Airframe Design and Construction

Maximum stresses due to applied loads

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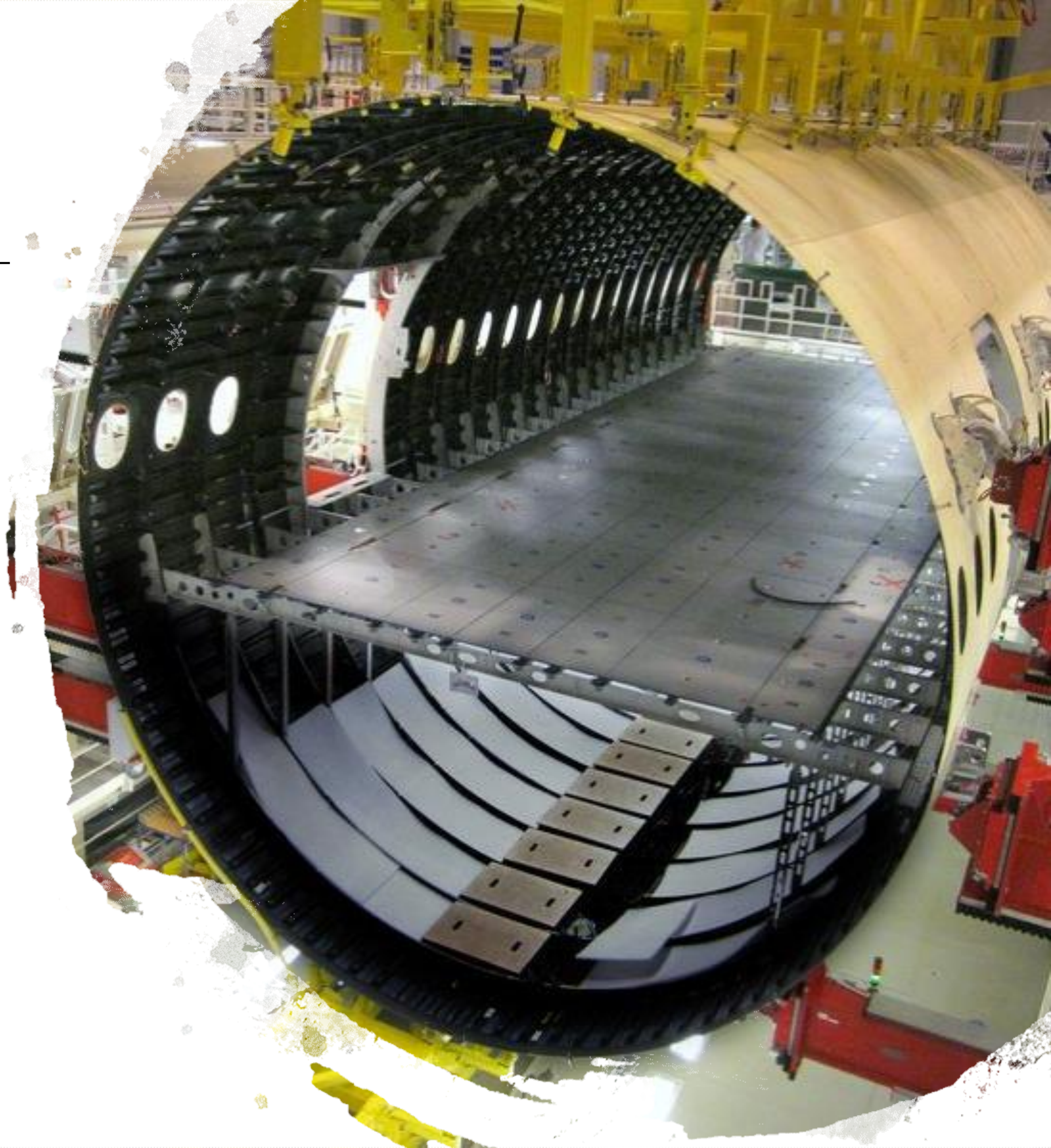
Fuselage Structure

- Given fuselage structure and determine the *<u>ultimate bending strength</u>*.

- **Given loads and determine the *<u>maximum stresses</u>* applied to the fuselage structure.**

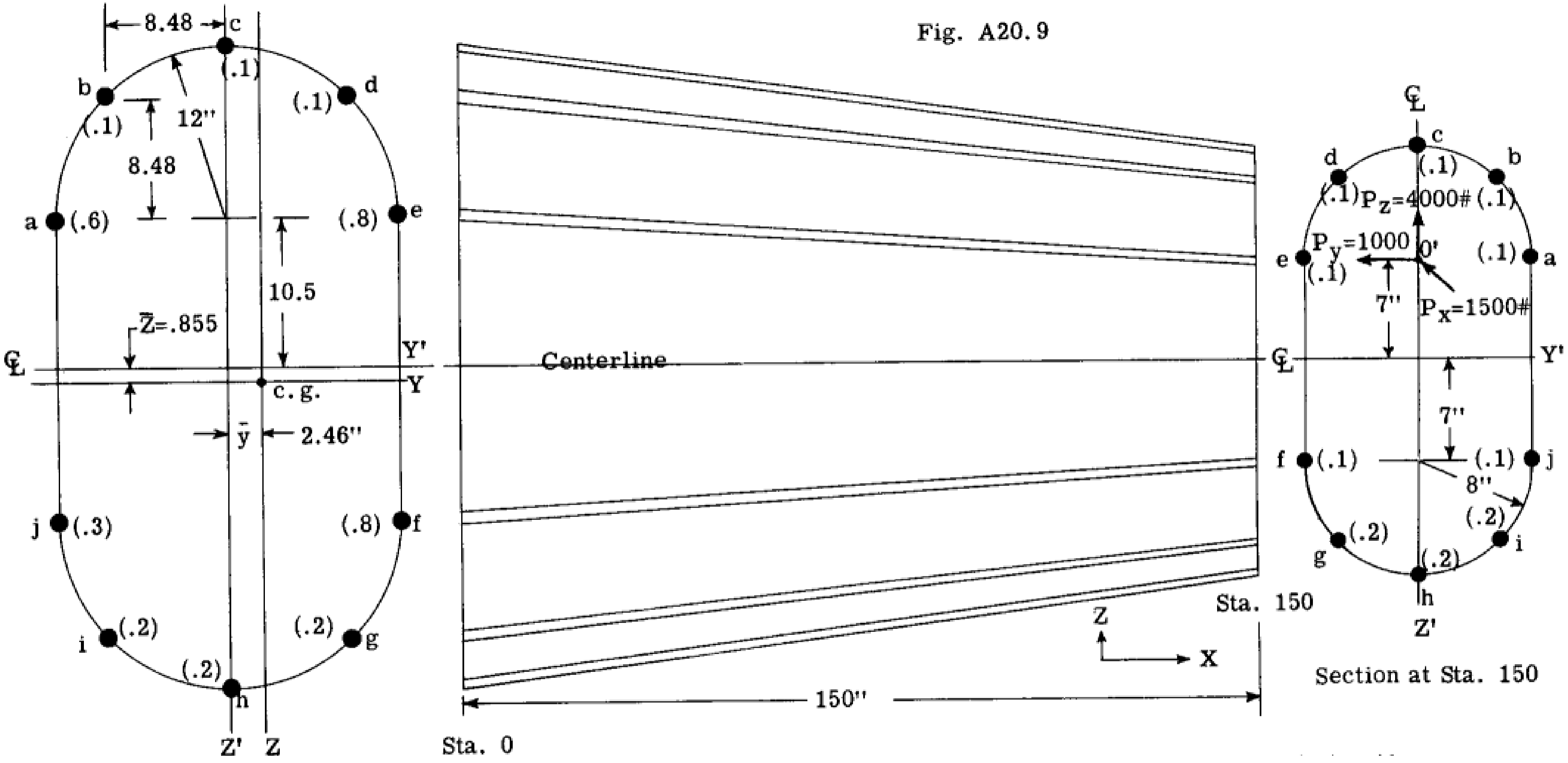
- Given loads and determine the *<u>shear flow distribution.</u>*



Unsymmetrical tapered fuselage- Example

Determine the stringer stresses and forces at station 0 and station 30 due to the given loads applied at station (150), $P_z = 4000\ Ib, P_y = 1000\ Ib, P_x = 1500\ Ib.$

Neglect the skin effect.



Unsymmetric tapered fuselage- Example

Solution strategy:

Since the fuselage is unsymmetrical and under general applied loading. We will use the general bending stresses equation

$$\sigma_b = -(K_3 M_z - K_1 M_y)y - (K_2 M_y - K_1 M_z)\,z$$

where

$$K_1 = I_{yz}/(I_y I_z - I_{yz}{}^2)$$

$$K_2 = I_z/(I_y I_z - I_{yz}{}^2)$$

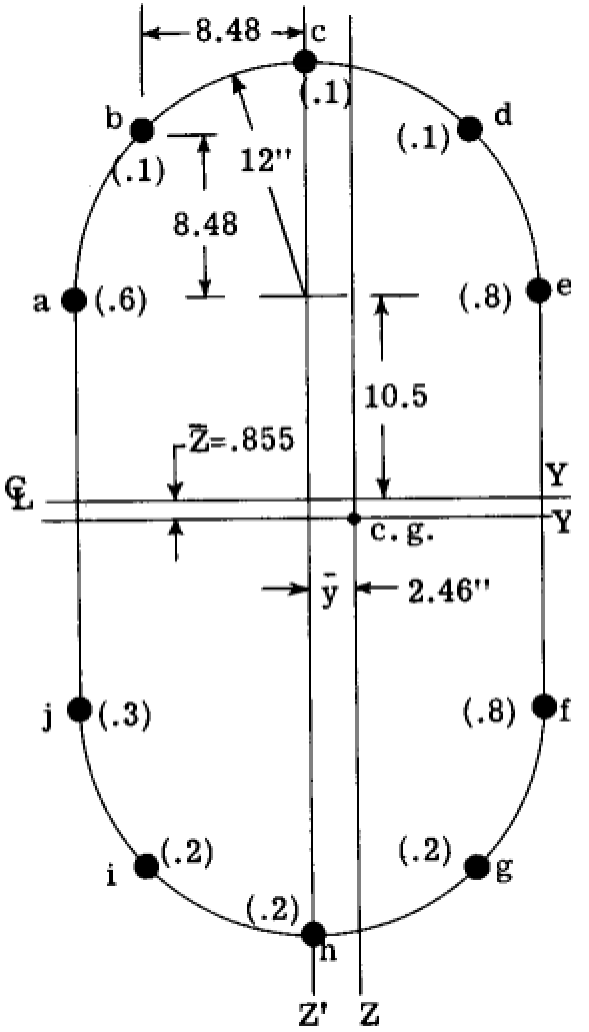
$$K_3 = I_y/(I_y I_z - I_{yz}{}^2)$$

And we need to calculate the centroid position w.r.t. Z and Y axes.

Unsymmetrical tapered fuselage- Example

Section 0:

1	2	3	4	5	6	7	8	9
Stringer No.	Area a	Arm z'	Arm y'	az'	az'^{2}	ay'	ay'^{2}	az'y'
a	.60	10.5	-12.00	6.30	66.20	-7.20	86.50	- 75.50
b	.10	18.98	- 8.48	1.90	36.00	-0.85	7.20	- 16.10
c	.10	22.50	0	2.25	50.80	-0	0	0
d	.10	18.98	8.48	1.90	36.00	0.85	7.20	16.10
e	.80	10.5	12.00	8.40	88.10	9.60	115.10	100.80
f	.80	-10.5	12.00	-8.40	88.10	9.60	115.10	-100.80
g	.20	-18.98	8.48	-3.80	72.00	1.70	14.40	- 32.30
h	.20	-22.50	0	-4.50	101.60	0	0	0
i	.20	-18.98	- 8.48	-3.80	72.00	-1.70	14.40	32.30
j	.30	-10.50	-12.00	-3.15	33.10	-3.60	43.25	37.80
Sum	3.40			-2.90	643.9	8.40	403.2	- 37.70



Unsymmetrical tapered fuselage- Example

<u>Section 0:</u>

Location of centroid and transfer of properties to centroidal axes.

$\bar{z} = -2.90/3.40 = -.855''$

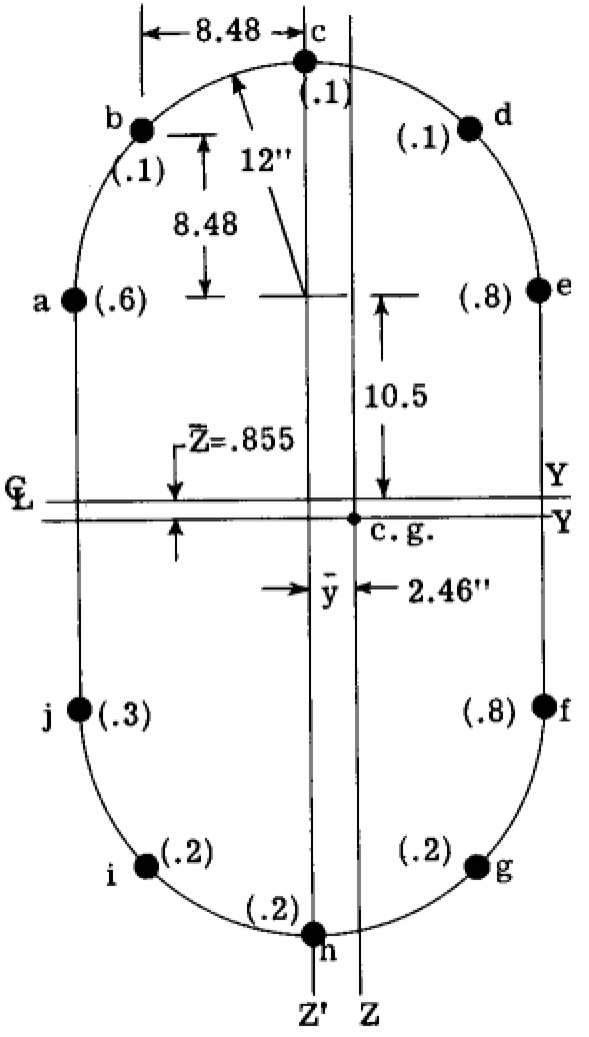
$\bar{y} = 8.40/3.40 = 2.46''$

$I_y = 643.9 - 3.40 \times 855^2 = 641.4$

$I_z = 403.2 - 3.40 \times 2.46^2 = 382.6$

$I_{zy} = -37.7 - 3.40 \times 2.46 \times -.855 = -30.55$

10	11
$z = z' - \bar{z}$	$y = y' - \bar{y}$
11.36	-14.46
19.84	-10.94
23.36	- 2.46
19.84	6.02
11.36	9.54
- 9.65	9.54
-18.13	6.02
-21.65	- 2.46
-18.13	-10.94
- 9.65	-14.46



Unsymmetrical tapered fuselage- Example

<u>Section 0:</u>

$$M_y = P_z\ (150) + P_x\ (7.85)$$

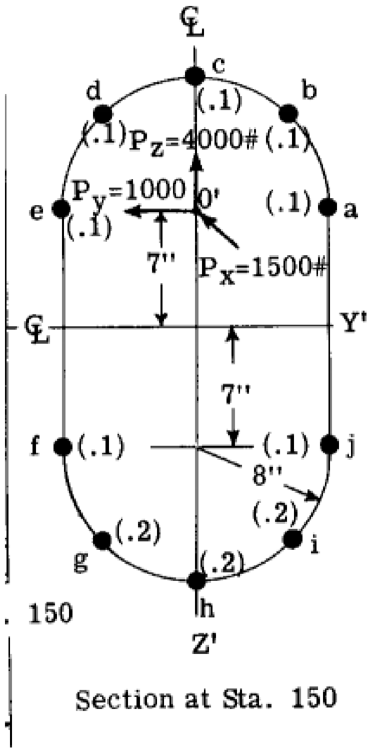
$$= 4000 \times 150 + 1500 \times 7.85 = 611800 \text{ in.lb.}$$

$$M_z = P_y\ (150) - P_x\ (2.46)$$

$$= -1000 \times 150 + 1500 \times 2.46 = -146310 \text{ in.lb.}$$

The shears at station (0) are $V_z = P_z =$ 4000 lb. and $V_y = P_y = -1000$ lb.

The normal load P_n at station (0) referred to centroid of section equals $\Sigma P_x = -1500$ lb.



Section at Sta. 150

Unsymmetrical tapered fuselage- Example

<u>Section 0:</u>

Substituting K values in equation for σ_b:

$$\sigma_b = -\left[.00262 \times -146310 - (-.0001248 \times 611800)\right] y - \left[.00156 \times 611800 - (-.0001248 \times -146310)\right] z$$

$\sigma_b = 307.0\, y - 936.1\, z$ (plus σ_b is tension)

$$\sigma_b = -(K_3 M_Z - K_1 M_y) y - (K_2 M_y - K_1 M_Z) z$$

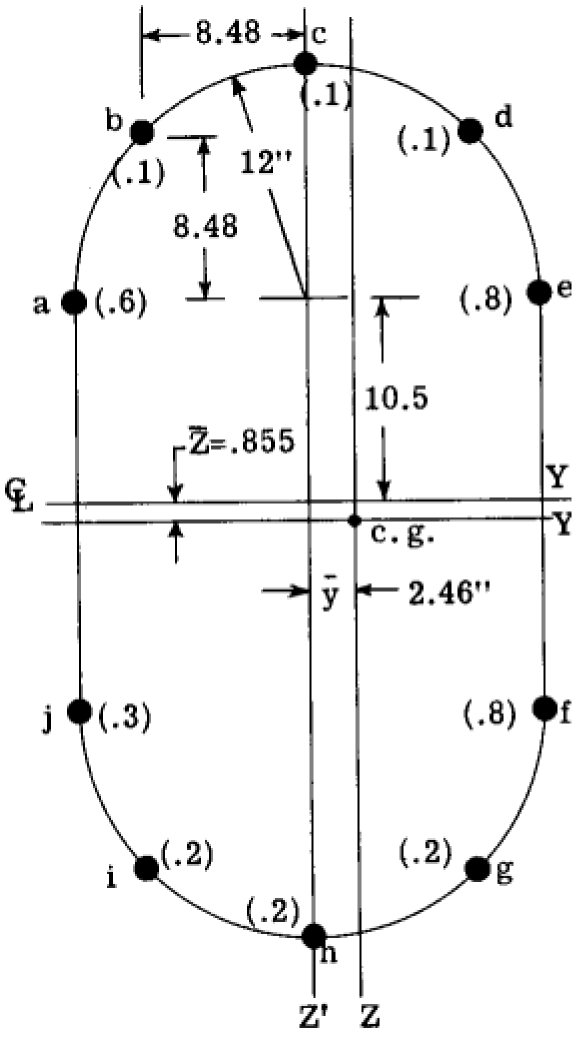
where

$$K_1 = I_{yz}/(I_y I_Z - I_{yz}^2)$$
$$K_2 = I_Z/(I_y I_Z - I_{yz}^2)$$
$$K_3 = I_y/(I_y I_Z - I_{yz}^2)$$

$$K_1 = -30.55/(641.4 \times 382.6 - 30.55^2) = -30.55/244670 = -.0001248$$

$$K_2 = 382.6/244670 = .00156$$

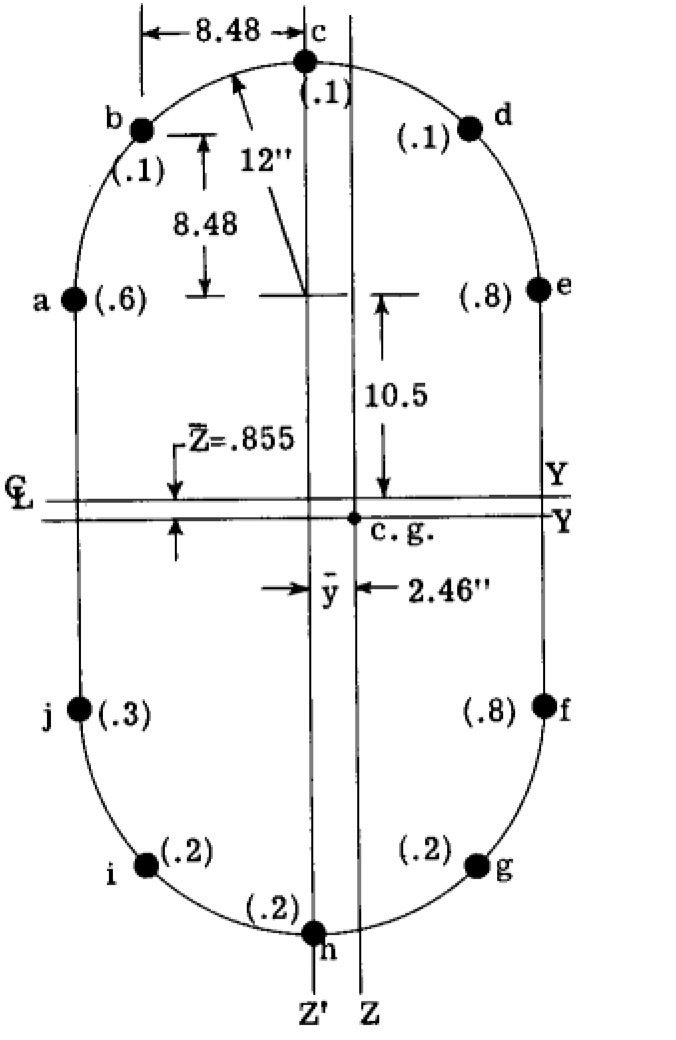
$$K_3 = 641.4/244670 = .00262$$



Unsymmetrical tapered fuselage- Example

Section 0:

12	13	14
σ_b	$\sigma_c = F/\Sigma a$ = -1500/3.40	$P_s = a(\sigma_b + \sigma_c)$ = (2) (12 + 13)
-15080	-441	-9312
-21960	-441	-2239
-22600	-441	-2304
-16742	-441	-1719
- 7692	-441	-6506
11958	-441	9216
18798	-441	3673
19485	-441	3809
13610	-441	2634
4592	-441	1246
		-1500

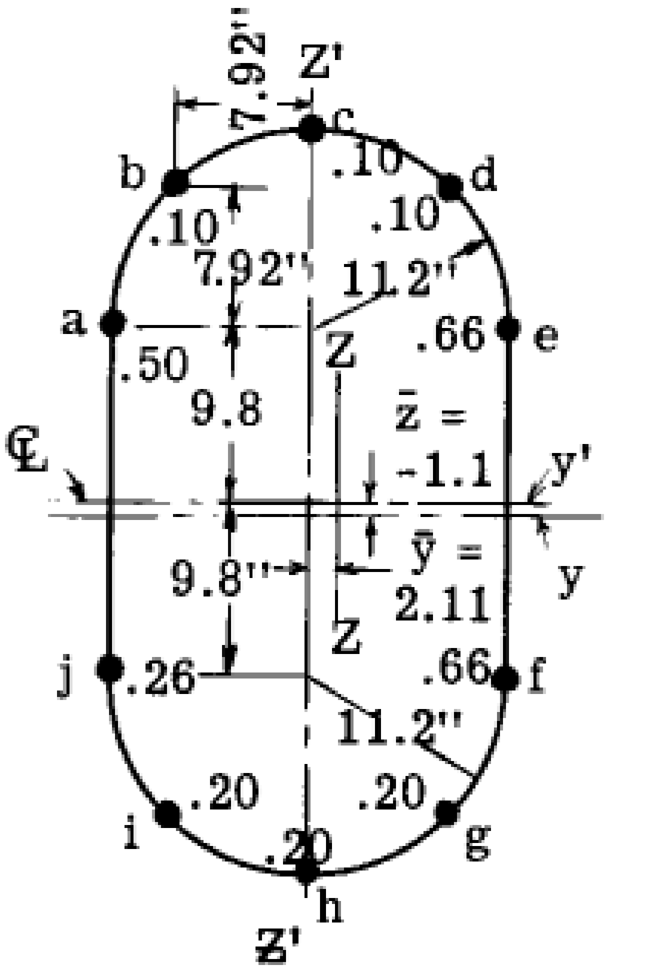


σ_b = 307.0 y −936.1 z (plus σ_b is tension)

Unsymmetrical tapered fuselage- Example

Section 30:

1	2	3	4	5	6	7	8	9
Stringer No.	Area a	Arm z'	Arm y'	az'	az'^{2}	ay'	ay'^{2}	az'y'
a	.50	9.80	-11.2	4.90	48.1	-5.60	62.8	-54.9
b	.10	17.72	- 7.92	1.77	31.4	-0.79	6.3	-14.0
c	.10	21.00	0	2.10	44.1	0	0	0
d	.10	17.72	7.92	1.77	31.4	0.79	6.3	14.0
e	.66	9.8	11.20	6.47	63.2	7.40	83.0	72.5
f	.66	- 9.8	11.20	-6.47	63.2	7.40	83.0	-72.5
g	.20	-17.72	7.92	-3.54	62.8	1.58	12.6	-28.0
h	.20	-21.00	0	-4.20	88.2	0	0	0
i	.20	-17.72	- 7.92	-3.54	62.8	-1.58	12.6	28.0
j	.26	- 9.8	-11.20	-2.55	25.0	-2.92	32.6	28.6
Sum	2.98			-3.29	520.2	6.28	299.2	-26.3



Unsymmetrical tapered fuselage- Example

<u>*Section 30:*</u>

Reference Z' and Y' axes are taken as the centerline axes.

$\bar{z} = -3.29/2.98 = -1.10''$

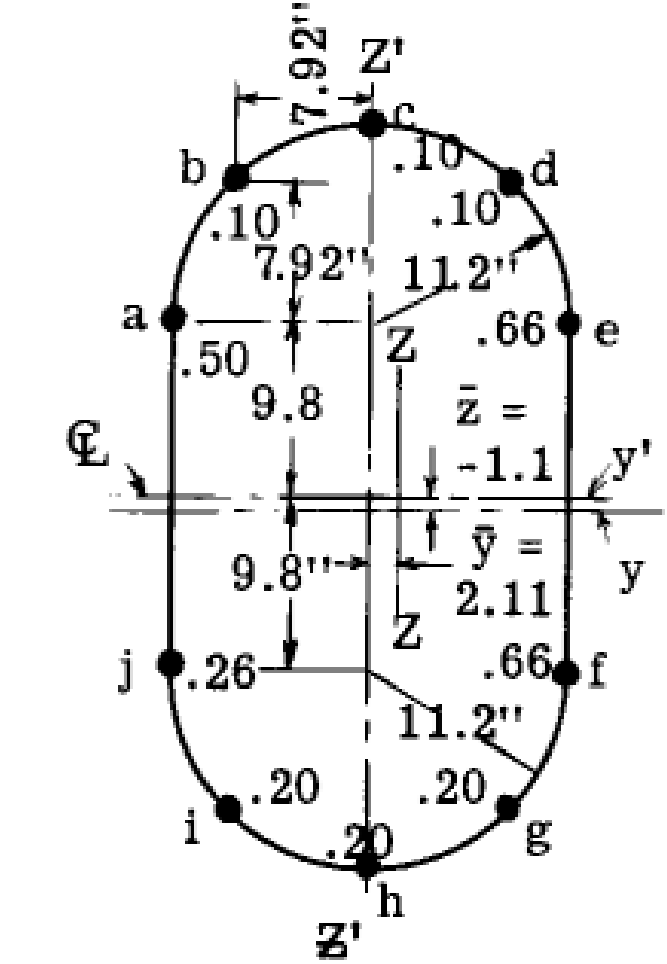
$\bar{y} = 6.28/2.98 = 2.11$

$I_y = 520.2 - 2.98 \times 1.10^2 = 516.6$

$I_z = 299.2 - 2.98 \times 2.11^2 = 286.0$

$I_{zy} = -26.3 - 2.98 \times 2.11 \times -1.10 = -19.4$

10	11
$z =$	$y =$
$z' - \bar{z}$	$y' - \bar{y}$
10.90	-13.31
18.82	-10.03
22.10	- 2.11
18.82	5.81
10.90	9.09
- 8.7	9.09
-16.60	5.81
-19.90	- 2.11
-16.60	-10.02
- 8.70	-13.31



Unsymmetrical tapered fuselage- Example

Section 30:

$$K_1 = -19.4/(516.6 \times 286 - 19.4^2)$$

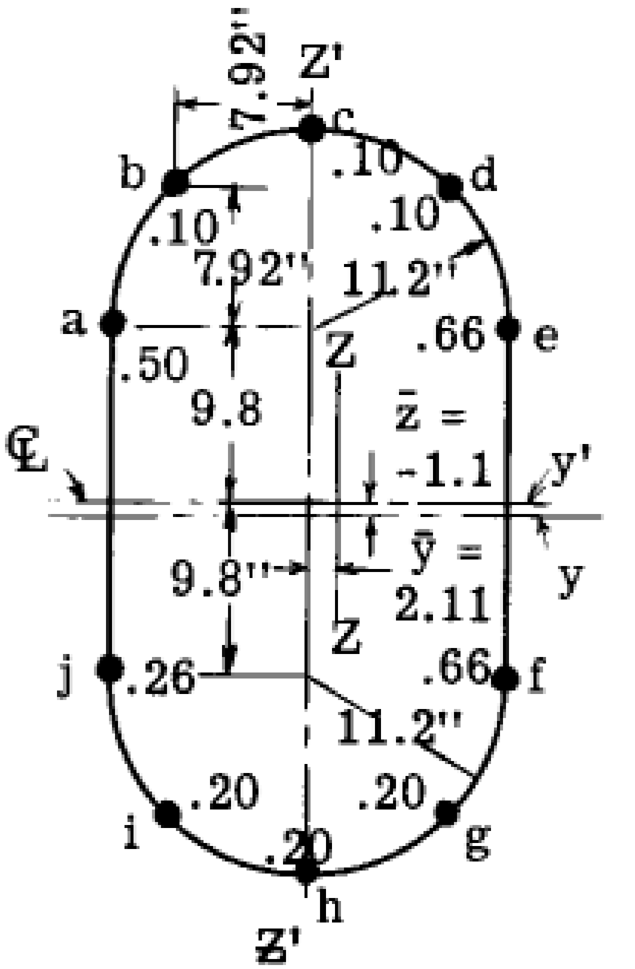
$$= -19.4/147620 = -.0001315$$

$$K_2 = 286/147620 = .001936$$

$$K_3 = 516.6/147620 = .0035$$

$$\sigma_b = -\left[.0035 \text{ c} - 116800 - (-.0001315 \times 492150)\right] y - \left[.001936 \times 492150 - (-.0001315 \times 116820)\right] z$$

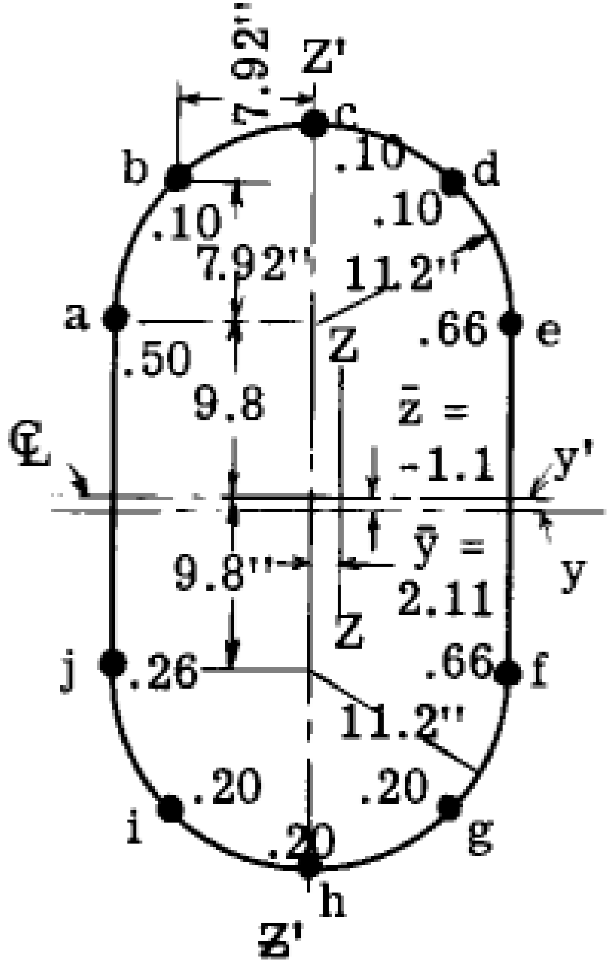
$$\sigma_b = 344.3\, y - 937.7\, z$$



Unsymmetrical tapered fuselage- Example

Section 30:

12	13	14
σ_b	$\sigma_c = F/\Sigma a$ $= -1500/2.98$	$P_s =$ $a(\sigma_b + \sigma_c)$
-14800	-503	-7651
-21090	-503	-2159
-21447	-503	-2195
-15647	-503	-1615
- 7088	-503	-5011
-11282	-503	7100
-17583	-503	3416
17943	-503	3489
12135	-503	2327
3570	-503	797
		-1500



$\sigma_b = 344.3\,y - 937.7\,z$