.56005 00
0.135	0.53200 35	0.010	0.56140 99
0.130	0.53303 02	0.005	0.56278 96
0.125	0.53406 72	0.000	0.56418 96

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