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DESIGN OF SOLID PROPELLANT GRAINS USING THE HEWLETT-PACKARD 41C--ETC(U)
MAR 82 J C HODGES
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TECHNICAL REPORT RK-82-3

DESIGN OF SOLID PROPELLANT GRAINS USING THE
HEWLETT-PACKARD 41C CALCULATOR

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Propulsion Directorate
US Army Missile Laboratory

March 1982



U.S. ARMY MISSILE COMMAND

Redstone Arsenal, Alabama 35898

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) ✓ This report describes the solution of a typical solid propellant grain design requirement using the Hewlett-Packard 41C hand held calculator and a program for the solution of Wagon Wheel, Modified Wagon Wheel and Star Grain designs. A grain design for an experimental rocket, PLUME is given. The HP41C Program is given in Appendix A.		

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THE DESIGN OF SOLID PROPELLANT GRAINS USING THE HEWLETT PACKARD 41C CALCULATOR

J. C. HODGES

The design of a solid propellant rocket motor grain is in many ways as much an art as it is a science. Typically, the grain designer has many years of design experience to call upon in designing a grain for a specific application and over the years very sophisticated computer codes have been written to evaluate a given grain design. However, the initial design had to come from the tedious and often time consuming method of graphically laying out a design based on the designer's experience. There have been computer calculated curves published that aid the designer in his choice but for the most part these approaches virtually ignore propellant characteristics and dwell on such parameters as loading fraction. Consequently, it would be advantageous for the designer to have a simple method that would give him a quick solution to his design problem. With this in mind, a program has been written for the H/P 41C Programmable Calculator that will solve for three basic solid propellant grain designs - Standard Wagon Wheel, Modified Wagon Wheel ($W_1=W_2=W_3$), and Star. The program uses ballistic requirements and propellant characteristics selected by the design engineer and calculates a design output that can be used as an excellent first order solution for input to more sophisticated computer codes, such as the Solid Propellant Rocket Motor Internal Ballistics Computer Program.

Using the first order solution as a "seed" will greatly simplify the computer code input and reduce computer run time. For simplification, only cylindrical grains without forward or aft end domes are considered, however the engineer does have the option of considering both ends of the grain inhibited, one end of the grain inhibited or both ends uninhibited. Stable combustion and non-erosive burning are assumed and the number of spokes or star points have been limited to what has been considered practical and useful geometric limits. The equations for the star grain have been established to achieve as close to neutral surface versus time as is feasible within these limits.

User inputs for this program are: grain outside diameter, web burn time, propellant burn rate and K_b ratio at the selected operating pressure, propellant density, propellant expected delivered impulse and the total impulse required by the mission. Program outputs include predicted ballistic parameters, average thrust, etc., and a geometric description of the grain as shown in Figures A, B, and C.

1. "Solid Propellant Rocket Motor Internal Ballistics Computer Program",
Report Number RK-TR-67-7, US Army Missile Command, Redstone Arsenal, Alabama.

The equations used in this program are based on a paper by Max W. Stone.² The program format has been fashioned after that of the Hewlett/Packard format for the submission of user programs to the H/P Users Library because this format is considered the standard for H/P 41C users. Equipment necessary to use the "SPGD" program are: a H/P 41C with quad memory module or a 41CV, and a H/P 82143A Peripheral Printer. Any suggestions for improvement of the program will be welcomed by the author. One word of caution, negative outputs indicate geometric limits have been exceeded or incorrect data has been entered.

An example of a grain designed using this program is the PLUME grain. PLUME is an experimental rocket for the evaluation of the interaction between the rocket exhaust and the command guidance link. The desired ballistic parameters for PLUME were a velocity of 4000 fps at the end of a 1 second boost, and to maintain 4000 fps for 2 seconds using a sustainer. The motor I.D. was 6.4 inches and minimum smoke propellant had to be used in the boost and sustain phase. The total inert weight of the missile was 57.3 lb.

Preliminary trajectory analysis³ using the H/P 41C indicated a boost total impulse of 13,500 lb-sec would meet the desired end-of-boost velocity. Drag at the end of boost was 925 lbf, therefore the sustain total impulse would be 1850 lb-sec. A minimum smoke propellant, Propulsion Directorate formulation B-59, of the lacquer type was chosen. Its ballistic characteristics at the selected operating pressure of 2000 psi are: burn rate-0.47 ips, Kn ratio-450 and delivered I_{sp} -245 lb-sec per lb. The density of this formulation is 0.06 lb per cubic inch.

A two part booster grain was selected for the first analysis - a forward boost grain that would burn into a "cylindrical port" sustainer and an aft boost grain that would burn to the case wall during boost burning. The aft section of the boost grain was considered to have one end burning. The forward grain section and the aft section were considered to be inhibited. The "Solid Propellant Grain Design" program was used to determine the geometric and ballistic parameters of the two booster grains. The data inputs and output is shown in Table 1.

The nozzle throat area is sized by the booster requirements and the sustainer ballistic characteristics are "backed into." Propellant experimental data indicated the minimum desirable chamber pressure for stable combustion would probably be 500 psi. The initial burning surface for the sustainer would be the final burning surface for the booster and can be found in the printout (Table 1). This surface will change very quickly as the slivers of the aft booster burn away, however the slivers from the forward grain will remain as cusps on a basically cylindrical port grain.

2. "A Practical Mathematical Approach to Grain Design," Jet Propulsion, Volume 28, Number 1, January 1958.

3. "Multi-Stage Trajectory Analysis" by Karl L. Remmler, Hewlett/Packard Users Library Number 00617C.

Assuming that the sustainer burning surface is 898 square inches subsequent to aft sliver burnout, the motor K_n will be 207. This K_n will cause the chamber pressure to be approximately 500 psi and hence a propellant burn rate of 0.29 ips. The final sustainer burn surface will be approximately 495 square inches giving a chamber pressure of less than 200 psi. This gives an average sustainer burn surface of 696 square inches which calculates to an average thrust of 2755 lbf. It will be noted that this is more thrust than required to overcome drag, but is the minimum condition for sustainer operations using the required minimum smoke propellant. A cross-section sketch of the grain is shown in Figures 1 and 2 and the predicted booster interior ballistics in Table 1. Propellant distribution is shown in Table 2. Table 3 lists the inputs and outputs of a two dimension trajectory analysis of the PLUME missile using the 41C. This design was then used as a "seed" for the Boeing Solid Propellant Rocket Motor Internal Ballistic Computer Program. There was a very good correlation between the ballistics predicted by the H/P 41C and the large-scale computer code.



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TABLE 1

PLUME BOOST GRAIN INPUT/OUTPUT

AFT BOOST GRAIN

SPGD GRAIN
GRAIN O.D. ?
6.40 RUN
BURN TIME ?
1.00 RUN
PROP K ?
450.00 RUN
PROP DENSITY
.06 RUN
BURN RATE ?
.47 RUN
DEL ISP ?
245.00 RUN
TOT ISP ?
7,500.00 RUN
LBL A,B, OR C?
XEQ B
N=? 4 TO 16
8.00 RUN
Z=?
.25 RUN
MOD W.W. GRN.

AVG F = 7,500.00 LBF
NET I TOT = 7,500.00 SEC
NET PROP WT = 30.61 LB
TOT PROP WT = 33.95 LB
BURN TIME = 1.00 SEC
INL Ab = 1.072.75 SQ IN
FML Ab = 1.098.33 SQ IN
P.R. = 1.02
L.F. = 0.70
SLVR FRAC = 0.07
GRAIN L = 25.18 IN
GRAIN O.D. = 6.40 IN
WEB = 0.47 IN
STRESS R = 0.19 IN
SYM NR = 8.00
BETA = 45.00 DEG
ALPHA = 29.88 DEG
THETA = 105.12 DEG
GAMMA = 15.12 DEG
K = 0.96 IN
M = 0.66 IN
L = 1.63 IN
Z = 0.25 IN
PORT A = 9.70 SQ IN
THROAT A = 2.41 SQ IN
PORT/THROAT = 4.02

ONE END BURNING

INL Ab = 1.095.23 SQ IN
FML Ab = 1.077.83 SQ IN
P.R. = 0.98
THROAT A = 2.41 SQ IN
PORT/THROAT = 4.02

FORWARD BOOST GRAIN

GRAIN O.D. ?
5.24 RUN
BURN TIME ?
1.00 RUN
PROP K ?
450.00 RUN
PROP DENSITY
.06 RUN
BURN RATE ?
.47 RUN
DEL ISP ?
245.00 RUN
TOT ISP ?
6,000.00 RUN
LBL A,B, OR C?
XEQ B
N=? 4 TO 16
8.00 RUN
Z=?
.25 RUN
MOD W.W. GRN.

AVG F = 6,000.00 LBF
NET I TOT = 6,000.00 SEC
NET PROP WT = 24.49 LB
TOT PROP WT = 28.19 LB
BURN TIME = 1.00 SEC
INL Ab = 853.81 SQ IN
FML Ab = 883.05 SQ IN
P.R. = 1.03
L.F. = 0.76
SLVR FRAC = 0.10
GRAIN L = 20.79 IN
GRAIN O.D. = 5.24 IN
WEB = 0.47 IN
STRESS R = 0.16 IN
SYM NR = 8.00
BETA = 45.00 DEG
ALPHA = 26.66 DEG
THETA = 108.34 DEG
GAMMA = 18.34 DEG
K = 0.40 IN
M = 0.66 IN
L = 1.07 IN
Z = 0.25 IN
PORT A = 5.25 SQ IN
THROAT A = 1.93 SQ IN
PORT/THROAT = 2.72

TABLE 2
PLUME PROPELLANT WEIGHT DISTRIBUTION (LBS)

	<u>TOTAL LOADED</u>	<u>NET</u>	<u>SLIVER</u>
Fwd Boost Wt =	28.19	24.49	3.70
Aft Boost Wt =	<u>33.95</u>	<u>30.61</u>	<u>3.34</u>
<u>TOTAL BOOST WT =</u>	62.14	55.10	7.04*
Sustain Cycl Wt =	18.63	16.38	2.25
Boost Slvr Wt =	<u>7.04*</u>	<u>7.04*</u>	<u>-0-</u>
<u>TOTAL SUSTAIN WT =</u>	25.67	23.42	2.25
G. T. Propellant Wt =	87.81	78.52	2.25
Inert Weight =	<u>57.31</u>		
<u>MISSILE WT =</u>	145.12		

*NOTE: Boost sliver consumed during sustain.

Total Grain Length = 25.18 in Aft Boost + 28.79 Fwd Boost = 53.97 in

TABLE 3
PLUME TRAJECTORY ANALYSIS

BOOST INPUT/OUTPUT			SUSTAIN INPUT/OUTPUT		
A=			A=		
	.230	RUN		.230	RUN
WP=?			WP=?		
	55.100	RUN		23.420	RUN
VAC. ISP=?			VAC. ISP=?		
	270.000	RUN		265.000	RUN
TB=?			TB=?		
	0.000	RUN		3.000	RUN
TB=?			TF=?		
	1.000	RUN		3.000	RUN
TF=?			ALPHA=?		
	1.000	RUN		0.000	RUN
ALPHA=?			AEXIT=?		
	0.000	RUN		.230	RUN
AEXIT=?			N=?		
	.230	RUN		20.000	RUN
N=?			M=?		
	10.000	RUN		5.000	RUN
M=?			WD=?		
	5.000	RUN		0.000	RUN
WD=?					XEQ A
	145.120	RUN			
V=?			TIME=1.500 SEC		TIME=3.000 SEC
	0.000	RUN	VEL=3,957.099 FPS		VEL=4,778.121 FPS
PATH ANGLE=?			PATH ANGLE=1.698 DEG		PATH ANGLE=1.086 DEG
	3.500	RUN	RANGE=1.134 KM		RANGE=3.153 KM
RANGE=?			ALT=129.790 FT		ALT=287.958 FT
	0.000	RUN	Q=18,719.448 PSF		Q=27,890.223 PSF
ALT=?			T=2,614.296 LBS		T=0.000 LBS
	1.000	RUN	DRAG=990.259 LBS		DRAG=1,475.393 LBS
		XEQ A	WEIGHT=84.165 LBS		WEIGHT=66.600 LBS
TIME=0.500 SEC			TIME=2.000 SEC		
VEL=1,754.235 FPS			VEL=4,262.866 FPS		
PATH ANGLE=2.281 DEG			PATH ANGLE=1.479 DEG		
RANGE=0.129 KM			RANGE=1.762 KM		
ALT=19.658 FT			ALT=186.652 FT		
Q=3,659.912 PSF			Q=21,687.893 PSF		
T=14,386.160 LBS			T=2,615.313 LBS		
DRAG=337.108 LBS			DRAG=1,147.290 LBS		
WEIGHT=117.570 LBS			WEIGHT=78.310 LBS		
TIME=1.000 SEC			TIME=2.500 SEC		
VEL=3,643.860 FPS			VEL=4,558.518 FPS		
PATH ANGLE=1.935 DEG			PATH ANGLE=1.276 DEG		
RANGE=0.554 KM			RANGE=2.436 KM		
ALT=69.674 FT			ALT=239.585 FT		
Q=18,127.872 PSF			Q=24,762.021 PSF		
T=0.000 LBS			T=2,616.258 LBS		
DRAG=958.964 LBS			DRAG=1,309.911 LBS		
WEIGHT=90.020 LBS			WEIGHT=72.455 LBS		

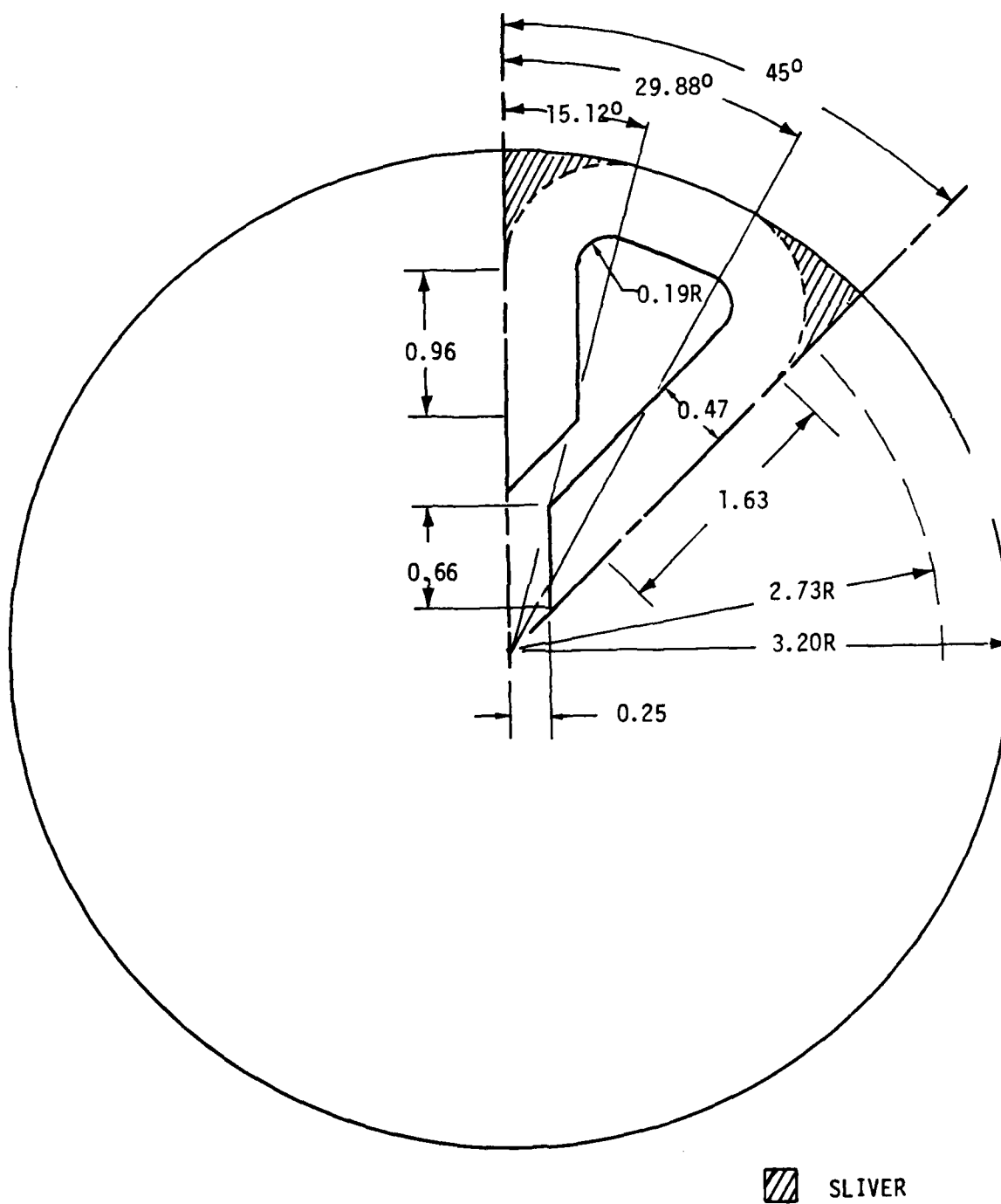


Figure 1. PLUME aft boost grain

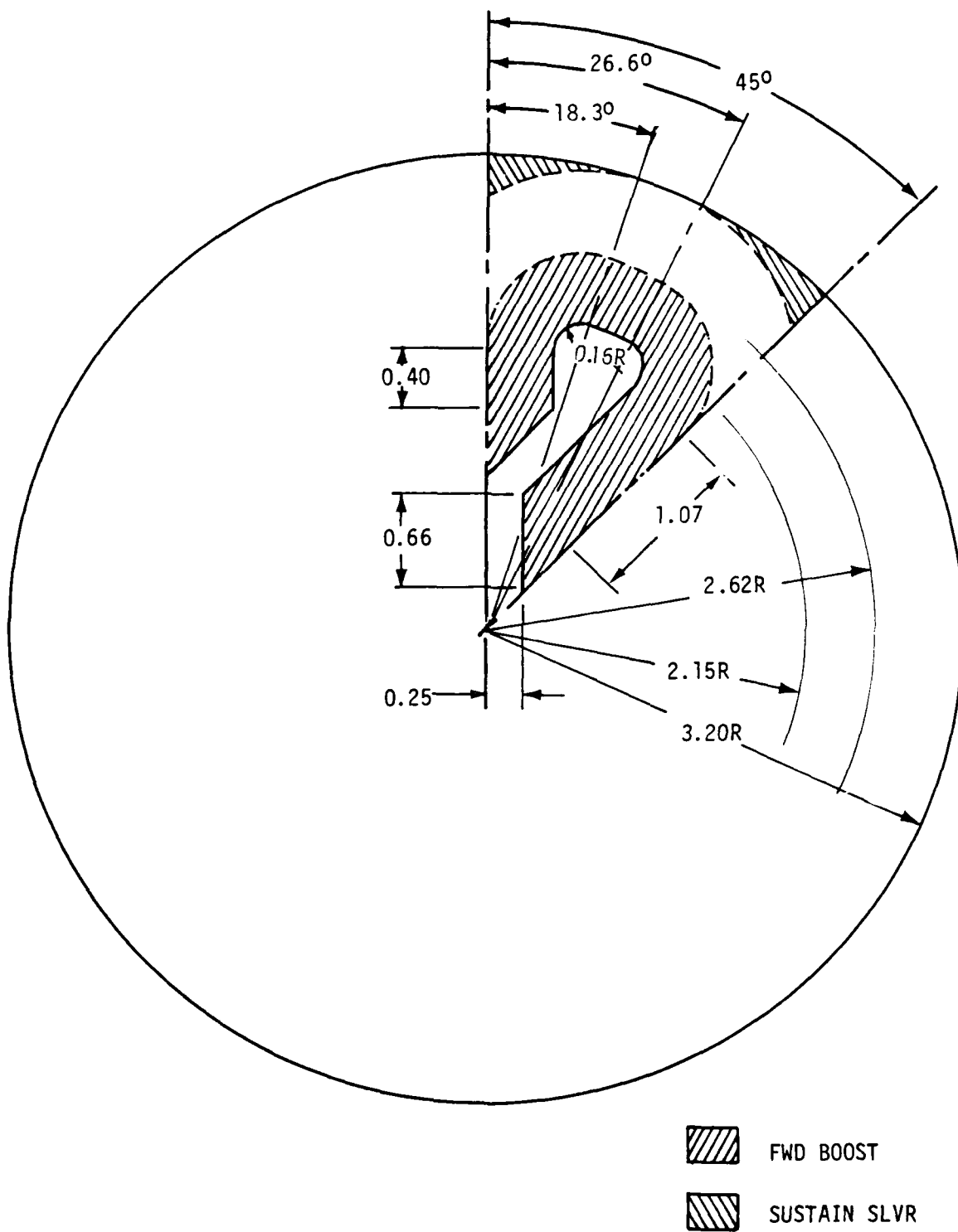


Figure 2. PLUME forward boost grain and sustain grain

APPENDIX A
SOLID PROPELLANT GRAIN DESIGN
PROGRAM FOR H/P 41C

GLOSSARY OF TERMS

<u>SYMBOL</u>	<u>DESCRIPTION</u>	<u>UNITS</u>
A_b	Area of Burning Surface	sq in
A_c	Cross-section Area of Case	sq in
A_g	Cross-section Area of Grain	sq in
A_{slvr}	Cross-section Area of Grain Sliver	sq in
A_t	Motor Nozzle Throat Area	sq in
Avg	Average	
F	Motor Thrust	Lbf
FNL	Final Conditions at burn-out	
INL	Initial Conditions at ignition	
I_{sp}	Propellant Specific Impulse	Lbf-sec/Lb _m
I_T	Motor Total Impulse	Lbf-sec
K	Length of Short Spoke	in
K_n	Ratio of A_b to A_t	
L	Length of Long Spoke	in
L_g	Length of Grain	in
L'_g	Length of Grain with ends burning.	in
L.F.	Loading Fraction, Ratio of A_g to A_c	
m	Length of Spoke Face	in
N	Symetry Number, Number of Spokes or Star Points	
O.D. or D.	Outside Diameter of Grain	in
PROP	Propellant	
P.R.	Progressivity Ratio, Ratio of FNL A_b to INL A_b	
$\dot{r}$	Burning Rate of Propellant	in/sec
r	Stress Relief Radius of Grain	in

S	Burning Periphery of Grain Cross-section	in
S.F.	Sliver Fraction, Ratio of A_{slvr} to A_c	
t_b	Time required to burn web distance	sec
W	Grain Web	in
Wt	Propellant Weight	Lb _m
$\bar{L}$	Distance between parallel sides of spokes and distance between spoke face and center line (See Figures)	in

<u>SYMBOL</u>	<u>DEFINITION</u>	
α	Alpha, Angle Locating r (see figures)	Deg
β	Beta, Angle Defining Propellant Sector	Deg
γ	gamma, Angle Locating r (see figures)	Deg
ρ	rho, Propellant Density	Lb _m /cu in
θ	Theta, Angle Defining Arc of r	Deg

PROGRAM DESCRIPTION
(EQUATIONS)

STANDARD WAGON WHEEL, FIGURE A

1. $N =$ Number of spokes or symmetry number
2. $\beta = \frac{\pi}{N}$
3. $\gamma = \sin^{-1} \left[\frac{\frac{r+w}{D}}{\frac{1}{2}r-w} \right]$
4. $\alpha = \beta - \gamma$
5. $\theta = \frac{\beta}{2} + \beta - \alpha$
6. Maximum allowable web = $(0.2)(O.D.)$
7. $m = \frac{W}{\sin \beta}$
8. $L_{\text{minimum}} = m$
9. $L_{\text{maximum}} = \frac{r+w}{\tan \gamma} - \frac{W}{\tan \beta}$
10. $L = \frac{(\sin \beta)(L_{\text{max}}) - Z}{\sin \beta}$
11. $INL_{Ab} = Lg2N \left[L+m+r\theta + \left(\frac{D}{2} - W \right)(\alpha) \right]$
12. $Ag = N \left[\alpha(Dw-W^2) + 2LW + \frac{W^2}{\tan \beta} + \frac{D^2\gamma}{4} - r^2\theta - \frac{(r+W)^2}{\tan \gamma} \right]$
13. $Aslvr = N \left[\frac{D^2\gamma}{4} - (r+W)^2\theta - \frac{(r+W)^2}{\tan \gamma} \right]$
14. $L.F. = \frac{Ag}{A_{case}}$
15. $S.F. = \frac{Aslvr}{A_{case}}$
16. Weight of slvr = $(Aslvr)(\rho)(Lg)$
17. $FNL_{Ab} = (Lg)(2N) \left[L = \left(\frac{D}{2} \right)(\alpha) + (W+r)\theta + \frac{W}{\tan \beta} - m \right]$
18. $P.R. = \frac{FNL_{Ab}}{INL_{AF}}$

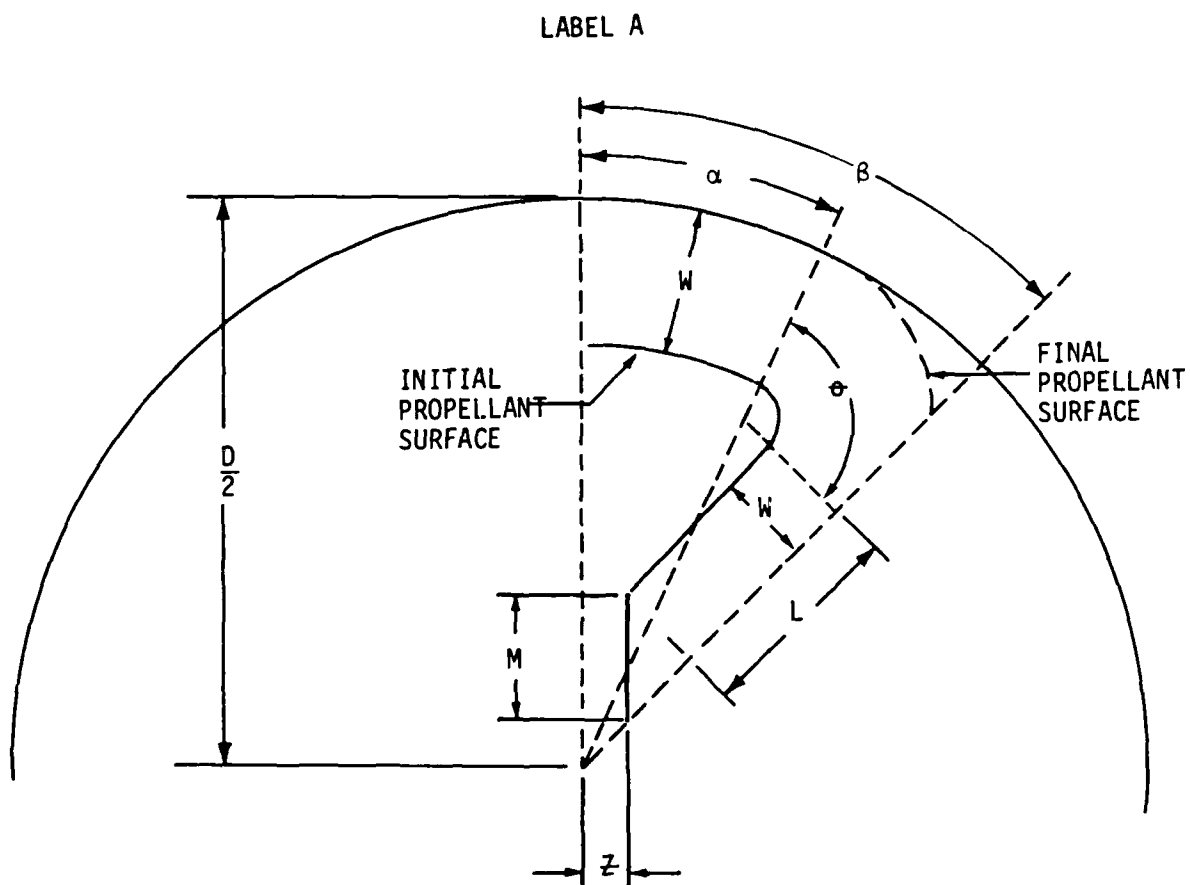


Figure A. Sector of a standard wagon wheel configuration

MODIFIED WAGON WHEEL, ($WEB_1 = WEB_2 = WEB_3$), FIGURE B.

1. N = Number of spokes of symmetry number
2. $\beta = \frac{2\pi}{N}$
3. $\gamma = \sin^{-1} \left[\frac{r+W}{\frac{D}{2} - r - W} \right]$
4. $\alpha = \beta - \gamma$
5. $\theta = \frac{\pi}{2} + \gamma$
6. $m = \frac{W}{\sin \beta}$
7. $K = L - m$
8. $L_{max} = \frac{r+W}{\tan \gamma} - \frac{W}{\tan \beta}$
9. $L = \frac{(\sin \beta)(L_{max}) - Z}{\sin \beta}$
10. $INL Ab = (Lg)(2N)(L) + N \left[m + 2r\theta + \frac{D}{2} - W)(\alpha + \gamma) \right]$
11. $Ag = N \left[\frac{W^2}{\tan \beta} + 2LW - mW - r^2\theta + \frac{D^2\beta}{8} - \frac{(r+W)^2}{\tan \gamma} - \left(\frac{D - W}{2} \right)^2 (\alpha - \gamma) \right]$
12. $Aslvr = N \left[\frac{D^2\gamma}{4} - (r+W)^2 \theta - \frac{(r+W)^2}{\tan \gamma} \right]$
13. $L.F. = \frac{Ag}{Acase}$
14. $S.F. = \frac{Aslvr}{Acase}$
15. $Wt. slvr = (Aslvr)(\rho)(Lg)$
16. $FNL Ab = (Lg)(N) \left[2L - 3m + 2(r+W)\theta + \frac{2W}{\tan \beta} + \left(\frac{D}{2} \right)(\alpha - \gamma) \right]$
17. $P.R. = \frac{FNL Ab}{INL Ab}$

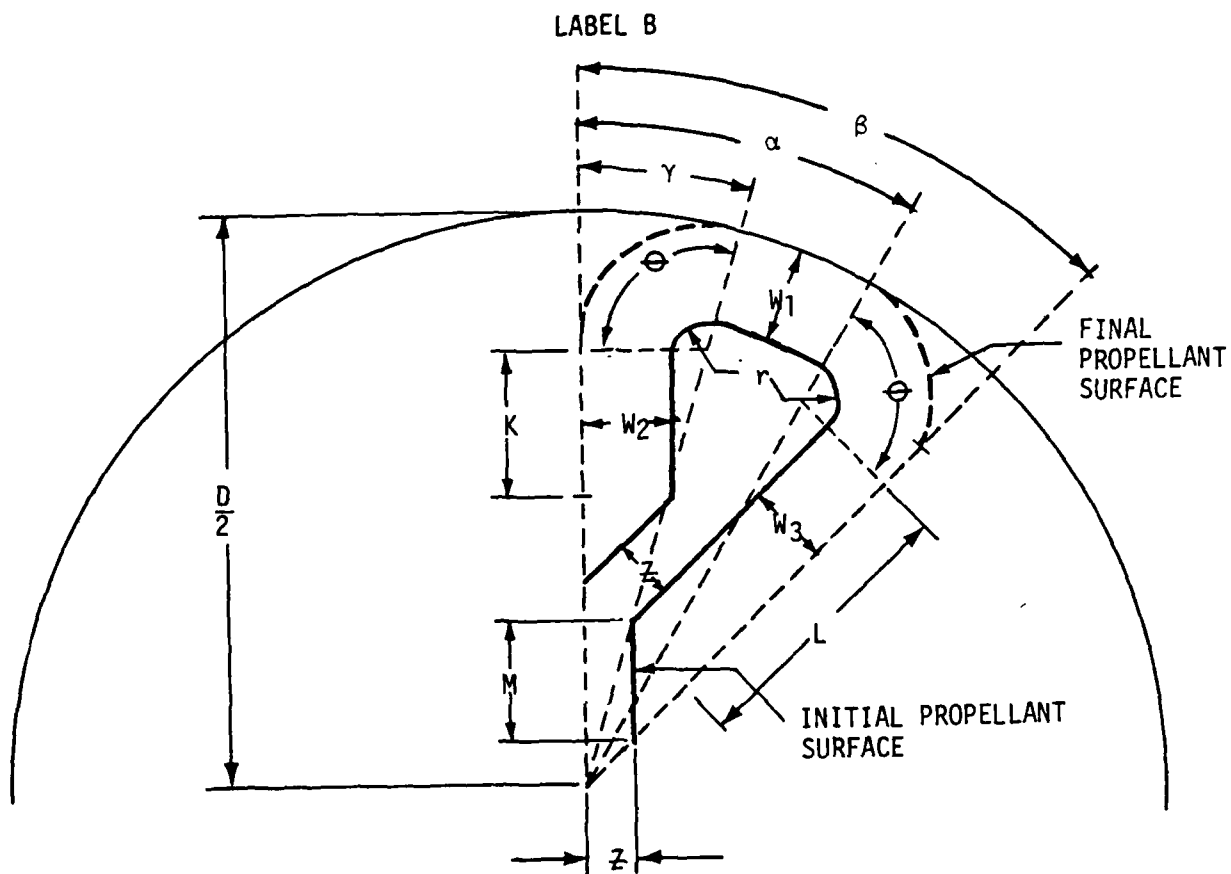


Figure B. Sector of a modified wagon wheel configuration, $W_1=W_2=W_3$

STAR, FIGURE C.

1. N = Number of Star Points or symmetry number

$$2. \beta = \frac{\pi}{N}$$

$$3. \theta = \beta + \sin^{-1} \left[\frac{\left(\frac{D}{2} - r - W\right) (\sin \beta)}{r + w} \right]$$

4. $\alpha = \tan^{-1}(\alpha - \beta)$ for maximum neutrality

5. Maximum Web = (0.33)(O.D.)

$$6. \text{INL Ab} = (L_g)(2N) \left[r(\alpha - \tan \alpha) + \frac{\left(\frac{D}{2} - r - W + \frac{r}{\cos \alpha}\right) \sin \beta}{\cos(\alpha - \beta)} \right]$$

$$7. \text{FNL Ab} = (L_g)(2N) [(r+W)\theta]$$

$$8. A_g = \frac{\pi D^2}{4} - N \left[\frac{\left(\frac{D}{2} - r - W + \frac{r}{\cos \alpha}\right)^2 \sin \beta \cos \alpha + r^2 (\alpha - \tan \alpha)}{\cos(\alpha - \beta)} \right]$$

$$9. A_{slvr} = \frac{\pi D^2}{4} - N \left[(r+W)^2 \theta + (r+W) \left(\frac{D}{2} - r - W\right) \sin \theta \right]$$

10. Iteration for $\alpha = \tan^{-1}(\alpha - \beta)$:

$$\text{Change in } \alpha = \frac{\alpha - \tan^{-1}(\alpha - \beta)}{\frac{1}{\cos^2(\alpha - \beta)} - 1}$$

CORRECTIONS FOR END BURN, ALL CASES

1. New INL Ab = Old INL Ab + (A_g * 2), for two ends

2. New FNL Ab = $\left(\frac{\text{OLD FNL Ab}}{L_g}\right)(L_g - 2W)$, for two ends

3. New P.R. = $\frac{\text{New FNL Ab}}{\text{New INL Ab}}$

4. New A_t = $\frac{\text{Avg Ab}}{K_n}$

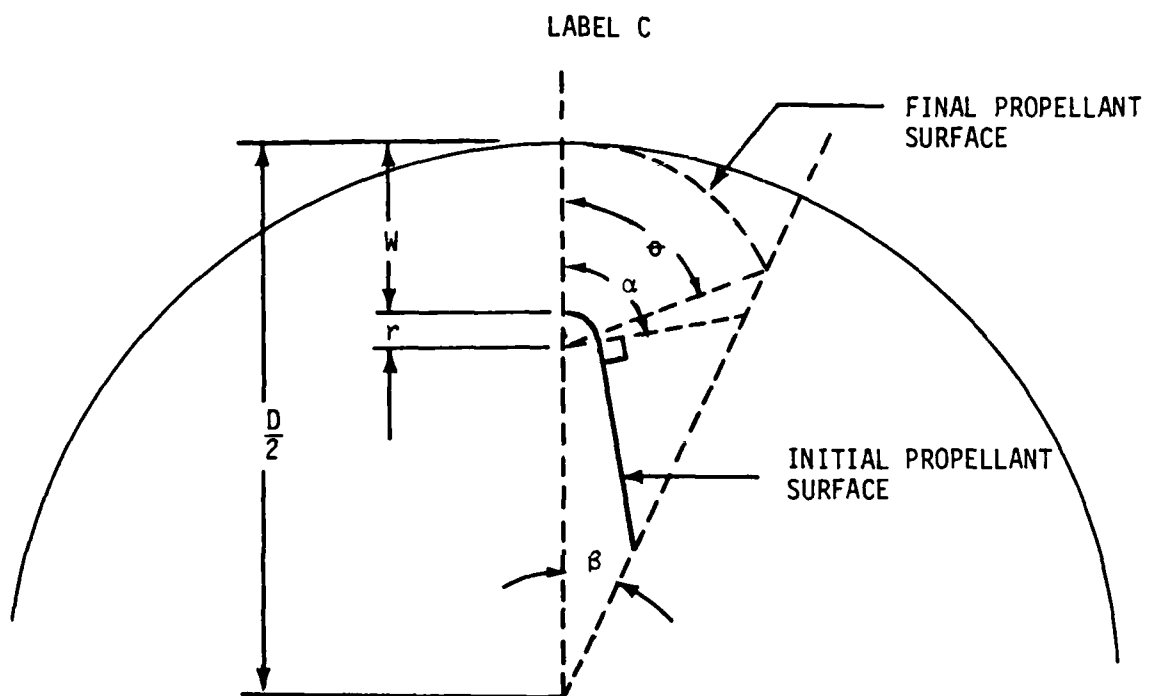


Figure C. Sector of Star Design, side burns out at web

GENERAL BALLISTIC EQUATIONS

1. $AVG F = \frac{NET I_{total}}{tb}$

2. $NET PROP. WT. = (Lg)(Ag - As_{ivr})(\rho)$

3. $TOTAL PROP. WT. = (Lg)(Ag)(\rho)$

4. $I_{total} = (NET PROP. WT.)(Isp)$

5. $Lg = \frac{I_{total}}{\frac{(\rho)(Isp)}{Ag - As_{ivr}}}$

6. $W = (\dot{r})(tb)$

7. $K_n = \frac{Ab}{At}$

8. $A_t = \frac{INL Ab + FNL Ab}{(2)(K_n)}$

PROGRAM DESCRIPTION

SAMPLE PROBLEM:

GIVEN: GRAIN O.D. = 4.25 IN.
BURN TIME = 1.0 SEC
TOTAL IMPULSE = 7000 LB-SEC

REQUIRED: CALCULATE A STD W. W. GRAIN WITH BOTH ENDS BURNING, A MOD W.W.
AND A STAR GRAIN WITH NO ENDS BURNING.

SELECTED: CHAMBER PRESSURE = 2000 PSI
PROPELLANT K_n = 460 @ 2000 PSI
PROPELLANT BURN RATE = 0.5 IPS₃ @ 2000 PSI
PROPELLANT DENSITY = 0.062 LB/IN³
PROPELLANT DEL. ISP = 235 LB-SEC/LB

SOLUTION:

INPUT	FUNCTION	DISPLAY	COMMENTS
	PRINTER: ON/NORM		
	(XEQ) SIZE 037		
	(EQ) SPGD	READY	
4.25	R/S	GRAIN O.D. ?	ENTER GRAIN O.D.
1.0	R/S	BURN TIME ?	ENTER BURN TIME
460	R/S	PROP K ?	ENTER PROPELLANT K_n
.062	R/S	PROP DENSITY	ENTER PROPELLANT DENSITY
.5	R/S	BURN RATE ?	ENTER PROPELLANT BURN RATE
235	R/S	DEL ISP ?	ENTER EXPECTED DELIVERED ISP
7000	R/S	TOT ISP ?	ENTER TOTAL IMPULSE REQ'D
	(A)	LBL A.B. OR C ?	SELECT LBL A FOR STD W.W.
5.	R/S	N=? 2 TO 16	SELECT SYMENTRY NR
.2	R/S	Z=?	SELECT VALUE FOR Z
		STD W.W. GRAIN	OUTPUT PRINTED
	(D)	NEXT CMD	SELECT LBL D FOR END BRN
	R/S	1 END: SF02	SELECT 2 END BRN (NO FLAG)
			CORRECTION FOR END BRN PRINTED
		NEXT CMD	SELECT LBL B FOR MOD W.W.
6.	R/S	N=? 4 TO 16	SELECT SYMENTRY NR (MULT OF 2)
.2	R/S	L=?	SELECT VALUE FOR Z
		MOD W.W. GRN	OUTPUT PRINTED
	(C)	NEXT CMD	SELECT LBL C FOR STAR
10.	R/S	N=? 4 TO 10	SELECT SYMENTRY NR
		STAR	OUTPUT PRINTED
	(E)	NEXT CMD	SELECT LBL E TO EXIT PROGRAM
		0.00	CALCULATOR RTN TO NORMAL

SAMPLE PROBLEM INPUT/OUTPUT

SPGD READY XEQ "SPGD"

SPGD GRAIN RUN

GRAIN O.D. ? 4.25 RUN

BURN TIME ? 1.00 RUN

PROP K ? 460.00 RUN

PROP DENSITY .062 RUN

BURN RATE ? .50 RUN

DEL ISP ? 235.00 RUN

TOT ISP ? 7,000.00 RUN

LBL A,B, OR C? XEQ A

N=? 2 TO 16 5.00 RUN

Z=? .20 RUN

STD W.W. GRN.

AVG F = 7,000.00 LBF

NET I TOT = 7,000.00 SEC

NET PROP WT = 29.79 LB

TOT PROP WT = 34.93 LB

BURN TIME = 1.00 SEC

INL Ab = 937.79 SQ IN

FNL Ab = 983.97 SQ IN

P.R. = 1.05

L.F. = 0.74

SLVR FRAC = 0.11

GRAIN L = 53.41 IN

GRAIN O.D. = 4.25 IN

WEB = 0.50 IN

STRESS R = 0.13 IN

SYN NR = 5.00

BETA = 36.00 DEG

ALPHA = 11.23 DEG

THETA = 114.77 DEG

N = 0.85 IN

L = 0.33 IN

Z = 0.20 IN

PORT A = 3.64 SQ IN

THROAT A = 2.09 SQ IN

PORT/THROAT = 1.74

1 END: SF02 XEQ D

TWO END BURNING W/ RUN

INL Ab = 958.89 SQ IN

FNL Ab = 965.54 SQ IN

P.R. = 1.01

THROAT A = 2.09 SQ IN

PORT/THROAT = 1.74

N=? 4 TO 16 XEQ B

Z=? 6.00 RUN

MOD W.W. GRN. .20 RUN

AVG F = 7,000.00 LBF

NET I TOT = 7,000.00 SEC

NET PROP WT = 29.79 LB

TOT PROP WT = 35.49 LB

BURN TIME = 1.00 SEC

INL Ab = 907.25 SQ IN

FNL Ab = 1,014.51 SQ IN

P.R. = 1.12

L.F. = 0.82

SLVR FRAC = 0.13

GRAIN L = 49.34 IN

GRAIN O.D. = 4.25 IN

WEB = 0.50 IN

STRESS R = 0.13 IN

SYN NR = 6.00

BETA = 60.00 DEG

ALPHA = 35.23 DEG

THETA = 114.77 DEG

GAMMA = 24.77 DEG

K = 0.26 IN

M = 0.58 IN

L = 0.84 IN

Z = 0.20 IN

PORT A = 2.59 SQ IN

THROAT A = 2.09 SQ IN

PORT/THROAT = 1.24

N=? 4 TO 10 XEQ C

STAR GRN 10.00 RUN

AVG F = 7,000.00 LBF

NET I TOT = 7,000.00 SEC

NET PROP WT = 29.79 LB

TOT PROP WT = 34.49 LB

BURN TIME = 1.00 SEC

INL Ab = 960.87 SQ IN

FNL Ab = 961.65 SQ IN

P.R. = 1.00

L.F. = 0.59

SLVR FRAC = 0.08

GRAIN L = 67.01 IN

GRAIN O.D. = 4.25 IN

WEB = 0.50 IN

STRESS R = 0.13 IN

SYN NR = 10.00

BETA = 18.00 DEG

ALPHA = 67.00 DEG

THETA = 65.52 DEG

PORT A = 5.88 SQ IN

THROAT A = 2.09 SQ IN

PORT/THROAT = 2.82

XEQ E

USER INSTRUCTIONS

(HP 41C SIZE 037)

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	LOAD PROGRAM			
2	PRINTER ON, MODE: NORM			
3	INITIALIZE PROGRAM		(XEQ) SPGD	SPGD READY
4	PRESS R/S		R/S	GRAIN O.D. ?
	● ENTER GRAIN O.D. (INCHES)	NN	R/S	BURN TIME ?
	● ENTER BRN TIME (SEC)	NN	R/S	PROP K ?
	● ENTER PROP K_n	NN	R/S	PROP DENSITY
	● ENTER PROP DENSITY (LB/IN ³)	NN	R/S	BURN RATE ?
	● ENTER PROP BRN RATE (IPS)	NN	R/S	DEL ISP ?
	● ENTER PROP DEL ISP (LB-SEC/LB)	NN	R/S	TOT ISP ?
	NOTE: PROP K_n , BRN RATE, AND DEL ISP MUST BE AT SAME CHAMBER PRESSURE			
	● ENTER REQ'D TOTAL ISP (LB-SEC)	NN	R/S	LBL A,B OR C ?
5	SELECT TYPE GRAIN:			N = ? <u>N</u> TO <u>N</u>
	● STD. W.W.		(A)	
	● MOD. W.W.		(B)	
	● STAR		(C)	
	(SEE FIGURES A, B, AND C)			
6	ENTER SYMENTRY NUMBER	N	R/S	Z = ?
	● N MUST BE WITHIN LIMITS SHOWN. MOD. W.W. N MUST BE MULTP OF 2.			
7	ENTER SELECTED VALUE FOR Z (IN)	N	R/S	NEXT CMD
	NOTE: NOT APPLICABLE TO STAR			
8	SELECT NEXT CMD			
	● SELECT DIFFERENT GRN TYPE		(A) (B) (C)	(SEE STEP 6)
	● SELECT CORRECTION FOR END BRN		(D)	1 END: SF02
	● FOR ONE END BRN SF02		SF02	
			R/S	NEXT CMD
	● FOR TWO END BRN		R/S	NEXT CMD
	● TO TERMINATE PROGRAM		(E)	0.0 0
	● RETURNS CALCULATOR TO NORMAL MODE			
	● TO CHANGE INPUTS, ENTER NEW VALUE IN PROPER REG		(F)	LBL A.B. OR C

USER INSTRUCTIONS

(HP 41C SIZE 037)

USER MESSAGES

<u>STEP</u>	<u>INSTRUCTIONS</u>	<u>INPUT</u>	<u>FUNCTION</u>	<u>DISPLAY</u>
1	● KEY SAME GRN LBL. INPUT SMALLER N VALUE OR ● STORE SMALLER O.D. VALUE IN R00 XEQ (F)	N N	(A) (B) OR (C) (F)	LOWER N OR D
2	● STORE SMALLER BRN TIME R02 XEQ (F) OR ● STORE SMALLER BRN RATE R05 CHANGE Kn AND DEL ISP AS REQ'D Kn IN R03, DEL ISP IN R06	N NN	(F) (F)	REDUCE WEB
3	● KEY IN LOWER VALUE FOR Z	N	R/S	REDUCE Z Z = ?
4	● KEY IN LOWER VALUE FOR N	N	R/S	REDUCE N N = ?
5	● KEY IN SAME TYPE GRN REDUCE VALUE FOR N, OR ● STORE REDUCED O.D. IN R00 AND SELECT SAME TYPE GRN LBL	N NN	(A) (B) OR (C) R/S (F) (A) (B) OR (C)	INC: N OR DEC: D LBL A,B, OR C

PROGRAM LISTING		
LINE	KEY ENTRY	COMMENTS
01	LBL "SPG	
02	FIX 2	
03	SF 27	
04	RAD	
05	"SPGD GR	
06	AVIEW	
07	LBL 00	DATA INPUT
08	"GRAIN 0	
09	PROMPT	
10	STO 00	
11	"BURN TI	
12	PROMPT	
13	STO 02	
14	"PROP K	
15	PROMPT	
16	STO 03	
17	"PROP DE	
18	PROMPT	
19	STO 04	
20	"BURN RA	
21	PROMPT	
22	STO 05	
23	"DEL ISP	
24	PROMPT	
25	STO 06	
26	"TOT ISP	
27	PROMPT	
28	STO 07	
29	LBL F	CAL WEB
30	RCL 00	r, A _c
31	X↑2	
32	PI	
33	*	
34	4	
35	/	
36	STO 18	A _c
37	RCL 00	
38	.03	
39	*	
40	STO 12	r
41	RCL 00	
42	.2	
43	*	
44	STO 15	MAX W FOR
45	RCL 02	WW GRN
46	RCL 05	
47	*	
48	STO 10	W
49	RCL 15	
50	X<>Y	
51	X>Y?	
52	GTO 17	
53	"LBL A,B	
54	PROMPT	
55	RTN	
56	LBL A	CAL STD
57	SF 05	WW GRN
58	CF 06	
59	CF 07	
60	"N=? 2 T	
61	PROMPT	
62	STO 13	N
63	PI	
64	RCL 13	
65	/	
66	STO 14	BETA
67	XEQ 01	
68	XEQ 02	
69	RCL 21	
70	RCL 19	
71	+	
72	RCL 12	
73	RCL 23	
74	*	
75	+	
76	RCL 00	
77	2	
78	/	
79	RCL 10	
80	-	
81	RCL 17	
82	*	
83	+	
84	RCL 13	
85	2	
86	*	
87	*	
88	STO 11	INL S
89	RCL 00	
90	RCL 10	
91	*	
92	RCL 10	
93	X↑2	

PROGRAM LISTING					
LINE	KEY ENTRY	COMMENTS	LINE	KEY ENTRY	COMMENTS
94	-		146	+	
95	RCL 17		147	RCL 10	
96	*		148	RCL 14	
97	RCL 21		149	TAN	
98	RCL 10		150	/	
99	*		151	+	
100	2		152	RCL 19	
101	*		153	-	
102	+		154	RCL 13	
103	RCL 10		155	*	
104	X↑2		156	2	
105	RCL 14		157	*	
106	TAN		158	RCL 01	
107	/		159	*	
108	+		160	STO 32	FNL A _b
109	RCL 00		161	SF 00	
110	X↑2		162	-STD W.W	
111	RCL 16			/ GRN."	
112	*		163	AVIEW	
113	4		164	ADV	
114	/		165	GTO 15	
115	+		166	RTN	
116	RCL 12		167	LBL B	CAL MOD
117	X↑2		168	SF 06	WW GRN
118	RCL 23		169	CF 05	
119	*		170	CF 07	
120	-		171	"N=? 4 T	
121	RCL 12			0 16"	
122	RCL 10		172	PROMPT	
123	+		173	STO 13	N
124	X↑2		174	PI	
125	RCL 16		175	2	
126	TAN		176	*	
127	/		177	RCL 13	
128	-		178	/	
129	RCL 13		179	STO 14	BETA
130	*		180	XEQ 01	
131	STO 24	A _g	181	RCL 17	
132	XEQ 04		182	RCL 16	
133	XEQ 03		183	X>Y?	
134	RCL 21		184	GTO 16	
135	RCL 00		185	XEQ 02	
136	2		186	RCL 19	
137	/		187	RCL 21	
138	RCL 17		188	X<Y?	
139	*		189	GTO 16	
140	+		190	RCL 19	
141	RCL 10		191	RCL 12	
142	RCL 12		192	2	
143	+		193	*	
144	RCL 23		194	RCL 23	
145	*		195	*	

PROGRAM LISTING					
LINE	KEY ENTRY	COMMENTS	LINE	KEY ENTRY	COMMENTS
196	+		248	TAN	
197	RCL 00		249	/	
198	2		250	-	
199	/		251	RCL 00	
200	RCL 10		252	2	
201	-		253	/	
202	RCL 17		254	RCL 10	
203	RCL 16		255	-	
204	-		256	X↑2	
205	*		257	RCL 17	
206	+		258	RCL 16	
207	RCL 13		259	-	
208	*		260	*	
209	RCL 21		261	2	
210	RCL 13		262	/	
211	*		263	-	
212	2		264	RCL 13	
213	*		265	*	
214	+		266	STO 24	Ag
215	STO 11	INL S	267	XEQ 04	
216	RCL 10		268	XEQ 03	
217	X↑2		269	RCL 21	
218	RCL 14		270	2	
219	TAN		271	*	
220	/		272	RCL 19	
221	RCL 10		273	3	
222	RCL 21		274	*	
223	*		275	-	
224	2		276	RCL 12	
225	*		277	RCL 10	
226	+		278	+	
227	RCL 10		279	2	
228	RCL 19		280	*	
229	*		281	RCL 23	
230	-		282	*	
231	RCL 12		283	+	
232	X↑2		284	RCL 10	
233	RCL 23		285	2	
234	*		286	*	
235	-		287	RCL 14	
236	RCL 00		288	TAN	
237	X↑2		289	/	
238	RCL 14		290	+	
239	*		291	RCL 00	
240	8		292	2	
241	/		293	/	
242	+		294	RCL 17	
243	RCL 12		295	RCL 16	
244	RCL 10		296	-	
245	+		297	*	
246	X↑2		298	+	
247	RCL 16		299	RCL 13	

PROGRAM LISTING					
LINE	KEY ENTRY	COMMENTS	LINE	KEY ENTRY	COMMENTS
300	*		350	2	
301	RCL 01		351	/	
302	*		352	RCL 12	
303	STO 32	FNL A _b	353	-	
304	"MOD W.W		354	RCL 10	
	. GRN."		355	-	
305	AVIEW		356	RCL 14	
306	ADV		357	SIN	
307	GTO 15		358	*	
308	RTN		359	RCL 12	
309	♦LBL C	CAL STAR	360	RCL 10	
310	SF 07		361	+	
311	CF 05		362	/	
312	CF 06		363	1	
313	10		364	X<Y?	
314	"N=?, 4		365	GTO 19	
	TO 10"		366	RCL Y	
315	PROMPT		367	ASIN	
316	X>Y?		368	RCL 14	
317	GTO 20		369	+	
318	STO 13	N	370	STO 23	THETA
319	PI		371	RCL 17	
320	RCL 13		372	X<Y?	
321	/		373	GTO 19	
322	STO 14	BETA	374	RCL 17	
323	1.87		375	TAN	
324	STO 17		376	-	
325	♦LBL 10	ALPHA	377	RCL 12	
326	RCL 17	ITERATION	378	*	
327	RCL 14		379	RCL 00	
328	-		380	2	
329	TAN		381	/	
330	CHS		382	RCL 12	
331	RCL 17		383	-	
332	+		384	RCL 10	
333	RCL 17		385	-	
334	RCL 14		386	RCL 12	
335	-		387	RCL 17	
336	COS		388	COS	
337	X↑2		389	/	
338	1/X		390	+	
339	1		391	RCL 14	
340	-		392	SIN	
341	/		393	*	
342	X=0?		394	RCL 17	
343	GTO 09		395	RCL 14	
344	X>0?		396	-	
345	GTO 09		397	COS	
346	ST+ 17		398	/	
347	GTO 10		399	+	
348	♦LBL 09	CONT STAR	400	RCL 13	
349	RCL 00	CAL	401	*	

PROGRAM LISTING					
LINE	KEY ENTRY	COMMENTS	LINE	KEY ENTRY	COMMENTS
402	2		454	/	
403	*		455	RCL 12	
404	STO 11	INL S	456	-	
405	RCL 00		457	RCL 10	
406	2		458	-	
407	/		459	*	
408	RCL 12		460	RCL 23	
409	-		461	SIN	
410	RCL 10		462	*	
411	-		463	+	
412	RCL 12		464	RCL 13	
413	RCL 17		465	*	
414	COS		466	CHS	
415	/		467	RCL 18	
416	+		468	+	
417	X↑2		469	STO 25	A _{s1vr}
418	RCL 14		470	XEQ 03	
419	SIN		471	RCL 12	
420	*		472	RCL 10	
421	RCL 17		473	+	
422	COS		474	RCL 23	
423	*		475	*	
424	RCL 17		476	RCL 13	
425	RCL 14		477	*	
426	-		478	RCL 01	
427	COS		479	*	
428	/		480	2	
429	RCL 12		481	*	
430	X↑2		482	STO 32	
431	RCL 17		483	SF 01	
432	RCL 17		484	-STAR GR	
433	TAN			N-	
434	-		485	AVIEW	
435	*		486	ADV	
436	+		487	GTO 15	
437	RCL 13		488	RTN	
438	*		489	LBL 01	CAL ANGLES
439	CHS		490	RCL 12	M. Lmax
440	RCL 18		491	RCL 10	
441	+		492	+	
442	STO 24	A _g	493	RCL 00	
443	RCL 12		494	2	
444	RCL 10		495	/	
445	+		496	RCL 12	
446	X↑2		497	-	
447	RCL 23		498	RCL 10	
448	*		499	-	
449	RCL 12		500	/	
450	RCL 10		501	ASIN	
451	+		502	STO 16	GAMMA
452	RCL 00		503	RCL 14	
453	2		504	X<>Y	

PROGRAM LISTING					
LINE	KEY ENTRY	COMMENTS	LINE	KEY ENTRY	COMMENTS
505	X>Y?		557	RCL 04	
506	GTO 16		558	/	
507	CHS		559	RCL 06	
508	+		560	/	
509	STO 17	ALPHA	561	RCL 24	
510	CHS		562	RCL 25	
511	RCL 14		563	-	
512	+		564	/	
513	PI		565	STO 01	LENGTH
514	2		566	RCL 11	GRN
515	/		567	*	
516	+		568	STO 09	
517	STO 23	THETA	569	RTN	
518	RCL 10		570	LBL 04	CAL Aslvr
519	RCL 14		571	RCL 00	
520	SIN		572	X↑2	
521	/		573	RCL 16	
522	STO 19	M	574	*	
523	RCL 12		575	4	
524	RCL 10		576	/	
525	+		577	RCL 12	
526	RCL 16		578	RCL 10	
527	TAN		579	+	
528	/		580	X↑2	
529	RCL 10		581	RCL 23	
530	RCL 14		582	*	
531	TAN		583	-	
532	/		584	RCL 12	
533	-		585	RCL 10	
534	STO 20	L max	586	+	
535	RTN		587	X↑2	
536	LBL 02	DATA INPUT	588	RCL 16	
537	"Z=?"		589	TAN	
538	PROMPT		590	/	
539	STO 22	Z	591	-	
540	RCL 20		592	RCL 13	
541	RCL 14		593	*	
542	SIN		594	STO 25	A slvr
543	*		595	RTN	
544	RCL 22		596	LBL 15	CAL OUTPUT
545	-		597	RCL 32	
546	RCL 14		598	RCL 09	
547	SIN		599	/	
548	/		600	STO 33	P.R.
549	STO 21	CALCULATED	601	RCL 24	
550	0	L	602	RCL 18	
551	RCL 21		603	/	
552	X<=Y?		604	STO 27	L.F.
553	GTO 18		605	RCL 25	
554	RTN		606	RCL 18	
555	LBL 03		607	/	
556	RCL 07		608	STO 28	S.F.

PROGRAM LISTING					
LINE	KEY ENTRY	COMMENTS	LINE	KEY ENTRY	COMMENTS
609	RCL 18		659	LBL 06	
610	RCL 24		660	"USE LBL	
611	-			C"	
612	STO 26	Ap	661	PROMPT	
613	RCL 01		662	RTN	
614	RCL 24		663	LBL 18	
615	*		664	TONE 7	
616	RCL 04		665	"REDUCE	
617	*			Z"	
618	STO 35	TOT. PROP.	666	AVIEW	
619	RCL 01	WT.	667	GTO 02	
620	RCL 24		668	RTN	
621	RCL 25		669	LBL 19	
622	-		670	TONE 7	
623	*		671	"INC:N 0	
624	RCL 04			R DEC:D"	
625	*		672	PROMPT	
626	STO 29	NET PROP.	673	RTN	
627	RCL 06	WT.	674	LBL 20	
628	*		675	TONE 7	
629	STO 30	NET TOTAL	676	"REDUCE	
630	RCL 02	IMPULSE		N"	
631	/		677	AVIEW	
632	STO 31	AVG F	678	GTO C	
633	RCL 09		679	RTN	
634	RCL 32		680	LBL 05	
635	+		681	"AVG F =	PRINT
636	2			-	OUTPUT
637	/		682	ARCL 31	
638	RCL 03		683	"F LBF"	
639	/		684	PRA	
640	STO 34	At	685	"NET I T	
641	GTO 05			OT ="	
642	RTN		686	ARCL 30	
643	LBL 16	USER	687	"F SEC"	
644	TONE 8	MESSAGES	688	PRA	
645	"LOWER N		689	"NET F D	
	OR D"			P WT = "	
646	PROMPT		690	ARCL 29	
647	RTN		691	"F LB"	
648	LBL 17		692	PRA	
649	RCL 00		693	"TOT PRO	
650	.33			P WT = "	
651	*		694	ARCL 35	
652	RCL 10		695	"F LB"	
653	X<Y?		696	PRA	
654	GTO 06		697	"BURN TI	
655	TONE 8			ME = "	
656	"REDUCE		698	ARCL 02	
	WEB"		699	"F SEC"	
657	PROMPT		700	PRA	
658	RTN		701	"INL Ab	
				= "	

PROGRAM LISTING					
LINE	KEY ENTRY	COMMENTS	LINE	KEY ENTRY	COMMENTS
702	ARCL 09		743	RCL 17	
703	"F SQ IN		744	R-D	
"			745	"ALPHA =	
704	PRA		"		
705	"FNL AB		746	ARCL X	
= "			747	"F DEG"	
706	ARCL 32		748	PRA	
707	"F SQ IN		749	RCL 23	
"			750	R-D	
708	PRA		751	"THETA =	
709	"P.R. =		"		
"			752	ARCL X	
710	ARCL 33		753	"F DEG"	
711	PRA		754	PRA	
712	"L.F. =		755	FS?C 00	
"			756	GTO 07	
713	ARCL 27		757	FS?C 01	
714	PRA		758	GTO 08	
715	"SLVR FR		759	RCL 16	
AC = "			760	R-D	
716	ARCL 28		761	"GAMMA =	
717	PRA		"		
718	"GRAIN L		762	ARCL X	
= "			763	"F DEG"	
719	ARCL 01		764	PRA	
720	"F IN"		765	RCL 21	
721	PRA		766	RCL 19	
722	"GRAIN O		767	-	
.D. = "			768	"K = "	
723	ARCL 00		769	ARCL X	
724	"F IN"		770	"F IN"	
725	PRA		771	PRA	
726	"WEB = "		772	LBL 07	CONT OUTPUT
727	ARCL 10		773	"M = "	FOR W.W.
728	"F IN"		774	ARCL 19	
729	PRA		775	"F IN"	
730	"STRESS		776	PRA	
R = "			777	"L = "	
731	ARCL 12		778	ARCL 21	
732	"F IN"		779	"F IN"	
733	PRA		780	PRA	
734	"SYM NR		781	"Z = "	
= "			782	ARCL 22	
735	ARCL 13		783	"F IN"	
736	PRA		784	PRA	
737	RCL 14		785	LBL 08	CONT OUTPUT
738	R-D		786	RCL 26	FOR MOD
739	"BETA =		787	"PORT A	WIN
"			= "		
740	ARCL X		788	ARCL X	
741	"F DEG"		789	"F SQ IN	
742	PRA		"		

PROGRAM LISTING					
LINE	KEY ENTRY	COMMENTS	LINE	KEY ENTRY	COMMENTS
790	PRA		835	RCL 32	
791	RCL 34		836	RCL 01	
792	THROAT		837	/	
A = -			838	RCL 01	
793	ARCL X		839	RCL 10	
794	TH SQ IN		840	2	
-			841	*	
795	PRA		842	FS?C 02	
796	/		843	XEQ 11	
797	PORT/TH		844	-	
ROAT = -			845	*	
798	ARCL X		846	STO 32	FNL Ab
799	PRA		847	RCL 09	
800	TONE 6		848	+	
801	ADV		849	2	
802	CF 21		850	/	
803	NEXT CM		851	RCL 03	
D-			852	/	
804	AVIEW		853	STO 34	At
805	SF 21		854	RCL 32	
806	RTN		855	RCL 09	
807	LBL D	CAL END	856	/	
808	SF 08	BRN	857	STO 33	P.R.
809	W/-		858	INL Ab=	
810	ACA		-		
811	1 END:		859	ARCL 09	
SF02-			860	TH SQ IN	
812	PROMPT		-		
813	FS? 02		861	PRA	
814	GTO 25		862	FNL Ab=	
815	GTO 26		-		
816	LBL 25		863	ARCL 32	
817	ONE END		864	TH SQ IN	
BURNING-			-		
818	ACA		865	PRA	
819	PRBUF		866	P.R.= -	
820	GTO 27		867	ARCL 33	
821	LBL 26		868	PRA	
822	TWO END		869	THROAT	
BURNING-			A= -		
823	ACA		870	ARCL 34	
824	PRBUF		871	TH SQ IN	
825	LBL 27		-		
826	ADV		872	PRA	
827	RCL 09		873	RCL 26	
828	RCL 24		874	RCL 34	
829	FS? 02		875	/	
830	XEQ 11		876	PORT/TH	
831	2		ROAT= -		
832	*		877	ARCL X	
833	+		878	PRA	
834	STO 09	INL Ab	879	TONE 8	

PROGRAM LISTING					
LINE	KEY ENTRY	COMMENTS	LINE	KEY ENTRY	COMMENTS
880	CF 21				
881	"NEXT CM				
	D"				
882	AVIEW				
883	SF 21				
884	ADV				
885	RTN				
886	◆LBL 11				
887	2				
888	/				
889	RTN				
890	◆LBL E	EXIT PROGRAM			
891	CF 27				
892	DEG				
893	CLX				
894	END				

REGISTER	DATA
00	GRN O.D.
01	GRN LNTH, Lg
02	BRN TIME, tb
03	Kn
04	DENSITY ρ
05	BRN RATE, $\dot{r}$
06	DEL ISP
07	TOTAL ISP
08	(NOT USED)
09	INL, Ab
10	WEB, w
11	INL Si
12	STRESS RAD, r
13	SYM. NR., N
14	BETA, β
15	MAX WEB
16	GAMMA, γ
17	ALPHA,
18	Acase
19	M
20	MAX L
21	CALCULATED L
22	Z
23	THETA, θ
24	Agrain
25	Aslvr
26	Aport
27	L.F.
28	S.F.
29	NET PROP. WT.
30	NET I TOTAL
31	AVG F
32	FNL Ab
33	P.R.
34	At
35	TOTAL PROP. WT.

<u>FLAGS</u>			
#	INIT S/C	SET INDICATES	CLEAR INDICATES
00	C	STD. W.W. CALCULAT	NOT STD. W.W. CAL
01	C	STAR CALCULATION	NOT STAR CAL
02	C	ONE END BRN	TWO END BRN
27	S	USER MODE	PROGRAM TERMINATED

<u>STATUS</u>			
SIZE	037	TOTAL REG.	315
ENG		FIX	02
SCI		DEG	
		RAD	X
		GRAD	

ASSIGNMENTS

NONE

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DRSMI-LP, Mr. Voigt
DRSMI-RPR
DRSMI-RPT

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