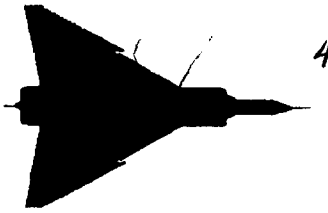
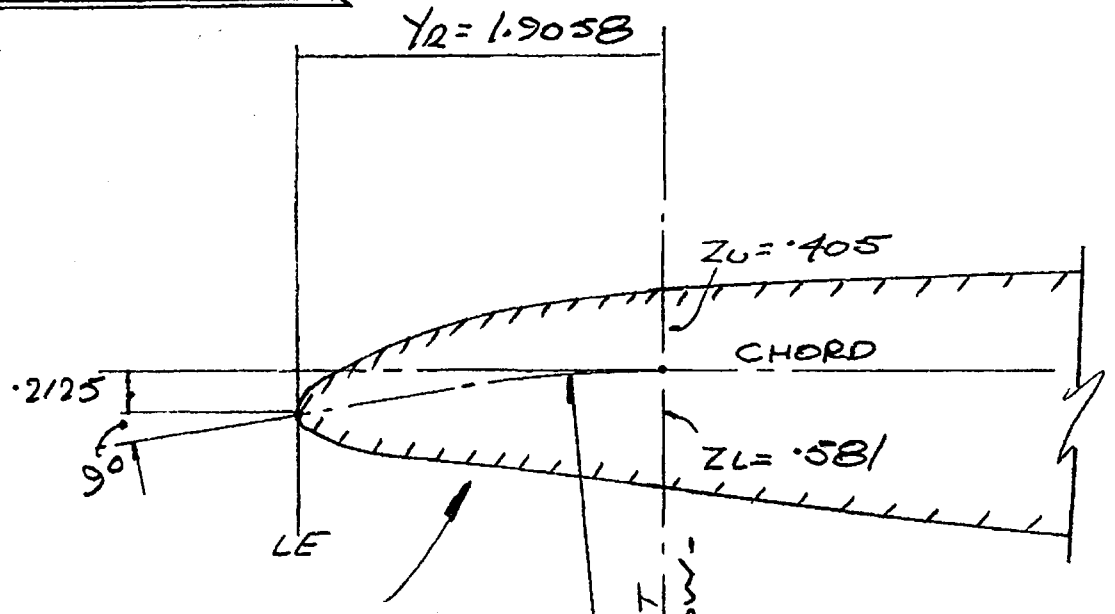
AVRO AIRCRAFT

CENTRE LINE of AIRCRAFT RIB

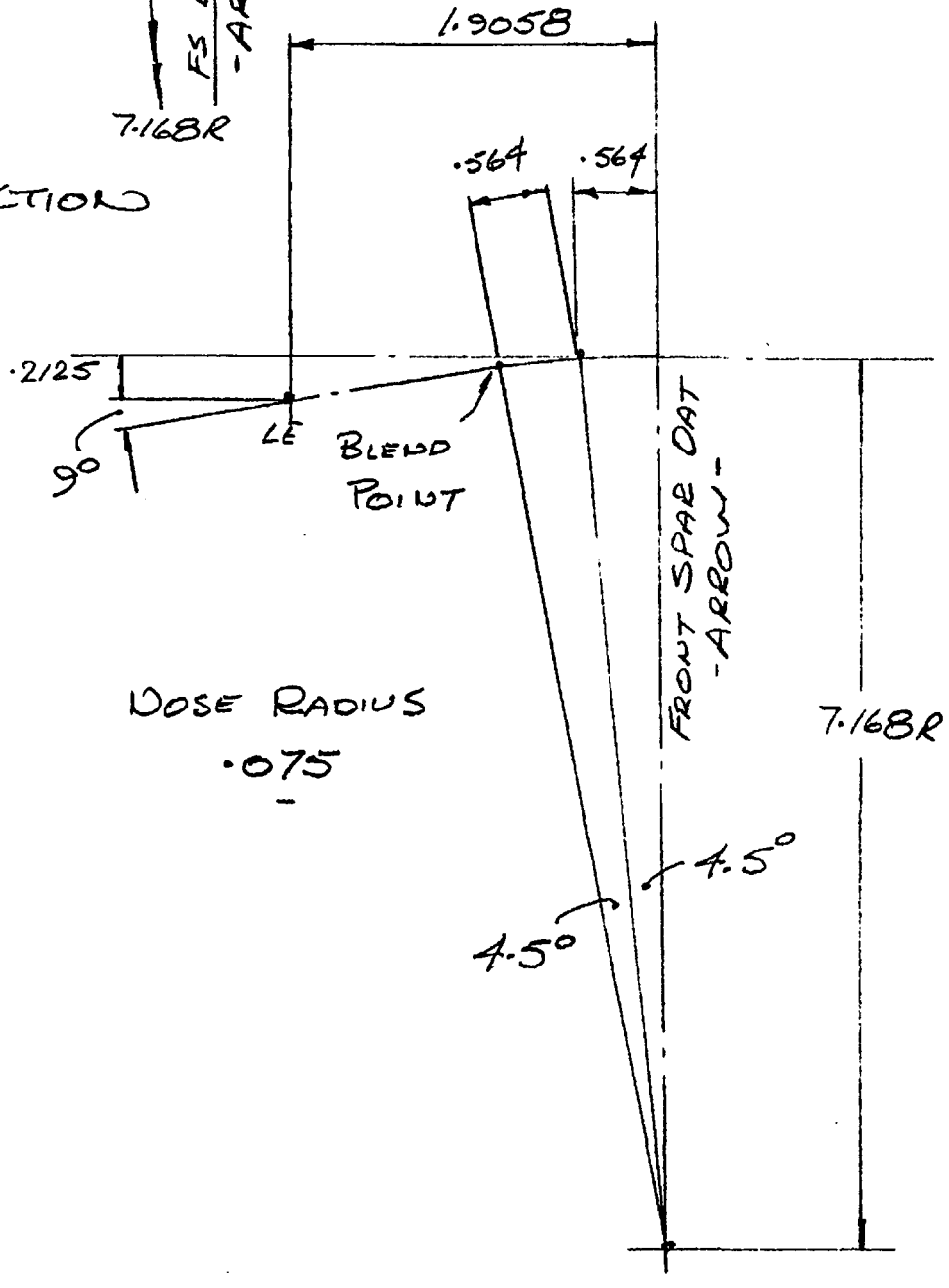
STN	YR	-C	ZU	ZL	T	NOTES
1						
2						
3						
4						
5						
6						
7						
8	7.627		.657	1.245		FRONT SPAR C-105
9	8.795		.665	1.321		
10	11.297		.683	1.457		
11	13.796		.692	1.567		
12	16.297		.695	1.645		
13	18.796		.691	1.696		
14	21.294		.688	1.725		
15	23.796		.678	1.725	-	
16	26.295		.665	1.711		
17	28.796		.645	1.683		
18	31.226		.625	1.639		
19	32.92		.606	1.602		MAIN SPAR
20	35.044		.575	1.529		
21	37.544		.534	1.429		
22	39.794		.498	1.330		
23	42.544		.453	1.198		
24	44.544		.416	1.097		
25	46.294		.375	1.023		
26	48.794		.347	.890		
27	51.294		.307	.775		
28	53.794		.265	.665		
29	56.152		.233	.556		REAR SPAR
30	67.50		.056	.056	.112	TRAILING EDGE
31						
32	31.00		.626	1.640		AUX SPAR
33						
34						

STN	Y_R	-C	Z_U	Z_L	T	NOTES
1	0	0	0	0	0	PLOT ALONG
2	.071	.006	.103	.116	.219	9° DROOP
3	.416	.022	.229	.273	.502	OF CHORD
4	1.246	.059	.353	.472	.825	LINE
5	2.077	.094	.419	.608	1.027	
6	3.323	.143	.478	.764	1.242	
7	4.569	.187	.513	.887	1.400	
8	6.300	.243	.542	1.028	1.570	FRONT SPAR C-105
9	7.148	.267	.548	1.083	1.631	
10	8.966	.311	.561	1.183	1.744	
11	10.782	.348	.568	1.265	1.833	
12	12.600	.377	.571	1.325	1.896	
13	14.416	.397	.570	1.365	1.935	
14	16.232	.411	.568	1.390	1.958	m = 3.5% AT 29.08%
15	18.050	.417	.561	1.395	1.956	
16	19.866	.418	.553	1.389	1.942	
17	21.684	.417	.540	1.374	1.914	t = .0075%c AT 35.593
18	23.450	.410	.526	1.347	1.873	
19	24.682	.405	.513	1.324	1.837	MAIN SPAR
20	26.487	.394	.493	1.282	1.775	
21	28.612	.377	.464	1.219	1.683	
22	30.525	.356	.438	1.151	1.589	CS FWD
23	32.862	.326	.406	1.058	1.464	
24	34.575	.303	.379	.985	1.364	
25	36.050	.290	.349	.930	1.279	
26	38.175	.251	.327	.829	1.156	CS AFT
27	40.300	.221	.295	.738	1.033	
28	42.425	.191	.263	.645	.908	
29	44.467	.161	.233	.556	.789	REAR SPAR
30	55.814	0	.056	.056	.112	TRAILING EDGE
31						
32						
33	1.9058	.088	.405	.581	.986	ARROW FRONT SPAR
34						





NB: PLOT THE ORDINATES AT 90° TO CHORD LINE IN THIS SECTION



NOSE RADIUS
.075

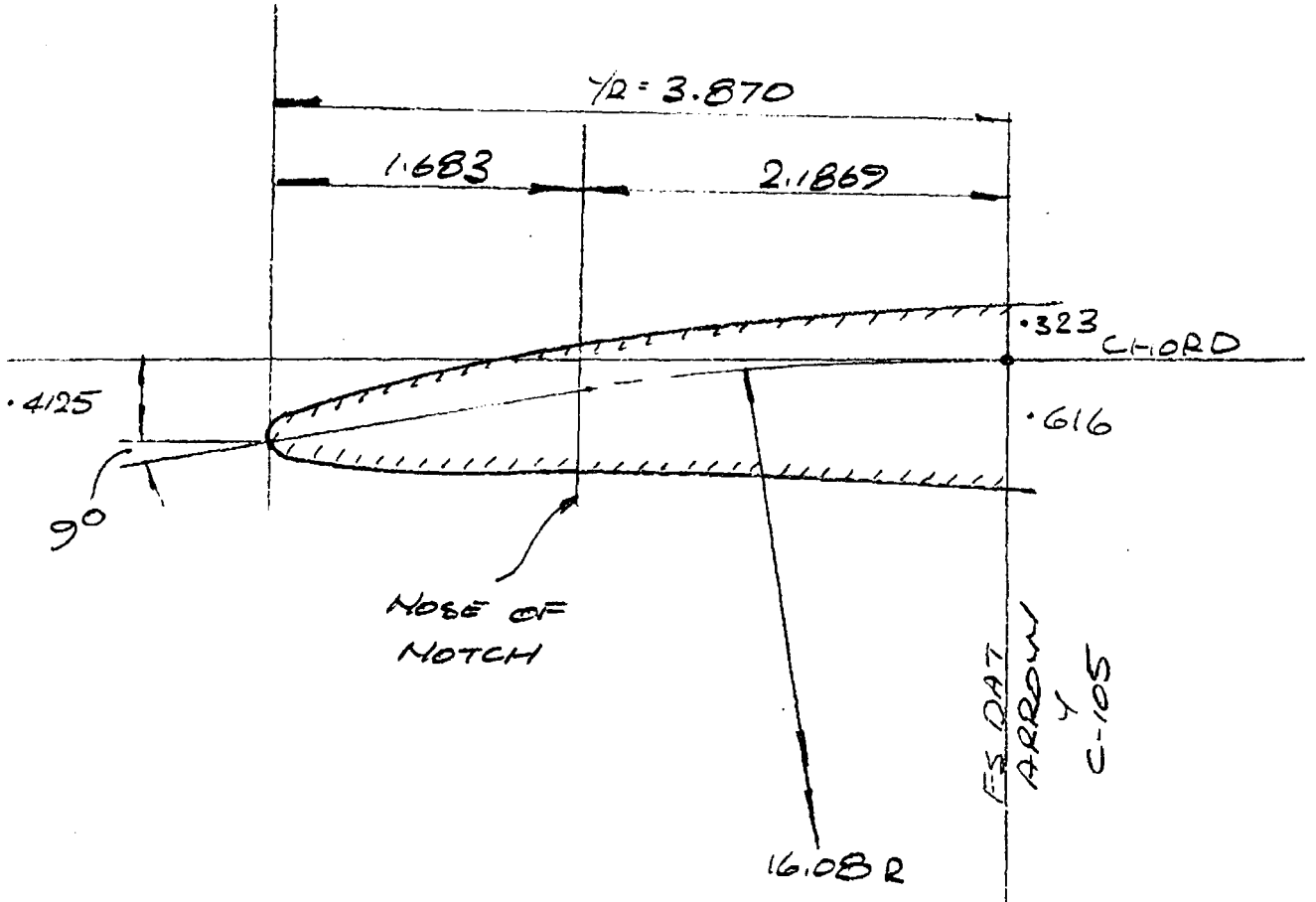
AVRO AIRCRAFT

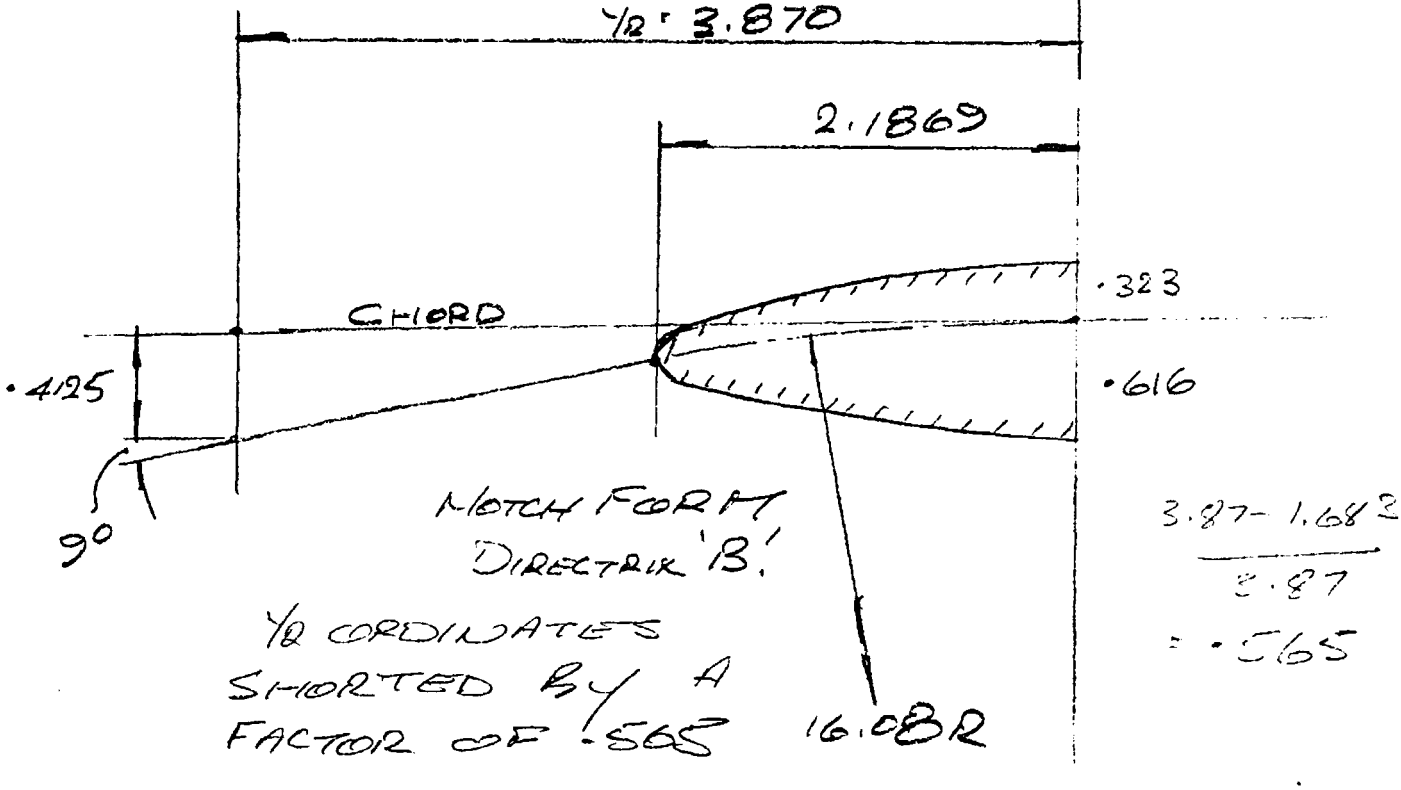
DIRECTRIX B-ARROW BASIC

STN	Y_R	-C	Z_U	Z_L	T	NOTES
1	0	0	0	0	0	
2	.044		.048	.054		
3	.255		.136	.163		
4	.765		.206	.281		
5	1.276		.246	.362		
6	2.041		.280	.458		
7	2.807		.305	.531		
8	3.870		.323	.616		FRONT SPAR C.105
9	4.114		.325	.632		& ARROW
10	4.637		.329	.664		
11	5.159		.333	.692		
12	5.682		.336	.717		
13	6.204		.340	.737		
14	6.727		.341	.754		
15	7.250		.340	.769		
16	7.772		.340	.780		
17	8.295		.340	.788		
18	8.803		.338	.794		
19	9.157		.337	.797		MAIN SPAR
20	10.359		.337	.814		
21	11.773		.330	.820		
22	13.047		.325	.811		
23	14.602		.316	.793		
24	15.734		.309	.7716		
25	16.724		.299	.753		
26	18.139		.289	.713		
27	19.553		.271	.667		
28	20.968		.259	.606		
29	22.327		.233	.556		REAR SPAR
30	33.675		.056	.056	.112	TRAILING EDGE
31						
32						
33						
34						

AVRO AIRCRAFT

DIRECTRIX B-BASIC

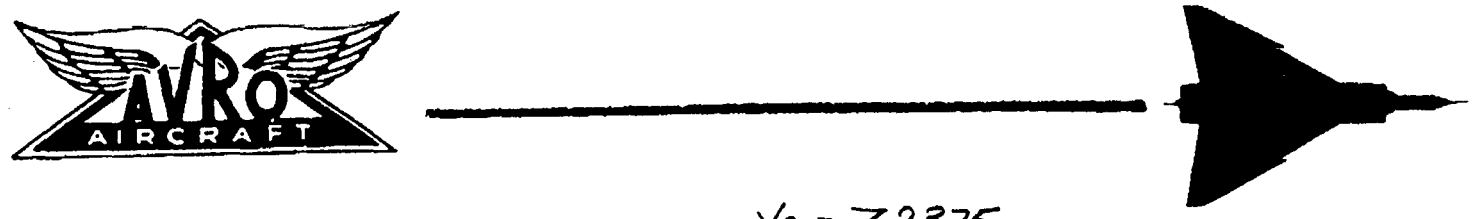


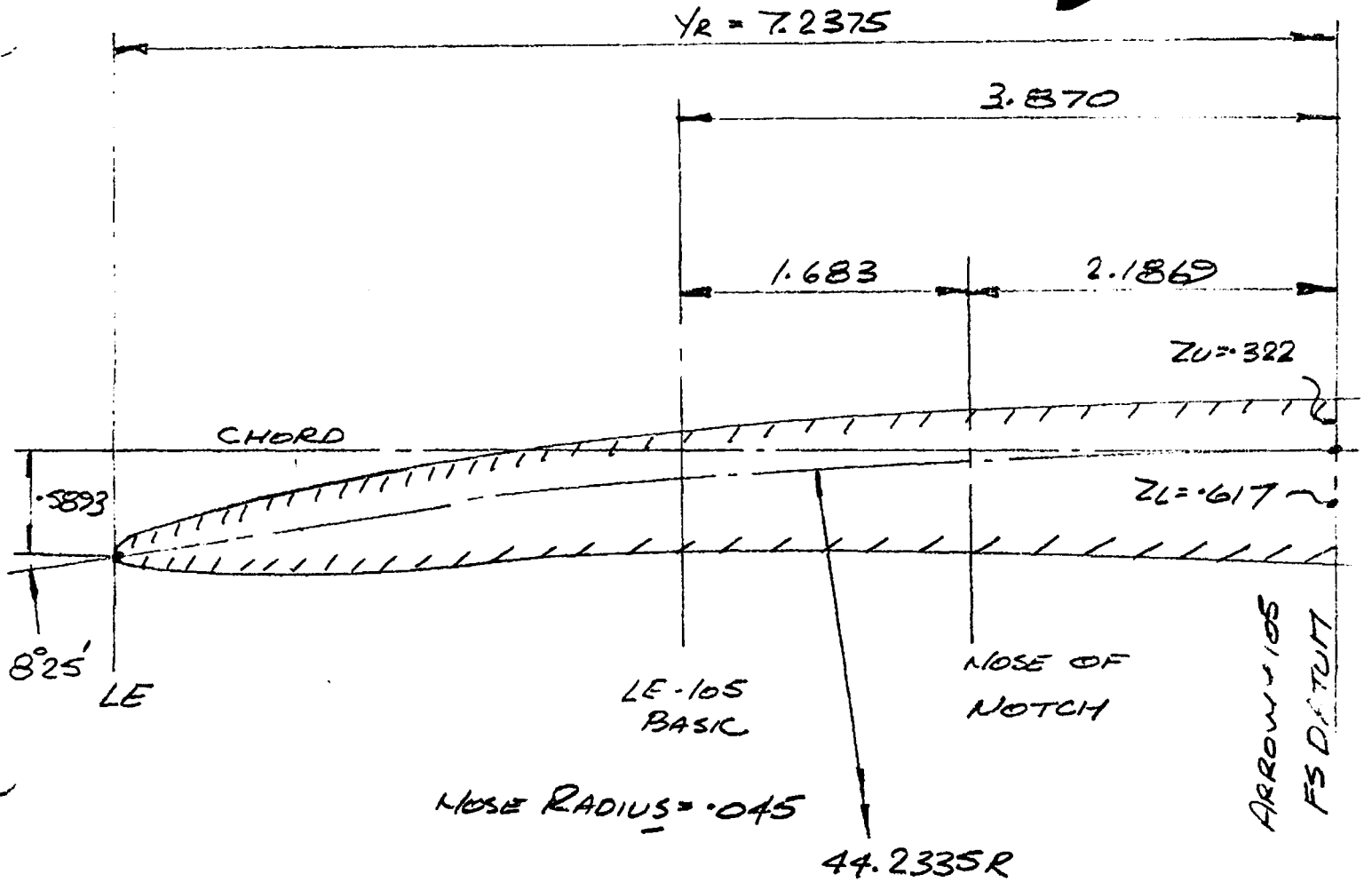


NOTCH FOR FT DIRECTRIX 'B'

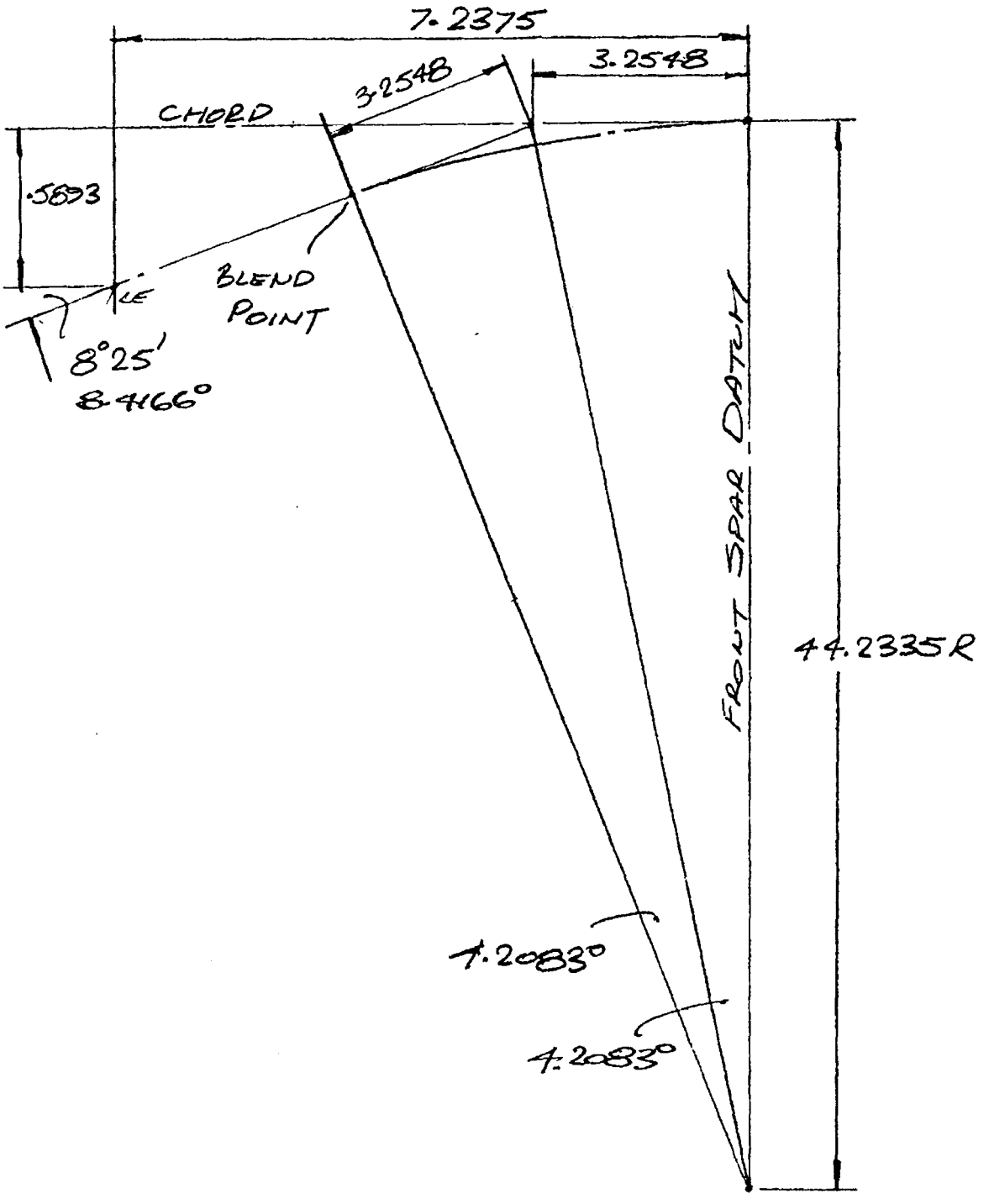
Y/2 CORDINATES SHORTED BY A FACTOR OF .565

$$\frac{3.87 - 1.683}{3.87} = .565$$

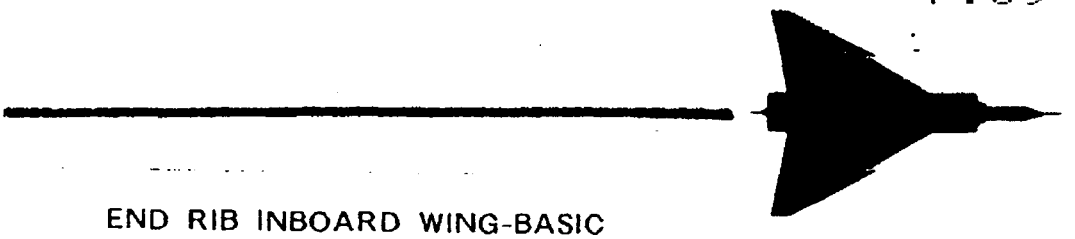




DIRECTRIX B (ARROW) EXTENDED LEADING EDGE



DIRECTRIX B (ARROW) EXTENDED LEADING EDGE

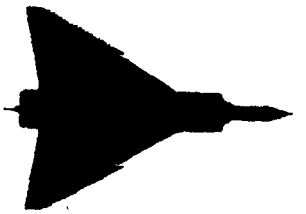


END RIB INBOARD WING-BASIC

STN	YR	-C	ZU	ZL	T	NOTES
1						
2	.043		.047	.052		
3	.251		.133	.160		
4	.73		.201	.275		
5	1.25		.240	.354		
6	2.0		.274	.448		
7	2.75		.298	.520		
8	3.792		.316	.603		FRONT SPAR C105
9	4.016		.318	.618		
10	4.497		.322	.647		
11	4.978		.326	.674		
12	5.459		.329	.698		
13	5.940		.332	.717		
14	6.420		.333	.734		
15	6.901		.333	.749		
16	7.382		.334	.760		
17	7.863		.333	.769		
18	8.330		.332	.776		
19	8.656		.3317	.780		MAIN SPAR
20	9.438		.3317	.799		
21	11.230		.326	.807		
22	12.483		.321	.800		
23	14.013		.313	.784		
24	15.135		.306	.765		
25	16.101		.297	.748		
26	17.492		.288	.709		
27	18.884		.270	.664		
28	20.275		.259	.605		
29	21.612		.233	.556		REAR SPAR
30			.056	.056	.112	TRAILING EDGE
31						
32	3.933					FS-ARROW
33						
34						

AVRO AIRCRAFT

INBOARD NOTCH PROFILE



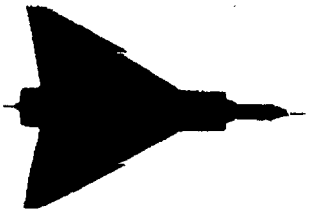
Yr Reduction Factor = .5589

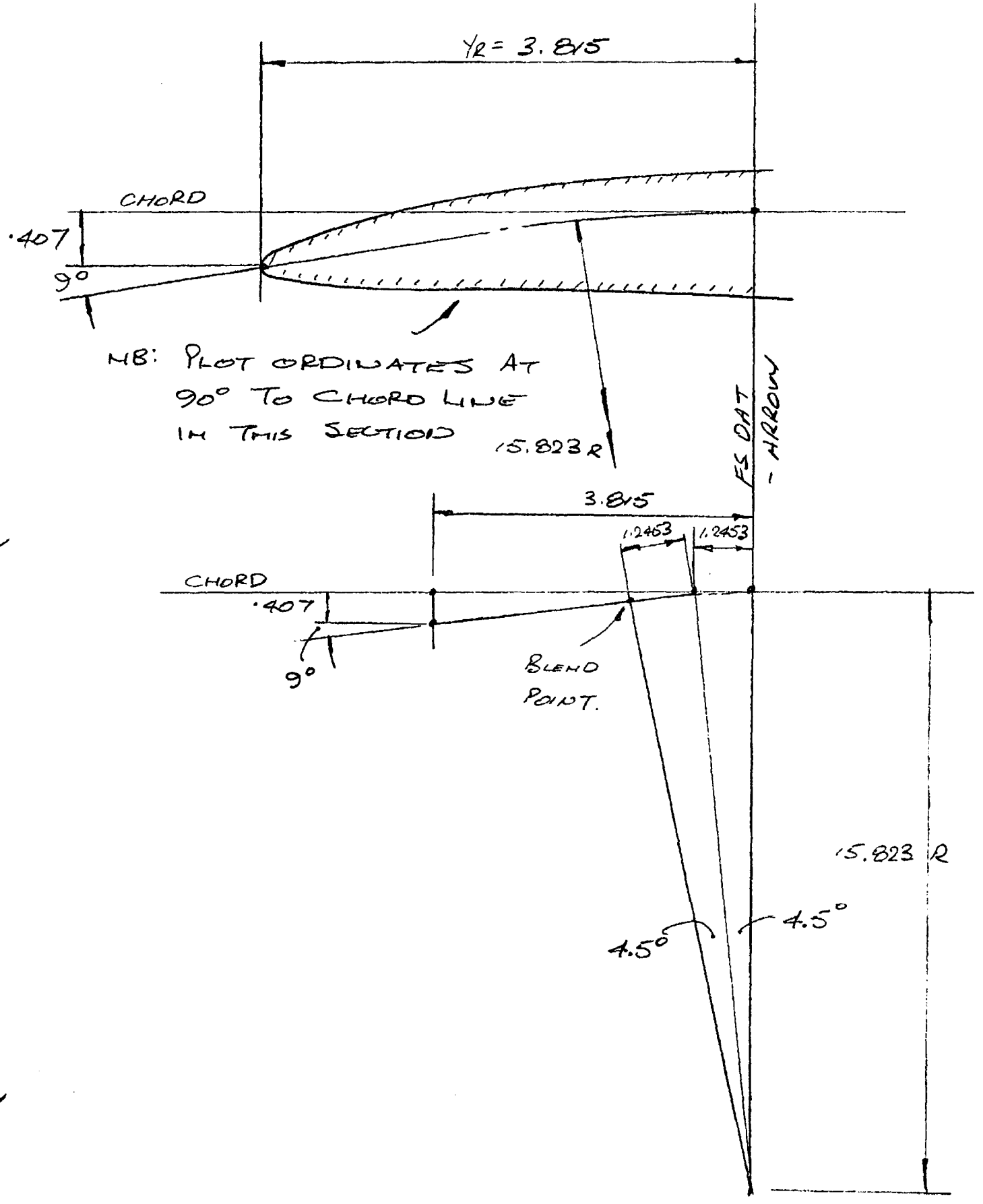
Yr Reduction Factor after FS 105 = -1.683

Stn	Yr	-C	Zu	Zl	T	Notes
1	0	0	0	0		Plot Along
2	.025		.050	.056		9° Droop
3	.145		.138	.166		Chord
4	.435		.210	.287		
5	.725		.251	.369		
6	1.161		.286	.467		
7	1.596		.311	.541		
8	2.254		.329	.627		FS 105
9						
10	2.1326					FS Arrow
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
32						
33						
34						

AVRO AIRCRAFT

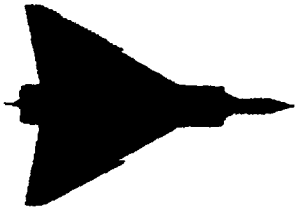
INBOARD NOTCH RIB-BASIC





AVRO AIRCRAFT

END RIB WITH NOTCH



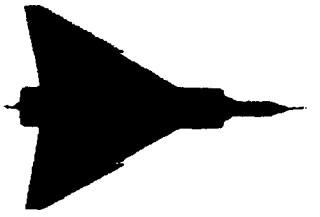
REDUCTION FACTOR = .572

AFTER FS-105 REDUCE YR BY — 1.683

STN	YR	-C	ZU	ZL	T	NOTES
1	0	0	0	0		
2	.024		.047	.052		
3	.143		.133	.160		
4	.417		.201	.275		
5	.715		.240	.354		
6	1.144		.274	.448		
7	1.573		.296	.520		
8	2.108		.316	.603		FS - C-105
9	2.333		.318	.618		
10	2.814		.322	.647		
11	3.295		.326	.674		
12	3.776		.329	.698		
13	4.257		.332	.717		
14	4.737		.333	.734		
15	5.218		.333	.749		
16	5.699		.334	.760		
17	6.180		.333	.769		
18	6.647		.332	.776		
19	6.973		.3317	.780		MAIN SPAR
20	8.155		.3317	.799		
21	9.547		.326	.807		
22	10.80		.321	.800		
23	12.33		.313	.784		
24	13.452		.306	.765		
25	14.418		.297	.748		
26	15.809		.288	.709		
27	17.201		.270	.664		
28	19.592		.259	.605		
29	19.929		.233	.556		REAR SPAR
30	31.275		.056	.056	.112	TE
31						
32						
33	2.250					FS - ARROW
34						

AVRO AIRCRAFT

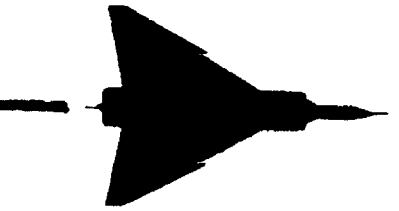
END RIB-EXTENDED

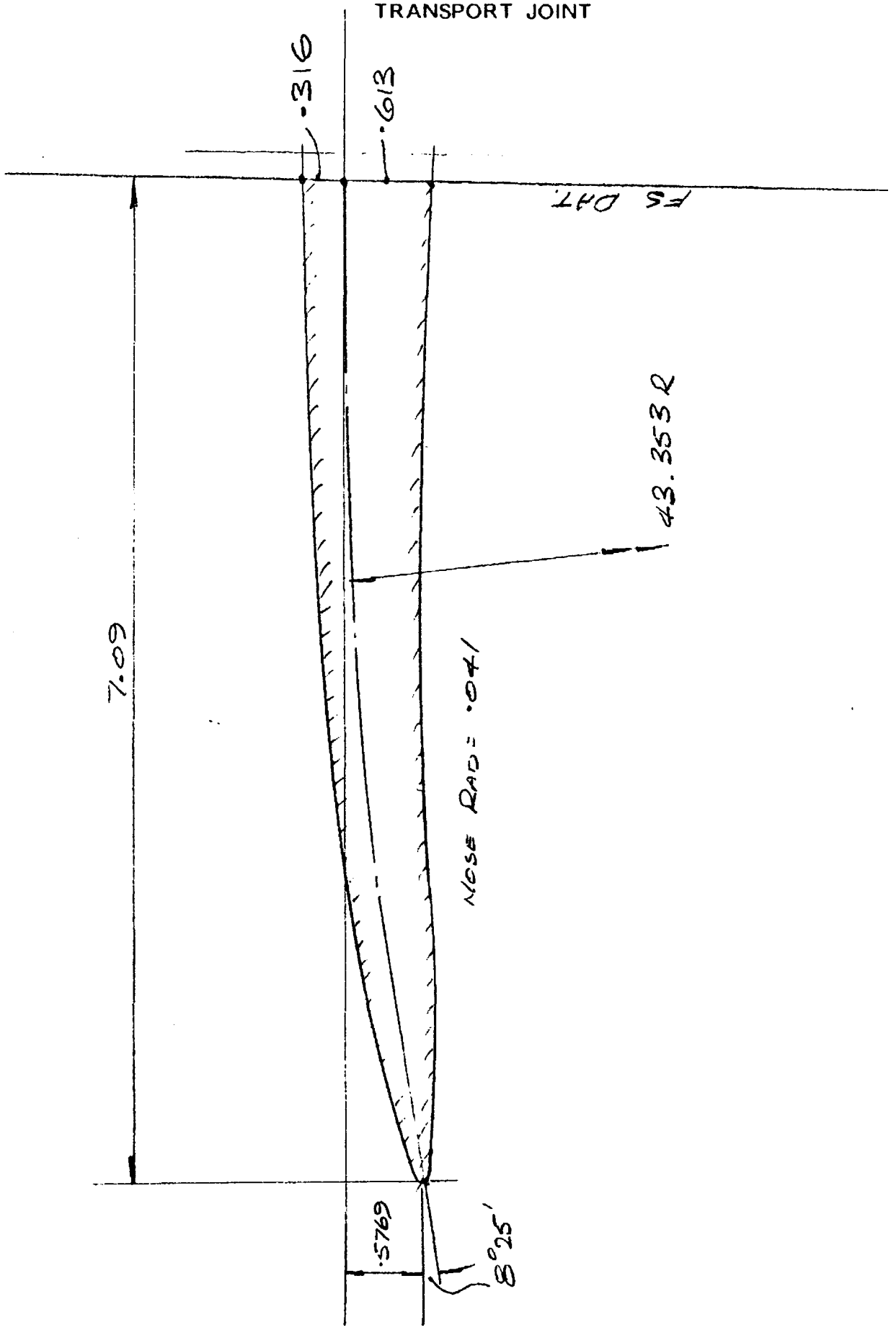


STN	Y_R	-C	Z_U	Z_L	T	NOTES
1	0	0	0	0	0	PLOT ALONG
2	.080		.047	.052		DROOPED
3	.469		.133	.160		CHORD
4	1.365		.201	.275		8°25'
5	2.337		.240	.354		
6	3.740		.274	.448		
7	5.142		.298	.520		
8	7.09		.316	.603		FRONT SPAR
9	7.314		.318	.618		
10	7.795		.322	.647		
11	8.276		.326	.674		
12	8.757		.329	.698		
13	9.238		.332	.717		
14	9.718		.333	.734		
15	10.199		.333	.749		
16	10.678		.334	.760		
17	11.161		.333	.769		
18	11.628		.332	.776		
19	11.954		.332	.760		MAIN SPAR
20	13.136		.332	.799		
21	14.528		.326	.807		
22	15.781		.321	.800		
23	17.311		.313	.784		
24	18.433		.306	.765		
25	19.399		.297	.748		
26	20.790		.288	.709		
27	22.182		.270	.664		
28	23.573		.259	.605		
29	24.91		.233	.556		REAR SPAR
30	36.256		.056	.056	.112	TRAILING EDGE
31						
32						
33						
34						

AVRO AIRCRAFT

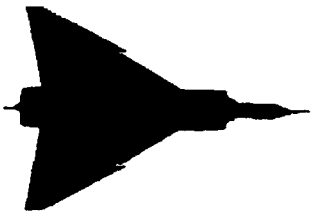
END RIB-EXTENDED





AVRO AIRCRAFT

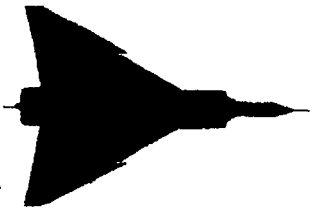
DIRECTRIX B (C-105)



STN	YR	-C	ZU	ZL	T	NOTES
1	0	0	0	0	0	
2	.039	.002	.041	.046	.087	
3	.232	.012	.123	.148	.271	
4	.698	.034	.186	.255	.441	
5	1.164	.053	.222	.328	.550	
6	1.864	.081	.253	.416	.669	
7	2.562	.103	.276	.482	.758	
8	3.532	.133	.293	.559	.852	FRONT SPAR C-105
9	3.693	.138	.294	.570	.864	
10	4.035	.147	.297	.592	.889	
11	4.378	.156	.301	.613	.914	
12	4.721	.164	.304	.633	.937	
13	5.064	.171	.308	.650	.958	
14	5.407	.178	.309	.666	.975	
15	5.748	.186	.309	.682	.991	
16	6.091	.192	.311	.695	1.006	
17	6.434	.197	.312	.707	1.019	
18	6.777	.202	.312	.717	1.029	
19	7.000	.205	.313	.724	1.037	MAIN SPAR
20	8.118	.217	.315	.749	1.064	
21	9.433	.226	.312	.765	1.077	m =
22	10.750	.227	.309	.764	1.073	CS FWD — IF USED
23	12.066	.226	.304	.756	1.060	
24	13.127	.221	.299	.742	1.041	
25	14.039	.218	.292	.729	1.021	
26	15.318	.206	.284	.697	.981	CS AFT — IF USED
27	16.671	.194	.268	.657	.925	
28	17.987	.171	.259	.601	.860	
29	19.252	.161	.233	.556	.789	REAR SPAR
30	30.600	0	.056	.056	.112	TRAILING EDGE
31						
32						
33						
34						

AVRO AIRCRAFT

ELEVATOR TIP RIB

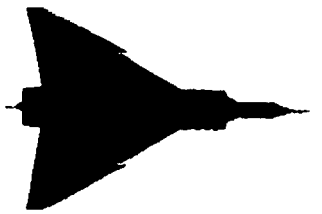


DIRECTRIX B. EXTENDED-ARROW

STN	YR	-C	Zu	Zl	T	NOTES
1	0	0	0	0	0	PLOT ALONG
2	·073	·002	·041	·046	·087	8°25' DROOPED
3	·434	·012	·123	·148	·271	CHORD.
4	1·305	·034	·186	·255	·441	ORDINATES
5	2·177	·053	·222	·328	·550	X 1.8"=0
6	3·445	·081	·253	·416	·669	
7	4·791	·103	·276	·482	·758	
8	6·592	·133	·293	·559	·852	FRONT SPAR
9	6·753	·138	·294	·570	·864	
10	7·095	·147	·297	·592	·889	
11	7·438	·156	·301	·613	·914	
12	7·781	·164	·304	·633	·937	
13	8·124	·171	·308	·650	·958	
14	8·467	·178	·309	·666	·975	
15	8·808	·186	·309	·682	·991	
16	9·151	·192	·311	·695	1·006	
17	9·494	·197	·312	·707	1·019	
18	9·837	·202	·312	·717	1·029	
19	10·060	·205	·313	·724	1·037	
20	11·178	·217	·315	·749	1·064	
21	12·493	·226	·312	·765	1·077	
22	13·810	·227	·309	·764	1·073	
23	15·126	·226	·304	·756	1·060	
24	16·187	·221	·299	·742	1·041	
25	17·099	·218	·292	·729	1·021	
26	18·368	·206	·284	·697	·981	
27	19·731	·194	·268	·657	·925	
28	21·047	·171	·259	·601	·860	
29	22·312	·161	·233	·556	·789	REAR SPAR
30	33·66	0	·056	·056	·112	TRAILING EDGE
31						
32						
33						
34						

AVRO AIRCRAFT

DIRECTRIX C



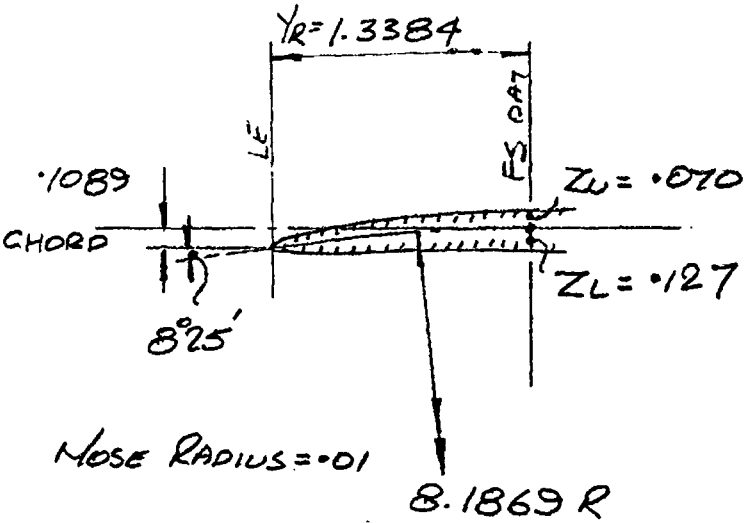
STN	Y_R	-C	Z_U	Z_L	T	NOTES
1	0	0	0	0	0	
2	.020	.001	.020	.023	.043	
3	.096	.004	.037	.046	.083	
4	.209	.010	.050	.070	.120	
5	.391	.018	.059	.095	.154	
6	.628	.025	.067	.118	.185	
7	.716	.028	.070	.127	.197	FRONT SPAR
8	.859	.030	.074	.134	.208	
9	1.080	.035	.077	.147	.224	
10	1.294	.038	.078	.155	.233	
11	1.502	.042	.079	.163	.242	
12	1.702	.044	.079	.167	.246	
13	1.734	.044	.079	.167	.246	
14	1.896	.045	.079	.170	.249	
15	2.084	.045	.079	.170	.249	
16	2.266	.045	.079	.170	.249	
17	2.443	.044	.079	.167	.246	
18	2.616	.043	.079	.165	.244	
19	2.782	.043	.077	.163	.240	
20	2.944	.042	.076	.161	.237	
21	2.980	.041	.076	.159	.235	
22	3.102	.040	.076	.157	.233	
23	3.253	.038	.074	.150	.224	
24	3.403	.037	.072	.147	.219	
25	3.548	.035	.070	.140	.210	
26	3.689	.033	.070	.136	.206	
27	3.825	.031	.067	.130	.197	
28	3.900	.029	.067	.125	.192	AILERON HINGE
29	6.000	0	.023	.023	.046	TRAILING EDGE
30						
31						
32						
33						
34						

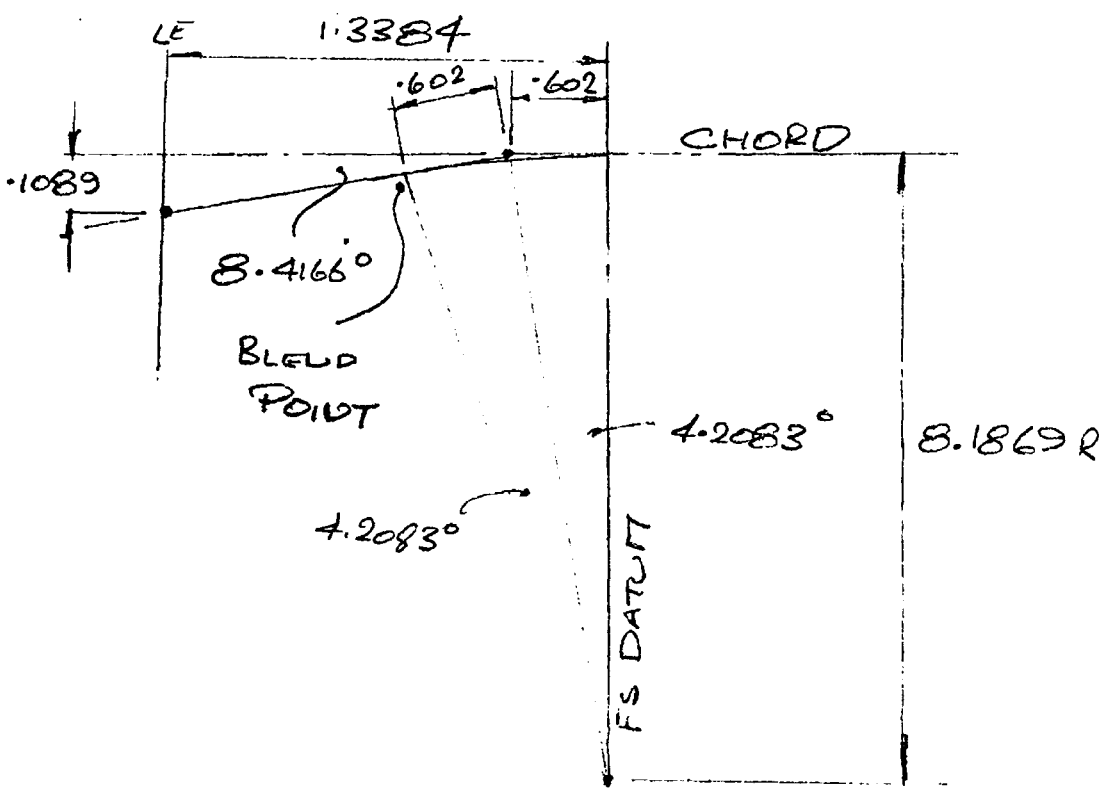
DIRECTRIX C. EXTENDED-ARROW

STN	Y_R	-C	Z_U	Z_L	T	NOTES
1	0	0	0	0	0	PLOT ALONG
2	.037	.001	.020	.023	.043	8°25' DROOPED
3	.179	.004	.037	.046	.083	CHORD.
4	.391	.010	.050	.070	.120	ORDINATES
5	.731	.018	.059	.095	.154	x 1.87
6	1.174	.025	.067	.118	.185	
7	1.339	.028	.070	.127	.197	FRONT SPAR
8	1.482	.030	.074	.134	.208	
9	1.703	.035	.077	.147	.224	
10	1.917	.038	.078	.155	.233	
11	2.125	.042	.079	.163	.242	
12	2.325	.044	.079	.167	.246	
13	2.357	.044	.079	.167	.246	
14	2.519	.045	.079	.170	.249	
15	2.707	.045	.079	.170	.249	
16	2.889	.045	.079	.170	.249	
17	3.066	.044	.079	.167	.246	
18	3.239	.043	.079	.165	.244	
19	3.405	.043	.077	.163	.240	
20	3.567	.042	.076	.161	.237	
21	3.603	.041	.076	.159	.235	
22	3.725	.040	.076	.157	.233	
23	3.876	.038	.074	.150	.224	
24	4.026	.037	.072	.147	.219	
25	4.171	.035	.070	.140	.210	
26	4.312	.033	.070	.136	.206	
27	4.448	.031	.067	.130	.197	
28	4.523	.029	.067	.125	.192	AILERON HINGE
29	6.623	0	.023	.023	.046	TRAILING EDGE
30						
31						
32						
33						
34	2.279					REAR SPAR

AVRO AIRCRAFT

DIRECTRIX C





DIRECTRIX C (ARROW) EXTENDED LEADING EDGE

AVRO AIRCRAFT

FIN BASE CHORD 26.5

WING MAC = 1.05

FIN BASE CHORD

STN	YR	-C	ZU	ZL	T	NOTES
1	0	0	0	0		
2	.171		.128	.128		
3	.228		.142	.142		
4	.356		.180	.180		
5	.712		.246	.248		
6	1.425		.338	.338		
7	2.137		.399	.399		
8	2.850		.445	.445		
9	4.275		.508	.508		
10	5.700		.545	.545		
11	7.125		.564	.564		
12	8.550		.570	.570		
13	11.400		.551	.551		
14	14.250		.503	.503		
15	17.100		.433	.433		
16	19.950					
17	22.800					
18	25.650					
19	27.075					
20	26.500		.056	.056		
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
32						
33						
34						

AVRO AIRCRAFT

FIN TIP CHORD S.S

FIN TIP CHORD

STN	YR	-C	ZU	ZL	T	NOTES
1	0	0	0	0		
2	.051		.038	.038		
3	.068		.042	.042		
4	.106		.054	.054		
5	.212		.074	.074		
6	.425		.101	.101		
7	.637		.119	.119		
8	.850		.133	.133		
9	1.275		.151	.151		
10	1.700		.162	.162		
11	2.125		.168	.168		
12	2.550		.170	.170		
13	3.400		.164	.164		
14	4.250		.150	.150		
15	5.100		.129	.129		
16	5.950					
17	6.800					
18	7.650					
19	8.075					
20	8.500		.025	.025		
21						
22						
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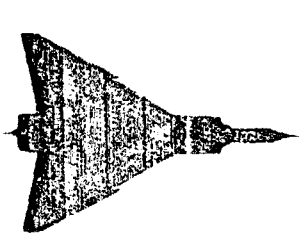

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① SEPT/OCT 1995 #59. "STRIKE RIVALS"
PAGES 12 - 23.

② NOV/DEC 1995 #60 "RESEARCH RIVALS"
PAGES 54 - 62

③ JAN/FEB 1996 #61 "FUTURE RIVALS"
PAGES 65 - 73

④ MAY/JUNE 1997 #69 "EARLY WING SWINGERS
PAGES 40 - 49

~~DOUG~~ PAUL

SORRY - I FORGOT

THIS SHEET,

BY THE WAY, HYLE

SCHMIDT IS WRONG

AIRFOIL IS; —

INNER WING —

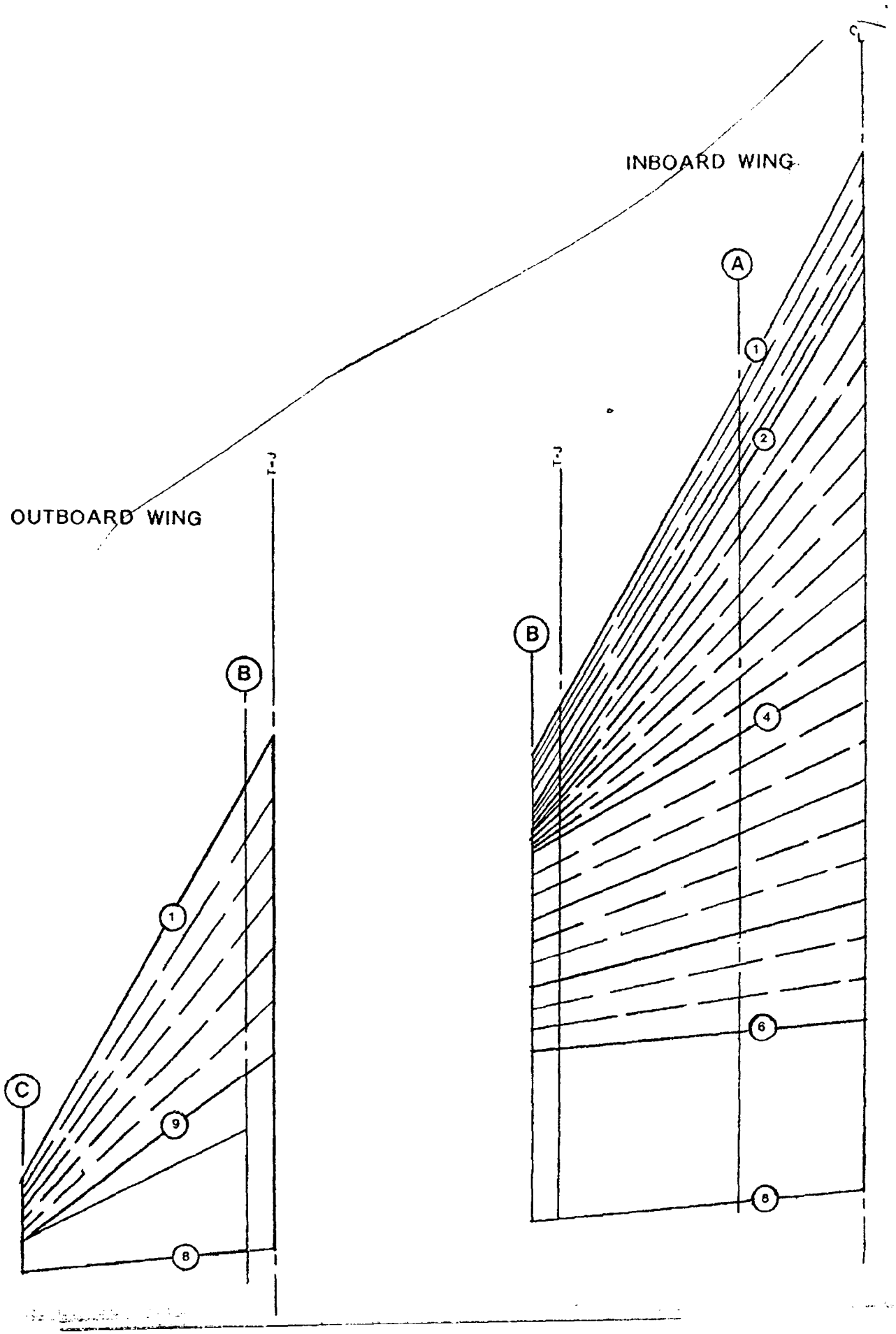
NACA 0003.5-6-3.7

OUTER WING —

NACA 0003.7-6-3.8

JIM

APR - 1-97 THC - 12:40



RULED SURFACE PATTERN. C-105 WING

PAUL

DOUG.

I AM RE-WRITING CH 4 & HAVE FOUND AN ERROR WHICH I HAVE CORRECTED. I THOUGHT THAT YOUR FRIENDS WOULD APPRECIATE THE FOLLOWING.

Sam

PS SEEING THAT THIS IS FROM MY BOOK - PLEASE BE CAREFUL TO WHOM YOU SHOW IT

T.....Belly tank.
SB.....Speed brakes.

Tunnel configurations. (Applicable only to NAE No.3 tunnel)

U .....Model upright on 3-point suspension.
UD.....U plus dummy struts.
I..... .Model inverted on 3-point suspension.
ID.....I plus dummy struts.
B.....Single strut support.
BTS.....B with addition of tail sting.

WING DATA C-105.

The profiles of the wing and vertical tail do not follow the usual conical pattern having the leading and trailing edge a generator of a single cone. Wing percent lines will therefore, not be straight unless they coincide with the generatrix pattern of the local "ruled surface".

The wing will contain two separate compatible groups of "ruled surfaces" terminating at the transport joint. (This joint on the Arrow Mk1 is at 3.5 inches outboard of Directrix B). These groups are generated from a pattern of three directrix curves located span-wise at wing chord stations "A - B & C". This now implies that at the transport joint, the inner and outer wing profiles are the same up to the front spar, whereas in the original design, they were not as the outer wing panel was generated from station "C".

The directrix at chord "C" (tip), is a basic NACA 0003.8-6-3.7 section having its maximum thickness value (m) at 36.5% of the local chord. At chord "B", the (m) value has been factored to 34% of the local chord and at "A" the (m) value has been factored to 32.122% of the local chord with a basic section of NACA 0003.5-6-3.7.

The main panel extends from the aircraft centre line to the transport joint and is made up of four separate ruled surfaces. Ruled section 2-4 will have as outer generators the front and main spars. Ruled section 4-6 will have as outer generators the main and rear spars with the centre spars being generated within the ruled section 4-6. Ruled section 6-8 will have as outer generators the rear spar and trailing edge and will be flat in profile.

The outer panel extends from the transport joint (Directrix B). Ruled section 1-9 will have as outer generators the front spar and the flat plane tangent line at 62.5% of the local chord. Ruled section 9-8 will have as outer generators the tangent line and the trailing edge and being flat, the generators are not sensitive to any pattern.

The leading edge sections of both inner and outer panels will follow their own

generators with the front spars and leading edges.

Since all three section aero-foils are different, it follows that no two generators are parallel or intersecting hence - a warped wing.

The camber 'mean line' is not sensitive to position and follows a normal pattern from root to tip. Its (m) value remains constant at 32.122% and its flat plane tangency at 62.5% of the local chord.

WING DATA - ARROW.

The ordinates at the transport joint (Arrow Directrix B), are derived from the ordinates at the elevator tip datum (Directrix B on the C-105), with the original ordinates factored to 3.5% thickness.

The Arrow front spar on the inner wing has the same origin on the Arrow Directrix B as on the C-105 front spar, therefore the generators will be the original front spar position (C-105) and the Arrow front spar position, rotated at the intersection point on Arrow Directrix B to Zu and Zl values at Directrix A.

On the Arrow, the leading edge portions of the wing are drooped ahead of the front spars. The inboard wing portion is drooped at 9 degrees and the outboard portion is drooped at 8 degrees 25 minutes of angle.

The radius of curvature of the chord line varies from 51.380" at Directrix A to 128.64" at Directrix B for the inboard wing, and from 353.868" at Arrow Directrix B to 65.495" at Directrix C for the outboard wing.

On the outboard wing, the leading edge is extended also by 10% of local chord (basic), thus giving a multiplying factor obtained by dividing the total extension ahead of the front spar by its original distance.

For example:

The original distance of the front spar to the leading edge at Directrix B was 30.960". The chord at Directrix B (basic) is 269.400", giving a 10% extension of 26.940". When added to the original length this gives 30.96 + 26.940 = 57.900". Dividing this by 30.960 we have 57.900/30.960 = 1.870 (factor).

The Yr ordinates up to 30.96 are multiplied by this factor. The same factor is used at Directrix C thus giving the two generating aero-foils. Once these Yr units are plotted along the new "drooped" chord line and the Zu and Zl ordinates plotted in the usual manner. The notch profile at Directrix B was derived by shortening the Yr ordinates by a factor which was obtained as follows:

(30.960 - 13.464)/30.960 = .565 (factor). Multiplying the Yr ordinates by this factor and plotting along the radius of curvature will result in the correct profile.

LEADING EDGE NOTCH, EXTENSION AND DROOP.

Once again we must use the words of Jim Floyd in his lecture to the Royal Aeronautical Society:-

> "Early in the design stages, modifications were made to the original clean wing. These were the addition of leading edge droop, and a semi-span notch with outer wing chord extension. These modifications were made as a result of wind tunnel tests, carried out at Cornell Laboratories in Buffalo on a 3% complete model, sting mounted. The approximate Reynolds number used during the tests was between 1 and 2 million. These tests showed that a pitch-up or non-linearity in the CM - curve was occurring at moderate angles of attack. This phenomenon is not peculiar to delta wings, being common to all swept wing aircraft. In flight it could easily cause a tightening in the turn.
>
> Crudely, the condition appears to be caused by vortices which start at the tip and move to the apex of the swept wing. Low pressure air is collected from the fuselage and causes a break-away outboard of the area covered by the vortex, which is mainly at the trailing edge. This is shown in the illustration and causes the effective aerodynamic centre to shift forward, giving a "pitch-up" or an abrupt change in the moment curve.
>
> While the pitch-up appeared on test to be of small magnitude, and since very moderate amounts of pitch-up could be embarrassing to the pilot, an attempt was made to eliminate it.
>
> Avro was aware of the work that had been done by NACA and the RAE, and the fact that a number of other aircraft which had exhibited this tendency, had used either notches in the leading edge at about mid-span, or extensions of the wing leading edge outboard, in an attempt to prevent flow separation. The notch had been used, for instance, on the English Electric F-23, and the leading edge extension had been installed on a Grumman F9F9, and a Chance-Vought aircraft. The notch has a similar effect to a fence and causes the disturbing vortices to move away from the apex of the swept wing toward the notch, which is at mid-span, and reduces the area of disturbed flow over the wing. The notch however, produces these effects by air flow rather than as a physical barrier. It was the opinion at Avro that the effects of the notch were present over the whole speed range, whereas a fence is usually only effective over smaller speed ranges, and the notch was expected to increase the drag by a lesser amount than a fence.

In the tests however, it was found that with the notch alone, the test results were not repeatable; in other words, the same results could not be obtained in subsequent tests. When the leading edge extension was installed in addition to the notch, the results were far more repeatable. Eight different notches and three extended leading edges in various combinations were tried. The depth of the notch appeared to be the most critical parameter, and it had to be bourne in mind that too deep a notch would cause structural problems."

The illustrations show the effect of the 5% notch and 10% extension of the local chord on the outer wing, which was finally adopted, against the unmodified 3-1/2% wing at Mach 0.9, and at an elevator angle of -20 degrees.

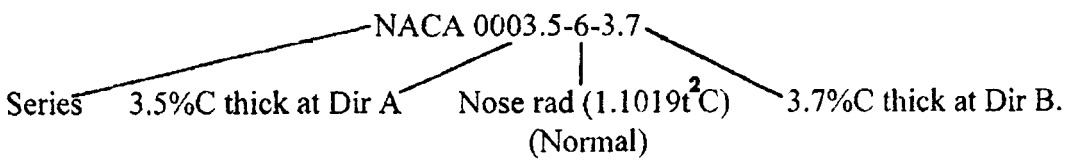
DROOPING THE LEADING EDGE.

During the time that the tests were being carried out on the notch and leading edge extension, the work being done on the F-102 was being followed very closely with regard to a reduction in induced drag by drooping the wing leading edge, and also the work that was going on at Avro Manchester on the 707 series and Vulcan. They were drooping the leading edge to increase the buffet boundary by preventing leading edge breakaway at high angles of attack. This also influenced the choosing of the 10% increase in the outboard leading edge, to cure pitch-up. Since it was realized that, if after investigation it was found that it would be advantageous to droop the leading edge, the extension would increase the amount of effective droop.

Droop was then installed on the wind tunnel model, 9 degrees inboard and 8 degrees 25 minutes outboard. This increased the buffet boundary considerably. For instance, at Mach 0.925, which is the normal subsonic cruise Mach number, the CL at which the onset of buffet was estimated, was increased from .26 with the extension alone, to .41 with the extension plus droop. The buffet, or flow separation, was indicated by pressure plots on the ailerons in the Cornell Laboratory tunnel tests. The subsequent drag did not appear to be increased appreciably".

The progression of leading edge design is shown in the illustration entitled "Transition from the C-104/2 to the CF-105". It is of interest to note that the drooping, notching and extension of the leading edge was also carried out on the SAAB J29, the McDonnell Douglas F4 Phantom and the Convair F6 Delta Dart.

Explanation of the aerofoil specification - Inner Wing :-



LOFTING

The *"Lofting"* procedure as used at AVRO was a very exact method of drawing contoured parts to very tight tolerances. These drawings were drawn on Class Cloth or Mylar, both of which are very inert materials and are capable of holding the exact shape or profile of whatever is traced or drawn on them. AVRO was one of the first in Canada to introduce and apply this process and it was one of the reasons why the ARROW tooling was completed in a minimum time span and that it was so accurate, a definite requirement in order to control interchangeability. This process of *"Lofting"*, was not new, as shipbuilders had used it for hundreds of years in order to lay out the lines of a ship, and the term comes from the fact that in order to do this, a large building or LOFT as it was called, was required.

The term *"Lofting"*, is the drafting procedure used to develop a curved surface such that any cutting plane intersecting it will produce a smooth curved line. *"Lofting"* also is used to establish intersections of curved surfaces with each other. In view of the numerous curved surfaces in an airplane, it is evident that *"Lofting"* is an important function of the engineering department.

The process involves the drawing of the basic lines of the aircraft on aluminum sheets with the aid of a very hard pencil. Say a 9H, or some similar material, and using aids such as ship curves, splines and ducks for laying out faired lines. The ducks are simply lead weights fitted with metal prongs which rest on the splines, holding them in place. The splines are lengths of hardwood or in some cases, plastic, and are used to connect the basic points of a curve under construction. A duck is used at each point, and when each duck can be lifted in turn and the spline does not move, then the curve can be said to be *"Faired in"*. To loft a set of lines, plan and elevation views are laid out in their proper sequence. *"Station lines"* are then drawn vertically in the elevation view to form vertical transfer reference planes, and *"Buttock lines"* are then drawn parallel to the airplane centre line in the plan view to form vertical longitudinal reference planes, and finally, *"Water lines"* are drawn perpendicular to the station lines in the elevation view to form horizontal reference planes. Since three dimensions are required to locate a point in space, a point could be thus located as follows:-

STATION 37.5
WATERLINE 20.56
PORT BUTTOCK LINE 13.57

On the ARROW, a decision was made early in the design that all curves should be of a *"Second degree"* nature. This was desirable as it had been shown in previous practice that curved surfaces could be faired in easier by using the limits from the master lines loft. Examples of the AVRO sheets on their construction are shown, points A, B and C and P1, P2, and P3 being taken from the master lines.

3.3 Construction of a Second-Degree Curve

This method of construction of a second degree curve is applicable to all conic sections and if carefully done will produce a curve which will satisfy the mathematical equation for any point on the curve.

Given: Two points of tangency A and B; tangents normal to the x and y axis; point C on the required curve.

Construction:

Plate 1: Extend tangents A and B to meet at tangent intersection T_1.

Draw construction lines AN and BM to pass through point C, the point on the required curve, which is within the boundaries of the tangent lines A and B.

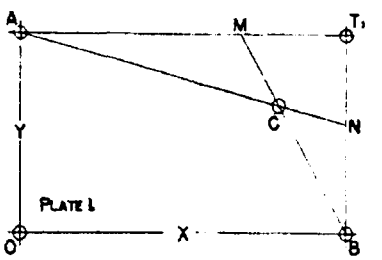


Plate 2: With centre T_1 draw ray lines cutting construction lines AN and BM at a suitable number of places.

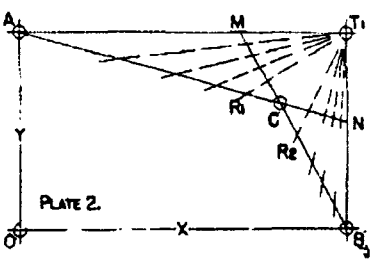


Plate 3: From centre A draw rays through ray intersections on BC. From centre B draw rays through ray intersections on AC.

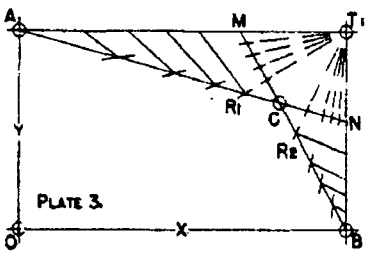


Plate 4: Draw lines from A to ray intersections on CM, beginning at point M. Where these lines cut the rays from B will be points on the required curve.

Similarly, draw lines from B to ray intersections on CN, beginning at point N. Where these lines cut the rays from A will be further points on the required curve.

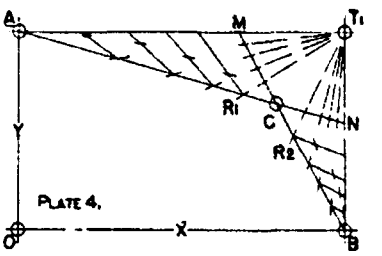
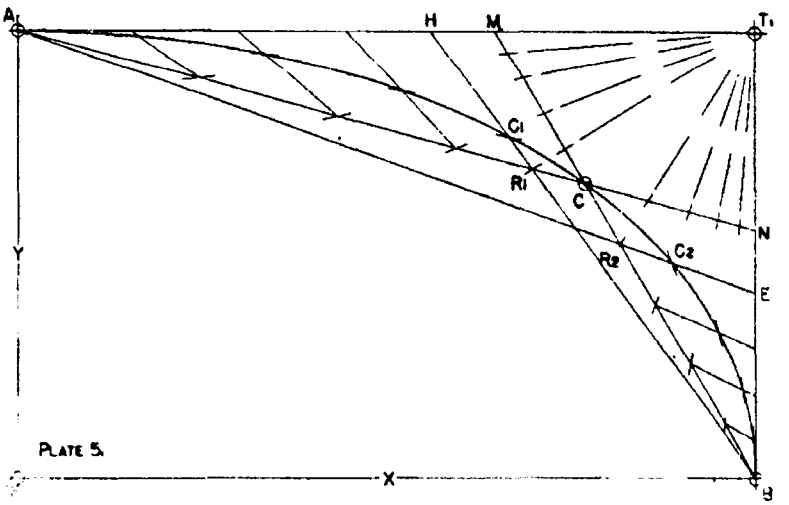


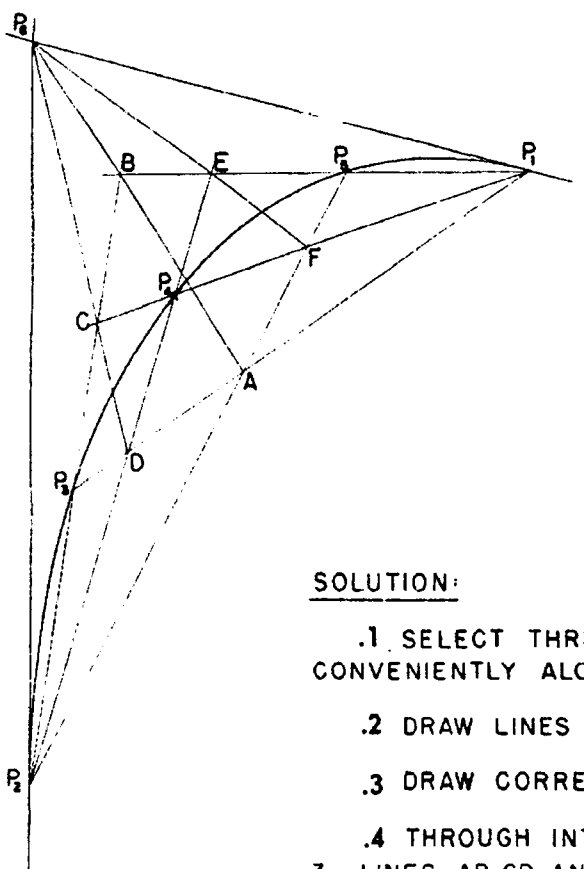
Plate 5: This is the final construction of a second degree curve. The points are joined to give the required curve through point C.

As examples, C_1 and C_2 are points on the required curve. A ray T_1R_1 (Plate 2) is drawn to cut AN at R_1. BH is then drawn through R_1 (Plates 3 and 5). Point C_1 is the intersection of BH and a line from A to the point where T_1R_1 crosses CM.

Similarly C_2 is found by drawing T_1R_2 to BM, drawing AE, and then a line from B to CN.



3.4 Construction of a Tangent to a Second-Degree Curve at Two Given Points



REQUIRED:

TO DRAW TANGENTS TO THE GIVEN POINTS P_1 AND P_2

SOLUTION:

.1 SELECT THREE POINTS (P_3, P_4, P_5) SPACED CONVENIENTLY ALONG THE CURVE.

.2 DRAW LINES P_1P_5 EXTENDED, P_1P_4 EXTENDED AND P_1P_3.

.3 DRAW CORRESPONDING LINES P_2P_3, P_2P_4 AND P_2P_5.

.4 THROUGH INTERSECTION POINTS A,B,C,D,E & F, DRAW 3 LINES AB, CD AND EF WHICH INTERSECT AT THE COMMON POINT P_6.

.5 LINES P_1P_6 AND P_2P_6 ARE THE REQUIRED TANGENTS.

NOTE: THE METHOD DESCRIBED ABOVE IS ACCURATE FOR SECOND-DEGREE CURVES ONLY.