

APPENDIX A

A TABLE OF CAM PROFILE DESIGN LIFT DATA—TYPICAL EXAMPLE

This profile designed for use with a nominal—
35.000-inch spherical radius tappet.

Base Circle Radius = .xxxxx Inches

The profile lift as generated by a nominal
35.000-inch spherical radius tappet is given in the
column marked (z_o). The identical profile may be
generated with a flat-faced follower with the data
given in the column marked (z_e).

[Note at cam angle equal to 40.0 degrees marked (*)
the difference between the spherical tappet lift and
and the flat-faced follower lift is .00261 inches!]

Opening Side Lift Values			Cam Angle	Spherical Tappet	Flat-faced Follower
Cam Angle	Spherical Tappet	Flat-faced Follower	(Degrees)	Lift (Inches)	Lift (Inches)
(Degrees)	Lift (Inches)	Lift (Inches)	θ	z_o	z_e
θ	z_o	z_e			
0	.26745	.26745	17.0	.23479	.23543
.5	.26741	.26741	17.5	.23286	.23354
1.0	.26732	.26732	18.0	.23088	.23160
1.5	.26716	.26717	18.5	.22884	.22960
2.0	.26696	.26696	19.0	.22675	.22755
2.5	.26669	.26671	19.5	.22460	.22544
3.0	.26637	.26639	20.0	.22240	.22329
3.5	.26599	.26602	20.5	.22014	.22108
4.0	.26556	.26560	21.0	.21784	.21881
4.5	.26507	.26512	21.5	.21547	.21650
5.0	.26453	.26459	22.0	.21306	.21413
5.5	.26393	.26400	22.5	.21059	.21171
6.0	.26327	.26336	23.0	.20807	.20923
6.5	.26256	.26266	23.5	.20549	.20671
7.0	.26179	.26191	24.0	.20287	.20413
7.5	.26097	.26110	24.5	.20019	.20150
8.0	.26009	.26024	25.0	.19746	.19882
8.5	.25916	.25932	25.5	.19467	.19609
9.0	.25817	.25835	26.0	.19184	.19330
9.5	.25712	.25733	26.5	.18895	.19047
10.0	.25602	.25625	27.0	.18602	.18759
10.5	.25486	.25511	27.5	.18303	.18466
11.0	.25365	.25392	28.0	.18000	.18168
11.5	.25238	.25268	28.5	.17691	.17865
12.0	.25106	.25138	29.0	.17378	.17557
12.5	.24968	.25003	29.5	.17060	.17244
13.0	.24825	.24863	30.0	.16738	.16927
13.5	.24676	.24717	30.5	.16410	.16606
14.0	.24521	.24565	31.0	.16079	.16279
14.5	.24361	.24408	31.5	.15743	.15949
15.0	.24196	.24245	32.0	.15403	.15614
15.5	.24025	.24078	32.5	.15059	.15275
16.0	.23848	.23905	33.0	.14710	.14931
16.5	.23666	.23726	33.5	.14358	.14584
			34.0	.14003	.14234
			34.5	.13644	.13879

Cam Angle (Degrees) θ	Spherical Tappet Lift (Inches) z_0	Flat-faced Follower Lift (Inches) z_e	Cam Angle (Degrees) θ	Spherical Tappet Lift (Inches) z_0	Flat-faced Follower Lift (Inches) z_e
35.0	.13282	.13521	63.0	.00627	.00629
35.5	.12917	.13160	63.5	.00606	.00608
36.0	.12549	.12796	64.0	.00586	.00587
36.5	.12179	.12429	64.5	.00566	.00567
37.0	.11807	.12060	65.0	.00546	.00547
37.5	.11432	.11688	65.5	.00526	.00527
38.0	.11057	.11315	66.0	.00506	.00507
38.5	.10680	.10940	66.5	.00486	Engine .00487
39.0	.10302	.10563	67.0	.00466	Idle .00467
39.5	.09925	.10186	67.5	.00446	Speed .00447
*40.0	*.09547	*.09808	68.0	.00426	Opening { .00427 Point .00407
40.5	.09170	.09431	68.5	.00406	
41.0	.08794	.09053	69.0	.00386	.00387
41.5	.08420	.08677	69.5	.00366	.00367
42.0	.08048	.08302	70.0	.00346	.00347
42.5	.07679	.07930	70.5	.00326	.00327
43.0	.07314	.07560	71.0	.00306	.00307
43.5	.06953	.07193	71.5	.00286	.00287
44.0	.06597	.06831	72.0	.00266	.00267
44.5	.06246	.06473	72.5	.00246	.00247
45.0	.05902	.06121	73.0	.00226	.00227
45.5	.05566	.05775	73.5	.00206	.00207
46.0	.05237	.05436	74.0	.00186	.00187
46.5	.04916	.05105	74.5	.00166	.00167
47.0	.04606	.04784	75.0	.00147	.00148
47.5	.04305	.04472	75.5	.00129	.00130
48.0	.04016	.04170	76.0	.00111	.00112
48.5	.03738	.03880	76.5	.00095	.00095
49.0	.03473	.03602	77.0	.00079	.00079
49.5	.03221	.03337	77.5	.00065	.00065
50.0	.02982	.03086	78.0	.00053	.00053
50.5	.02758	.02849	78.5	.00042	.00042
51.0	.02547	.02627	79.0	.00032	.00032
51.5	.02351	.02420	79.5	.00024	.00024
52.0	.02169	.02228	80.0	.00017	.00017
52.5	.02002	.02052	80.5	.00011	.00011
53.0	.01849	.01891	81.0	.00007	.00007
53.5	.01710	.01744	81.5	.00004	.00004
54.0	.01584	.01611	82.0	.00002	.00002
54.5	.01470	.01492	82.5	.00001	.00001
55.0	.01368	.01386	83.0	.00000	.00000
55.5	.01276	.01291			
56.0	.01194	.01206			
56.5	.01121	.01130			
57.0	.01055	.01062			
57.5	.00996	.01002			
58.0	.00942	.00947			
58.5	.00895	Engine .00898			
59.0	.00852	Design .00855			
59.5	.00814	Speed { .00816 Opening .00782			
60.0	.00780				
60.5	.00749	Point .00751			
61.0	.00721	.00723			
61.5	.00695	.00697			
62.0	.00671	.00673			
62.5	.00649	.00651			

Only the opening side lift is given with this example solution. The lift values for the spherical radius tappet (z_0) may be compared with those given in Appendix D—cam lift for radius follower (z_0).

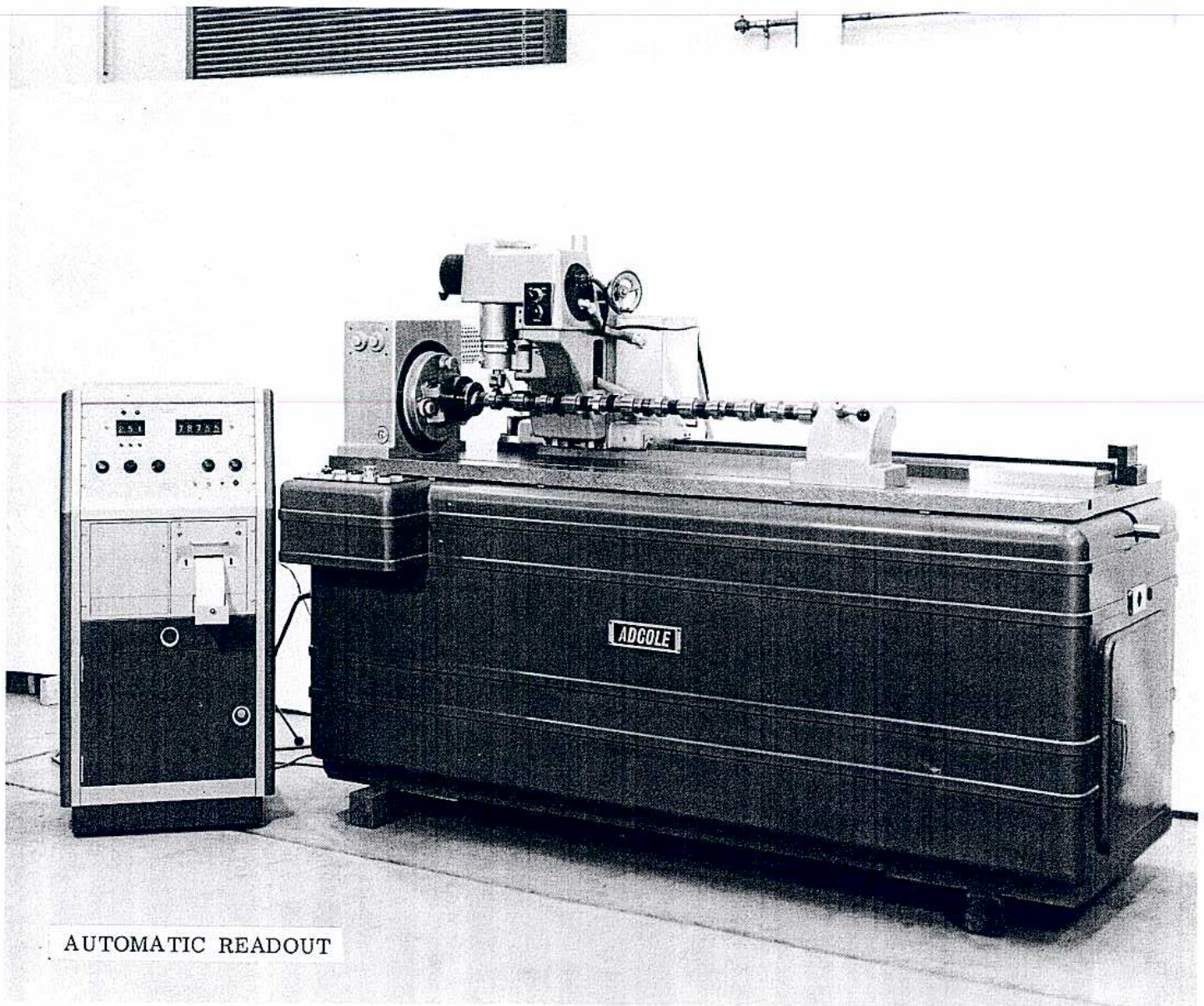
APPENDIX B

CAM PROFILE MEASUREMENT INSTRUMENTATION

This appendix provides information on cam profile measurement instrumentation. A brief statement and photograph of each system is given.

The major differences in the systems are found to be in cost, speed of operation, and the quality of the profile lift data measurements. All of the instrumentation systems shown are capable of producing cam profile raw lift data as required for input to

the Camcheck computer programs—but would not produce final evaluations of equal quality. None of the systems will produce cam profile measurement data able to satisfy (directly) the CPM&E problem as defined under Part II in this paper. Indeed, the error normally introduced into the measured data from any one of the five major sources for error is sufficient to destroy the minimum required accuracy.



AUTOMATIC READOUT

	0	3	0	2	4	0	3	8	7	5
	0	3	0	2	3	0	4	5	6	0
CAM NUMBER	0	3	0	2	2	0	5	3	9	0
	0	3	0	2	1	0	6	0	7	5
	0	3	0	2	0	0	6	5	7	0
	0	3	0	1	9	0	7	6	5	5
ANGLE	0	3	0	1	8	0	8	4	1	0
	0	3	0	1	7	0	9	1	2	5
	0	3	0	1	6	0	9	7	9	5
	0	3	0	1	5	1	0	4	1	0
CAM RISE	0	3	0	1	4	1	0	3	8	5
	0	3	0	1	3	1	1	5	2	5
	0	3	0	1	2	1	2	0	3	0
	0	3	0	1	1	1	2	5	0	0
	0	3	0	1	0	1	2	9	2	5
	0	3	0	0	9	1	3	3	2	0
	0	3	0	0	8	1	3	6	7	5
	0	3	0	0	7	1	3	9	9	0

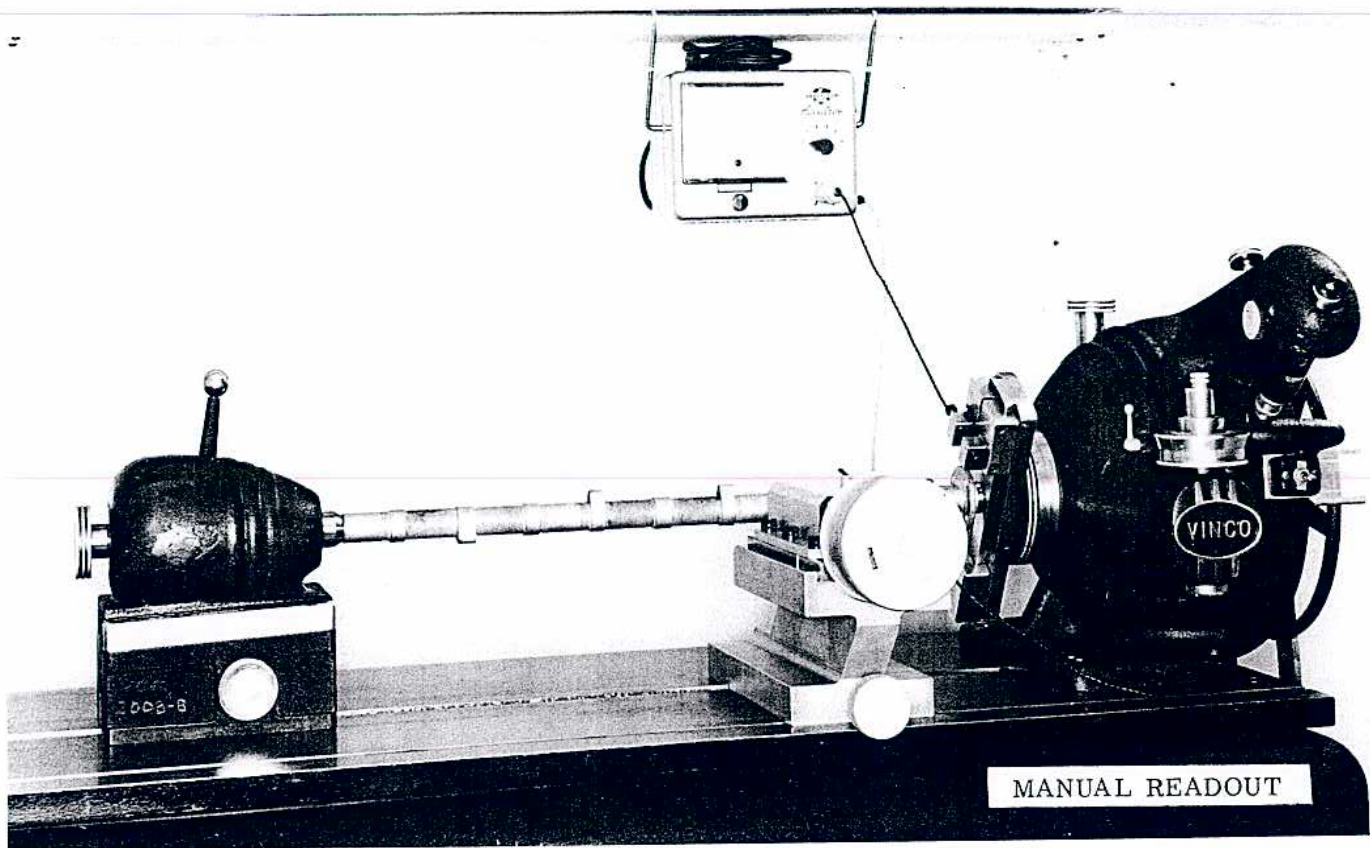
Cam rise display—.00005 increment from preset zero.

Angle display gives degrees of rotation from a preset zero.

Rotation angle selector gives total rotational angle from start to stop.

Printer—Hewlett Packard Model 602.

Prints cam number, angle of rotation and cam rise. Print out every 1, 2 or 3 degrees, selectable. Sample of Printer Tape is shown.



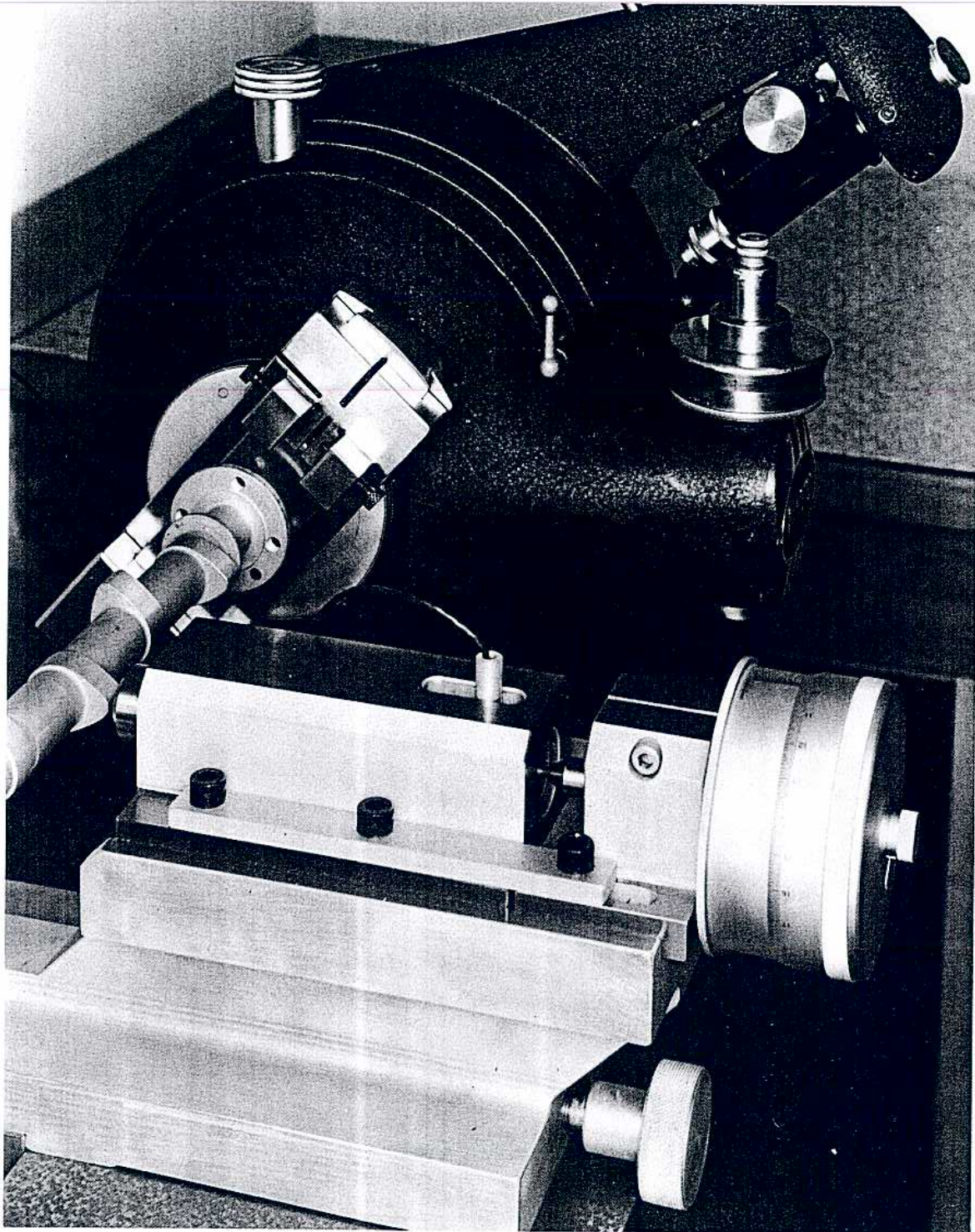
General Description

The Camcheck cam measurement instrumentation includes the environmentally controlled gage room as a necessary part of the system—temperature $(68.0 \pm .5)$ degrees Fahrenheit, dust free, and relative humidity (50 ± 5) per cent. Most of the components of instrumentation are purchaseable "off-the-shelf" items. The overall Camcheck cam measurement system (in addition to the instrumen-

tation and gage room) includes the Camcheck computer programs described in this paper.

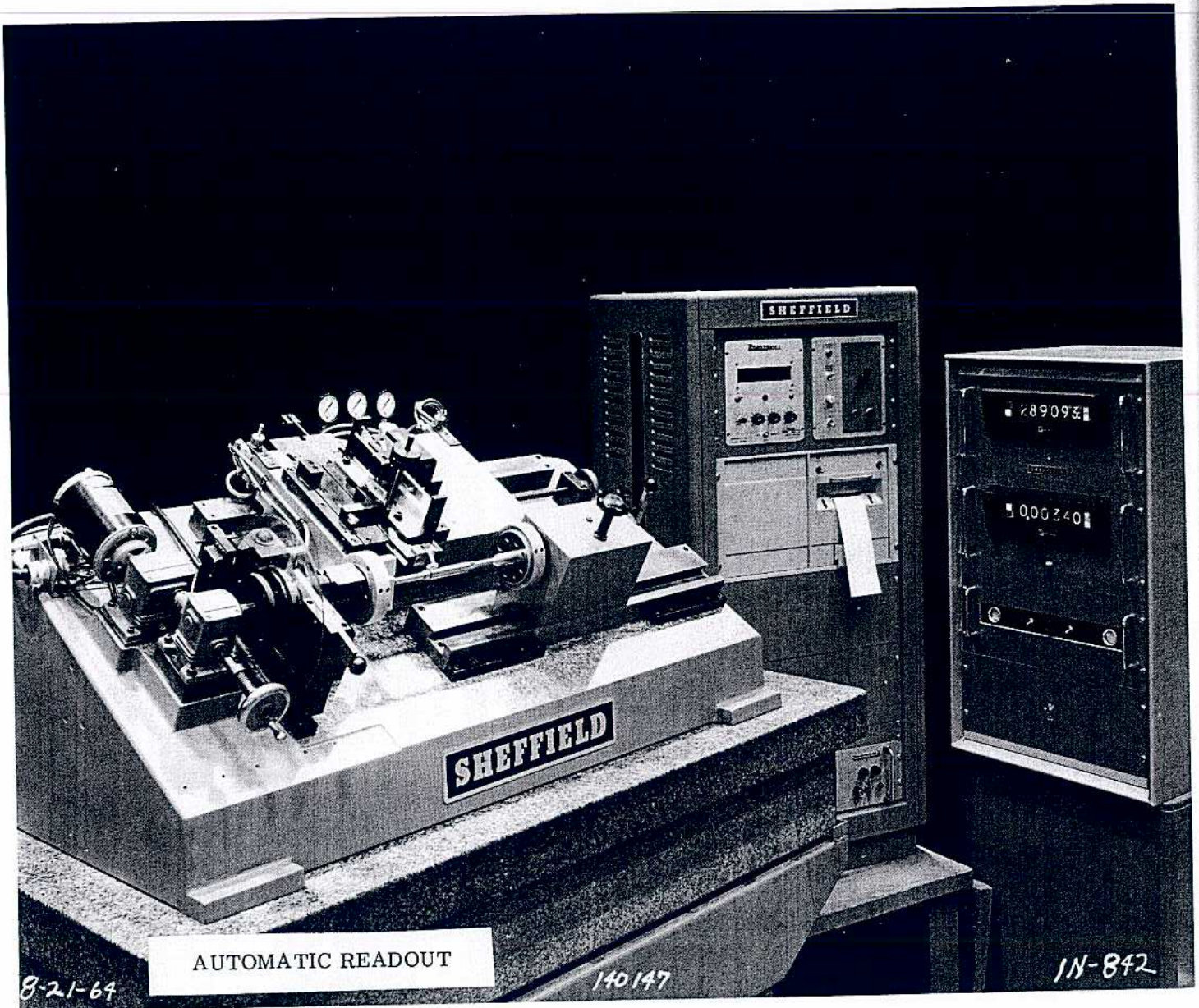
Accuracy

The following statements apply to cam profile lift measurements taken in a single plane normal to the axis of cam rotation. The magnitude of the random and systematic errors is considered separately.



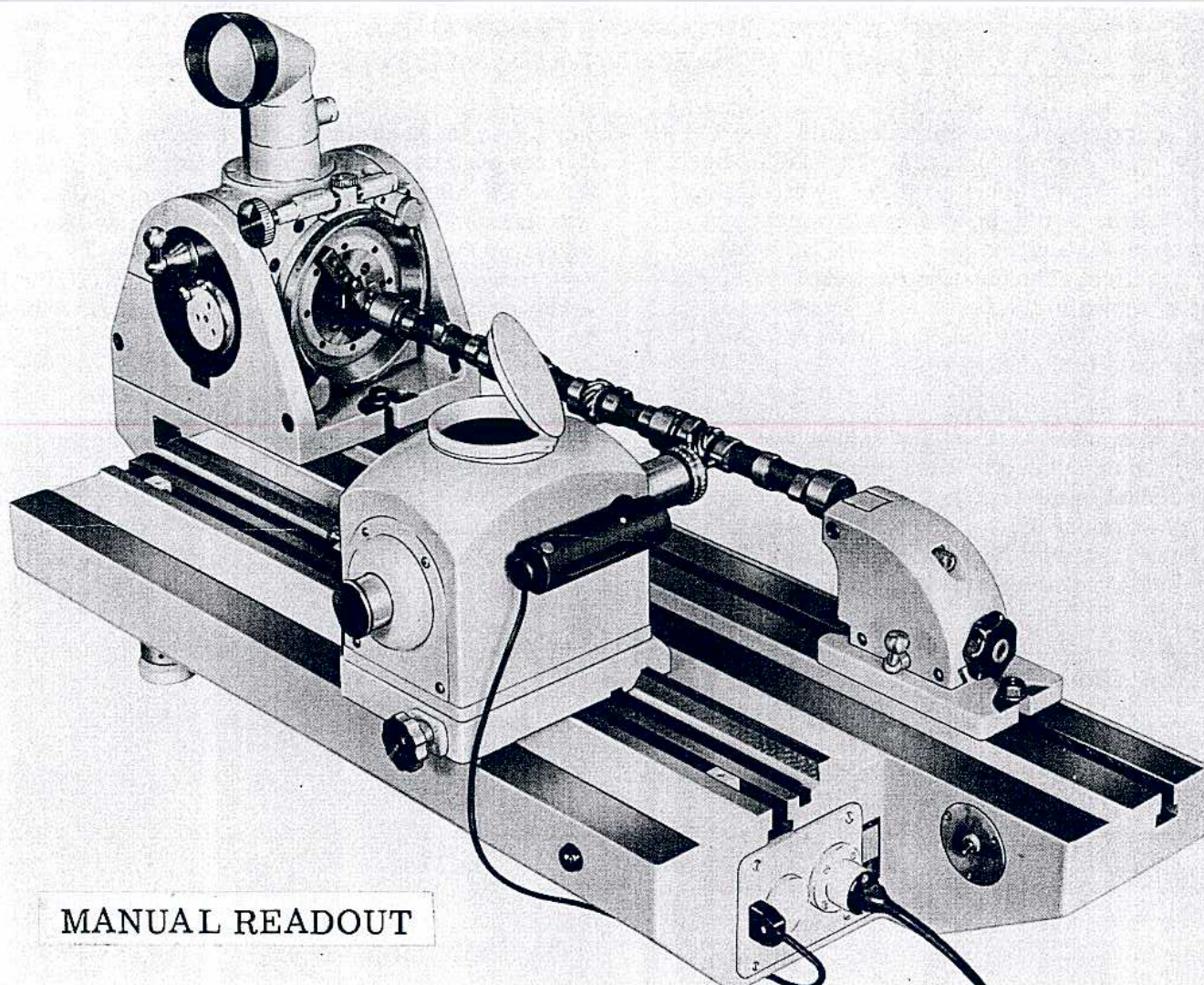
Random errors—The Camcheck instrumentation produces raw lift data with a calibrated Mean Standard Deviation (σ_m) of .000013 inches. This random error size is derived from the sum of both linear and angular displacements.

Systematic errors—in the Camcheck system include the errors due to the instrumentation plus the Camcheck computer program. The calculated upper bound is .000040 inches—see text and error evaluation page 16 for detailed explanation.



The Sheffield cam inspection unit can be designed to automatically provide a digital display and print out of cam rise versus cam angle. The units are cus-

tom designed and built to special order. In the unit shown, the basic element of the measuring system is a Transmission Grating.

**MANUAL READOUT**

Camshaft measurements can be carried out with high precision. For checking angle measurements, the large optical dividing head is used; linear (lift) measurements are made with an Abbe-type measuring unit. Both measuring devices are combined

in this camshaft tester by mounting them together on a precision base plate ($27\frac{1}{2}$ " between the ends. On request, a base plate ($70\frac{3}{4}$ " between centers) is available, primarily intended for large motor production.

APPENDIX C

A TYPICAL "CURRENT PRACTICE" CAM PROFILE MEASUREMENT AND EVALUATION

A typical current practice "profile check" for a prototype cam is given in Fig. 1. This table is a photocopy of a final report prepared by a company that specializes in this type of measurement and uses instrumentation and methods of long established practice. The notation for cam base circle run-out is shown in the lower right-hand corner; the zero degree angular index position was determined by the mechanical method.

Based on the profile lift data of Fig. 1, the differences between the measured and design data would, normally, be calculated by hand (the clerical work is not included in the profile check report) and plotted as shown at the top of Fig. 2. A careful study of the (Fig. 2) differences data shows that the angular index positioning "balance points" appear to

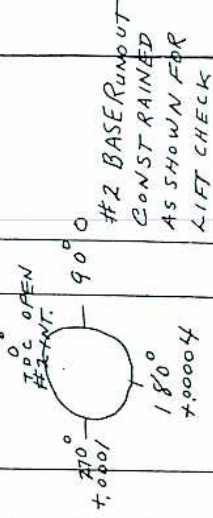
have been taken at thirty-five degrees from top center (as suggested in the example of the main text, Fig. 14). After balancing, the maximum cam lift was assumed equal to the design lift value—as also shown by the differences diagram of Fig. 2. This "current practice" method for determining the differences diagram can be compared directly with the new CPM&E diagram for the identical profile shown in figure of Appendix E.

Figure 2 also shows the acceleration diagram for the data of Fig. 1 prepared by the "method of second differences." The acceleration diagram given by the Camcheck computer program (for the profile "as made"—see also figure, Appendix E) is shown for comparison.

FIGURE 1. TYPICAL "CURRENT PRACTICE" CAM PROFILE LIFT DATA REPORT

ANGLE	OPEN LIFT	CLOSE LIFT	ANGLE	OPEN LIFT	CLOSE LIFT	OPEN LIFT	CLOSE LIFT	ANGLE	OPEN LIFT	CLOSE LIFT	GLOBE LIFT
0	.2672	.26717	22.5	.2133	.2141	.0658	.06813	67.5	.0031	.0055	.0055
5	.2672	.26717	23.0	.2109	.2117	.0623	.0647	68.0	.0029	.0052	.0052
10	.2671	.26715	23.5	.2085	.2093	.05885	.0613	68.5	.0027	.00495	.00495
15	.26695	.267	24.0	.2059	.2068	.05545	.05795	69.0	.0025	.0046	.0046
20	.26673	.26685	24.5	.2034	.2043	.05215	.05465	69.5	.0023	.0044	.0044
25	.26647	.2666	25.0	.20085	.2017	.04895	.05145	70.0	.0021	.0041	.0041
30	.26617	.2663	25.5	.1982	.1991	.0458	.0484	70.5	.0019	.0037	.0037
35	.2658	.26617	26.0	.1955	.1964	.0428	.04545	71.0	.00175	.00345	.00345
40	.2654	.2656	26.5	.1927	.1937	.0398	.0425	71.5	.0016	.00315	.00315
45	.26497	.2652	27.0	.1899	.19095	.037	.03975	72.0	.00145	.0029	.0029
50	.26443	.2647	27.5	.1871	.1881	.0343	.0371	72.5	.0013	.0026	.0026
55	.26385	.26415	28.0	.1842	.1852	.0317	.03455	73.0	.0012	.00235	.00235
60	.26325	.26357	28.5	.1812	.18235	.0293	.0321	73.5	.0011	.0021	.0021
65	.2626	.26295	29.0	.1782	.17935	.027	.0298	74.0	.0009	.00185	.00185
70	.26185	.2622	29.5	.1752	.17635	.02485	.02767	74.5	.0008	.00165	.00165
75	.2611	.2615	30.0	.1721	.17335	.0228	.02567	75.0	.0007	.00145	.00145
80	.2602	.26065	30.5	.169	.1702	.0209	.02385	75.5	.00065	.0012	.0012
85	.25935	.2598	31.0	.1658	.1671	.01925	.0222	76.0	.0006	.00105	.00105
90	.2584	.25885	31.5	.1626	.1639	.0177	.0206	76.5	.00055	.0009	.0009
95	.2574	.2579	32.0	.15935	.1607	.0162	.0191	77.0	.00055	.0008	.0008
100	.25637	.2569	32.5	.15605	.15745	.0149	.0178	77.5	.00055	.0007	.0007
105	.25527	.2558	33.0	.1527	.1541	.0137	.01665	78.0	.00055	.0006	.0006
110	.25413	.25465	33.5	.1493	.1508	.01265	.0156	78.5	.00055	.00055	.00055
115	.25295	.2535	34.0	.1459	.1474	.0117	.0146	79.0	.00055	.0005	.0005
120	.25165	.2522	34.5	.1424	.1444	.0108	.01375	79.5	.00055	.0005	.0005
125	.2503	.251	35.0	.1389	.1405	.010	.01295	80.0	.0005	.0005	.0005
130	.249	.2496	35.5	.1354	.137	.0093	.01225	80.5	.0005	.0005	.0005
135	.2476	.2482	36.0	.1318	.13347	.0086	.0117	120	.0006		
140	.246	.2467	36.5	.1283	.12995	.008	.0112	180	.0006		
145	.2446	.2452	37.0	.12465	.12637	.0075	.01075	240	.0005		
150	.243	.2436	37.5	.121	.12277	.007	.0103				
155	.24143	.24195	38.0	.11735	.1191	.0066	.0099				
160	.23985	.2403	38.5	.1137	.1155	.00625	.0096				
165	.23805	.2386	39.0	.110	.1118	.0059	.00925				
170	.23625	.23685	39.5	.1062	.1082	.0056	.00895				
175	.2344	.23505	40.0	.10255	.10445	.00535	.0086				
180	.23255	.23315	40.5	.0988	.10077	.00505	.0083				
185	.2306	.23125	41.0	.0951	.0971	.0048	.008				
190	.22865	.2293	41.5	.0914	.0934	.0045	.00765				
195	.2266	.22725	42.0	.0876	.0897	.0043	.00735				
200	.22455	.2252	42.5	.0839	.08605	.0041	.0071				
205	.2224	.2231	43.0	.0802	.08235	.0039	.0068				
210	.2202	.2209	43.5	.0766	.07875	.0037	.0065				
215	.218	.2187	44.0	.07295	.0752	.0035	.0062				
220	.21565	.2164	44.5	.0693	.07165	.0033	.00585				

.0001 Runout around dwell.



shaft bent .0005 inches static

Identification and Date
Blocked Out 63

Engineering Drawing Number
Blocked Out

WTAKE

CURRENT PRACTICE — CAM PROFILE EVALUATION OLD METHODS

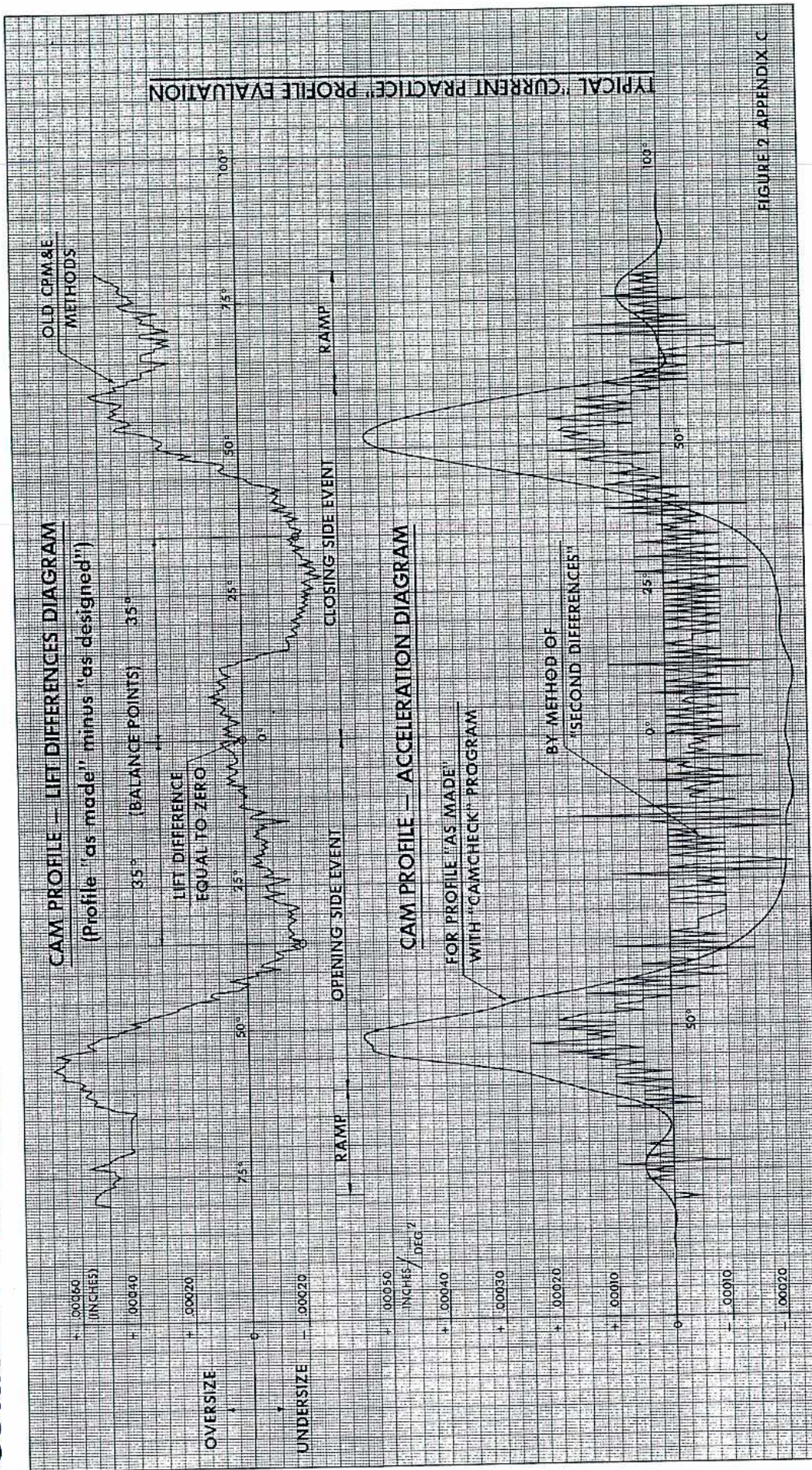


FIGURE 2 APPENDIX C

APPENDIX D

A TYPICAL CAM DESIGN COMPUTER RUN

Comments of special interest:

1. This sample computer run is a typical trial design for an exhaust cam—opening side only. Data for eighteen design parameters are shown; more than forty are available from the program.
2. The computer programming and the method of application to a specific design problem parallel that given in SAE Paper 202A, "Recent Developments in Cam Design." See also SAE Transactions 1961, page 585.
3. Program improvements following SAE Paper 202A are:
 - a. Gas Load—correction for valve train deflection due to gas load at the valve face, especially important in super-charged engines and/or engines with low valve train spring rates—see Data I.D. 13, 14.
 - b. Follower Radius—the kinematic equations as well as stress equations are revised for a finite follower radius—see Data I.D. 29. For importance, see Appendix A.
 - c. Design Lift Data—is calculated for any given design follower radius. Also, with that profile fixed, the equivalent flat-faced follower lift values are calculated; this is important to prototype cost and cam profile measurement. See Appendix A.
 - d. Rocker Arm Ratio—variable with equation of second degree (parabola fitted to measured data). See Data I.D. 15, 16, 17.
 - e. Polynomial Equations—the number of terms have been increased to seven; this allows a greater degree of control over the profile acceleration diagram. See Data I.D. 32 and 33.
 - f. Computer programming revised and operational on C.D.C. G-20 and IBM 7094 equipment. Computational accuracy is certain to the number of significant figures shown.
4. Computer programs are operational for other valve train kinematics, i.e., pivoted roll follower, etc. The example case above is a translating follower of large spherical radius with .070 inches offset. See I.D. 31. Also operational are programs for cam multi-stage ramp design.

ENGINE CHARACTERISTICS

DIMENSION DATA I.D.

ENGINE DESIGN SPEED	= 4500.	RPM	20
CAMSHAFT DESIGN SPEED	= 2250.	RPM	CALC
VALVE TRAIN RESONANT FREQUENCY	= 53979.	CPM	CALC
EFFECTIVE WEIGHT OF TRAIN AT VALVE	= 0.372	LBS	26
EFFECTIVE WEIGHT OF TRAIN AT CAM	= 0.689	LBS	27
VALVE TRAIN SPRING RATE	= 30700.	LBS/IN.	19
VALVE SPRING RATE	= 280.	LBS/IN.	10
VALVE SPRING PRELOAD	= 70.	LBS	9
CAM BASE CIRCLE RADIUS	= 0.732	IN.	18
TAPPET SPHERICAL RADIUS	= 35.000	IN.	29
TAPPET FACE RADIUS	= 0.452	IN.	30
CAM TO TAPPET OFFSET	= 0.070	IN.	31
YOUNGS MODULUS, CAM	= .2000E+08		24
YOUNGS MODULUS, TAPPET	= .2000E+08		25
POISSONS RATIO, CAM	= 0.300		22
POISSONS RATIO, TAPPET	= 0.300		23
ROCKER ARM RATIO	= 1.45000 +		15
	.0 X (Y) +		16
	.0 X (Y SO.)		17

The numbered items are required as input data. Those marked "calc" are calculated by the program.

VALVE EVENT CHARACTERISTICS

EVENT LENGTH	= 59.50	DEG.	5
MAXIMUM VALVE LIFT	= 0.375000	IN.	6
AREA UNDER VALVE LIFT CURVE	= 12.44114	IN.-DEG.	CALC
RESONANT FREQ. PERIOD LOCATION AT D.S.	= 44.49	DEG.	CALC
GAS LOAD AT VALVE FACE	= 85.00	LBS	13
GAS LOAD EVENT = PERCENT OF TOTAL	= 0.5000		14
RAMP HEIGHT AT (X=0)	= 0.011226	IN.	11
RAMP SLOPE AT (X=0) X EVENT LENGTH	= -0.002196	IN.	12
HEIGHT	= 0.011799	IN.	CALC
VELOCITY	= 0.001044	IN./DEG.	7
ACCELERATION	= 0.000232	IN./DEG. SO.	8
	= 1.00912	DEG. SO.	CALC
	= 5.71109	DEG. SO.	CALC

DESIGN SOLUTION CHARACTERISTICS

EXONENTS	P	32
	Q	1
	R	2
	S	3
	T	4
COEFFICIENTS	P	33
	Q	CALC
	R	CALC
	S	CALC
	T	CALC

4.
10.
20.
30.
40.
2.5000000E=02
2.6464923E=01
-1.2904422E=01
3.9786088E=02
-5.4844293E=03

SAE 9644
CALC
CALC
CALC

= -1.2904422,=01
= 3.9786088,=02
= -5.4844293,=03

S
T

SAMPLE COMPUTER RUN EXHAUST CAM OPENING SIDE ONLY (12 JAN 1965) SAE 9644

Y VALVE LIFT INCHES

NO INTERIOR MAXIMA Data given every one-half degree. To read valve lift at 33.50°, find intersection of
NO INTERIOR MINIMA 30.00 in the left margin and 3.50 at the top--197699 inches.

DEG	.0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
.0	0.375000	0.374960	0.374839	0.374638	0.374356	0.373994	0.373551	0.373028	0.372425	0.371741
5.00	0.370977	0.370132	0.369207	0.368202	0.367117	0.365951	0.364706	0.363380	0.361974	0.360488
10.00	0.358922	0.357276	0.355551	0.353745	0.351860	0.349896	0.347852	0.345728	0.343525	0.341242
15.00	0.338881	0.336440	0.333921	0.331322	0.328645	0.325888	0.323054	0.320141	0.317149	0.314080
20.00	0.310932	0.307707	0.304404	0.301024	0.297566	0.294031	0.290420	0.286732	0.282968	0.279128
25.00	0.275213	0.271222	0.267157	0.263017	0.258804	0.254518	0.250159	0.245729	0.241227	0.236656
30.00	0.232015	0.227307	0.222531	0.217690	0.212784	0.207816	0.202787	0.197699	0.192554	0.187355
35.00	0.182103	0.176803	0.171456	0.166066	0.160637	0.155172	0.149676	0.144155	0.138612	0.133053
40.00	0.127484	0.121912	0.116343	0.110786	0.105247	0.099736	0.094261	0.088832	0.083459	0.078153
45.00	0.072926	0.067788	0.062753	0.057833	0.053040	0.048389	0.043893	0.039565	0.035418	0.031467
50.00	0.027723	0.024198	0.020904	0.017849	0.015043	0.012490	0.010196	0.008162	0.006385	0.004861
55.00	0.003582	0.002537	0.001708	0.001078	0.000623	0.000318	0.000133	0.000039	0.000005	0.000000

Y PRIME VALVE VELOCITY IN/DEG

NO INTERIOR MAXIMA

MINIMA =0.011143
AT 40.50

DEG	.0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
.0	.0	=0.000161	-0.000322	-0.000483	-0.000644	-0.000805	-0.000966	-0.001127	-0.001287	-0.001448
5.00	-0.001609	=0.001769	-0.001930	-0.002091	=0.002251	-0.002411	-0.002572	-0.002732	=0.002892	-0.003052
10.00	=0.003212	=0.003371	=0.003531	=0.003690	=0.003850	-0.004009	-0.004168	-0.004327	=0.004485	-0.004644
15.00	-0.004802	=0.004960	-0.005118	-0.005276	-0.005434	-0.005591	-0.005748	=0.005905	=0.006061	-0.006217
20.00	-0.006373	=0.006528	-0.006683	-0.006838	-0.006992	-0.007146	-0.007299	-0.007452	=0.007604	-0.007756
25.00	-0.007906	=0.008056	-0.008205	-0.008353	-0.008500	-0.008645	-0.008789	-0.008932	=0.009073	-0.009212
30.00	-0.009350	=0.009485	-0.009617	-0.009747	=0.009874	-0.009998	-0.010118	-0.010234	=0.010345	-0.010452
35.00	-0.010553	=0.010649	-0.010738	-0.010820	-0.010895	-0.010962	-0.011019	-0.011067	=0.011104	-0.011130
40.00	=0.011143	=0.011143	-0.011129	-0.011099	-0.011053	-0.010989	-0.010907	-0.010805	=0.010682	-0.010537
45.00	=0.010369	=0.010177	-0.009960	-0.009717	-0.009448	-0.009152	-0.008829	-0.008479	=0.008102	-0.007700
50.00	=0.007273	=0.006823	-0.006352	-0.005863	-0.005360	-0.004847	-0.004329	-0.003810	=0.003299	-0.002799
55.00	=0.002320	=0.001868	=0.001452	-0.001077	=0.000751	-0.000481	-0.000268	-0.000118	=0.000029	0.000000

Y 2PRIME VALVE ACCELERATION IN/DEG²

MAXIMA 0.001039
AT 53.00

NO INTERIOR MINIMA

DEG	.0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
.0	=0.000322	=0.000322	=0.000322	-0.000322	-0.000322	-0.000322	-0.000322	=0.000322	=0.000322	-0.000321
5.00	=0.000321	=0.000321	-0.000321	-0.000321	-0.000321	-0.000321	-0.000320	-0.000320	=0.000320	-0.000320
10.00	=0.000320	=0.000319	-0.000319	=0.000319	-0.000318	-0.000318	-0.000318	-0.000318	=0.000317	-0.000317
15.00	=0.000316	=0.000316	-0.000316	=0.000315	-0.000315	-0.000315	-0.000314	-0.000313	=0.000313	-0.000312
20.00	=0.000311	=0.000311	-0.000311	=0.000309	-0.000308	-0.000307	-0.000306	-0.000305	=0.000303	-0.000302
25.00	=0.000300	=0.000299	-0.000299	=0.000295	-0.000292	-0.000290	-0.000287	-0.000284	=0.000280	-0.000277
30.00	=0.000272	=0.000268	-0.000263	=0.000257	-0.000251	-0.000244	-0.000236	-0.000228	=0.000218	-0.000208
35.00	=0.000197	=0.000185	-0.000172	=0.000157	-0.000141	-0.000124	-0.000105	=0.000085	=0.000063	-0.000039
40.00	=0.000014	0.000014	0.000044	0.000075	0.000109	0.000145	0.000184	0.000225	0.000268	0.000313
45.00	0.0000360	0.000409	0.000460	0.000512	0.000565	0.000619	0.000673	0.000727	0.000779	0.000830
50.00	0.0000878	0.000922	0.000960	0.000993	0.001017	0.001033	0.001039	0.001033	0.001014	0.000981
55.00	0.0000933	0.000871	0.000793	0.000702	0.000598	0.000484	0.000363	0.000239	0.000117	0.000000

S VALVE SPRING LOAD LB

NO INTERIOR MAXIMA

NO INTERIOR MINIMA

DEG	.0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
.0	175.000000	174.988731	174.954926	174.898586	174.819712	174.718308	174.594378	174.447925	174.278956	174.087477
5.00	173.873495	173.637017	173.378053	173.096613	172.792706	172.466345	172.117540	171.746306	171.352656	170.936605
10.00	170.498168	170.037363	169.554205	169.048713	168.520908	167.970807	167.398433	166.803808	166.186955	165.547897
15.00	164.886661	164.203272	163.497759	162.770150	162.020478	161.248773	160.455071	159.639409	158.801823	157.942357
20.00	157.061054	156.157961	155.233128	154.286612	153.318470	152.328767	151.317572	150.284962	149.231020	148.155836
25.00	147.059511	145.942155	144.803887	143.644842	142.465167	141.265023	140.044591	138.804068	137.543675	136.263653
30.00	134.964271	133.645825	132.308643	130.953086	129.579554	128.188487	126.780371	125.355739	123.915179	122.459338
35.00	120.988924	119.504713	118.007558	116.498389	114.978221	113.448162	111.909418	110.363300	108.811231	107.254751
40.00	105.695525	104.135349	102.576158	101.020030	99.469188	97.926010	96.393031	94.872941	93.368587	91.882975
45.00	90.419258	88.980737	87.570845	86.193133	84.851254	83.548937	82.289956	81.078099	79.917120	78.810694
50.00	77.762357	76.775442	75.853007	74.997755	74.211947	73.497311	72.854948	72.285237	71.787741	71.361124
55.00	71.003080	70.710280	70.478351	70.301882	70.174489	70.088914	70.037194	70.010887	70.001339	70.000000

RAMP HEIGHT PLUS GAS LOAD DEFLECTION INCHES

H SUB R + G.L. DEFLECTION

NO INTERIOR MAXIMA

MINIMA 0.009862
AT 40.50

DEG	.0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
.0	0.011226	0.011208	0.011189	0.011171	0.011152	0.011134	0.011115	0.011097	0.011078	0.011060
5.00	0.011041	0.011023	0.011005	0.010986	0.010968	0.010949	0.010931	0.010912	0.010894	0.010875
10.00	0.010857	0.010838	0.010820	0.010802	0.010783	0.010765	0.010746	0.010728	0.010709	0.010691
15.00	0.010672	0.010654	0.010635	0.010617	0.010599	0.010580	0.010562	0.010543	0.010525	0.010506
20.00	0.010488	0.010469	0.010451	0.010432	0.010414	0.010396	0.010377	0.010359	0.010340	0.010322
25.00	0.010303	0.010285	0.010266	0.010248	0.010229	0.010211	0.010193	0.010174	0.010156	0.010137
30.00	0.010119	0.010100	0.010082	0.010064	0.010046	0.010029	0.010012	0.009995	0.009979	0.009964
35.00	0.009949	0.009936	0.009923	0.009911	0.009900	0.009891	0.009883	0.009876	0.009870	0.009866
40.00	0.009863	0.009862	0.009863	0.009865	0.009869	0.009875	0.009884	0.009894	0.009906	0.009921
45.00	0.009938	0.009958	0.009979	0.010004	0.010031	0.010061	0.010094	0.010129	0.010168	0.010209
50.00	0.010254	0.010302	0.010353	0.010407	0.010465	0.010526	0.010591	0.010660	0.010733	0.010809
55.00	0.010889	0.010973	0.011061	0.011153	0.011250	0.011351	0.011456	0.011566	0.011680	0.011799

V. T. DEFLECTION VALVE TRAIN INERTIA LOAD DEFLECTION INCHES

(Measured at the valve)

MAXIMA 0.006026
AT 53.00

MINIMA 0.000502
AT 33.00

DEG	.0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
.0	0.001581	0.001581	0.001580	0.001578	0.001576	0.001573	0.001569	0.001565	0.001560	0.001555
5.00	0.001548	0.001541	0.001534	0.001525	0.001516	0.001507	0.001496	0.001485	0.001474	0.001461
10.00	0.001449	0.001435	0.001421	0.001406	0.001390	0.001374	0.001357	0.001340	0.001322	0.001303
15.00	0.001283	0.001263	0.001243	0.001222	0.001200	0.001178	0.001155	0.001131	0.001107	0.001083
20.00	0.001058	0.001033	0.001007	0.000981	0.000955	0.000928	0.000902	0.000875	0.000848	0.000821
25.00	0.000794	0.000768	0.000741	0.000716	0.000690	0.000666	0.000642	0.000620	0.000599	0.000579
30.00	0.000561	0.000544	0.000530	0.000519	0.000510	0.000504	0.000502	0.000503	0.000509	0.000519
35.00	0.000535	0.000556	0.000583	0.000617	0.000657	0.000706	0.000763	0.000828	0.000903	0.000989
40.00	0.001084	0.001191	0.001310	0.001441	0.001584	0.001741	0.001910	0.002093	0.002289	0.002498
45.00	0.002720	0.002953	0.003197	0.003450	0.003711	0.003977	0.004245	0.004512	0.004775	0.005028
50.00	0.005266	0.005484	0.005675	0.005832	0.005948	0.006015	0.006026	0.005972	0.005848	0.005646
55.00	0.005363	0.004996	0.004547	0.004020	0.003422	0.002768	0.002076	0.001367	0.000667	0.000000

SAMPLE COMPUTER RUN EXHAUST CAM OPENING SIDE ONLY (12 JAN 1965) SAE 964A

INERTIA LOAD OF THE VALVE TRAIN AT THE VALVE END-115% DESIGN SPEED

L SUB V (115 PC)

MAXIMA 407.102159
AT 52.50

NO INTERIOR MINIMA

DEG	.0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
5.00	-140.871285=140.868666=140.860808=140.847711=140.829376=140.805801=140.776987=140.742933=140.703636=140.659094									
10.00	-140.609302=140.554255=140.493942=140.428350=140.357462=140.281254=140.199693=140.112738=140.020335=139.922414									
15.00	-139.818900=139.709652=139.594568=139.473469=139.346155=139.212380=139.071849=138.924208=138.769037=138.605839									
20.00	-138.434029=138.252920=138.061713=137.859479=137.645144=137.417470=137.175039=136.916225=136.639177=136.341794									
25.00	-136.021693=135.676183=135.302236=134.896449=134.455012=133.973666=133.447665=132.871731=132.240010=131.546019									
30.00	-130.782662=129.041867=129.015137=127.992889=126.864691=125.619143=124.243809=122.725155=121.048480=119.197852									
35.00	-117.123869=114.807946=112.262247=109.465297=106.394100=103.024105=99.329181=95.281605=90.452076=86.009744									
40.00	-80.722273=74.955941=68.675774=61.845736=54.428972=46.388124=37.685719=28.284652=18.148769=7.243570									
45.00	168.377173 188.959951 209.994482 231.324286 252.760883 274.081418 295.026786 315.300547 334.568900 352.462112									
50.00	368.577821 382.486697 393.740985 401.886490 406.478508 407.102159 403.397350 395.088279 382.016823 364.178294									
55.00	341.756744 315.155137 285.012978 252.200261 217.771278 182.854684 148.446357 115.058387 82.159776 47.320814									

S + L SUB V

MAXIMA 480.690455
AT 52.00

MINIMA 15.600476
AT 27.00

DEG

DEG	.0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
5.00	34.128715 34.120066 34.094119 34.050875 33.990336 33.912507 33.817390 33.704992 33.575320 33.428383									
10.00	33.264192 33.082762 32.884412 32.668263 32.435244 32.185091 31.917847 31.633568 31.332322 31.014191									
15.00	30.679279 30.327710 29.959637 29.575244 29.174752 28.758427 28.326585 27.879601 27.417918 26.942058									
20.00	26.452632 25.950352 25.436046 24.910671 24.375334 23.831303 23.280033 22.723184 22.162646 21.600563									
25.00	21.039361 20.481778 19.930893 19.390163 18.863458 18.355101 17.869908 17.413231 16.991010 16.609817									
30.00	16.276910 16.000288 15.788750 15.651953 15.600476 15.645880 15.800781 16.078913 16.495194 17.065801									
35.00	17.840401 18.437879 20.046395 21.487789 23.185454 25.164382 27.451190 30.074133 33.063103 36.449594									
40.00	40.266650 44.548772 49.331784 54.652653 60.549249 67.060038 74.223699 82.078648 90.662462 100.011181									
45.00	110.158488 121.134731 132.965790 145.671765 159.265473 173.750745 189.120508 205.354655 222.417712 240.256299									
50.00	258.796431 277.940688 297.565327 317.517419 337.612138 357.630354 377.316743 396.378646 414.486020 431.272806									
55.00	446.340179 459.262139 469.593993 476.884245 480.690455 480.599470 476.252298 467.373515 453.804563 435.539417									
	412.759824 385.865417 355.491329 322.502143 287.945767 252.943598 218.483551 185.069274 152.161115 117.320814									

SPRING LOAD PLUS INERTIA LOAD OF VALVE TRAIN AT VALVE END-AT 115%
DESIGN SPEED LB

(Must have positive margin)

CAM PROFILE LIFT-FOR RADIUS FOLLOWER INCHES

(See Data I.D. No. 29. Also compare with Appendix E.)

Z ZERO

NO INTERIOR MAXIMA

NO INTERIOR MINIMA

DEG	.0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
.0	0.267453	0.267413	0.267316	0.267163	0.266955	0.266690	0.266370	0.265993	0.265561	0.265073
5.00	0.264529	0.263929	0.263273	0.262561	0.261794	0.260970	0.260091	0.259157	0.258166	0.257120
10.00	0.256019	0.254862	0.253649	0.252381	0.251058	0.249679	0.248245	0.246755	0.245211	0.243611
15.00	0.241956	0.240247	0.238482	0.236663	0.234788	0.232859	0.230876	0.228838	0.226746	0.224599
20.00	0.222399	0.220144	0.217836	0.215474	0.213058	0.210590	0.208068	0.205493	0.202866	0.200187
25.00	0.197455	0.194672	0.191838	0.188952	0.186017	0.183031	0.179996	0.176912	0.173780	0.170601
30.00	0.167376	0.164104	0.160788	0.157429	0.154028	0.150585	0.147104	0.143584	0.140029	0.136440
35.00	0.132819	0.129168	0.125491	0.121789	0.118065	0.114323	0.110567	0.106799	0.103024	0.099246
40.00	0.095470	0.091700	0.087942	0.084201	0.080483	0.076794	0.073141	0.069530	0.065969	0.062464
45.00	0.059023	0.055655	0.052365	0.049163	0.046037	0.043053	0.040160	0.037384	0.034731	0.032209
50.00	0.029822	0.027575	0.025470	0.023509	0.021694	0.020022	0.018492	0.017099	0.015838	0.014701
55.00	0.013679	0.012763	0.011943	0.011208	0.010549	0.009956	0.009424	0.008946	0.008518	0.008137

CAM PROFILE VELOCITY IN/DEG

Z ZERO PRIME

NO INTERIOR MAXIMA

MINIMA ≤ 0.007556
AT 39.50

DEG	.0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
.0	-0.000025	=0.000137	-0.000249	=0.000361	-0.000473	-0.000585	-0.000697	=0.000809	=0.000921	-0.001032
5.00	=0.001144	=0.001256	=0.001368	=0.001479	=0.001591	-0.001702	-0.001814	-0.001925	=0.002036	-0.002148
10.00	=0.002259	=0.002370	=0.002481	=0.002592	=0.002702	-0.002813	-0.002924	=0.003034	=0.003144	-0.003254
15.00	=0.003365	=0.003474	=0.003584	=0.003694	=0.003803	-0.003912	-0.004021	=0.004130	=0.004239	-0.004347
20.00	=0.004455	=0.004563	=0.004670	=0.004778	=0.004884	-0.004991	-0.005097	=0.005202	=0.005307	-0.005411
25.00	=0.005515	=0.005618	=0.005720	=0.005821	=0.005921	-0.006021	-0.006119	=0.006216	=0.006311	-0.006405
30.00	=0.006497	=0.006588	=0.006676	=0.006761	=0.006844	-0.006924	-0.007001	=0.007075	=0.007145	-0.007211
35.00	=0.007272	=0.007329	=0.007381	=0.007427	=0.007466	-0.007500	-0.007526	=0.007544	=0.007554	-0.007556
40.00	=0.007548	=0.007530	=0.007501	=0.007461	=0.007409	-0.007344	-0.007266	=0.007175	=0.007049	-0.006948
45.00	=0.006812	=0.006661	=0.006494	=0.006311	=0.006113	-0.005900	-0.005672	=0.005430	=0.005176	-0.004911
50.00	=0.004636	=0.004353	=0.004066	=0.003776	=0.003486	-0.003200	-0.002921	=0.002652	=0.002396	-0.002156
55.00	=0.001934	=0.001733	=0.001552	=0.001391	=0.001249	-0.001123	-0.001009	=0.000904	=0.000807	-0.000720

SAMPLE COMPUTER RUN EXHAUST CAM OPENING SIDE ONLY (12 JAN 1965) SAE 964A

Z ZERO 2PRIME
CAM PROFILE ACCELERATION IN/DEG²

MAXIMA 0.000581
AT 51.50

NO INTERIOR MINIMA

DEG	.0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
.0	=0.000224	=0.000224	=0.000224	=0.000224	=0.000224	=0.000224	=0.000224	=0.000224	=0.000224	=0.000224
5.00	=0.000223	=0.000223	=0.000223	=0.000223	=0.000223	=0.000223	=0.000223	=0.000223	=0.000223	=0.000223
10.00	=0.000222	=0.000222	=0.000222	=0.000222	=0.000221	=0.000221	=0.000221	=0.000221	=0.000220	=0.000220
15.00	=0.000220	=0.000220	=0.000219	=0.000219	=0.000219	=0.000218	=0.000218	=0.000217	=0.000217	=0.000216
20.00	=0.000216	=0.000215	=0.000215	=0.000214	=0.000213	=0.000212	=0.000211	=0.000210	=0.000209	=0.000208
25.00	=0.000207	=0.000205	=0.000203	=0.000202	=0.000200	=0.000197	=0.000195	=0.000192	=0.000189	=0.000186
30.00	=0.000182	=0.000178	=0.000174	=0.000169	=0.000163	=0.000157	=0.000151	=0.000144	=0.000136	=0.000128
35.00	=0.000118	=0.000108	=0.000098	=0.000086	=0.000073	=0.000059	=0.000045	=0.000029	=0.000012	=0.000006
40.00	0.000026	0.000047	0.000069	0.000092	0.000116	0.000142	0.000169	0.000197	0.000227	0.000257
45.00	0.000287	0.000318	0.000350	0.000381	0.000412	0.000441	0.000470	0.000496	0.000520	0.000541
50.00	0.000558	0.000571	0.000578	0.000581	0.000577	0.000566	0.000549	0.000526	0.000497	0.000462
55.00	0.000424	0.000383	0.000342	0.000302	0.000267	0.000239	0.000217	0.000201	0.000186	0.000160

R SUB C (RADIUS FOLLOWER)
INSTANTANEOUS RADIUS OF CURVATURE INCHES

MAXIMA 2.767222
AT 51.50

MINIMA 0.257987
AT 22.00

DEG	.0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
.0	0.279373	0.279344	0.279285	0.279196	0.279075	0.278924	0.278742	0.278530	0.278286	0.278013
5.00	0.277708	0.277374	0.277009	0.276614	0.276188	0.275733	0.275249	0.274735	0.274192	0.273622
10.00	0.273024	0.272399	0.271748	0.271073	0.270375	0.269655	0.268916	0.268160	0.267389	0.266607
15.00	0.265818	0.265025	0.264234	0.263450	0.262680	0.261932	0.261213	0.260533	0.259904	0.259337
20.00	0.258847	0.258448	0.258159	0.257998	0.257987	0.258150	0.258515	0.259110	0.259969	0.261127
25.00	0.262625	0.264505	0.266817	0.269612	0.272948	0.276888	0.281500	0.286858	0.293043	0.300140
30.00	0.308591	0.318496	0.329619	0.342079	0.355999	0.371515	0.388766	0.407906	0.429091	0.452491
35.00	0.478281	0.506644	0.537768	0.571850	0.609088	0.649684	0.693838	0.741749	0.793608	0.849596
40.00	0.909875	0.974589	1.043846	1.117722	1.196238	1.279360	1.366978	1.458895	1.554809	1.654299
45.00	1.756801	1.861595	1.967781	2.074263	2.179735	2.282669	2.381312	2.473693	2.557638	2.630812
50.00	2.690771	2.735046	2.761251	2.767222	2.751181	2.711935	2.649079	2.563215	2.456153	2.331073
55.00	2.192614	2.046851	1.901084	1.763379	1.641708	1.542511	1.468372	1.414352	1.362384	1.273072

ECCENTRICITY--CAM-TAPPET INTERFACE INCHES

E (RADIUS FOLLOWER)

MAXIMA 0.422838
AT 39.50

NO INTERIOR MINIMA

DEG	.0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
.0	0.001418	0.007653	0.013889	0.020124	0.026358	0.032591	0.038824	0.045055	0.051285	0.057513
5.00	0.063740	0.069964	0.076186	0.082406	0.088623	0.094837	0.101048	0.107256	0.113460	0.119661
10.00	0.125858	0.132050	0.138238	0.144421	0.150600	0.156773	0.162941	0.169103	0.175259	0.181408
15.00	0.187550	0.193685	0.199813	0.205932	0.212042	0.218143	0.224234	0.230314	0.236382	0.242437
20.00	0.248479	0.254506	0.260516	0.266508	0.272481	0.278433	0.284361	0.290263	0.296137	0.301979
25.00	0.307786	0.313555	0.319282	0.324962	0.330591	0.336162	0.341669	0.347107	0.352468	0.357743
30.00	0.362924	0.367995	0.372946	0.377766	0.382440	0.386957	0.391301	0.395456	0.399404	0.403128
35.00	0.406606	0.409818	0.412741	0.415349	0.417618	0.419518	0.421022	0.422098	0.422714	0.422838
40.00	0.422435	0.421469	0.419904	0.417705	0.414835	0.411258	0.406941	0.401850	0.395955	0.389230
45.00	0.381653	0.373208	0.363885	0.353683	0.342610	0.330686	0.317943	0.304427	0.290200	0.275342
50.00	0.259947	0.244129	0.228022	0.211772	0.195544	0.179512	0.163859	0.148767	0.134412	0.120954
55.00	0.104522	0.097209	0.087053	0.078033	0.070059	0.062981	0.056607	0.050747	0.045301	0.040399

SCRUB VELOCITY IN/DEG

(Cam-tappet Interface)

S SUB B

NO INTERIOR MAXIMA

MINIMA 0.006772
AT 42.00

DEG	.0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
.0	0.017418	0.017306	0.017192	0.017077	0.016962	0.016845	0.016728	0.016609	0.016490	0.016370
5.00	0.016249	0.016126	0.016003	0.015879	0.015754	0.015628	0.015502	0.015374	0.015245	0.015116
10.00	0.014986	0.014854	0.014722	0.014589	0.014455	0.014321	0.014185	0.014049	0.013911	0.013773
15.00	0.013634	0.013494	0.013354	0.013213	0.013071	0.012928	0.012784	0.012640	0.012495	0.012349
20.00	0.012202	0.012055	0.011907	0.011759	0.011610	0.011461	0.011311	0.011160	0.011010	0.010859
25.00	0.010707	0.010556	0.010404	0.010252	0.010101	0.009950	0.009798	0.009648	0.009498	0.009348
30.00	0.009200	0.009052	0.008907	0.008762	0.008620	0.008480	0.008342	0.008207	0.008075	0.007946
35.00	0.007821	0.007701	0.007585	0.007475	0.007370	0.007272	0.007180	0.007096	0.007020	0.006952
40.00	0.006894	0.006847	0.006810	0.006785	0.006772	0.006772	0.006786	0.006815	0.006858	0.006918
45.00	0.006994	0.007086	0.007196	0.007323	0.007467	0.007628	0.007805	0.007998	0.008206	0.008427
50.00	0.008661	0.008904	0.009154	0.009410	0.009668	0.009925	0.010177	0.010422	0.010656	0.010876
55.00	0.011080	0.011266	0.011433	0.011581	0.011711	0.011827	0.011931	0.012027	0.012117	0.012198

LOAD AT CAM-TAPPET INTERFACE AT ENGINE CRANK SPEED LB

L SUB C (CRANK SPEED)

NO INTERIOR MAXIMA

NO INTERIOR MINIMA

DEG	.0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
.0	253.750000	253.733661	253.684643	253.602950	253.488583	253.341547	253.161848	252.949491	252.704486	252.426841
5.00	252.116567	251.773675	251.398177	250.990089	250.549424	250.076200	249.570433	249.032144	248.461352	247.858077
10.00	247.222344	246.554176	245.853597	245.120634	244.355316	243.557670	242.727729	241.865522	240.971085	240.044451
15.00	239.085658	238.094744	237.071750	236.016718	234.929693	233.810721	232.659854	231.477142	230.262644	229.016418
20.00	227.738528	226.429043	225.088036	223.715587	222.311781	220.876712	219.410480	217.913195	216.384979	214.825963
25.00	213.236291	211.616124	209.965636	208.285021	206.574492	204.834284	203.064657	201.265899	199.438328	197.582297
30.00	195.438192	193.786446	191.847532	189.881974	187.890353	185.873306	183.831537	181.765821	179.677010	177.566040
35.00	175.433939	173.281835	171.110960	168.922664	166.718420	164.499834	162.268656	160.026785	157.776285	155.519389
40.00	153.258511	150.996256	148.735430	146.479043	144.230322	141.992715	139.769895	137.565764	135.384451	133.230313
45.00	131.107924	129.022069	126.977725	124.980043	123.034319	121.145958	119.320437	117.563244	115.879824	114.275507
50.00	112.755418	111.324391	109.986861	108.746745	107.607323	106.571101	105.639675	104.813593	104.092224	103.473630
55.00	102.954466	102.529906	102.193608	101.937729	101.753009	101.628925	101.553931	101.515785	101.501942	101.500000

STRESS-CAM-TAPPET INTERFACE AT ENGINE CRANK SPEED LB/IN²

STRESS AT CRANK (THOUSANDS) (RF)

MAXIMA 132.344179
AT 15.50MINIMA 35.816084
AT 52.00

DEG	.0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
.0	131.910699	131.914077	131.918530	131.924060	131.930665	131.938347	131.947105	131.956936	131.967836	131.979800
5.00	131.992818	132.006877	132.021958	132.038034	132.055073	132.073028	132.091842	132.111438	132.131724	132.152580
10.00	132.173859	132.195380	132.216922	132.238216	132.258938	132.278698	132.297031	132.313387	132.327113	132.337443
15.00	132.343481	132.344179	132.338326	132.324518	132.301141	132.266344	132.218017	132.153760	132.070860	131.966259
20.00	131.836535	131.677872	131.486043	131.256389	130.983816	130.662792	130.287358	129.851153	129.347461	128.769273
25.00	128.109373	127.360449	126.515232	125.566660	124.508064	123.333380	122.037366	120.615834	119.065871	117.386038
30.00	115.516659	113.468137	111.307470	109.040731	106.675588	104.221168	101.687887	99.087238	96.431549	93.733737
35.00	91.007062	88.264896	85.520513	82.786906	80.076630	77.401658	74.773249	72.201803	69.696688	67.266020
40.00	64.916385	62.652480	60.476668	58.388462	56.383952	54.455261	52.590127	50.839538	49.190232	47.634500
45.00	46.172019	44.802485	43.525682	42.341555	41.250277	40.252326	39.348564	38.540322	37.829496	37.218650
50.00	36.711139	36.311229	36.024227	35.856605	35.816084	35.911642	36.153348	36.551891	37.117534	37.858128
55.00	38.775635	39.860549	41.084008	42.388904	43.685061	44.859651	45.818364	46.567274	47.342505	48.796286

INERTIA LOAD OF THE VALVE TRAIN AT THE CAM-TAPPET INTERFACE--
115% DESIGN SPEED

L SUB C (115 PC)

MAXIMA 697.001159
AT 52.00

MINIMA 22.620690
AT 27.00

DEG	.0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
.0	49.486637	49.474095	49.436472	49.373769	49.285988	49.173135	49.035216	48.872239	48.684214	48.471155
5.00	48.233079	47.970006	47.681962	47.368981	47.031104	46.668382	46.280878	45.868674	45.431866	44.970577
10.00	44.484954	43.975180	43.441474	42.884104	42.303391	41.699719	41.073548	40.425421	39.755981	39.065984
15.00	38.356316	37.428010	36.882266	36.120474	35.344234	34.555389	33.756047	32.948617	32.135837	31.320816
20.00	30.507074	29.698578	28.899794	28.115736	27.352014	26.614897	25.911366	25.249185	24.636965	24.084235
25.00	23.601519	23.200417	22.893688	22.695333	22.620690	22.686526	22.911133	23.314424	23.918032	24.745411
30.00	25.868582	27.314924	29.067273	31.157294	33.618908	36.488354	39.804225	43.607493	47.941499	52.851911
35.00	58.386643	64.595720	71.531087	79.246347	87.796411	97.237055	107.624364	119.014040	131.460569	145.016213
40.00	159.729808	175.645360	192.800395	211.224059	230.934936	251.938581	274.224736	297.764250	322.505682	348.371634
45.00	375.254825	403.013997	431.469724	460.400257	489.537600	518.564014	547.109277	574.749037	601.004730	625.345569
50.00	647.193259	665.930102	680.911290	691.482155	697.001159	696.869231	690.565832	677.691597	658.016617	631.532155
55.00	598.501745	559.504854	515.462426	467.628108	417.521362	366.768216	316.801149	268.350447	220.633617	170.115181

STRESS AT 115 PC (THOUSANDS) (RF)

MAXIMA 65.965420 70.458042
AT 41.50 56.00

MINIMA 58.716419 65.356503
AT 29.00 47.50

DEG	.0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
.0	76.496338	76.493476	76.481588	76.460652	76.430629	76.391469	76.343103	76.285446	76.218400	76.141847
5.00	76.055652	75.959664	75.853710	75.737599	75.611120	75.474039	75.326099	75.167022	74.996502	74.814211
10.00	74.619793	74.412865	74.193017	73.959812	73.712785	73.451445	73.175276	72.883739	72.576276	72.252315
15.00	71.911277	71.552584	71.175670	70.779997	70.365072	69.930473	69.475873	69.001078	68.506068	67.991045
20.00	67.456498	66.903263	66.332611	65.746330	65.146824	64.537214	63.921445	63.304379	62.691876	62.090849
25.00	61.509261	60.956065	60.441048	59.974574	59.567201	59.229183	58.969878	58.716419	58.4730720	58.230720
30.00	58.844591	59.051752	59.339015	59.696300	60.111571	60.571502	61.062175	61.569745	62.081019	62.583934
35.00	63.067903	63.524060	63.945398	64.326822	64.665133	64.958956	65.208604	65.415884	65.583823	65.716295
40.00	65.817511	65.891355	65.940518	65.965420	65.962920	65.924885	65.836775	65.764117	65.695416	65.624830
45.00	65.555829	65.491883	65.436468	65.393077	65.365231	65.356503	65.370526	65.411018	65.481795	65.586773
50.00	65.729963	65.915425	66.147167	66.428953	66.763946	67.154102	67.599146	68.094915	68.630734	69.185392
55.00	69.721331	70.176932	70.458042	70.432657	69.937500	68.809334	66.947791	64.387821	61.326805	57.962323

.. LB/IN²

APPENDIX E

A TYPICAL "CAMCHECK" CAM PROFILE MEASUREMENT AND EVALUATION FINAL REPORT

Based upon the new CPM&E methods described in the preceding text, this appendix provides a typical cam profile measurement and evaluation solution prepared with Camcheck instrumentation and computer programs. The report (output format) is designed to be self-explanatory; however, several comments may be of interest.

This example is a prototype cam profile; the identification numbers and base circle radius dimension have been deleted to obtain anonymity. This solution is the identical profile given in the "current practice" profile measurement of Appendix C; therefore, the two solutions can be compared directly. The new solution shows the maximum cam lift to be .26683 inches which (see Table 7) is -.00033 inches less than the design value; the new analytical methods determined the "as made" base

circle radius, then calculated the lift above that level—as in the manner of the design data. By contrast, the solution of Appendix C assumed the maximum cam lift equal to the design value—which resulted in showing the base circle oversize, whereas, in fact, the base circle was undersize.

The Camcheck solution front page format shows, for this example, a cam follower radius of 35.000 inches. The cam profile design lift values furnished to the cam manufacturer were (only) the "flat-faced" follower lift values—after the manner of those shown (z_e) in Appendix A. After the prototype cam was manufactured, the profile was measured with the 35.000-inch radius follower. This data was used for the profile evaluation given in this appendix. The profile acceleration diagrams "as designed" and "as made" are shown for comparison.

Information Required by Camcheck Services To Prepare A Cam Profile Measurement And Evaluation Final Report

The following information is listed in the order of importance. The first two items are the minimum information necessary to prepare cam follower lift, velocity and acceleration data for the cam profile "as made." Item 3 is necessary to prepare lift differences data. The additional items are for identification only.

1. Camshaft

- a. Tag or mark, lobes to be checked.
- b. Pack carefully, to avoid nicks and scratches on finished surfaces.

2. Tappet--Cam Follower Radius

- a. Engineering drawing of tappet or cam follower, or
- b. Statement of cam follower radius to be used for profile measurement.

3. Camshaft Engineering Drawings

- a. Design--cam profile lift data.
- b. Camshaft--finished machine drawing.

4. Identification Only.

- a. Camshaft source—i.e., Engineering, Experimental, Manufacturing or other.
- b. Camshaft—production or prototype.
- c. Manufactured by—i.e., plant number and/or machine number or vendor name.

Important Notice

The Camcheck Company recognizes the proprietary right and interest on the part of the engine manufacturer in all engine design and manufacturing information. Engineering design and quality control data is accepted, processed and retransmitted to the source in confidence.

C A M C H E C K - - C A M P R O F I L E M E A S U R E M E N T A N D E V A L U A T I O N

CAMCHECK NO. SAE-964A

MANUFACTURER AND LOCATION - -NAME---PLANT NUMBER---OR VENDOR

ENGINE IDENTIFICATION - - - - NUMBER I.E. SAE-964A

CAMSHAFT SOURCE - - - ENGINEERING OR MANUFACTURING

PROTOTYPE CAM - MANUFACTURED BY COMPANY E, DETROIT

CAMSHAFT DRAWING NO. - - - - - XYZ - 54321
CAM LOBE TYPE AND NO. - - - INTAKE LOBE NO.X
CAM FOLLOWER RADIUS - - - - - 35.000 INCHES

12 JAN 1965

A C C U R A C Y THE CAM PROFILE DATA PRESENTED IN THIS REPORT ARE BASED ON MEASUREMENTS MADE WITH AN ACCURACY OF
LIFT MEASUREMENTS - - - - - PLUS OR MINUS 40 MILLIONTHS (.000040 INCHES)
ANGULAR MEASUREMENTS - - - - - PLUS OR MINUS 5 SECONDS OF ARC (.0014 DEGREES)

THE FOREGOING STATEMENT OF ACCURACY IS BASED ON THE MAXIMUM DIFFERENCE BETWEEN ANY POINT IN THE MEASURED DATA AND THE CORRESPONDING POINT AFTER PROFILE RANDOM ERROR SMOOTHING. THE RAW DATA MEASUREMENTS WERE OBTAINED IN A CONTROLLED ATMOSPHERE--I.E., GAGE ROOM TEMPERATURE 68.0 PLUS OR MINUS 0.5 DEGREES FAHRENHEIT, DUST FREE AND 50 PER CENT R. H. THE CAMCHECK INSTRUMENTATION SYSTEM HAS A CALIBRATED MEAN STANDARD DEVIATION OF 13 MILLIONTHS (.000013 INCHES). RANDOM ERROR SMOOTHING IS OBTAINED WITH A SPECIAL COMPUTER PROGRAM AS DESCRIBED IN S.A.E. PAPER NO. 964A. THE CAM BASE CIRCLE RUN-OUT APPEARS IN THE RAW LIFT DATA AS A SYSTEMATIC ERROR. THIS ERROR IS EVALUATED BY THE PROGRAM FOR OFFSET AND PHASE ANGLE WITH THE PROFILE LIFT VALUES CORRECTED TO THE TRUE BASE CIRCLE CENTER. BASED ON A CALCULATED CONFIDENCE LEVEL OF 95.4 PER CENT, THE AS MADE LIFT DATA AND THE LIFT DIFFERENCES FROM THE DESIGN PROFILE AS GIVEN IN THIS REPORT HAVE A MAXIMUM ERROR LESS THAN 34 MILLIONTHS (.000034 INCHES). FINALLY, THE VELOCITY AND ACCELERATION DATA ARE ALSO CALCULATED BY THE PROGRAM FOR USE IN EVALUATING THE DYNAMIC PERFORMANCE OF THE CAM PROFILE AS MADE.

M E A S U R E D 1. BASE CIRCLE RADIUS - - - .XXXXX INCHES 2. MAXIMUM CAM LIFT - - - .26683 INCHES
D A T A 3. OFFSET AND PHASE ANGLE BETWEEN THE CENTER OF ROTATION AND THE TRUE CENTER OF THE CAM BASE CIRCLE --
OFFSET EQUALS .00027 INCHES, PHASE ANGLE EQUALS 143.90 DEGREES FROM TOP CENTER ON THE CLOSING SIDE.

L I S T O F 1. CAM FOLLOWER LIFT -- AS MADE -- OPENING SIDE -- INCHES (VALUES CORRECTED TO TRUE BASE CIRCLE CENTER)
T A B L E S 2. CAM FOLLOWER LIFT -- AS MADE -- CLOSING SIDE -- INCHES (VALUES CORRECTED TO TRUE BASE CIRCLE CENTER)
3. CAM FOLLOWER VELOCITY -- AS MADE -- OPENING SIDE -- INCHES PER DEGREE
4. CAM FOLLOWER VELOCITY -- AS MADE -- CLOSING SIDE -- INCHES PER DEGREE
5. CAM FOLLOWER ACCELERATION -- AS MADE -- OPENING SIDE -- INCHES PER DEGREE SQUARED
6. CAM FOLLOWER ACCELERATION -- AS MADE -- CLOSING SIDE -- INCHES PER DEGREE SQUARED
7. LIFT DIFFERENCES -- OPENING SIDE -- LIFT AS MADE MINUS LIFT AS DESIGNED -- INCHES
8. LIFT DIFFERENCES -- CLOSING SIDE -- LIFT AS MADE MINUS LIFT AS DESIGNED -- INCHES

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1. CAM FOLLOWER LIFT -- AS MADE -- OPENING SIDE -- INCHES

DEG	.0	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
0	.26683	.26680	.26672	.26659	.26640	.26616	.26587	.26552	.26512	.26467
5	.26416	.26360	.26298	.26231	.26159	.26081	.25998	.25909	.25815	.25715
10	.25610	.25499	.25382	.25260	.25133	.25000	.24862	.24719	.24570	.24416
15	.24256	.24092	.23922	.23747	.23567	.23381	.23190	.22994	.22793	.22586
20	.22374	.22157	.21935	.21707	.21475	.21237	.20994	.20745	.20492	.20234
25	.19970	.19701	.19428	.19149	.18865	.18576	.18283	.17984	.17681	.17372
30	.17059	.16742	.16420	.16093	.15763	.15428	.15089	.14746	.14399	.14049
35	.13696	.13339	.12980	.12617	.12253	.11885	.11517	.11146	.10774	.10401
40	.10028	.09654	.09281	.08909	.08538	.08169	.07803	.07439	.07080	.06724
45	.06375	.06030	.05693	.05363	.05042	.04728	.04423	.04128	.03843	.03570
50	.03310	.03062	.02827	.02606	.02398	.02205	.02024	.01858	.01704	.01564
55	.01435	.01319	.01214	.01119	.01033	.00955	.00884	.00820	.00762	.00709
60	.00661	.00619	.00580	.00545	.00513	.00484	.00458	.00433	.00409	.00387
65	.00365	.00345	.00324	.00304	.00284	.00264	.00244	.00224	.00204	.00185
70	.00166	.00147	.00129	.00112	.00096	.00081	.00067	.00055	.00043	.00033
75	.00025	.00017	.00011	.00006	.00002	.00001	.00003	.00005	.00006	.00006
80	.00007	.00007	.00007	.00006	.00006	.00006	.00006	.00005	.00005	.00005
85	.00005	.00005	.00006	.00005	.00005	.00005	.00006	.00006	.00006	.00006
90	.00006	.00007	.00007	.00007	.00007	.00007	.00006	.00006	.00006	.00006

NOTE -- VALUES CORRECTED TO TRUE BASE CIRCLE CENTER

2. CAM FOLLOWER LIFT -- AS MADE -- CLOSING SIDE -- INCHES

0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
.26683	.26417	.25610	.24248	.22358	.19954	.17055	.13712	.10075	.06479	.03492	.01681	.00965	.00657	.00351	.00094	.00002	.00001	.00002
.26680	.26361	.25499	.24082	.22140	.19686	.16739	.13358	.09707	.06143	.03252	.01568	.00928	.00626	.00322	.00077	.00004	.00000	.00002
.26672	.26300	.25382	.23911	.21918	.19413	.16419	.13001	.09338	.05812	.03026	.01467	.00895	.00595	.00292	.00061	.00005	.00000	.00002
.26233	.25260	.23735	.21690	.19135	.16095	.12641	.08971	.05489	.02812	.01376	.00864	.00564	.00264	.00047	.00005	.00000	.00000	.00001
.26160	.25131	.23553	.21458	.18852	.15766	.12279	.08605	.05173	.02612	.01295	.00834	.00533	.00236	.00035	.00004	.00000	.00000	.00001
.26083	.24998	.23367	.21220	.18565	.15433	.11915	.08242	.04867	.02425	.01221	.00804	.00503	.00209	.00025	.00003	.00000	.00000	.00001
.25999	.24714	.22978	.20729	.18272	.15096	.11549	.07881	.04570	.02250	.01157	.00776	.00472	.00183	.00016	.00003	.00001	.00001	.00001
.24564	.22777	.20476	.17673	.14411	.10814	.07524	.04284	.02089	.01099	.00746	.00411	.00158	.00015	.00004	.00002	.00001	.00001	.00002
.22570	.20217	.17366	.14064	.10445	.06823	.03744	.01941	.01049	.00717	.00408	.00135	.00009	.00003	.00002	.00001	.00001	.00001	.00002
.26468	.25716	.24408	.22570	.20217	.17366	.14064	.10445	.06823	.03744	.01941	.01049	.00717	.00408	.00135	.00009	.00003	.00001	.00002

NOTE -- VALUES CORRECTED TO TRUE BASE CIRCLE CENTER

RUN FOR SAE PAPER

3. CAM FOLLOWER VELOCITY -- AS MADE -- OPENING SIDE -- INCHES PER DEGREE

DEG	.0	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
0	-.000000	.000105	.000211	.000318	.000425	.000532	.000640	.000748	.000855	.000963
5	.001070	.001178	.001286	.001394	.001502	.001611	.001720	.001830	.001941	.002051
10	.002162	.002272	.002382	.002492	.002601	.002709	.002817	.002923	.003029	.003135
15	.003240	.003344	.003449	.003554	.003659	.003764	.003869	.003974	.004080	.004184
20	.004289	.004394	.004498	.004602	.004707	.004810	.004914	.005017	.005119	.005221
25	.005322	.005423	.005525	.005625	.005725	.005825	.005923	.006020	.006117	.006211
30	.006305	.006396	.006485	.006572	.006657	.006739	.006818	.006894	.006967	.007036
35	.007101	.007162	.007219	.007270	.007318	.007359	.007395	.007424	.007447	.007462
40	.007469	.007466	.007455	.007432	.007400	.007355	.007298	.007229	.007147	.007050
45	.006939	.006812	.006670	.006518	.006357	.006184	.006001	.005798	.005572	.005336
50	.005086	.004828	.004558	.004287	.004010	.003738	.003470	.003206	.002942	.002690
55	.002443	.002214	.002000	.001807	.001638	.001485	.001351	.001227	.001111	.001004
60	.000906	.000816	.000736	.000665	.000606	.000556	.000516	.000483	.000458	.000438
65	.000425	.000415	.000408	.000404	.000402	.000400	.000398	.000396	.000393	.000386
70	.000377	.000364	.000348	.000330	.000309	.000287	.000263	.000239	.000213	.000188
75	.000162	.000137	.000113	.000091	.000070	.000052	.000037	.000025	.000016	.000008
80	.000002	-.000001	-.000004	-.000005	-.000005	-.000004	-.000003	-.000002	-.000000	.000001
85	.000001	.000001	-.000001	-.000001	.000000	.000000	.000000	.000000	.000000	.000000
90	.000004	.000004	.000004	.000004	.000004	.000002	.000003	.000004	.000004	.000004

4. CAM FOLLOWER VELOCITY -- AS MADE -- CLOSING SIDE -- INCHES PER DEGREE

0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
-.000000	-.000106	-.000211	-.000317	-.000423	-.000530	-.000637	-.000744	-.000851	-.000959	-.001066	-.001172	-.001279	-.001386	-.001493	-.001600	-.001707	-.001814	-.001921
-.001067	-.001174	-.001283	-.001391	-.001500	-.001611	-.001722	-.001833	-.001945	-.002058	-.002170	-.002283	-.002397	-.002511	-.002625	-.002739	-.002853	-.002967	-.003081
-.003265	-.003370	-.003473	-.003576	-.003679	-.003781	-.003883	-.003985	-.004088	-.004190	-.004293	-.004397	-.004500	-.004603	-.004706	-.004809	-.004911	-.005012	-.005113
-.005312	-.005411	-.005509	-.005607	-.005705	-.005802	-.005898	-.005993	-.006087	-.006179	-.006270	-.006360	-.006447	-.006533	-.006616	-.006696	-.006774	-.006850	-.006921
-.007053	-.007113	-.007168	-.007218	-.007262	-.007300	-.007332	-.007356	-.007373	-.007382	-.007389	-.007394	-.007397	-.007399	-.007400	-.007400	-.007400	-.007400	-.007400
-.007383	-.007374	-.007356	-.007328	-.007289	-.007239	-.007177	-.007103	-.007016	-.006916	-.006805	-.006683	-.006551	-.006409	-.006257	-.006105	-.005953	-.005801	-.005649
-.006803	-.006677	-.006538	-.006385	-.006216	-.006033	-.005836	-.005623	-.005398	-.005159	-.004914	-.004663	-.004407	-.004146	-.003881	-.003613	-.003343	-.003071	-.002800
-.004914	-.004659	-.004397	-.004139	-.003877	-.003613	-.003353	-.003094	-.002843	-.002598	-.002357	-.002119	-.001884	-.001652	-.001424	-.001199	-.000977	-.000758	-.000542
-.002364	-.002139	-.001928	-.001728	-.001544	-.001374	-.001219	-.001078	-.000955	-.000847	-.000752	-.000670	-.000602	-.000547	-.000494	-.000444	-.000394	-.000344	-.000294
-.000760	-.000694	-.000644	-.000613	-.000592	-.000584	-.000580	-.000585	-.000592	-.000603	-.000619	-.000640	-.000665	-.000694	-.000727	-.000764	-.000804	-.000847	-.000892
-.000597	-.000590	-.000580	-.000567	-.000550	-.000529	-.000504	-.000475	-.000444	-.000409	-.000368	-.000322	-.000272	-.000219	-.000164	-.000107	-.000049	-.000001	-.000000
-.000373	-.000336	-.000298	-.000260	-.000223	-.000186	-.000152	-.000120	-.000091	-.000064	-.000037	-.000014	-.000006	-.000005	-.000005	-.000005	-.000005	-.000005	-.000005
-.000042	-.000023	-.000009	-.000001	-.000004	-.000006	-.000006	-.000006	-.000006	-.000006	-.000006	-.000006	-.000006	-.000006	-.000006	-.000006	-.000006	-.000006	-.000006
-.000009	.000005	.000001	.000004	.000005	.000006	.000006	.000006	.000006	.000006	.000006	.000006	.000006	.000006	.000006	.000006	.000006	.000006	.000006
-.000001	.000001	.000002	.000004	.000005	.000006	.000006	.000006	.000006	.000006	.000006	.000006	.000006	.000006	.000006	.000006	.000006	.000006	.000006

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5. CAM FOLLOWER ACCELERATION -- AS MADE -- OPENING SIDE -- INCHES PER DEGREE SQUARED

DEG	.0	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
0	-.000211	-.000212	-.000213	-.000214	-.000214	-.000215	-.000216	-.000216	-.000215	-.000215
5	-.000215	-.000215	-.000216	-.000216	-.000218	-.000218	-.000219	-.000220	-.000221	-.000221
10	-.000221	-.000220	-.000216	-.000219	-.000217	-.000216	-.000214	-.000212	-.000211	-.000211
15	-.000210	-.000209	-.000209	-.000210	-.000210	-.000210	-.000211	-.000211	-.000210	-.000210
20	-.000209	-.000209	-.000208	-.000208	-.000208	-.000207	-.000207	-.000205	-.000204	-.000203
25	-.000202	-.000202	-.000202	-.000202	-.000199	-.000198	-.000196	-.000194	-.000191	-.000188
30	-.000185	-.000181	-.000176	-.000172	-.000167	-.000161	-.000155	-.000149	-.000142	-.000134
35	-.000126	-.000117	-.000109	-.000099	-.000088	-.000078	-.000066	-.000052	-.000038	-.000022
40	-.000004	-.000014	-.000034	-.000055	-.000078	-.000101	-.000126	-.000151	-.000179	-.000209
45	-.000238	-.000269	-.000295	-.000312	-.000334	-.000356	-.000386	-.000428	-.000462	-.000486
50	-.000508	-.000528	-.000541	-.000548	-.000549	-.000540	-.000533	-.000528	-.000516	-.000499
55	-.000476	-.000443	-.000407	-.000362	-.000323	-.000286	-.000258	-.000240	-.000222	-.000205
60	-.000188	-.000170	-.000151	-.000130	-.000110	-.000090	-.000073	-.000057	-.000044	-.000033
65	-.000024	-.000017	-.000011	-.000007	-.000004	-.000003	-.000004	-.000006	-.000010	-.000016
70	-.000022	-.000029	-.000034	-.000043	-.000049	-.000046	-.000049	-.000050	-.000051	-.000051
75	-.000051	-.000049	-.000046	-.000038	-.000038	-.000033	-.000027	-.000022	-.000017	-.000013
80	-.000009	-.000006	-.000003	-.000001	-.000000	-.000002	-.000002	-.000003	-.000003	-.000002
85	-.000000	-.000002	-.000002	-.000001	-.000000	-.000003	-.000002	-.000001	-.000000	-.000000
90	-.000000	-.000000	-.000000	-.000000	-.000000	-.000000	-.000000	-.000001	-.000000	-.000000

6. CAM FOLLOWER ACCELERATION -- AS MADE -- CLOSING SIDE -- INCHES PER DEGREE SQUARED

0	-.000211	-.000211	-.000211	-.000212	-.000213	-.000213	-.000214	-.000215	-.000215	-.000215
5	-.000215	-.000216	-.000217	-.000218	-.000220	-.000220	-.000223	-.000223	-.000224	-.000225
10	-.000225	-.000225	-.000224	-.000224	-.000222	-.000220	-.000218	-.000216	-.000213	-.000211
15	-.000209	-.000208	-.000206	-.000206	-.000205	-.000205	-.000204	-.000205	-.000205	-.000206
20	-.000206	-.000206	-.000207	-.000206	-.000206	-.000205	-.000204	-.000202	-.000200	-.000199
25	-.000198	-.000197	-.000196	-.000195	-.000194	-.000193	-.000191	-.000189	-.000186	-.000184
30	-.000180	-.000177	-.000173	-.000168	-.000164	-.000159	-.000153	-.000147	-.000140	-.000132
35	-.000124	-.000115	-.000105	-.000094	-.000082	-.000070	-.000056	-.000042	-.000026	-.000009
40	-.000008	-.000027	-.000047	-.000067	-.000089	-.000112	-.000136	-.000161	-.000186	-.000212
45	-.000239	-.000266	-.000293	-.000322	-.000351	-.000381	-.000411	-.000438	-.000464	-.000484
50	-.000500	-.000512	-.000520	-.000524	-.000526	-.000524	-.000519	-.000510	-.000496	-.000480
55	-.000459	-.000436	-.000411	-.000384	-.000354	-.000325	-.000296	-.000264	-.000231	-.000195
60	-.000154	-.000117	-.000081	-.000052	-.000029	-.000011	-.000001	-.000011	-.000018	-.000019
65	-.000014	-.000008	-.000000	-.000004	-.000005	-.000005	-.000004	-.000005	-.000006	-.000008
70	-.000012	-.000017	-.000023	-.000030	-.000038	-.000046	-.000054	-.000060	-.000066	-.000070
75	-.000073	-.000075	-.000076	-.000075	-.000073	-.000070	-.000067	-.000062	-.000056	-.000049
80	-.000040	-.000032	-.000025	-.000018	-.000011	-.000006	-.000002	-.000001	-.000003	-.000005
85	-.000006	-.000007	-.000006	-.000006	-.000004	-.000003	-.000000	-.000001	-.000003	-.000003
90	-.000003	-.000004	-.000003	-.000003	-.000002	-.000001	-.000000	-.000001	-.000002	-.000002

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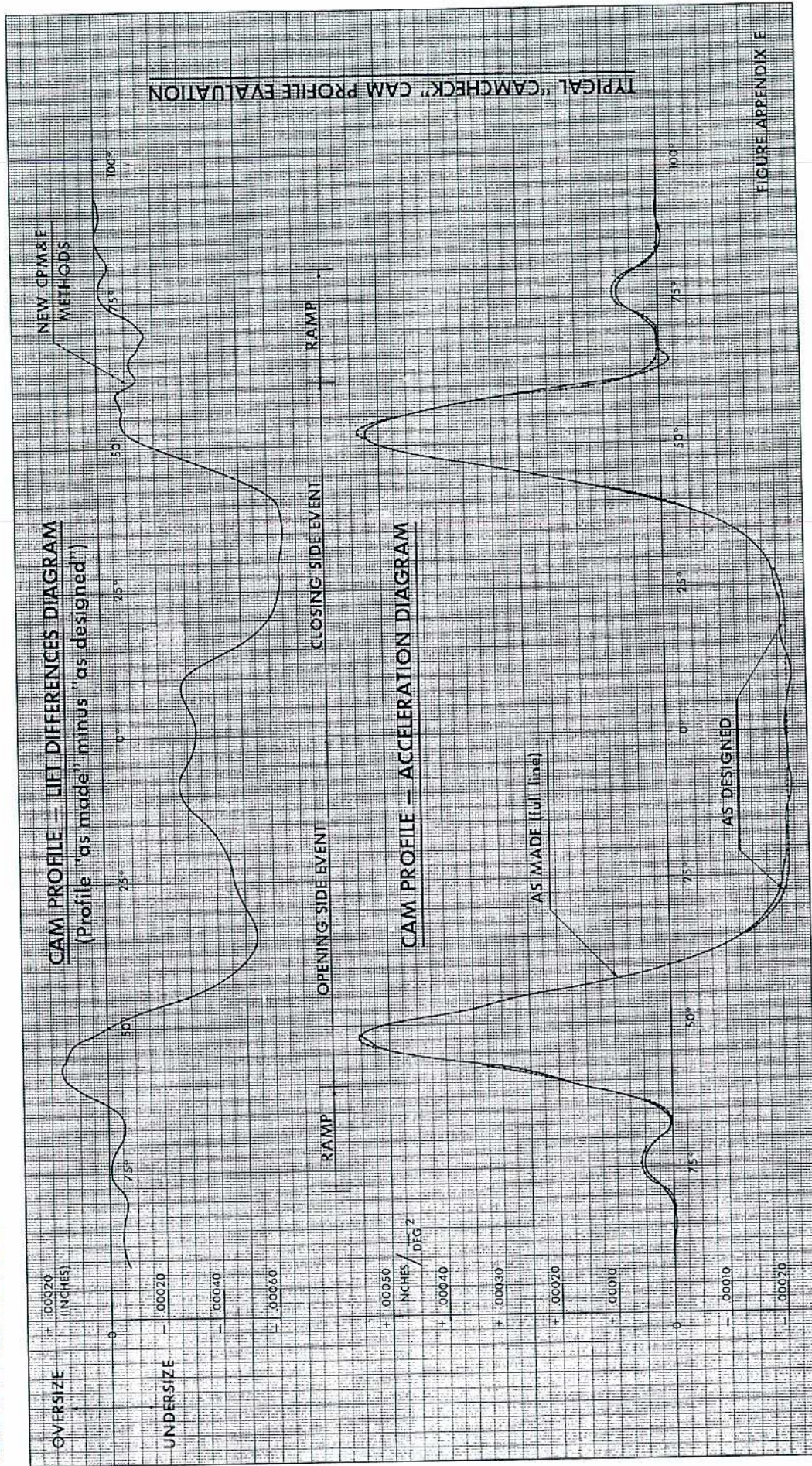
7. LIFT DIFFERENCES -- OPENING SIDE -- LIFT AS MADE MINUS LIFT AS DESIGNED -- INCHES

DEG	.0	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
0	-.00033	-.00033	-.00033	-.00032	-.00032	-.00032	-.00031	-.00031	-.00030	-.00030
5	-.00029	-.00029	-.00028	-.00028	-.00027	-.00027	-.00027	-.00027	-.00027	-.00027
10	-.00028	-.00028	-.00029	-.00030	-.00030	-.00030	-.00032	-.00033	-.00034	-.00036
15	-.00037	-.00038	-.00039	-.00039	-.00040	-.00041	-.00041	-.00042	-.00042	-.00043
20	-.00043	-.00044	-.00044	-.00045	-.00045	-.00045	-.00045	-.00046	-.00046	-.00046
25	-.00047	-.00047	-.00047	-.00047	-.00048	-.00048	-.00049	-.00049	-.00050	-.00050
30	-.00051	-.00051	-.00052	-.00052	-.00053	-.00053	-.00054	-.00054	-.00054	-.00054
35	-.00054	-.00054	-.00054	-.00053	-.00053	-.00052	-.00051	-.00050	-.00049	-.00048
40	-.00047	-.00046	-.00044	-.00043	-.00041	-.00039	-.00037	-.00035	-.00032	-.00030
45	-.00027	-.00025	-.00021	-.00018	-.00014	-.00011	-.00008	-.00007	-.00004	-.00003
50	-.00000	-.00002	-.00004	-.00006	-.00009	-.00011	-.00012	-.00013	-.00014	-.00014
55	-.00014	-.00015	-.00015	-.00016	-.00016	-.00017	-.00016	-.00016	-.00014	-.00014
60	-.00012	-.00011	-.00009	-.00007	-.00005	-.00003	-.00001	-.00001	-.00002	-.00004
65	-.00005	-.00005	-.00006	-.00006	-.00006	-.00006	-.00006	-.00006	-.00006	-.00005
70	-.00005	-.00004	-.00003	-.00002	-.00002	-.00001	-.00001	-.00001	-.00001	-.00001
75	-.00007	-.00007	-.00007	-.00006	-.00006	-.00006	-.00006	-.00005	-.00006	-.00006
80	-.00007	-.00007	-.00007	-.00006	-.00006	-.00006	-.00006	-.00005	-.00005	-.00005
85	-.00005	-.00005	-.00006	-.00005	-.00005	-.00005	-.00006	-.00006	-.00006	-.00006
90	-.00006	-.00007	-.00007	-.00007	-.00007	-.00007	-.00006	-.00006	-.00006	-.00006

8. LIFT DIFFERENCES -- CLOSING SIDE -- LIFT AS MADE MINUS LIFT AS DESIGNED -- INCHES

0	-.00033	-.00033	-.00033	-.00033	-.00033	-.00032	-.00032	-.00032	-.00031	-.00031
5	-.00031	-.00030	-.00030	-.00029	-.00029	-.00028	-.00028	-.00028	-.00028	-.00028
10	-.00029	-.00031	-.00031	-.00032	-.00034	-.00036	-.00038	-.00040	-.00042	-.00044
15	-.00046	-.00048	-.00050	-.00052	-.00053	-.00055	-.00056	-.00057	-.00058	-.00059
20	-.00059	-.00060	-.00060	-.00061	-.00061	-.00062	-.00062	-.00063	-.00063	-.00063
25	-.00064	-.00064	-.00064	-.00064	-.00064	-.00064	-.00063	-.00063	-.00063	-.00063
30	-.00064	-.00064	-.00064	-.00064	-.00064	-.00064	-.00065	-.00065	-.00065	-.00065
35	-.00065	-.00065	-.00066	-.00065	-.00065	-.00065	-.00065	-.00065	-.00065	-.00064
40	-.00064	-.00063	-.00062	-.00060	-.00059	-.00057	-.00056	-.00053	-.00052	-.00049
45	-.00047	-.00044	-.00042	-.00039	-.00037	-.00034	-.00032	-.00029	-.00027	-.00024
50	-.00021	-.00018	-.00016	-.00014	-.00012	-.00010	-.00009	-.00007	-.00006	-.00007
55	-.00008	-.00009	-.00009	-.00009	-.00008	-.00008	-.00007	-.00007	-.00006	-.00007
60	-.00008	-.00011	-.00012	-.00014	-.00014	-.00015	-.00016	-.00016	-.00017	-.00017
65	-.00011	-.00016	-.00013	-.00014	-.00013	-.00011	-.00009	-.00007	-.00006	-.00004
70	-.00017	-.00016	-.00015	-.00014	-.00013	-.00011	-.00009	-.00007	-.00006	-.00002
75	-.00003	-.00003	-.00002	-.00001	-.00001	-.00001	-.00001	-.00001	-.00002	-.00002
80	-.00003	-.00004	-.00004	-.00005	-.00004	-.00004	-.00003	-.00003	-.00001	-.00001
85	-.00001	-.00000	-.00000	-.00000	-.00000	-.00000	-.00001	-.00001	-.00001	-.00002
90	-.00002	-.00002	-.00002	-.00001	-.00001	-.00001	-.00001	-.00000	-.00000	-.00000

CAMCHECK — CAM PROFILE EVALUATION NEW METHODS



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