US Army Corps
of Engineers
Huntsville Division

STRUCTURAL ANALYSIS:

BLAST DOORS FOR CORBETTA-TYPE MAGAZINES

VOLUNTEER ARMY AMMUNITION PLANT
HOLSTON ARMY AMMUNITION PLANT

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OCTOBER 1986

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PREPARED BY
U. S. ARMY CORPS OF ENGINEERS
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ANALYSIS OF EXISTING BLAST DOORS
FOR CORBETTA-TYPE MAGAZINES

1.0 INTRODUCTION - BACKGROUND AND PURPOSE

The Department of Defense Explosive Safety Board (DDESB) regards the Corbetta-type magazines at Volunteer and Holston Army Ammunition Plants as being nonstandard and therefore suitable for storage of a maximum of 250,000 pounds, net explosive weight class 1.1. The subject magazines were intended to be standard and therefore capable of holding 500,000 pounds. The DDESB'S concern was whether the steel doors have sufficient strength to resist a blast loading from a neighboring magazine.

Huntsville Division, Corps of Engineers was requested by AMSMC-PBE to perform an analysis of the strength of the existing doors to resist the blast effects of 500,000 pounds net explosive weight (NEW). This report presents the results of that analysis.

2.0 DESCRIPTION OF CORBETTA MAGAZINE DOORS

The doors are double leaf type with a clear opening 5'-6" wide and 7'-6" high. (See Figure 1). Each door leaf consists of an inner and outer plate of No. 12 Ga. sheet steel. A 4.2 type corrugated asbestos sheet with 1 1/2 inch deep corrugations maintains separation between the inner and outer plates. The total door thickness is 1.709 inches plus or minus.

The inner and outer plates are attached to a perimeter frame. The perimeter frame has a horizontal cross member located at approximately mid height. The perimeter frame and cross member are rectangular tube sections 2 1/2" x 1 1/2" x 11 gage. Each door panel is attached to the jamb with two low carbon steel hinges, 3" x 5/16" minimum cross section. Each hinge is attached to the door with 3-1/2 rivets and anchored into the concrete wall with a 1" x 3" anchor plate with an embedment length of 7 inches plus turn down.

3.0 ASSUMPTIONS AND CRITERIA

The following blast loading parameters, assumptions and criteria were used in the analysis:

a. The minimum distance between magazines is 400 feet. (Worst case).

b. The orientation of the magazine's door is face on, thereby, making the reflected pressure, the principal loading. (Worst case).

c. Blast effects data and formulas were obtained from TM 5-1300, Structures to Resist the Effects of accidental explosions. (Ref. 1)

d. Inner and outer door plates are attached to the skeletal frame with continuous welds.

e. No attempt was made to assess the energy that would be absorbed by the donor magazine and earth cover in the event of an explosion.

f. Maximum permissible ductility ratios (μ) for non-reuseable members:

Plate bending, μ = Xm/Xe = 20
Beam bending, μ = Xm/Xe = 6

g. Material rupture will occur when $\mu > 50$.

h. Material Properties:

F_u = 75000 psi for hard bronze.
F_u = 72000 psi for structural steel
$F_y = 0.5F_u$
$F_v = 0.6F_u$

4.0 ANALYSIS METHODOLOGY

A preliminary investigation revealed that the 12 ga. steel plates were grossly inadequate to resist the overpressure when analysed as plates unrestrained in the plane of the plate. To more nearly assess the true capability of the doors, a membrane type analysis was performed.

In the membrane analysis, the plates enter the tension yield state early in the response time history and are held along the edges by the perimeter frame. The perimeter frame is thus loaded by a combination of axial load and bending and transverse pressure.

The primary ways in which door failure can occur are:

a. Combined bending and membrane tension in the plates ($\mu > 20$).

b. Combined bending in the perimeter frame ($\mu > 6$).

c. Latch mechanism ultimate failure during rebound.

d. Door hinge ultimate shear failure during rebound.

e. Hinge pin ultimate shear failure during rebound.

f. Hinge anchor ultimate pullout during rebound.

g. Weld failures (not addressed in this report).

Failure types a. and b. combined with hinge failure could produce a catastrophic failure in which case the door would become a missile. For purposes of this analysis, a plastic deformation ratio, $\mu > 50$ when combined with hinge failure is considered catastrophic. If one of the door components fails in the rebound mode, that is not considered catastrophic from the standpoint of damage to the contents of the magazine.

The sensitivity of the stored material to missile impact is not known. However, this analysis attempts to calculate a probable level of residual foot pounds energy in each door leaf that would result from 500,000 lb. NEW.

The overpressure time history was obtained from Figure 4-12 in TM 5-1300 as a function of charge weight and distance. A design increase factor of 1.2 was not applied to the charge weight. No attempt was made to assess the attentuation of explosive effects due to the presence of the magazine and earth cover.

The dynamic response of the door was calculated by elasto-plastic methods as described in in TM 5-1300 and the text book on dynamic structural analysis by John M. Biggs (Ref. 2). The key parameters for dynamic analysis were: element mass, stiffness, natural period, resistance and load function.

The Corps of Engineers' library computer program CSDOOR, which is based on TM 5-1300, was used to do initial investigations and to check final results (Ref. 3).

5.0 RESULTS

The results of this analysis show that the existing door panels will fail at 11 psi reflected pressure, corresponding to an explosive charge weight of 20,000 lb. Door hinge failure is also indicated for W=20,000 lb.

The principal failure made for the door is plastic bending in the interior vertical frame member (2 1/2" x 1 1/2" x 11 ga. tube). The door will extrude through the opening.

Rebound was not investigated since initial failure will occur in the positive overpressure direction.

6.0 EFFECTS OF DOOR FAILURE ON STORED EXPLOSIVES

The difference in impulse between 500,000 lb. NEW and 20,000 lb. NEW was calculated to be 14,700 lb.-sec. As stated earlier, no reduction in charge weight effectiveness, due to being stored in a magazine, was considered.

Subsequent to hinge failure, the differential impulse would produce an initial velocity of 1372 ft./sec in the 345 pound door leaf.

Subsequent effects of the door failure would be a function of the sensitivity of the stored material. Since the type, form and sensitivity of the stored material has not been furnished, and is unknown to this agency, the effects of the described impact energy has not been addressed in this report. Those knowledgeable of the explosive material stored and its sensitivity to impact should address the potential for propagation.

7.0 RECOMMENDATIONS

The doors should be modified or replaced. Modification can be accomplished in several ways. The primary objective of modification would be to eliminate the doors as a source of debris. This could be accomplished by strengthening the door and hinges or providing a safety net system of high strength (arresting) cables.

The alternative, would be a door redesign, which would consist of designing a door with multiple rolled section stiffeners capable of withstanding the maximum overpressure level (150 psi), so as not to become a source of debris.

8.0 REFERENCES

1. Department of the Army TM 5-1300, "Structures to Resist the Effects of Accidental Explosions", June 1969.

2. J. M. Biggs: "Introduction to Structural Dynamics", McGraw-Hill Book Co., 1964.

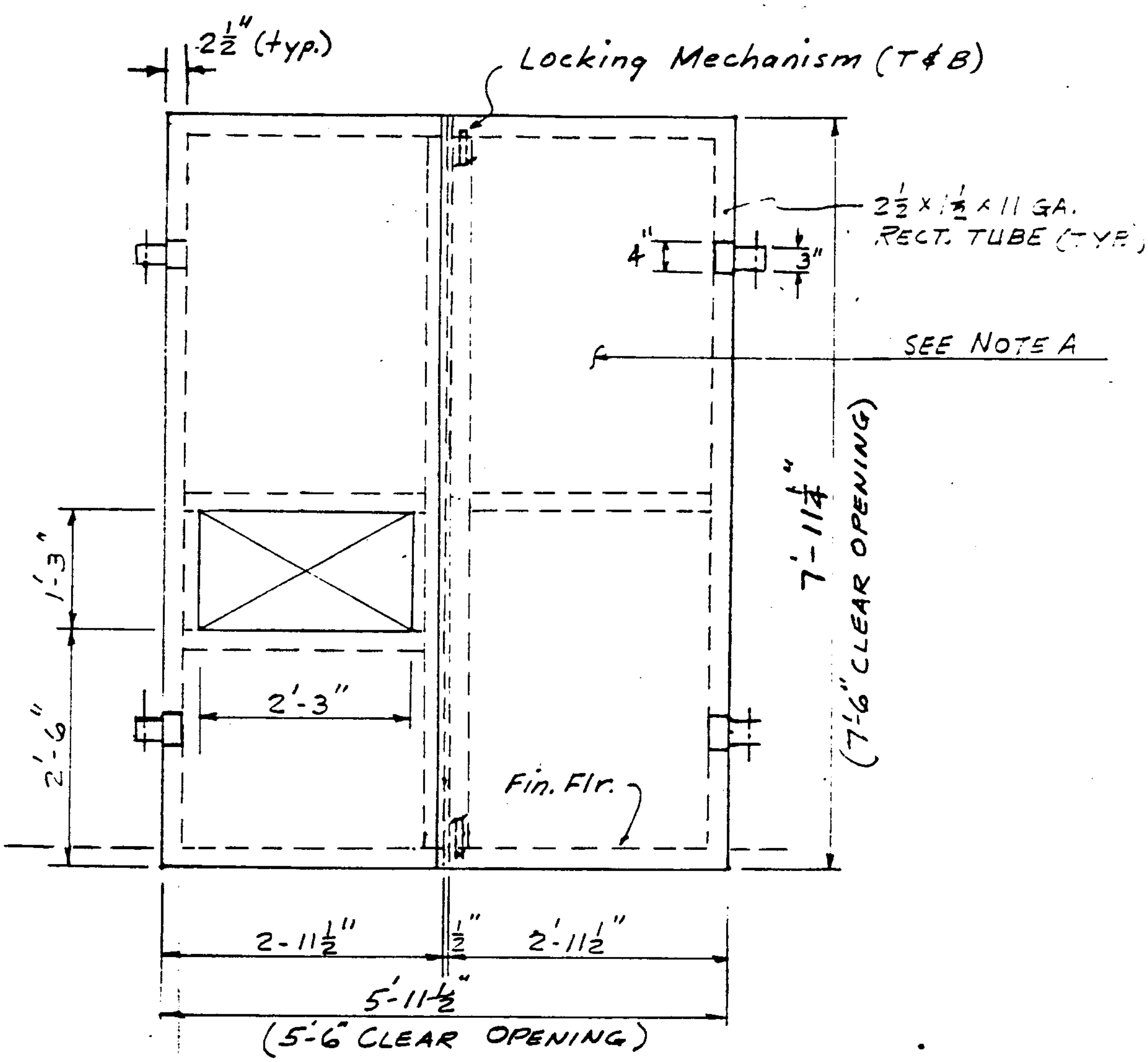
3. U. S. Army Engineer Waterways Experiment Station Instruction Report K-84-2, "Computer Program for Optimum Dynamic Design of Nonlinear Metal Plates Under Blast Loading (CSDOOR), January 1984.

APPENCIX A

STRUCTURAL CALCULATIONS

SUBJECT: ANALYSIS OF EXISTING CORBETTA MAGAZINE DOOR	COMPUTED BY: RMW	DATE: OCT. 86
	CHECKED BY: EHP	DATE:

REF. WAR DEPARTMENT DRAWING 652-1009 dated March 23, 1942



NOTE A. DOOR CONSISTS OF 2 SHEETS OF No. 12 GAGE STEEL WITH 4.2 TYPE CORR. ASBESTOS SEPARATOR & INSULATOR.

FIGURE 1

SUBJECT: ANALYSIS OF EXISTING CORBETTA MAGAZINE DOOR	COMPUTED BY: RMW	DATE: OCT 86
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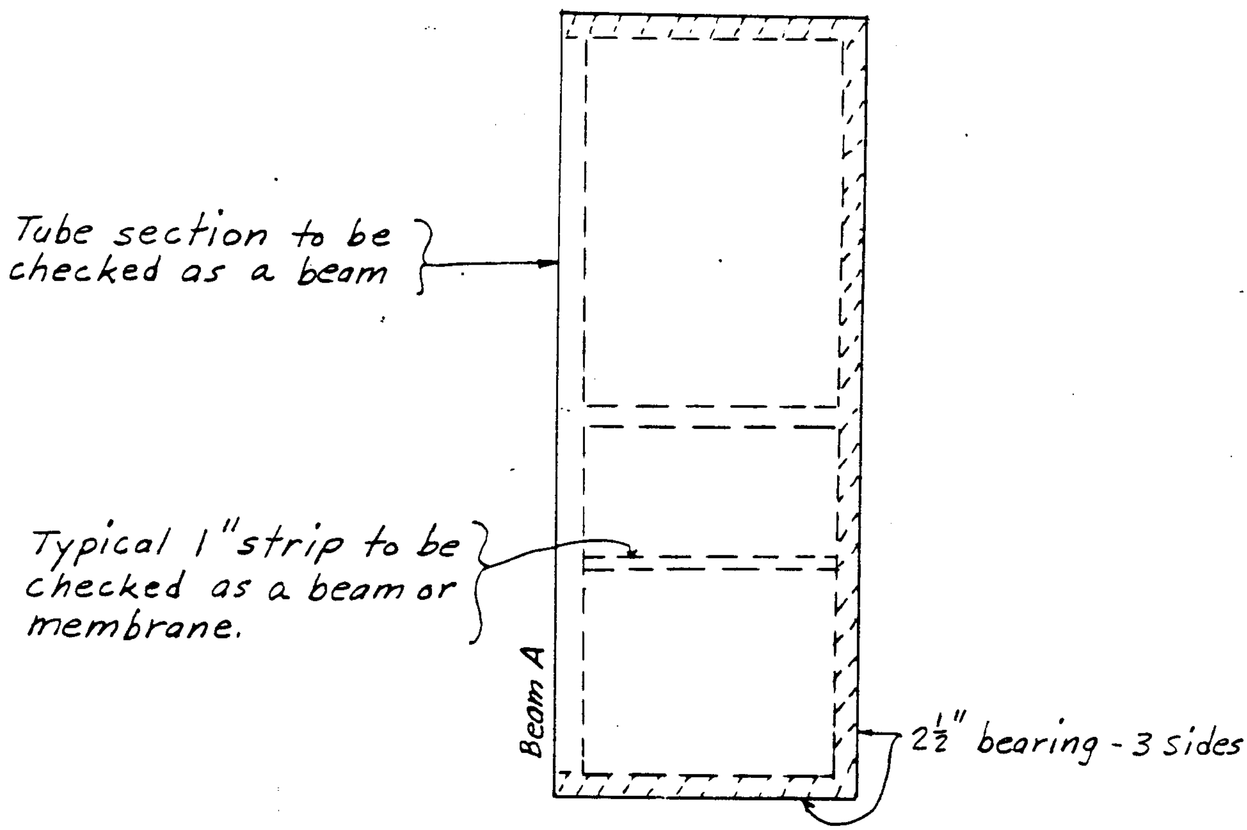
NOTES AND/OR ASSUMPTIONS

1. PLATE TO TUBE WELD DETAILS ARE NOT SHOWN.
2. 4.2 TYPE CORR. ASBESTOS SHEETS SHOULD CONTRIBUTE SOME ADDITIONAL STRENGTH AND STIFFNESS BUT WILL BE NEGLECTED.
3. THE DOOR VENTILATOR ASSEMBLY DOES NOT DEGRADE THE STRUCTURAL CAPABILITY OF THE DOOR.
4. WELD DETAILS ARE NOT SHOWN FOR ATTACHING THE 12 GA STEEL SHEET TO THE TUBES. ASSUME THE WELDS ARE SUFFICIENT TO DEVELOP MEMBRANE TENSION IN THE PLATES.
5. EACH DOOR LEAF HAS $2\frac{1}{2}''$ BEARING ON THREE SIDES.
6. THE DOOR CONSISTS OF TWO PLATES SEPARATED BY A CORRUGATED ASBESTOS SHEET. ASSUME EACH PLATE WILL BE EXPECTED TO CARRY ½ THE LOAD.

SUBJECT: ANALYSIS OF EXISTING CORBETTA MAGAZINE DOOR	COMPUTED BY: RMW	DATE: OCT 86
	CHECKED BY: EHW	DATE:



DOOR LEAF - 3 SIDES SUPPORTED

SUBJECT: ANALYSIS OF EXISTING CORBETTA MAGAZINE DOOR	COMPUTED BY: RMW	DATE: OCT 86
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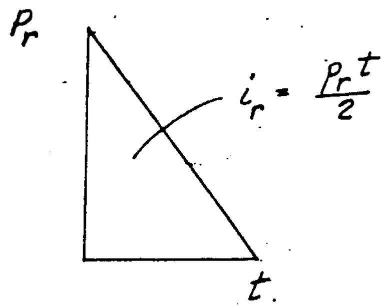

PRESSURE-TIME HISTORY

CALCULATE p-t HISTORY FOR 500,000 lb.
NET EXPLOSIVE WEIGHT (N.E.W.) AT R = 400 FEET.

$$W^{1/3} = (500000)^{1/3} = 79.4 \text{ lb.}^{1/3}$$

$$Z = \frac{R}{W^{1/3}} = \frac{400}{79.4} = 5.0 \text{ ft/lb}^{1/3}$$

FROM TM5-1300, FIGURE 4-12

$$\frac{i_r}{W^{1/3}} = 60 \text{ psi-ms/lb}^{1/3}$$

$$P_r = 150 \text{ psi}$$

$$i_r = 60(79.4) = 4764 \text{ psi-ms}$$

$$t = \frac{2 i_r}{P_r} = \frac{2(4764)}{150} = 63.5 \text{ ms}$$

SUBJECT: ANALYSIS OF EXISTING CORBETTA MAGAZINE DOOR	COMPUTED BY: RMW	DATE: OCT 86
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LOAD PARAMETERS

$R = 400$ ft.

$Z = R/W^{1/3}$

From TM5-1300, FIGURE 4-12

W	$W^{1/3}$	Z	$i_r/W^{1/3}$	i_r	P_r	t
500000	79.4	5	60	4764	150	63.5
250000	63.0	6.4	42	2646	80	66.2
100000	46.4	8.6	28	1300	35	74.3
50000	36.8	10.9	21	773	20	77.3
20000	27.1	14.7	15	407	11	74.0

SUBJECT: ANALYSIS OF EXISTING CORBETTA MAGAZINE DOOR	COMPUTED BY: RMW	DATE: OCT 86
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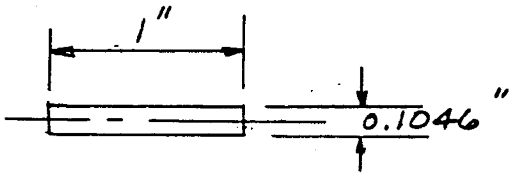
SECTION PROPERTIES FOR 12 GA. SHEET STEEL



$A = bt = (1)(.1046) = 0.1046\ in.^2$

$I_x = bt^3/12 = 0.0954 \times 10^{-3}\ in.^4$

$S_x = bt^2/6 = 0.182 \times 10^{-2}\ in.^3$

$Z_x = bt^2/4 = 0.274 \times 10^{-2}\ in.^3$

Wt. = 0.03 $lb/in.^2$

For 2 SHEETS

$A = 0.2092\ in.^2$

$I_x = 0.1908 \times 10^{-3}\ in.^4$

$S_x = 0.364 \times 10^{-2}\ in.^3$

$Z_x = 0.548 \times 10^{-2}\ in.^3$

Wt. = 0.06 $lb/in.^2$

SUBJECT: ANALYSIS OF EXISTING CORBETTA MAGAZINE DOOR	COMPUTED BY: RMW CHECKED BY: EHW	DATE: OCT 86 DATE:

SECTION PROPERTIES FOR BEAM "A"

$2\frac{1}{2} \times 1\frac{1}{2} \times 11$ GA. RECT. TUBE

$t = 0.1196$ in.

$A = 0.90$ in^2

$I_x = 0.74$ in.^{4}

$I_y = 0.33$ in.^{4}

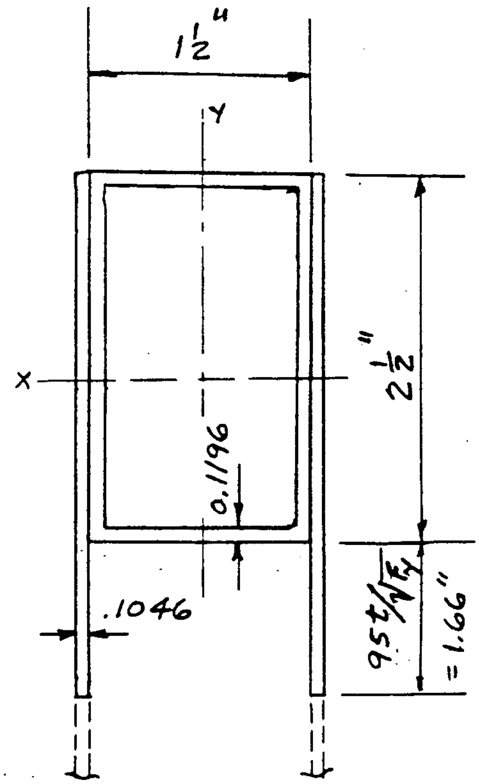
$S_x = 0.59$ in.^{3}

$S_y = 0.43$ in.^{3}

$Z_x = 0.73$ in.^{3}

$Z_y = 0.50$ in.^{3}

Wt = 0.254 lb./in.



COMPOSITE SECTION PROPERTIES

$A = 1.77$ in.^{2}

$I_x = 2.298$ in.^{4}

$I_y = 0.886$ in.^{4}

$S_x = 0.918$ in.^{3}

$S_y = 1.037$ in.^{3}

$Z_x = 1.714$ in.^{3}

$Z_y = 1.206$ in.^{3}

Wt. = .5 lb./in.

SUBJECT: ANALYSIS OF EXISTING CORBETTA MAGAZINE DOOR	COMPUTED BY: RMW	DATE: OCT 86
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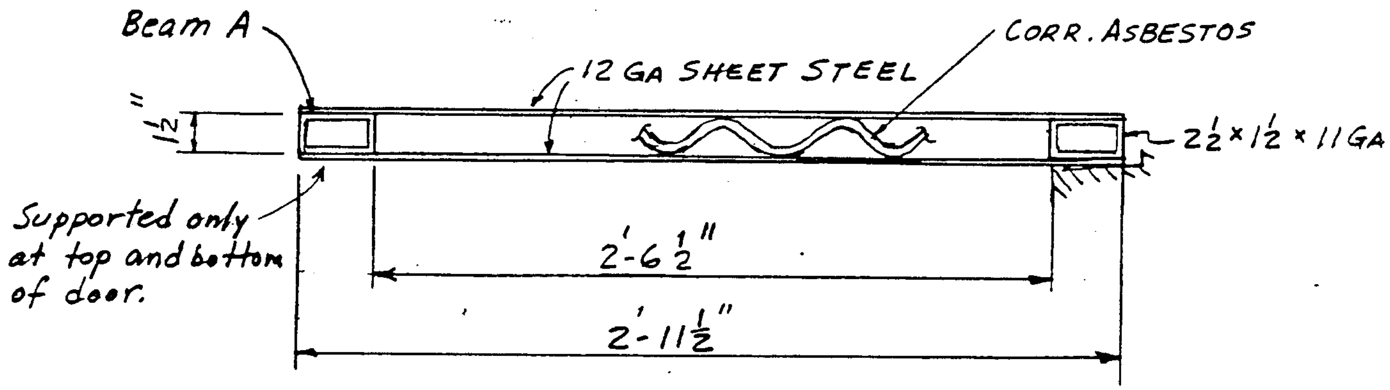
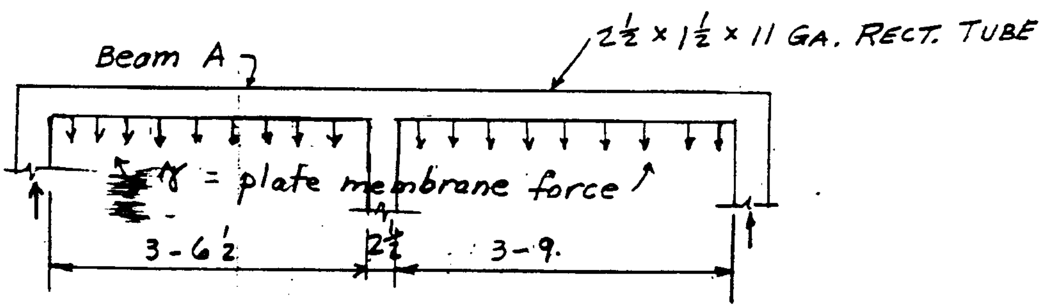
CHECK PERIMETER FRAME FOR MEMBRANE LOAD

$F_{dy} = 1.1 F_y = 1.1(36000) = 39600$ psi



ANALYSE THE DOOR AS A MEMBRANE TENSION MEMBER. CALCULATE THE RESISTANCE OF THE 2 1/2" × 1 1/2" FRAME FOR A PLATE TENSION LOAD IN THE PLANE OF THE DOOR.



γ = uniform load per inch due to membrane tension.

$M_p = Z_x f_{dy} = 1.714 \times 39600 = 67870$ in.-lb.

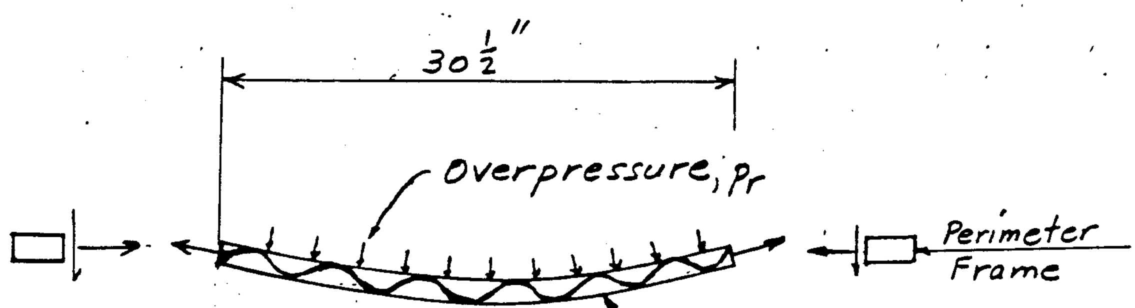
$$r_u = \frac{16 M_p}{L^2} = \frac{16 \times 67870}{45^2} = 536 \text{ lb./in.}$$

SUBJECT: ANALYSIS OF EXISTING CORBETTA MAGAZINE DOOR	COMPUTED BY: RMW CHECKED BY: EHW	DATE: OCT 86 DATE:

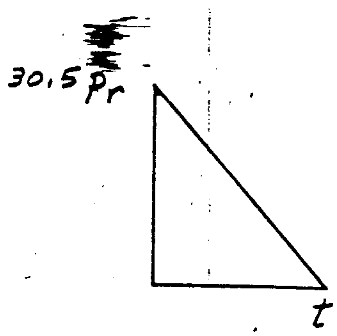
PLATE MEMBRANE YIELD FORCE

$T = F_{dy} \times 2t = 39600 \times 0.1046 \times 2 = 8284$ lb. per inch width

But, the frame plastic resistance is only 536 lb/in. Therefore, the maximum membrane force that can be developed in the plate is limited to 536 lb./in.



SCHEMATIC OF DOOR LOAD DISTRIBUTION



From p. 5

W	30.5p_r	t
20000	335.5	74.0
50000	610.0	77.3

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PLATE PROPERTIES FROM P.6

$A = 0.2092 \text{ in.}^2$

$I_x = 0.1908 \times 10^{-3} \text{ in.}^4$

$S_x = 0.364 \times 10^{-2} \text{ in.}^3$

$Z_x = 0.548 \times 10^{-2} \text{ in.}^3$

Equivalent $t_e = \sqrt{\frac{6 S_x}{b}} = \sqrt{\frac{6 \times .364 \times 10^{-2}}{1}} = 0.148$

$M = \frac{W}{g} = \frac{30.5 \times 0.2092 \times 490}{386.2 \times 1728} + \frac{30.5 \times 4.2}{386.2 \times 144} = 0.00699 \ \frac{\text{lb-sec}^2}{\text{in.}}$

$K = \frac{307 EI}{L^3} = \frac{307 \times 29 \times 10^6 \times .1908 \times 10^{-3}}{30.5^3} = 59.9 \text{ lb./in.}$

$T_N = 2\pi \sqrt{\frac{K_{LM} M}{K}} = 2\pi \sqrt{\frac{.57 \times .00699}{59.9}} = 0.051 \text{ sec.}$

$M_p = Z_x F_{dy} = .00548 \times 39600 = 217 \text{ in-lb.}$

$R_m = \frac{16 M_p}{\text{[illegible]}} = \frac{16 \times 217}{30.5} = 114$ lb./inch width, $r = \frac{114}{30.5} = 3.75$ psi

From Biggs [Ref. 2], Figure 2-24, with $\frac{R_m}{F} = \frac{114}{335.5} = 0.34$

and $\frac{t}{T_N} = \frac{0.074}{0.051} = 1.45$

Read $\mu = 50 = x_m / x_e$

$x_e = \frac{R_m}{K} = \frac{114}{59.9} = 1.9$ inches

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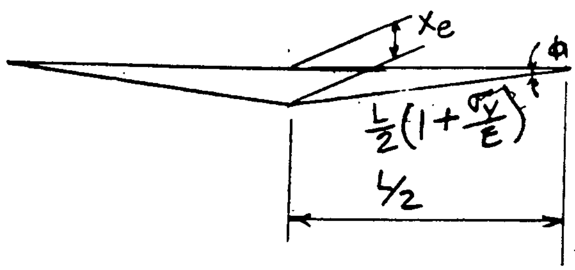
PLATE ANALYSIS Cont'd

$X_m = 50 X_e$ = very large. Such severe deformation, however, will not occur because the plates will go into membrane action for

$$\cos\phi = \frac{L/2}{L/2(1+\frac{\sigma_y}{E})} = \frac{1}{1+\sigma_y/E} = \frac{1}{1+\frac{36000}{29\times10^6}} = 0.99876$$



$\phi = 2.85°$

$X_e = \frac{L}{2}\tan\phi = 0.76''$

∴ For $X > .76''$ the plate is in the membrane condition and its load capability increases until the membrane μ exceeds $\simeq 20$.

For $\mu = 20$, $\cos\phi = \frac{1}{1+\frac{20\sigma_y}{E}} = \frac{1}{1+\frac{720000}{29\times10^6}} = 0.976$

$\phi = 12.5°$

$X = \sin\phi\left(\frac{L}{2}\right) = 3.4''$

Membrane Resistance $= 2\sigma_y t(\sin\phi) = 72000(.2092)(.2164) = 3266^{\#}$

But, in order to develop this resistance the supports must be unyielding which they are not.

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MAXIMUM RESISTANCE OF PLATES

Since 536 lb/in. will yield Beam A, that is the maximum membrane load in the plates. The corresponding plate membrane stress is

$$\sigma = \frac{\gamma}{t} = \frac{536}{.2092} = 2562 \text{ psi}$$

$$\epsilon = \frac{\sigma}{E} = \frac{2562}{29 \times 10^6} = 88. \times 10^{-6} \text{ in/in.}$$

$$\cos\phi = \frac{1}{1+\epsilon} = \frac{1}{1.000088} = 0.9999$$

$$\phi = 0.76^\circ < 2.85^\circ$$

∴ Plate does not function as a pure membrane until $\phi > 2.85^\circ$

Membrane resistance for $\phi = 2.85^\circ$ is

$$R = 2\sigma t(\sin\phi) = 2(2562)(.2092)(.04972) = 53 \text{ lb./in. width}$$

Membrane plus bending resistance is

$$R = 53 + 114 = 167 \text{ lb/in}$$

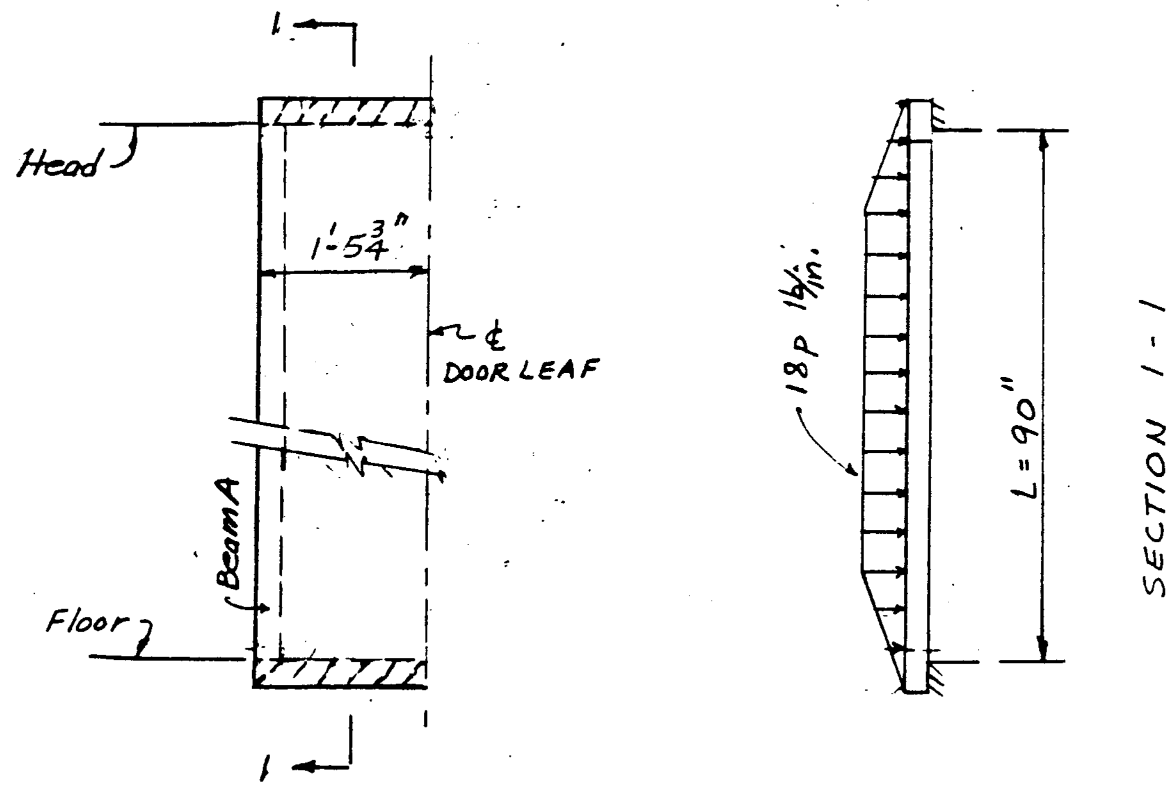
$$r = \frac{167}{30.5} = 5.5 \text{ psi}$$

From Biggs [Ref. 2], Figure 2-24 with $\frac{R_m}{F} = \frac{167}{335.5} = 0.5$ and $\frac{T}{T_N} = \frac{0.074}{0.051} = 1.45$

Read $\frac{X_m}{X_e} = \mu = 20$ Failure is imminent.

SUBJECT: ANALYSIS OF EXISTING CORBETTA MAGAZINE DOOR	COMPUTED BY: RMW CHECKED BY: EHW	DATE: OCT 86 DATE:

CHECK BEAM "A" FOR W=20,000 lb.



PARTIAL ELEVATION

See Page 7 For Section Properties

It is recognized that the load is not uniform for the full length of the beam and that a uniform distribution will overstate the actual load. However, if the load capacity is significantly less than the intended load the model is acceptable.

SUBJECT: ANALYSIS OF EXISTING CORBETTA MAGAZINE DOOR	COMPUTED BY: RMW CHECKED BY: EHW	DATE: OCT 86 DATE:

BEAM A

WEIGHT

BEAM: $.5 \times 90 =$ 45 lb.

PLATES: $2 \times .1046'' \times 14'' \times 90'' \times .283 =$ 75 lb.

FILLER: $4.2 \times 1.25' \times 7.5' =$ 39 lb.

TOTAL = 159 lb.

STIFFNESS

$$K = \frac{384 EI}{5 L^3} = \frac{384 \times 29 \times 10^6 \times 0.886}{5 \times 90^3} = 2707 \text{ lb./in.}$$

LOAD-MASS FACTOR - [Ref. 3, Table 5.1]

ELASTIC $K_{LM} = 0.64$

PLASTIC $K_{LM} = 0.50$

AVERAGE $K_{LM} = 0.57$

NATURAL PERIOD

$$T_N = 2\pi \sqrt{\frac{K_{LM} W}{K g}} = 2\pi \sqrt{\frac{.57 \times 159}{2707 \times 386.2}} = 0.059 \text{ sec.} = 59 \text{ ms}$$

PLASTIC MOMENT

$$M_p = (Z_y)(F_{dy}) = 1.206 \times 39600 = 47760 \text{ in.-lb.}$$

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BEAM A - CONT'D

RESISTANCE

$$R = \frac{8 M_p}{L} = \frac{8 \times 47760}{90} = 4245 \text{ lb.}$$

PEAK FORCE FOR W = 20,000 lb.

$$F = L \times W \times p_r = 90 \times 18 \times 11 = 17820 \text{ lb.}$$

$$\frac{R}{F} = \frac{4245}{17820} = 0.24$$

$$\frac{t}{T_N} = \frac{74}{59} = 1.25$$

From Ref. 3, Figure 2.24

For $\frac{R}{F} = 0.24$ and $\frac{t}{T_N} = 1.25$

$\mu = 90$ door fails

It is common practice to limit μ to 6 or less for blast door design.

The same result would be obtained from TM5-1300, Figure 6-7.

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HINGE ANALYSIS

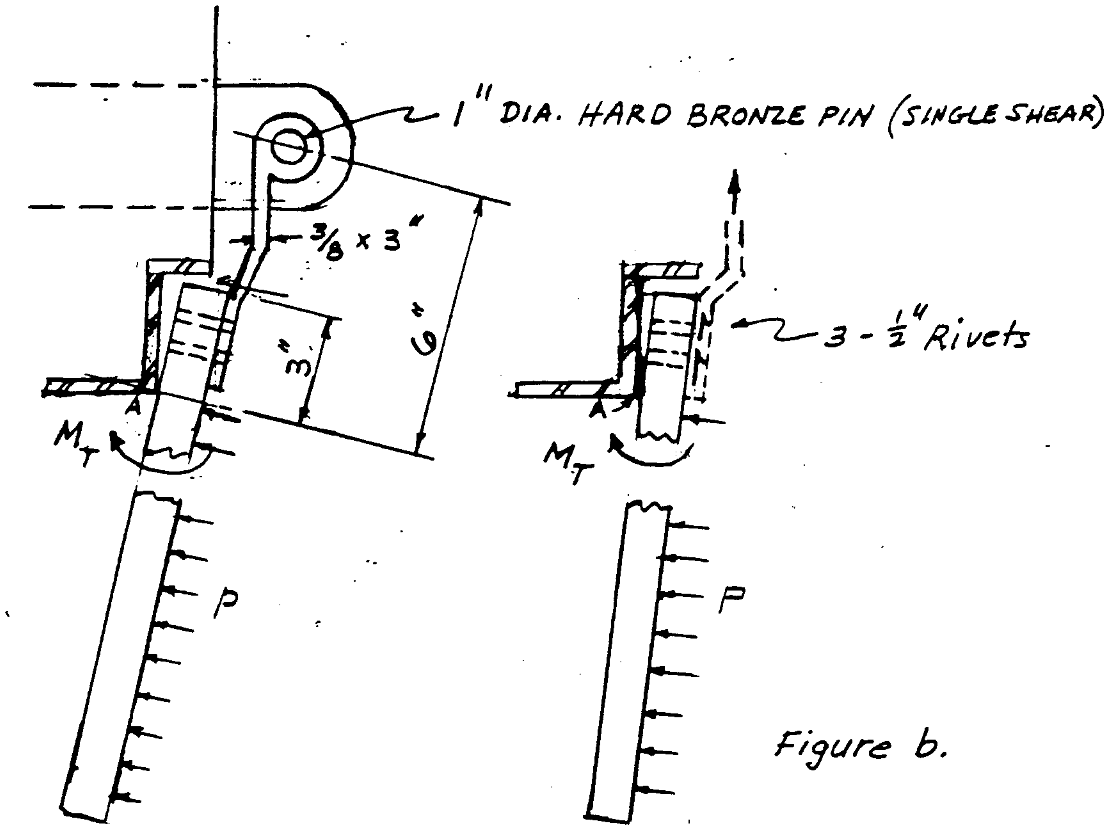

Figure a.   Figure b.

(a) Check Hinge Shear

$F_u = 72{,}000$ psi

$F_v = 0.6 F_u = 43{,}200$ psi

Total Moment per Hinge

$M_T \approx \frac{H}{2}(M_p \text{ from p. 17}) + 47760$

$M_T \approx 45(1663) + 47760 \doteq 122600$ in-lb.

Shear Stress in Hinge

$f_v \approx \frac{M_T}{3 \times .375 \times 3} = 36330$ psi

< 43200

(b) Check 3 - 1/2" Rivets

$F_v = 44000$ psi

$A_r = 0.196$ in.^{2}

Taking moments about A

$f_v = \frac{M_T}{3 \times .196 \times 1.5"}$

$f_v = \frac{122600}{.882}$

$f_v = 139000 \text{ psi} > 44000$

N.G.

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HINGE ANALYSIS CONT'D

As a cantilever, the door with corr. asbestos separator is stronger than two separate plates.

Use $Z_e \approx 0.25 \times$ (Z for two fully effective flange plates connected with a shear web.)

$Z = Ad = 0.1046 \times 1.6046 = 0.168 \text{ in.}^3$

$Z_e \approx 0.25 \times .168 = 0.042 \text{ in}^3$

$M_p \approx Z_e F_{dy} = 0.042 \times 39600 = 1663$ in.-lb./in. width

(c) Check Hard Bronze Pin (1"φ)

$F_u = 75000$ psi

$F_v = 0.6 F_u = 45000$ psi

$A = \frac{\pi d^2}{4} = \frac{\pi (1)^2}{4} = 0.7854 \text{ in.}^2$

Taking moments about A to obtain pin reaction

$P = \frac{M_T}{6} = \frac{122600}{6} = 20400$ lb.

$f_v = \frac{P}{A} = \frac{20400}{0.7854} = 26000 \text{ psi} < 45000 \text{ psi}$

SUBJECT: ANALYSIS OF EXISTING CORBETTA MAGAZINE DOOR	COMPUTED BY: RMW	DATE: OCT 86
	CHECKED BY: EHW	DATE:

HINGE ANALYSIS Cont'd.

(d) Check Hinge for Bending ($M = 3'' \times P = 122400$ in-lb.)

$$Z = \frac{bt^2}{4} = \frac{(3)(.375)^2}{4} = 0.1055 \text{ in.}^3$$

$$M_p = Z F_{dy} = 0.1055(39600) = 4180 \text{ in-lb.} < 122600 \text{ in-lb.}$$

∴ Hinge will yield in bending and go into tension as indicated in Figure b. (p.A16)

(e) Check tensile stress in hinge

Take moments about point A (p.16)

$$f_t A = \frac{M_T}{1.5''}$$

$$f_t = \frac{122600}{1.5 \times 3 \times .375} = 72700 \text{ psi} > 72{,}000 \text{ psi}$$ Borderline

GENERAL COMMENTS

The analysis of the hinge should only be considered as indicative of its strength, because the hinge load will be influenced by bending and twisting of the door.

Based on this analysis the door will become a missile unless the hinge system is modified.

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	CHECKED BY: EHW	DATE:

ESTIMATE THE RESIDUAL IMPULSE IN EACH DOOR LEAF SUBSEQUENT TO HINGE SYSTEM FAILURE.

(a) For W = 500,000 lb.

Initial impulse = Door height × door width × i_r (psi-sec)

$I_a = 95 \times 35.5 \times 4.764$

$I_a = 16070$ lb.-sec.

(b) For W = 20000 lb.

$I_b = 95 \times 35.5 \times 0.407$

$I_b = 1370$ lb.-sec.

(c) RESIDUAL IMPULSE = (a) − (b)

$I_c = I_a - I_b$

$I_c = 16070 - 1370 = 14700$ lb.-sec.

ESTIMATE THE INITIAL VELOCITY OF THE DOOR LEAF.

DOOR WEIGHT:

TUBES = $2\,[35.5 + 90]\,(.25\ \text{lb/in}) = 63$ lb.

PLATES = $35.5 \times 95 \times (.06\ \#/\text{in}^2) = 202$ lb.

FILLER = $\dfrac{30.5 \times 90}{144} \times (4.2\ \#/\text{ft}^2) = 80$ lb.

345 lb.

SUBJECT: ANALYSIS OF EXISTING CORBETTA MAGAZINE DOOR	COMPUTED BY: RMW	DATE: OCT 86
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VELOCITY Cont'd.

$$V = \frac{I}{M} = \frac{Ig}{W} = \frac{14700 \times 32.2}{345} \quad \left[\frac{lb\text{-}sec \times ft}{lb\text{-}sec^2}\right]$$

$$V = 1372 \text{ ft/sec.}$$

APPENDIX B

COMPUTER RESULTS

```
RUN
SDA42   SECTION PRPERTIES FOR 2 1/2 x 1 1/2 x 11 GA STEEL TUBE

ENTER MATERIAL DENSITY (LB/CUBIC IN)
? .283

ICODE = 0 TO ENTER B,H
ICODE = 1 TO ENTER A,I

ENTER ICODE
? 0

ELEMENTS ARE NUMBERED FROM TOP TO BOTTOM
BOTTOM OF ELEMENT I = TOP OF ELEMENT I+1
ENTER NUMBER OF ELEMENTS, N ABOUT THE      X AXIS
? 3

ENTER B(I),H(I)
? 1.5,.1196
ENTER B(I),H(I)
? .2392,2.2608
ENTER B(I),H(I)
? 1.5,.1196
D =               2.5

ZY =              1.25
YBAR              1.25
C                 1.25
BMAX              1.5
```

A	I_x	S_x	Z_x	WT
.8995833	.7390333	.5912267	.7326944	.2545821

```
DO YOU WANT TO PRINT SECTION PROPERTIES PER INCH WIDTH? NO

ENTER NUMBER OF ELEMENTS, N ABOUT THE      Y AXIS
? 3

ENTER B(I),H(I)
? 2.5,.1196
ENTER B(I),H(I)
? .2392,1.2608
ENTER B(I),H(I)
? 2.5,.1196
D =               1.5

ZY =              .7500001
YBAR              .75
C                 .75
BMAX              2.5
```

A	I_y	S_y	Z_y	WT
.8995833	.3255358	.4340477	.5077987	.2545821


```
DO YOU WANT TO PRINT SECTION PROPERTIES PER INCH WIDTH? NO
```

```
RUN
SDA42   SECTION PRPERTIES FOR BEAM "A" (COMPOSITE)

ENTER MATERIAL DENSITY (LB/CUBIC IN)
? .283

ICODE = 0 TO ENTER B,H
ICODE = 1 TO ENTER A,I

ENTER ICODE
? 0

ELEMENTS ARE NUMBERED FROM TOP TO BOTTOM
BOTTOM OF ELEMENT I = TOP OF ELEMENT I+1
ENTER NUMBER OF ELEMENTS, N
? 4

ENTER B(I),H(I)
? 1.709,.1196
ENTER B(I),H(I)
? .4484,2.2608
ENTER B(I),H(I)
? 1.709,.1196
ENTER B(I),H(I)
? .209,1.66
D =              4.16

ZY =             1.636864
YBAR             1.657824
C                2.502176
BMAX             1.709

    A              Ix            Sx           Zx            WT
 1.769476       2.297732      .9182934     1.714038      .5007615


DO YOU WANT TO PRINT SECTION PROPERTIES PER INCH WIDTH? N

ENTER NUMBER OF ELEMENTS, N
? 5

ENTER B(I),H(I)
? 4.16,.1046
ENTER B(I),H(I)
? 2.5,.1196
ENTER B(I),H(I)
? .2392,1.2608
ENTER B(I),H(I)
? 2.5,.1196
ENTER B(I),H(I)
? 4.16,.1046
D =              1.7092

ZY =             .8545999
YBAR             .8545999
C                .8545999
BMAX             4.16

    A              Iy            Sy           Zy            WT
 1.769855       .8865106      1.03734      1.206018      .5008691
```

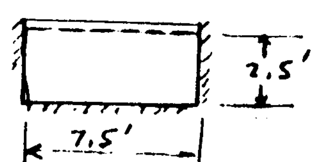
PRELIMINARY
W=20000 lb.

CORDOOR Data Format

FILENAME - CORDOOR

	HEADING (JOB DESCRIPTION)							
Line 1	STEEL DOOR - CORBETTA MAGAZINE							
	OPTIONS							
	FLAG1 0 = Analyze 1 = Optimize	FLAG2 0 = Calc. Blast Load 1 = Input p-t History	FLAG3 0 = Input Door TS 1 = Input Door Z	FLAG4 0 = Omit Grid 1 = Calculate Grid	FLAG5 0 = No Opening in Door 1 = Opening in Door	PC 0 = Standard Printout 1 = Print Response-Time History		COST $/lb (Default = 0.60)
Line 2	0	1	1	0	0	1		0
	WLB lb	ANUM (Default = 1.0)	BLOD (Default = 1.0)	CASE	APAMB, psia (Default = 14.69)	TAMB, °C (Default = 20.0)	ALTKFT 10^3 ft	
If FLAG2 = 0, Line 3 a								
	RA ft	H ft	HL ft	HLIT ft	WLIT ft	AV ft^3	AC ft^2	ICODE F R L R
If FLAG2 = 0, Line 4a 3b								
	TOTIM psi-msec	H ft	HL ft	PRES psi	TO msec	PO psi	TC msec	ICODE F R L R
If FLAG2 = 1, Line 4b 3	407	2.5	7.5	11	74.0	0	0	0 0 0 0
	FDY psi	TS in.	BN	BH ft	BHL, ft If ≠ HL	N	E, psi (Default = 29,000,000)	
Line 5 4	39600	.2092	4	2.5	7.5	10	0	
	ZHOR $in.^3/in.$	ZVERT $in.^3/in.$	IAVG $in.^4/in.$	WDR lb				
If FLAG3 = 1, Line 6 5	.00548	.00548	.000191	300				
	H2 ft	WT ft	D ft	RRA lb/in.	RD1 psi	H1 ft		
If FLAG5 = 1, Line 7								

NOTE: For time-sharing applications, all entries (including 0) must be made for each required line of data.
Optimization cannot be used if FLAG3 = 1 or FLAG5 = 1.
Door and wall are synonymous when BN = 5 and BHL = HL.
FLAG5 = 1 can only be used when BN = 2, 3, or 4.



B3 OF 6

```
HLIB*COED CORDOOR
E>P *

 STEEL DOOR FOR CORBETTA MAGAZINE
    0.0000       1.0000       1.0000       0.0000       0.0000
    0.0000       0.0000
    407.0        2.5000       7.5000       11.000       74.000
    0.0000       0.0000            0            0            0            0
    39600.       0.20920      4.0000       0.0000       0.0000
    20.000       0.0000
   5.48000E-03   5.48000E-03  1.91000E-04   300.0
EOT..
E>FIL
CORDOOR   EDITED
OK
CSDOOR
```

*******************CAUTION*******************

THIS PROGRAM SHOULD BE USED ONLY BY ENGINEERS
WHO ARE EXPERIENCED IN BLAST DESIGN AND ARE
THOROUGHLY FAMILIAR WITH METHODS OF ANALYSIS
DESCRIBED IN TM 5-1300STRUCTURES TO RESIST
THE EFFECTS OF ACCIDENTAL EXPLOSIONS.CONNECTIONS
AND DETAILS MUST BE CAREFULLY DESIGNED TO ACHIEVE
THE DEGREE OF FIXITY THAT IS ASSUMED IN THE PROGRAM

*******************CAUTION*******************

INPUT NAME OF DATA FILE IN 7 CHARACTERS OR LESS
HIT A CARRIAGE RETURN IF DATA TO COME FROM TERMINAL.
CORDOOR

INPUT NAME OF FILE FOR OUTPUT TO BE WRITTEN TO.
HIT A CARRIAGE RETURN IF OUTPUT TO TERMINAL

1

STEEL DOOR FOR CORBETTA MAGAZINE

BLAST WALL HEIGHT	2.50	FT
BLAST WALL LENGTH	7.50	FT
DURATION OF SHOCK PULSE	74.00000	MSEC
FICTITIOUS PEAK SHOCK PRESSURE	11.00	PSI
EFFECTIVE IMPULSE	407.00	PSI-MSEC
FS DYNAMIC	39600.00	PSI
PLATE THICKNESS	0.21	IN
SUPPORT CODE	4.00	
DOOR HEIGHT	0.00	FT
DOOR LENGTH	0.00	FT
PLASTICITY (MU)	20.00	
HORIZONTAL Z	0.01	IN3/IN
VERTICAL Z	0.01	IN3/IN
I AVERAGE	0.00	IN4/IN
DOOR WEIGHT	300.00	LBS

HEIGHT	30.00	IN	LENGTH	90.00 IN

POSITIVE VERTICAL MOMENT	217.01	IN-LBS/IN WIDTH
NEGATIVE VERTICAL MOMENT	217.01	IN-LBS/IN WIDTH
POSITIVE HORIZONTAL MOMENT	217.01	IN-LBS/IN WIDTH
NEGATIVE HORIZONTAL MOMENT	217.01	IN-LBS/IN WIDTH

SUPPORT ON 4 SIDES

YIELD LINE X FROM SIDE

LOCATION YIELD LINE LENGTH	20.49	IN
LOCATION YIELD LINE HEIGHT	15.00	IN
ULTIMATE LOAD CAPACITY RU	5.1671	PSI
SHEAR LOAD AT HORIZ SUPPORT	63.54	LB/IN WIDTH
SHEAR LOAD AT VERTICAL SUPPORT	64.77	LB/IN WIDTH

LOAD MASS FACTOR	0.6909	
MASS	198.68	LB-MSEC2/IN/IN2

FIRST YIELD POINT AT PT3

ELASTIC LIMIT RE PSI	2.90	
ELASTIC DEFLECTION XE	0.9903	IN

SECOND YIELD AT PT 2

ELASTO PLASTIC LIMIT	3.80	PSI
ELASTO-PLASTIC DEFLECTION	1.3027	IN
ULTIMATE RESISTANCE	5.17	PSI
PLASTIC DEFLECTION	3.4881	IN

ULTIMATE RESISTANCE RU	5.17	PSI
ELASTIC DEFLECTION LIMIT XE	2.2218	IN
STIFFNESS KE	2.33	LB/IN/IN2
ALLOWABLE MAX DEFLECTION	44.4356	IN

MASS	198.681	LB-MSEC2/IN/IN2
LOAD	11.000	PSI
DURATION	74.000	MSEC
RESISTANCE	5.167	PSI
STIFFNESS	2.326	LB/IN/IN2
GAS PRESSURE	0.00	PSI
DURATION	0.00	MSEC

MEMBRANE YIELD DEFLECTION	0.949114	IN
ELASTIC DEFLECTION LIMIT	2.221781	IN
MAXIMUM DEFLECTION	42.423107	IN
NATURAL PERIOD	58.074247	MSEC
TIME TO MAXIMUM DEFLECTION	84.745488	MSEC

DURATION/NATURAL PERIOD	1.274231
LOAD/RESISTANCE	2.128847
CALCULATED DIF FOR FDY	1.353249
TIME TO YIELD	9.41616531 MSEC

STOP