Part I
Metallic Repair Structural Repair for Engineers - Part I

/

99 12 5 -19
100 3 11

列印

提 要 表

系統識別號：	C09904447
計畫名稱：	波音公司飛機結構修理訓練「Structures - Metallic Repair: Structural Repair for Engineers - Part I」
報告名稱：	波音公司飛機結構修理訓練「Structures - Metallic Repair: Structural Repair for Engineers - Part I」
計畫主辦機關：	交通部民用航空局

出國人員：	姓名	服務機關	服務單位	職稱	官職等	E-MAIL 信箱
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前往地區：	美國
參訪機關：	波音公司訓練中心
出國類別：	實習
出國期間：	民國99年12月05日 至 民國99年12月19日
報告日期：	民國100年03月11日
關鍵詞：	結構修理、結構分析
報告書頁數：	63頁
報告內容摘要：	報告內容在說明本次參加美國波音公司飛機結構修理訓練課程：「Metallic Repair Structural Repair for Engineers - Part I」之課程重點。報告從飛機結構設計考量、結構修理對飛機氣動力之影響、飛機結構負載、飛機結構修理材料選用、結構修理用扣件選用、飛機搭接結構分析、修理方法之耐用性及飛機結構修理設計要求等方面進行說明。
電子全文檔：	C09904447_01.pdf
出國報告審核表：	C09904447_A.doc
限閱與否：	否
專責人員姓名：	陳碧雲
專責人員電話：	02-23496197

列印

Part I　　　　　Metallic

Repair Structural Repair for Engineers - Part I

12	12	12
5	6-17	18-19

2010/Dec/06
- Class Introduction
- Design Considerations
- Aerodynamic Forces
- External Loads and Structure
- Internal Loads and Load Paths

2010/Dec/07
- Internal Loads and Load Paths
- Materials and Processes
- Fasteners

2010/Dec/08
- Shear Joints
- Class Problems – Joints

2010/Dec/09
- Shear Joints
- Class Problems – Joints
- Shims, Plugs

2010/Dec/10
- Field Trip (Boeing Everret Factory)

2010/Dec/13
- Corrosion Protection
- Fatigue Design Requirements
- Class Problems – Fatigue
- Repair Design Concepts

2010/Dec/14	● Shear Beam Design
	● Chord Repair
	● Class Problem – Stringer Repair Review
2010/Dec/15	● Examination #1
	● Class Problems – Chord Repairs
	● Class Problems – Floor Beam
2010/Dec/16	● Class Problems – Floor Beam
	● Shear Web Repair
	● Class Problems – Shear Web
2010/Dec/17	● Examination #2

Part I

（ ）

（ ）

20

30　　　　B777　B737NG

（ ）

60%

(Chemical

Milling)　　　　(Pocket)

（ ）

9~16

(Downtime)

(Lift)　　　(Weight)　　　(Thrust)

(Drag)　　　　　　　　　　　　　　　　　(Aerodynamic

Efficiency)

$$\text{MACH NUMBER (M)} = \frac{\text{TRUE AIRSPEED}}{\substack{\text{SPEED OF SOUND} \\ \text{(AT ALTITUDE)}}}$$

$$\text{AERODYNAMIC EFFICIENCY} = M \times \frac{\text{LIFT}}{\text{DRAG}}$$

AERODYNAMIC EFFICIENCY

L/D　　　　13~18

0.7~0.85

(Patch)

(Internal Patch)

(External Patch)

(　　　　　　　/Pitot Tube)
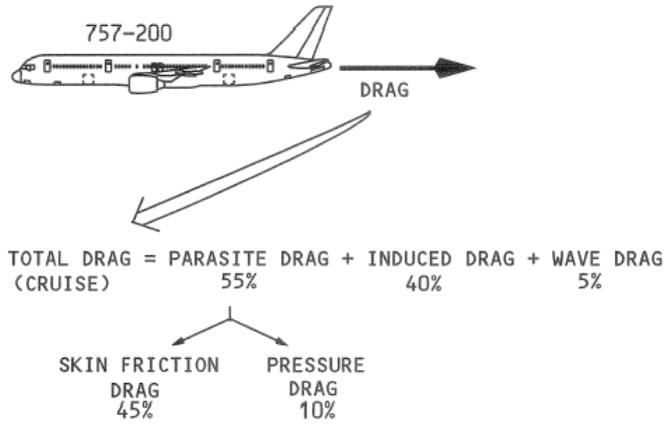
(Parasite Drag)

(Induced Drag)　　　　　(Wave Drag)

（　）　　　　(Parasite Drag)
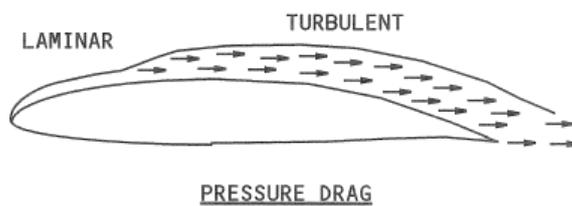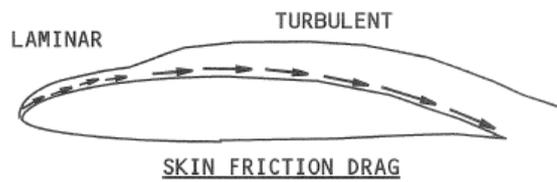
(Boundary Layer)

(Skin Friction Drag)

(Pressure Drag)
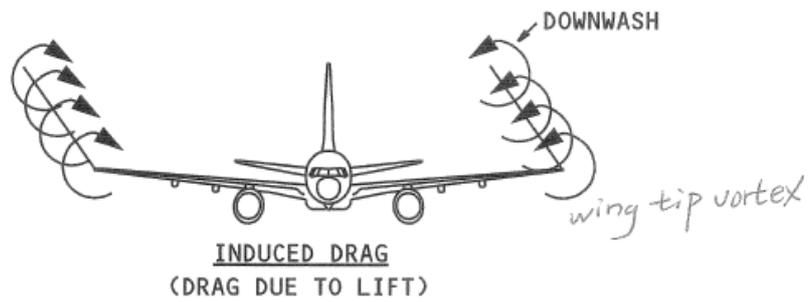
(Form Drag)　　　　　　　　　　　　　(Pressure-Retarding Forces)

( ) (Induced Drag)

(Vortex) (Downwash)

( ) (Wave Drag)

(Shock Waves)

0.7~0.85
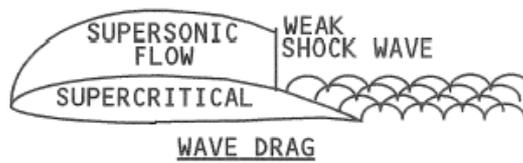
( ) (Excrescence Drag)

(Excrescence Drag) (Gap)

(Air Leak) (

) ( )

3.5~10%　　　　　　　　1

(Chamfer)　　　　(Sealing)

.10" POSITIVE STEP
AIRFLOW
1 UNIT
(BASELINE DRAG)

.10" POSITIVE STEP
45° CHAMFER
AIRFLOW
$\frac{1}{2}$ UNIT

.10" POSITIVE STEP
10:1 TAPER
AIRFLOW
$\frac{1}{17}$ UNIT

BUTT JOINT
NO GAP
AIRFLOW
0 UNIT

EXCRESCENCE DRAG PENALTY FOR STEPS

.04" INTO THE WIND
AIRFLOW
.04"
1 UNIT
(BASELINE DRAG)

.04" OUT OF THE WIND
AIRFLOW
.04"
$\frac{1}{8}$ UNIT

.02" OUT OF THE WIND
AIRFLOW
.02"
$\frac{1}{11}$ UNIT

SEALED FLUSH
AIRFLOW
0 UNIT

EXCRESCENCE DRAG PENALTY FOR GAPS WITH AERODYNAMIC SEALANT

.01" INTO THE WIND
AIRFLOW
.01"
1 UNIT
(BASELINE DRAG)

.01" OUT OF THE WIND
AIRFLOW
.01"
$\frac{1}{2}$ UNIT

INSTALLED FLUSH
AIRFLOW
0 UNIT

EXCRESCENCE DRAG PENALTY FOR FASTENERS

1

(Operating Loads)

FAR 25.301

(Limit Loads)

FAR 25.303   1.5

(Factory of Safety)   (Ultimate Loads)
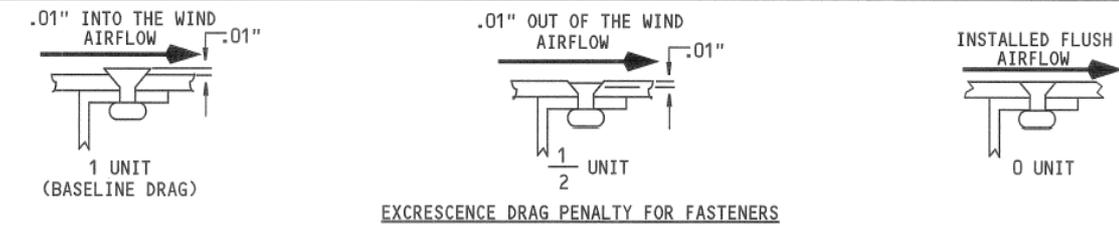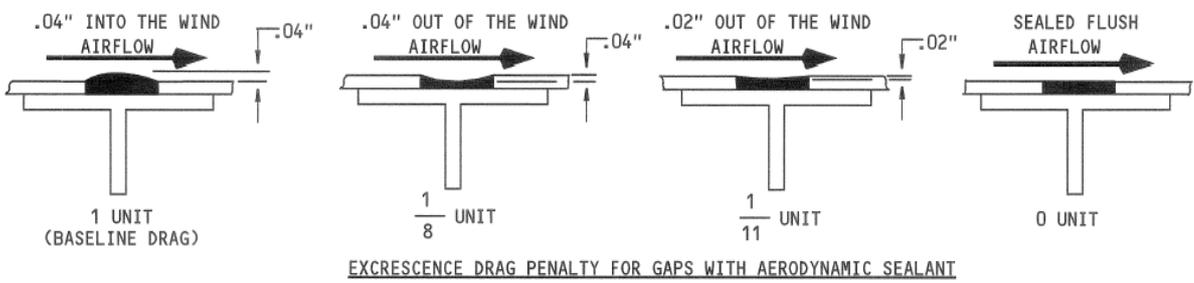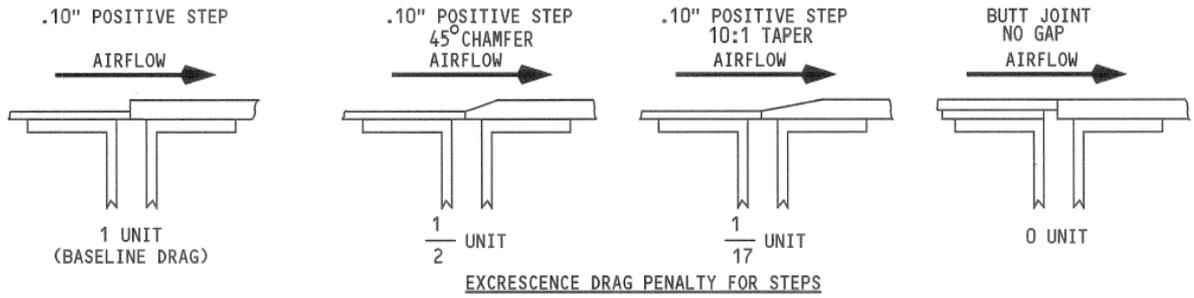
Design Criteria   FAR   FAR

OPERATING LOADS	LIMIT LOADS	ULTIMATE LOADS
• TYPICAL IN-SERVICE LOADS	• MAXIMUM LOAD EXPECTED AS SPECIFIED BY THE FAR	• LIMIT LOAD x Factor of Safety (FAR 25.301)
• FATIGUE LOADS (Damage Tolerance)	• NO PERMANENT DETRIMENTAL DEFORMATION (FAR 25.305) yield	• NO CATASTROPHIC FAILURE (FAR 25.305)
• LOAD FACTOR approx. 1.4g's	• LOAD FACTOR 2.5g's (FAR 25.337)	• LOAD FACTOR APPROX. 3.75g's HOLD LOAD FOR 3 SECONDS (FAR 25.305)
• 2-3 fps SINK SPEED ON LANDING	• 10 fps SINK SPEED ON LANDING (FAR 25.473)	• APPROX. 12 fps SINK SPEED ON LANDING
• ΔP = 8-9 psi Cabin Design	• ΔP = 1.33 x $\Delta P_{Pressure\ Relief\ Valve}$ (FAR 25.365) Limit load	• ΔP = 1.5 x 1.33 x $\Delta P_{Pressure\ Relief\ Valve}$ Ultimate load

LOAD CATEGORIES AND CHARACTERISTICS   (static testing)

2

( )　　　　　　(Wing Loads)

　　　　–　　　(Wing Box)

　　(　　　　　/Stiffener)

　　　(Compression)　　　　　　　　　　　　　(Tension)

WING BOX, END VIEW
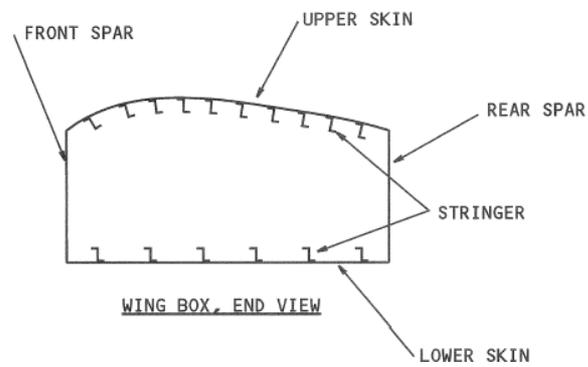
( )　　　　　(Fuselage Loads)

　　　　(Pitching Moment)

　　　　　　　(Payloads)

FUSELAGE LOADS

13
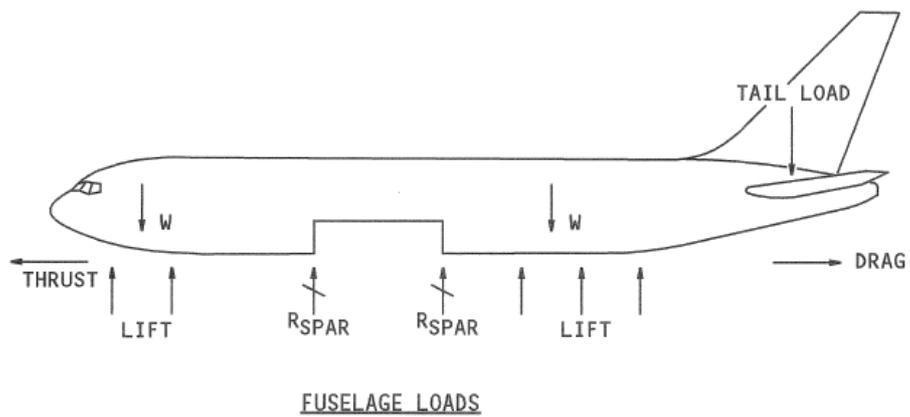
(Fuselage

Skin)　　　　(Stringer)/　　(Longeron)　　　　(Frame)

　　(Bulkhead)

1.　　　　(Fuselage Skin)

2.　　　　(Stringer)/　　(Longeron)

3.　　　　(Frame)

4.　　　　(Bulkhead)

　　　　　(Payloads)　　　　　　　(Floor Beam)

　　　　Shear Tie

　　3

　　4　　　　　B747

Stringer　　Skin　　　(Load Chart)

TYPICAL FUSELAGE CROSS SECTION
(FRAME NOT SHOWN)

FUSELAGE SKIN

TYPICAL LOWER LOBE CONSTRUCTION
DETAIL I

TYPICAL BODY FRAME

LOADS - FUSELAGE - INTERNAL
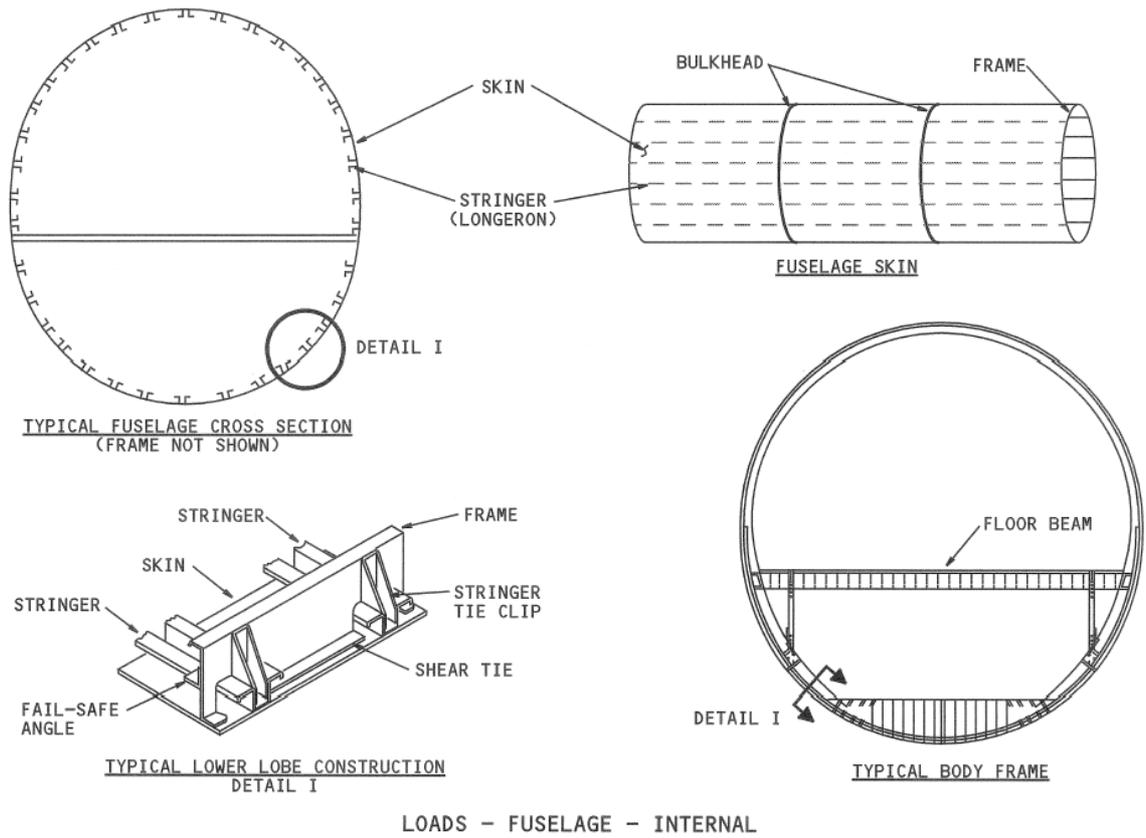
3

( )   (Empennage Loads)

        (Tension)   (Compression)

LOADS — DESIGN CRITERIA
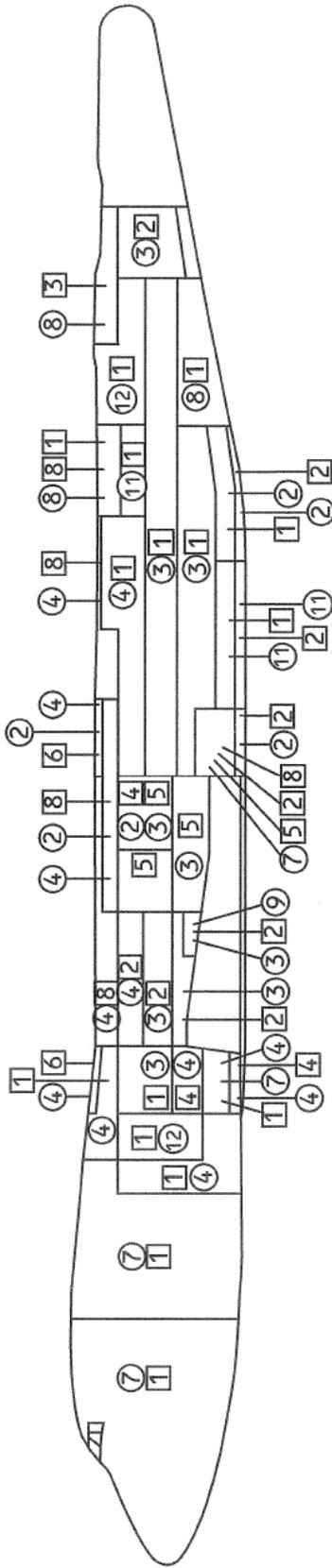
1. HOOP TENSION
   (18 psi diff. pressure at ultimate)

2. FLAPS DOWN MANEUVER
   (N = 3.0)(CRIT @ MAX LANDING WT)

3. ENGINE OUT (N = 1.5)
   (RUDDER MANEUVER)(CRIT @ MAX GW)

4. POS MANEUVER (N = 3.75)
   (CRIT FROM MAX OEW TO MAX GW)

5. 90 DEGREE GEAR TOW (CRIT @ MAX GW)

6. SKIN WORKS WITH STIFFENER AS
   BENDING MATERIAL

7. STIFFENER DESIGNED TO STABILIZE SKIN

8. INSTANT ELEVATOR
   (CRIT @ MAX GW)(NEG TAIL LOAD)

9. 4 POINT BRAKED ROLL (CRIT @ MAX TAXI WT)

10. 4 POINT LEVEL LANDING

11. INSTANT ELEVATOR
    (CRIT @ MAX GW)(POS TAIL LOAD)

12. BRAKED TURN

FUSELAGE CRITICAL LOAD CHART

for skin and stringer

○ STRINGER DESIGN CONDITION
☐ SKIN DESIGN CONDITION
▭ BOTH SKIN AND STRINGER

4 B747 Stringer   Skin   (Load Chart)

（ ）

80%

2XXX   (2024)

(Fracture Toughness)

7XXX

(Anodizing)

(Chemical Conversion Coating)

(Solution Heat Treatment)

(Age Hardening)   "T"

5

(Static Strength)   (Yield Strength)/Fty

(Ultimate Strength)/Fu

EXAMPLE: -T6   5   1   1

STANDARD HEAT TREATED
DESIGNATION

TEMPER DESIGNATION

-T3: Solution heat-treated, cold worked, and naturally aged to a substantially stable condition. Applies to products which are cold worked to improve strength after solution heat-treatment.

-T4: Solution heat-treated and naturally aged to a substantially stable condition. Applies to products which are not cold worked after solution heat-treatment.

-T42: Solution heat-treated and naturally aged by the user. Applies to 2024-0 and 6061-0. *(formed and heat treated)*

-T6: Solution heat-treated and artificially aged. Applies to products which are not cold worked after solution heat-treatment.

-T62: Solution heat-treated and artificially aged by user. Applies to a number of alloys such as 2024, 6061, and 7075 which have been heat-treated and aged by the user.

-T73: Solution heat-treated and overaged. This temper applies to several 7000 series alloys and indicates a greater degree of overaging required for higher stress *improve from T6* corrosion resistance. Material in this temper is also immune to exfoliation corrosion. As applied to the 7075 or 7175 alloys, the -T73 temper is virtually immune to stress corrosion.

INDICATES MINOR STRAIGHTENING USE TO MEET STRAIGHTNESS AND FLATNESS TOLERANCES. THIS DIGIT IS A 0 IF NO STRAIGHTENING IS ALLOWED.

MATERIAL WAS STRETCHED TO ACCOMPLISH STRESS RELIEF. THE DIGIT 2 WOULD BE USED HERE WHEN COMPRESSIVE METHODS ARE USED.

A "5" INDICATES THE MATERIAL HAS BEEN STRESS RELIEVED

A "2" INDICATES THE MATERIAL HAS BEEN HEAT TREATED BY THE USER, TYPICALLY AFTER FORMING

MATERIALS - ALUMINUM ALLOY HEAT TREATMENT

"T"

5

-

(Limit Loads)

FAR 25.303   1.5

(Factory of Safety)(=1.5Fty)   (Ultimate

Loads)   (Ultimate Strength)/Fu

(Design

Ultimate Stress)/Fdu
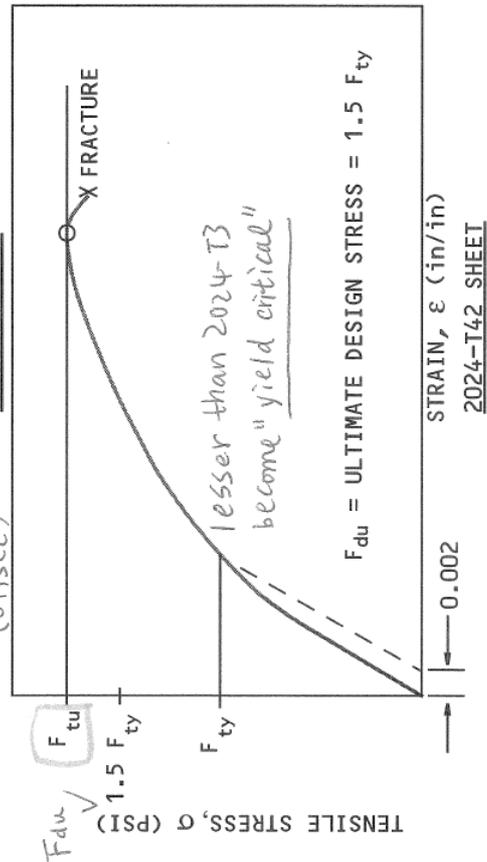
6

(Statistical Basis)   A, B, S   A-Basis

95%   99%(   )

B-Basis   95%

90%(   )   S-Basis

(   )   FAR 25.613

(   )

B-Basis   A-Basis

A-Basis

B-Basis   7   A, B

(Statistical Basis)
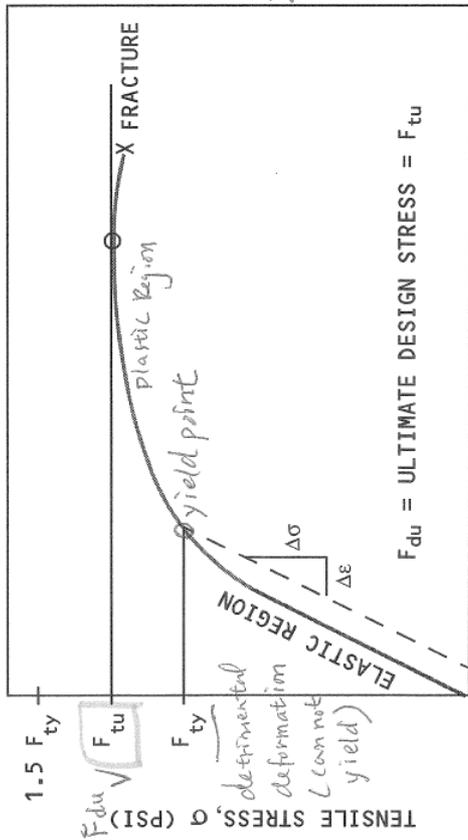
MATERIALS – STATIC STRENGTH

F_{ty} = MATERIAL YIELD STRENGTH AT 0.002in/in PERMANENT ELONGATION

F_{tu} = MATERIAL ULTIMATE STRENGTH

F_{du} = ULTIMATE DESIGN STRESS = LESSER OF F_{tu} OR (1.5 × F_{ty})

L_o = ORIGINAL LENGTH

L_f = FINAL LENGTH

STRAIN, $\varepsilon = \dfrac{L_f - L_o}{L_o}$

STRESS, $\sigma = \dfrac{P}{A_o}$

E = MODULUS OF ELASTICITY = $\dfrac{\Delta\sigma}{\Delta\varepsilon}$ (ELASTIC REGION) (stiffness)

L_o = 1.0 in
L_f = 1.002 in
At F_{ty}
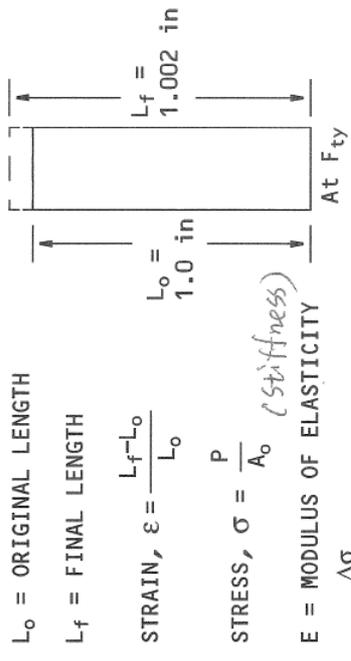
* Margin of Safety (MS)

$\left(\dfrac{F_{du}}{F_{tu-applied}} - 1\right) \times 100\%$
or
$\left(\dfrac{P_{allow}}{P_{applied}} - 1\right) \times 100\%$

* 全为标记为计算值

2024-T3 SHEET

X FRACTURE
plastic region
yield point
$\Delta\sigma$ / $\Delta\varepsilon$
ELASTIC REGION
detrimental deformation (can not yield)

F_{du} = ULTIMATE DESIGN STRESS = F_{tu}

0.002 (offset)

STRAIN, ε (in/in)

TENSILE STRESS, σ (PSI)

1.5 F_{ty}
F_{du} F_{tu}
F_{ty}

2024-T42 SHEET

X FRACTURE
lesser than 2024-T3 become "yield critical"

F_{du} = ULTIMATE DESIGN STRESS = 1.5 F_{ty}

0.002

STRAIN, ε (in/in)

TENSILE STRESS, σ (PSI)

F_{du} F_{tu}
1.5 F_{ty}
F_{ty}

Statistical Basis of Mechanical Properties

Aircraft Structural Repair for Engineers, Part I   LIFECYCLE

7   A, B   (Statistical Basis)
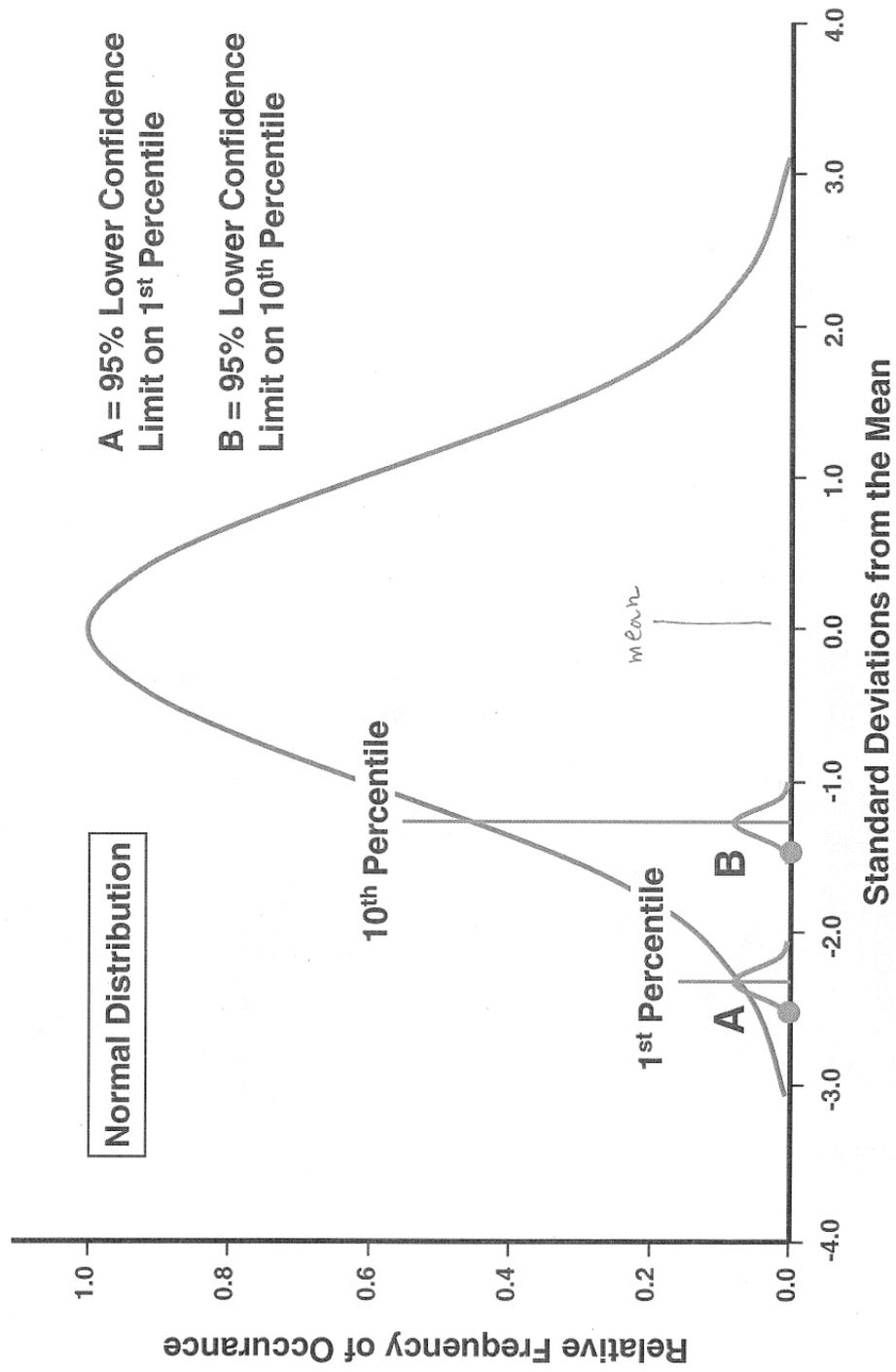
(Edge

Margin, e)   e/D

                                          e/D=2.0   =2.0D ±

0.05 inches   e/D

     1.7   2D

0.05 inches

                         (Grain)

                                                        L

          (Longitudinal Direction)   LT

          (Long Transverse Direction)   ST

(Short Transverse Direction)   8

GRAIN DIRECTIONS OF PRODUCT FORMS

                         8

(Fasteners)

(Load
Transfer)

(   )

(9)

BACR15BB8D8

10

NAS 523 FASTENER SYMBOL CODE

INSTALLATION: STD PER BAC 5004, FLUID TIGHT PER BAC 5047, TAPER SHANK PER BAC 5054

TAPER SHANK BOLT INFO ——

BASIC THREE-LETTER CODE——
ENCLOSED = FLUID TIGHT
OPEN = STANDARD
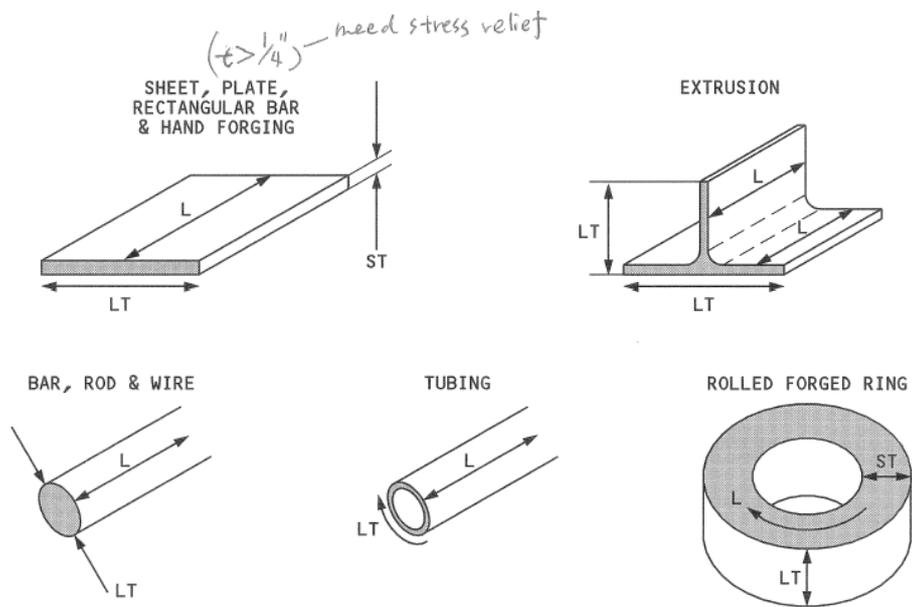
countersink

DIMPLE/C'SINK INFO ——
D = DIMPLE
X = NUMBER OF SHEETS DIMPLED
C = COUNTERSINK IN STRUCTURE

XX

XXX   X X

DX/C   X W

—— DIAMETER DASH NO. (1/32nd inch for
          permanent fasteners)

—— MANUFACTURED HEAD LOCATION
   N = NEAR SIDE (depend on view point)
   F = FAR SIDE (from the drawing view)

—— SPOT WELD OPTION

—— LENGTH DASH NO. (1/16th inch)

9

BOEING PART NUMBER PREFIXES

R = Rivet
B = Bolt

BACR15   Rivet
BACB30   Bolt, Lockbolt or Hex-drive (Hi-Lok)
BACC30   Collar
BACN10   Nut or Nutplate
BACW   Washer
BACF   Filler
BACS   Shim or Screw

FULL PART NUMBER FOR RIVETS

BACR15__*_**
__ = Head Style
* = Diameter (1/32")
_ = Material (letter code)
** = Grip Length (1/16")

FULL PART NUMBER FOR BOLTS

BACB30__*_**
__ = Head Style and Material
* = Diameter (1/32")
_ = Finish (letter code)
** = Grip Length (1/16")

10

（　）

(Permanent Fasteners)

(Removable Fasteners)

Tension Head　　Shear Head

(Blind Fasteners)

1.　　　　　　　(Permanent Fasteners)　　　　　　　(Removable

Fasteners)
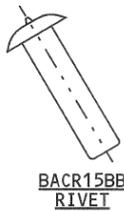
Rivets　Lockbolts

Hex-Drive Bolts (　　Hi-Lok)

(Fatigue or Structural Bolts)　　　11

protruding head
universal head

BACR15BA
RIVET

BACR15BB
RIVET
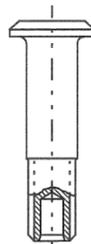
BACB30FM
HEX-DRIVE

BACB30DX
LOCKBOLT
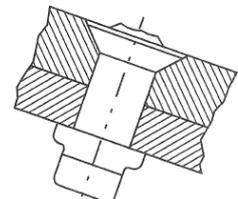
MS 90353
PULL RIVET

PERMANENT FASTENERS
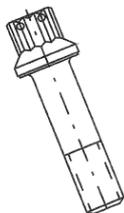
BACB30US
12 PT. TENSION BOLT
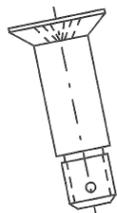
BACB30PC
SHOULDER BOLT
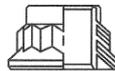
BACN10HR
12 PT. NUT
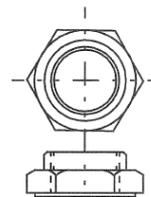
BACN10JC
SELF LOCKING NUT
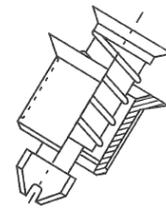
BACS21AE
QUICK-RELEASE SCREW

REMOVABLE FASTENERS

11

2. Tension Head   Shear Head

Shear Head   Shear
Head

Tension Head   Tension Protruding Head

Tension Flush Head   Tension Head

Shear Head   12

SHEAR JOINT

TENSION – PROTRUDING HEAD

SHEAR – PROTRUDING HEAD

TENSION – FLUSH HEAD

SHEAR – FLUSH HEAD

HEX-DRIVE OR HI-LOK

TENSION – FLUSH AND PROTRUDING HEAD

SHEAR – FLUSH AND PROTRUDING HEAD

LOCKBOLTS
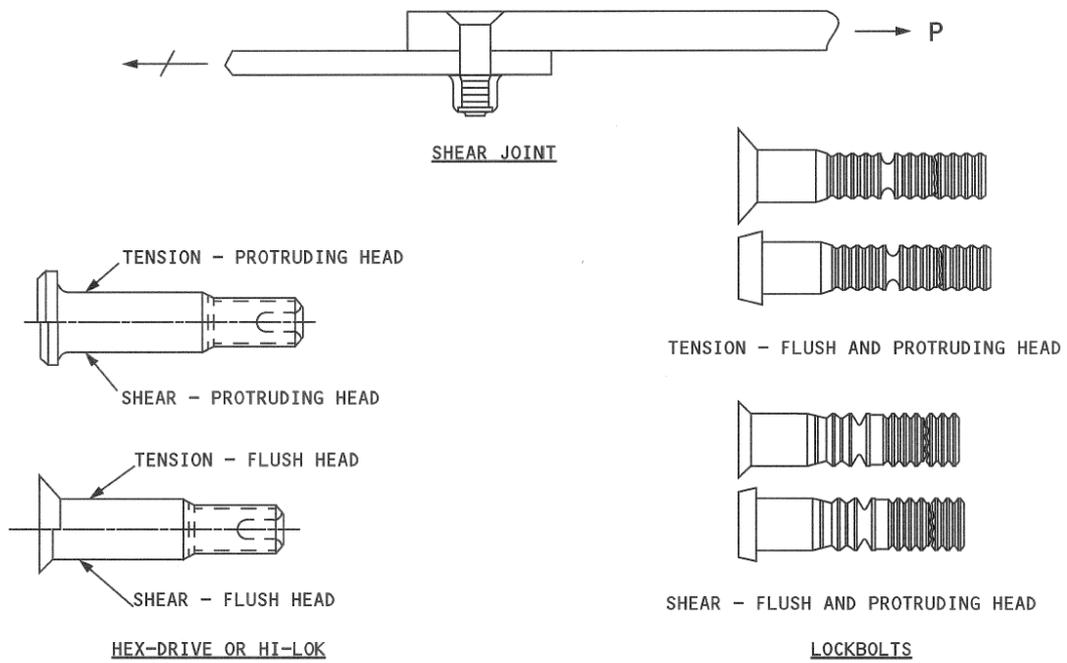
12 Tension Head   Shear Head

3.   (Blind Fastener)

(Blind Bolts)   (Blind Rivets)

(Grip Length)

SRM

(Time-Limited Repair)

(Repetitive Inspection)

(Blind Bolts)   (Blind Rivets)   13

BLIND BOLT INSTALLATION
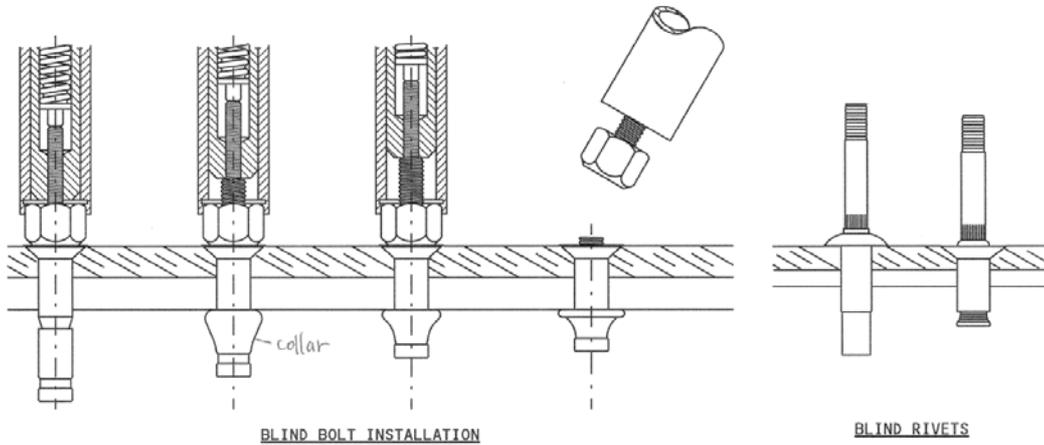
BLIND RIVETS

NOTES: SELECT CORRECT GRIP LENGTH

INSPECTION OF FORMED HEAD REQUIRED

REMOVAL REQUIRES DRILLING OUT
CENTER STEM (DRILL GUIDES AVAILABLE)

13   (Blind Bolts)   (Blind Rivets)

4.   (Hole Fit)

(Clearance

Fit)   (Transition Fit)   (Interference Fit)

(Clearance Fit)   (Shank

Diameter)   Class I, II,

III   Class I

(Removable Fastener) Class I

Class II   Nutplate   Class
III

(Interference Fit)

(Permanent Fasteners)

(Transition Fit)

(Permanent Fasteners)

5.   (Oversize)

(Transition Fit)

(Fatigue Resistance)   14   Hex-Drive Bolt

oversize the shank diameter

PART NUMBER	DESCRIPTION	A	D	H	TD	
BACB3OMY6K	3/16 HEX DRIVE	.295-.315	.1885-.1895	.045-.055	.181-.184	
BACB3OMY6K*X	1/64 OVERSIZE	.295-.315	.2016-.2026	.045-.055	.181-.184	1st Oversize
BACB3OMY6K*Y	1/32 OVERSIZE	.295-.315	.2172-.2182	.045-.055	.181-.184	2nd Oversize

FACTORY FASTENER	REPAIR FASTENER TYPE	TYPICAL REPAIR FASTENER SIZE
RIVET	RIVET	SAME DIAMETER
RIVET	HEX-DRIVE OR LOCKBOLT	1/32 OVERSIZE
HEX-DRIVE OR LOCKBOLT	HEX-DRIVE OR LOCKBOLT	1/64 OVERSIZE.

14   /Hex-Drive Bolt

（ ）

15, 16, 17   Rivet   Lockbolt/Hex Drive Bolt

Rivet   Lockbolt   Hex Drive Bolt

```
                    ┌─────────────────────────────┐
                    │  Rivet vs. Hex-Drive/Lockbolt │
                    └─────────────────────────────┘
                                  │
            ┌─────────────────────┴──────────────────────┐
            │                                             │
┌───────────────────────────────┐   ┌──────────────────────────────────────────┐
│      Rivet Advantages          │   │      Hex-Drive/Lockbolt Advantages        │
│ - Lower cost                   │   │ - Easier to install                       │
│ - Suitable for automation      │   │ - Much higher bolt shear and bolt tensile strength │
│ - No foreign object damage (FOD)│  │ - Higher Joint static strength            │
│ - Wet installation not required│   │ - Greater clamp-up                        │
│   for Al rivets in Al structure│   │ - Greater non-structural shim allowances  │
│ - Slightly longer joint fatigue life│ │ - Greater fixity for compression applications │
│ - Better hole fill (fluid tight)│  │                                           │
│ - Lightweight                  │   │                                           │
└───────────────────────────────┘   └──────────────────────────────────────────┘
```
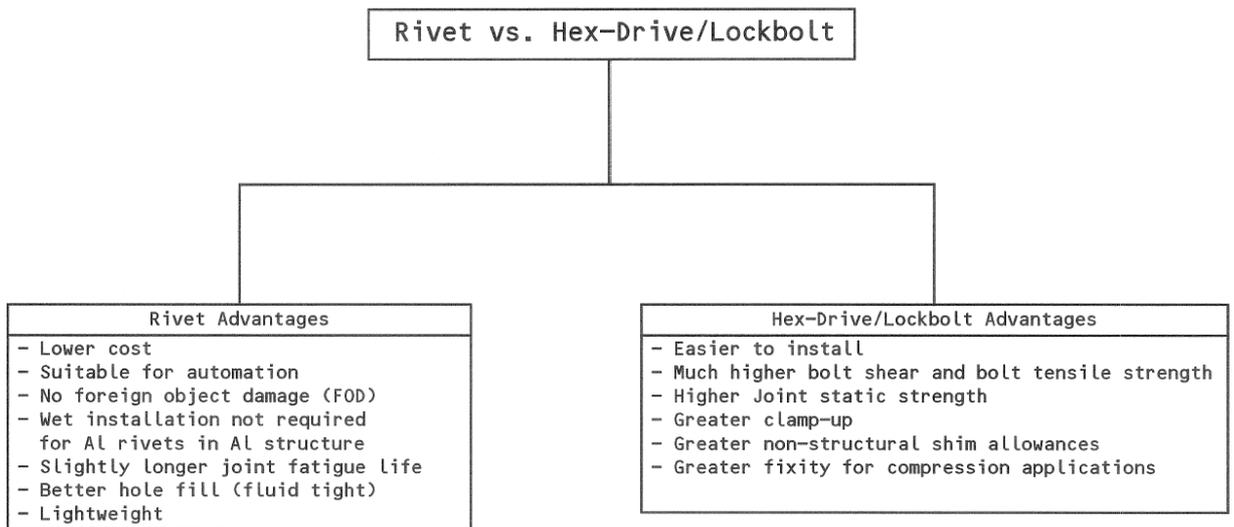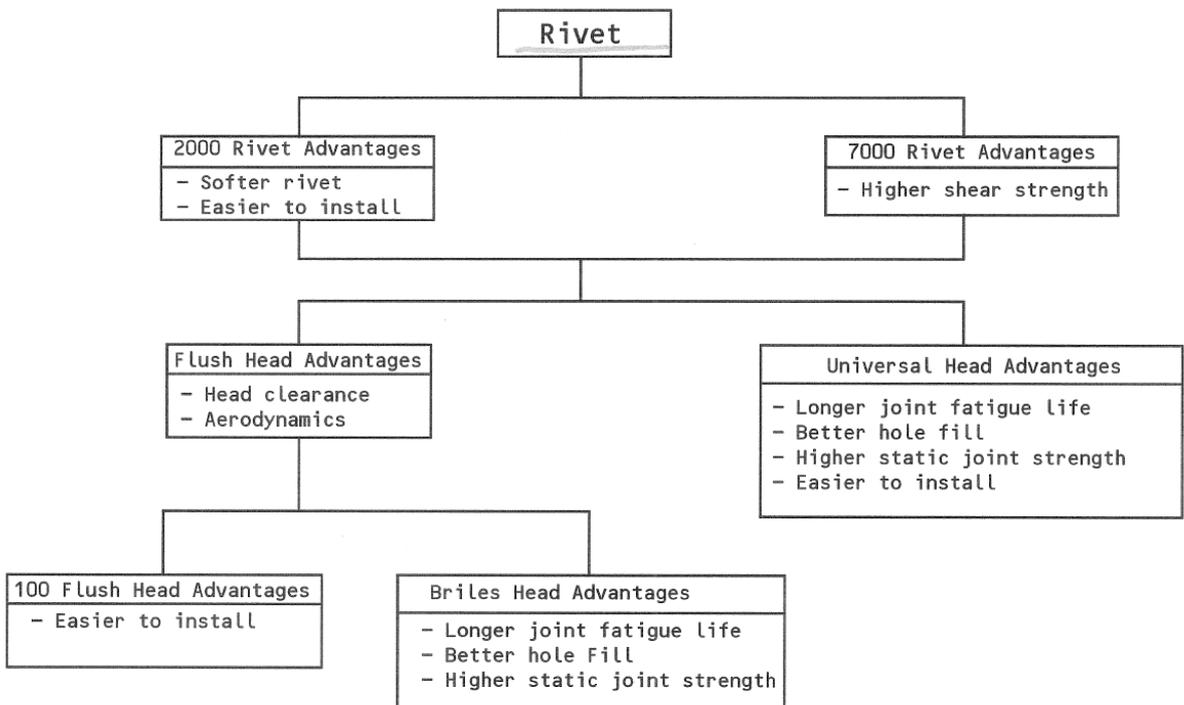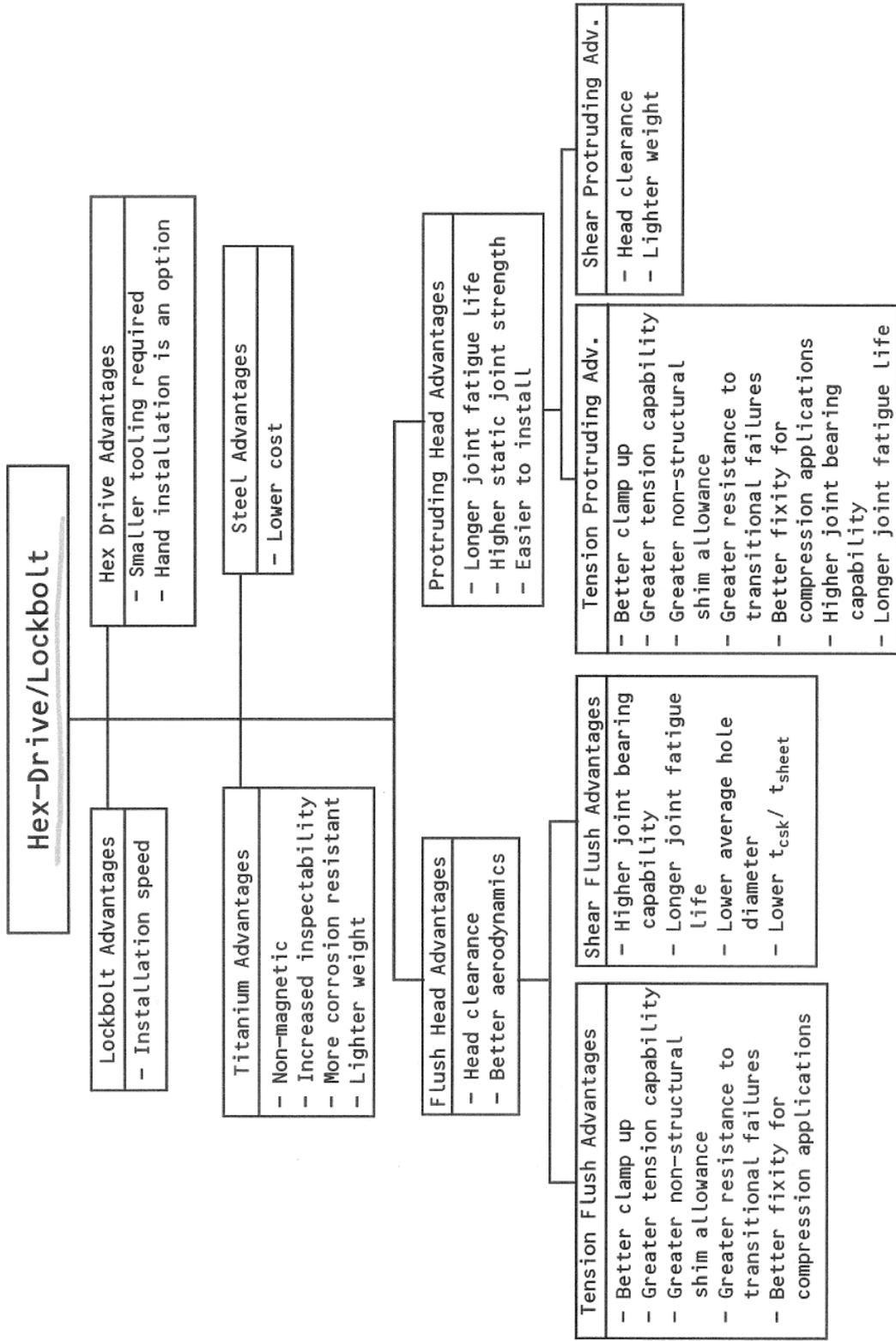
15 Rivet   Lockbolt/Hex Drive Bolt

```
                          ┌──────────┐
                          │  Rivet   │
                          └──────────┘
                                │
          ┌─────────────────────┴──────────────────────┐
┌────────────────────────────┐              ┌────────────────────────────┐
│   2000 Rivet Advantages     │              │   7000 Rivet Advantages     │
│ - Softer rivet              │              │ - Higher shear strength     │
│ - Easier to install         │              │                             │
└────────────────────────────┘              └────────────────────────────┘
                │
        ┌───────┴─────────────────────────────┐
┌────────────────────────────┐       ┌────────────────────────────────┐
│   Flush Head Advantages     │       │   Universal Head Advantages     │
│ - Head clearance            │       │ - Longer joint fatigue life     │
│ - Aerodynamics              │       │ - Better hole fill              │
└────────────────────────────┘       │ - Higher static joint strength  │
        │                            │ - Easier to install             │
   ┌────┴──────────────┐             └────────────────────────────────┘
┌──────────────────────────┐  ┌──────────────────────────────────┐
│ 100 Flush Head Advantages │  │    Briles Head Advantages         │
│ - Easier to install       │  │ - Longer joint fatigue life       │
└──────────────────────────┘  │ - Better hole Fill                │
                              │ - Higher static joint strength    │
                              └──────────────────────────────────┘
```

16 Rivet

Hex-Drive/Lockbolt

Hex Drive Advantages
- Smaller tooling required
- Hand installation is an option

Lockbolt Advantages
- Installation speed

Steel Advantages
- Lower cost

Titanium Advantages
- Non-magnetic
- Increased inspectability
- More corrosion resistant
- Lighter weight

Protruding Head Advantages
- Longer joint fatigue life
- Higher static joint strength
- Easier to install

Shear Protruding Adv.
- Head clearance
- Lighter weight

Tension Protruding Adv.
- Better clamp up
- Greater tension capability
- Greater non-structural shim allowance
- Greater resistance to transitional failures
- Better fixity for compression applications
- Higher joint bearing capability
- Longer joint fatigue life

Flush Head Advantages
- Head clearance
- Better aerodynamics

Shear Flush Advantages
- Higher joint bearing capability
- Longer joint fatigue life
- Lower average hole diameter
- Lower t_{csk}/t_{sheet}

Tension Flush Advantages
- Better clamp up
- Greater tension capability
- Greater non-structural shim allowance
- Greater resistance to transitional failures
- Better fixity for compression applications

JOINTS – FASTENER SELECTION

17 Lockbolt   Hex Drive Bolt

( )

1.   –   (Skin Longitudinal Lap Joint)

15

Finger Doubler

(Non-Eccentric Load Transfer)

(Double Shear)

(Eccentric Load
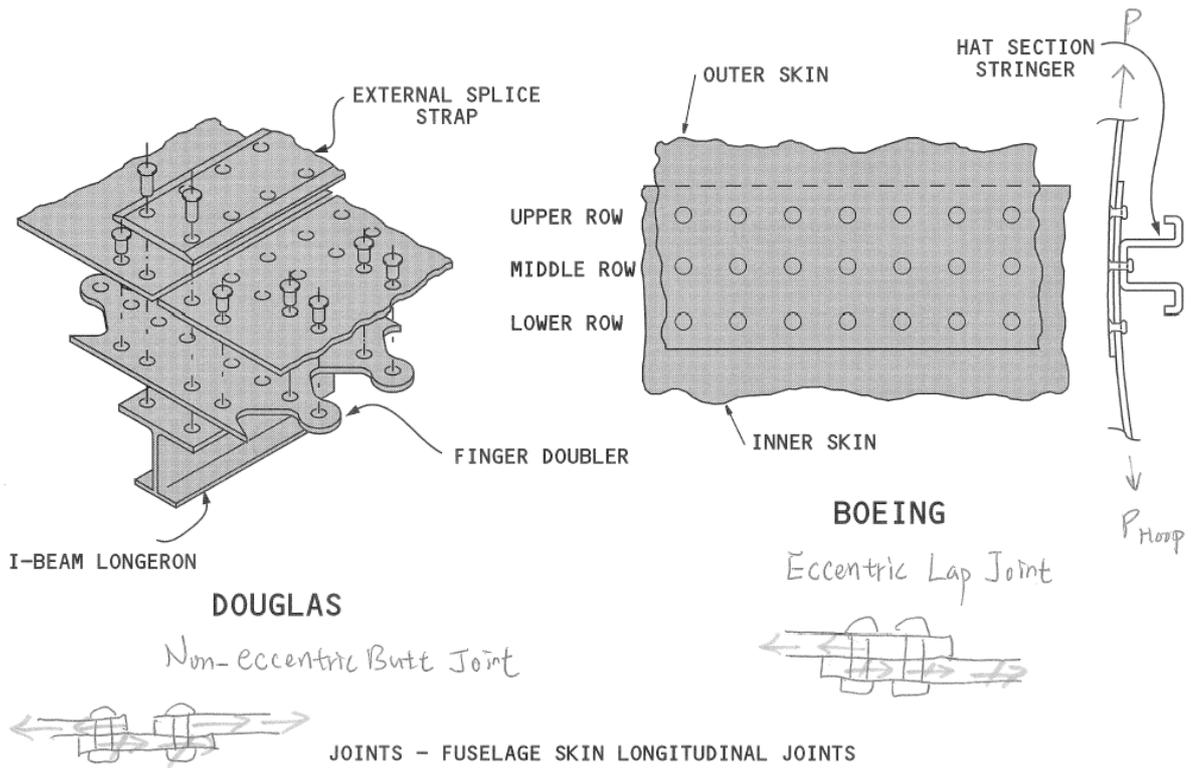
Transfer)   (Single Shear)

18

(Skin Lap Joint)

EXTERNAL SPLICE STRAP

OUTER SKIN

HAT SECTION STRINGER

UPPER ROW

MIDDLE ROW

LOWER ROW

FINGER DOUBLER

INNER SKIN

I-BEAM LONGERON

BOEING

DOUGLAS

Eccentric Lap Joint

Non-eccentric Butt Joint

JOINTS – FUSELAGE SKIN LONGITUDINAL JOINTS

18   (Skin Lap Joint)

2.   –   (Skin Circumferential Joint)

(Skin Butt Joint)   (Internal Splice Plate)

(Stringer)   Splice Fitting

(Bending Moment)

(Crown)   (Tension)

(Keel Beam)   (Compression)

Lockbolt   Hi-Lok

19   (Skin Circumferential Joint)
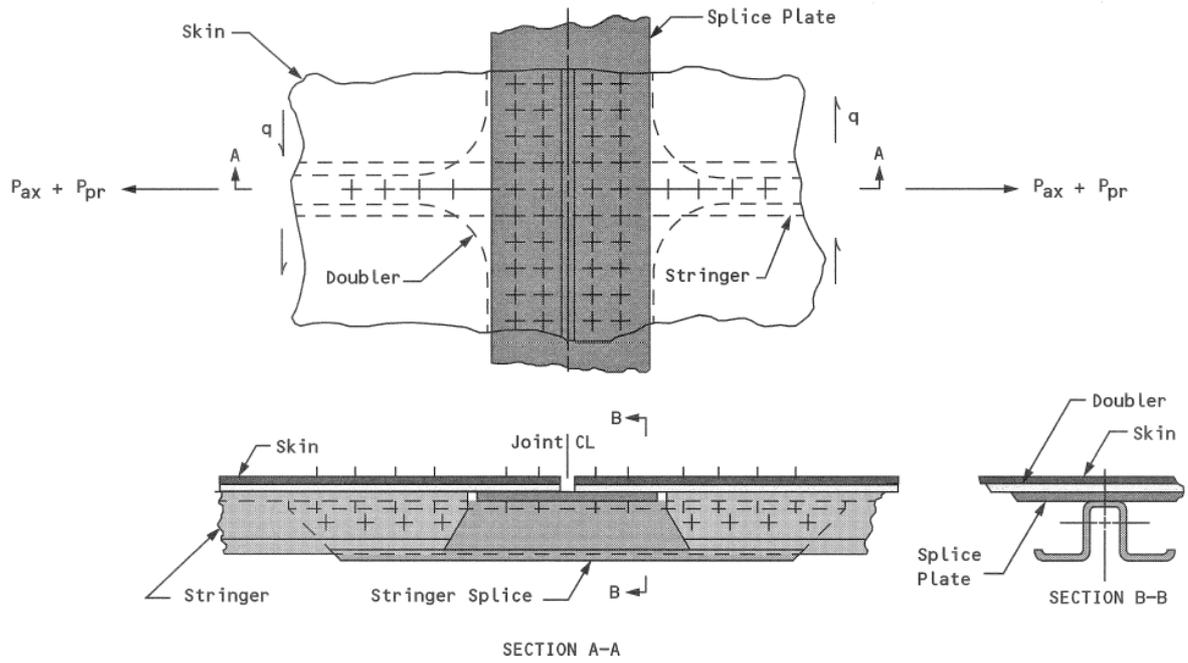
P_{ax} = skin stringer segment load due to body bending, lb.
P_{pr} = skin stringer segment load due to body internal pressure, lb.
 q = shear loading, lb./in.

19   (Skin Circumferential Joint)

3.   –   (Fuselage Frame Joint)

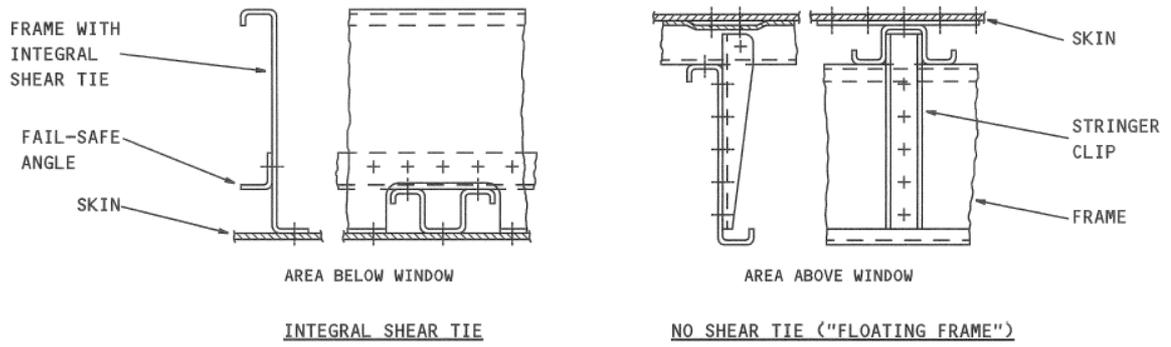   (Fuselage Frame)   Shear Tie

          (Stringer)   Shear Tie

                              Shear Tie   20

              Shear Tie   Shear Tie

                        Structural Clip   Clip   Shear

    Tie

              Integral Shear Tie   Fail-Safe Angle

                    (Hoop Stress)   Shear Tie

    Fuselage Stringer Clip

32

FRAME WITH INTEGRAL SHEAR TIE

FAIL-SAFE ANGLE

SKIN

AREA BELOW WINDOW

INTEGRAL SHEAR TIE

SKIN

STRINGER CLIP

FRAME

AREA ABOVE WINDOW

NO SHEAR TIE ("FLOATING FRAME")

SKIN

TEAR STRAP

SHEAR TIE

FRAME

SEPARATE SHEAR TIE

圖 20   各型 Shear Tie
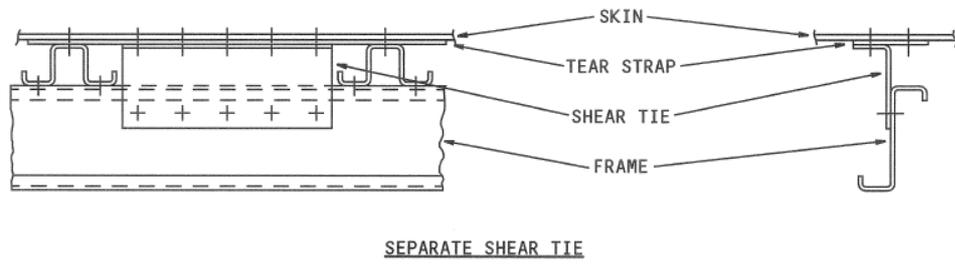
4.   機身框架 – 地板樑接頭 (Fuselage Frame to Floor Beam Joint)

此接頭由 Support Post、Shear Tie 及 Doubler 所組成

圖 21   機身框架 Shear Tie

TYPICAL FRAME AND FLOOR BEAM LOADS

747 FRAME TO FLOOR BEAM JOINT
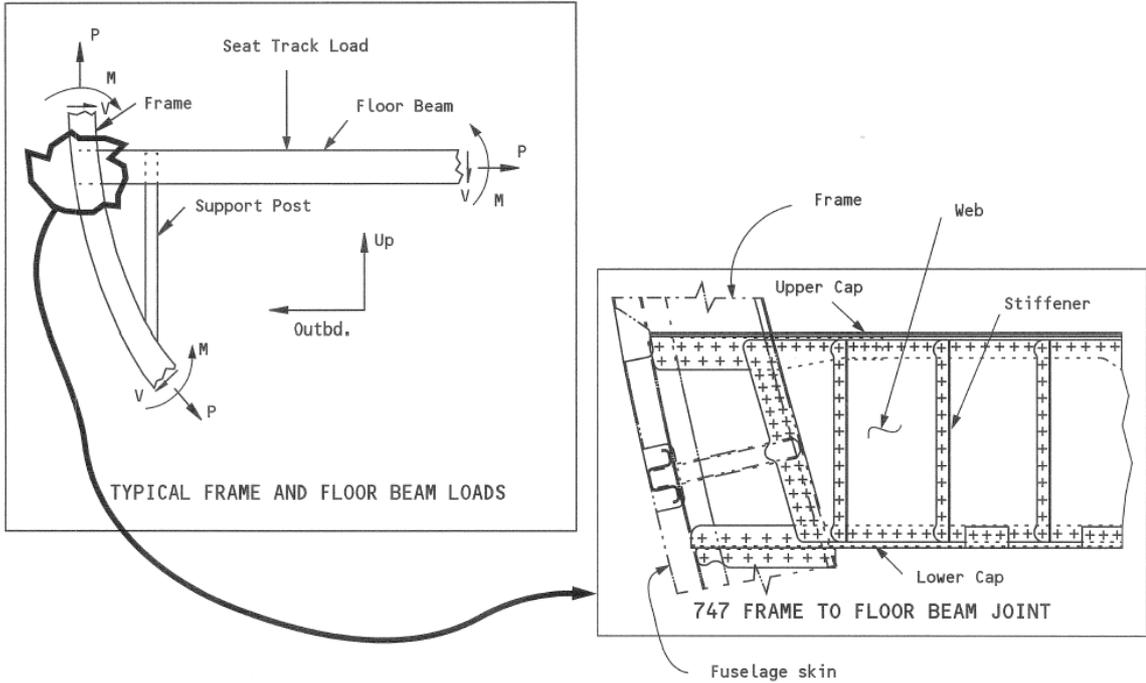
21

5.　　　　　　　　　　　　　　(Wing to Body Joint)

　　　　　　　　　(Fail-Safe)　　　　　　　　　　　　　　　　　(Wing

　　Spar)　　　　　　　　(Fuselage Bulkhead Forgings)

　　　　　　　　　　　　　　Spanwise Loads　　22

　　　　　　(Wing to Body Joint)

6.　　　　　　　　　　　　　(Wing Skin Spanwise Joint)

　　　　　　　　　　(Stringer)

WING FRONT SPAR

WING SPAR TERMINAL FITTING

WING FRONT SPAR

BODY BULKHEAD FITTING

BUSHING

BOTTLE PIN

BOLT SUPPORT

BOTTLE PIN RETAINING BOLT

OBSOLETE DESIGN (707 & 727)

UPPER BODY SKIN

BODY BULKHEAD FITTING

TOP OF WING

WING FRONT SPAR

LOWER LOBE BODY SKIN

CURRENT DESIGN (737 and on)

PIN JOINT LOAD DISTRIBUTION (Obsolete Design)

CONTINUOUS JOINT LOAD DISTRIBUTION (Current Design)

FUSELAGE BULKHEAD TO WING SPAR JOINT

22   (Wing to Body Joint)

( )   (Joint Failure Mode)

Net Tension Failure   Tear Out Failure   Bearing Failure   Fastener Shear Failure

Transitional Failure

(Load Capability)

(Critical Failure Mode)

1. Net Tension Failure

Net Tension Failure (Tension Stress)

23

Net Tension Stress = $f_t = P/[(W-D)t]$
Note: Use average hole diameter for flush head fasteners.

→ Net Tension

$P_{net} = F_{du} \times A_{net}$

P_{net} = Lesser of $(F_{tu} \times A_{net})$ or $(1.5 \times F_{ty} \times A_{net})$

NET TENSION FAILURE

23 Net Tension Failure/

2. Tear Out Failure (Shear Out Failure)

(1.7D)

(Shear Failure)

(shear out)
TEAR OUT FAILURE

due to not enough edge margin

by test

e = edge margin

40°

L

S

two shear out planes

$P_{tearout} = F_{su} \times t \times 2(e - S)$
$P_{tearout} = F_{su} \times t \times (2e - .766D)$

L = EFFECTIVE DISTANCE TO EDGE OF STRUCTURE OR TO NEXT HOLE
t = THICKNESS OF SHEET
S = (DIA/2) x COS 40° = D x .383
Note: Use average hole diameter for flush head fasteners.

D_{head}
D_{avg}
t_1 t_c
t_2
D_{shank}
W

(D_{avg})
* $D_{average}$ values may be found in the Appendix, page 29, 30, 31.
* $A_{Net} = t \times (W - D_{avg})$

24 Net Tension Failure

36

3.　　　Bearing Failure

Bearing Failure

(Hole　Deformation)

(Hole　Elongation)　　　　　　　　　　Bearing

Failure

25

1.7D　　　　　　　Bearing　Failure

SRM　　　2D　　　　0.05 inches
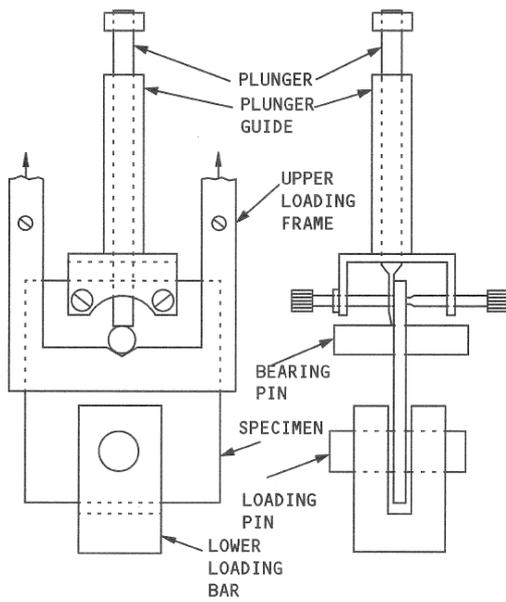
ULTIMATE BEARING FAILURE TEST SETUP

JOINTS — FAILURE MODES — BEARING, SHEAR

FROM MMPDS:

F_{brg} = Bearing Stress = P_{max} / (D x t)

P_{brg} = The lesser of (F_{bru} x D x t)
　　　　　or (1.5 x F_{bry} x D x t)

* In most cases, the above value is greater than actual bearing load, render it to be less conservative. See the HBK or manual for reasonable value.

BEARING FAILURE

25　　　Bearing Failure

4. Fastener Shear Failure(   )

26

Pfs

$P_{fs} = F_{su} \times \pi \times D^2 / 4$

<u>Note</u>: Use fastener shank diameter for all fastener types
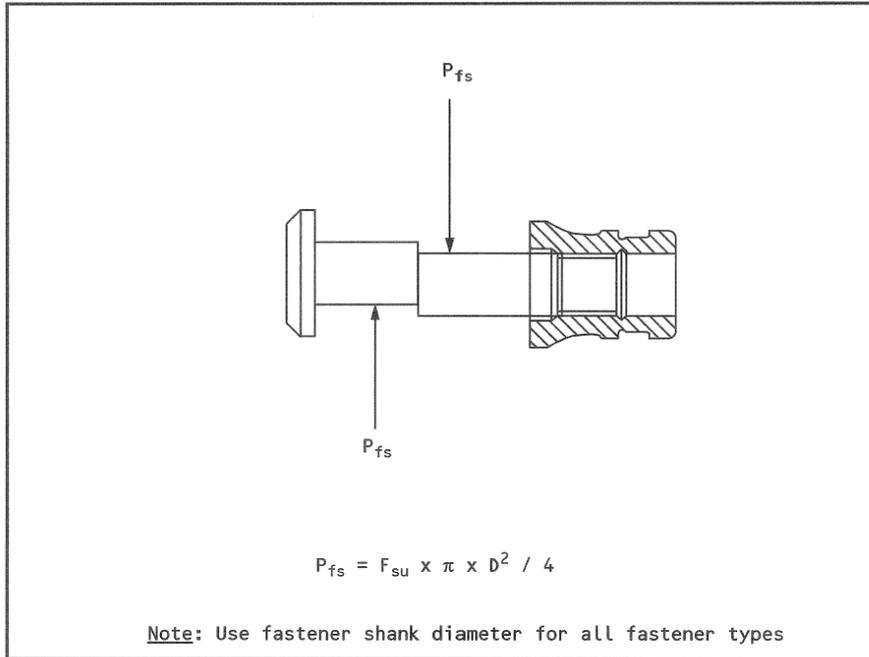
(Because shear happens in the shank area for all types)

<u>FASTENER SHEAR</u>

26 Fastener Shear Failure(   )

Net Tension Failure

Tear Out Failure Bearing Failure   Fastener

Shear Failure

(Joint Allowable Table)

1

$$P_{joint} = \text{Lowest of } P_{net}, P_{tearout}, P_{brg} \text{ or } P_{fs}$$

Failure Mode	Preferred Method of Solution	Allowable Alternate Method
Net Tension*	P_{net} = Lesser of (F_{tu} x A_{net}) or (1.5 x F_{ty} x A_{net})	None
Tear Out*	Use SRM or MMPDS Joint Tables	$P_{tearout}$ = F_{su} x t x (2e − .766D) *[handwritten: e = edge margin]*
Bearing	Use SRM or MMPDS Joint Tables	P_{brg} = Lesser of (F_{bru} x D x t) *(caution!)* or (1.5 x F_{bry} x D x t)
Fastener Shear**	Use SRM or MMPDS Joint Tables	P_{fs} = F_{su} x π x D^2 / 4

*Use D_{avg} for countersink fasteners.
**Use D_{shank} for both protruding and countersink fasteners

The joint allowable, P_{joint}, is the lowest value of P_{net}, $P_{tearout}$, P_{brg}, P_{fs}.

1

27 Joint Allowable Table

Bearing Failure

(Shear Failure) Bearing Failure

Bearing

Failure (Load Re-Distribution)

Oversize Fastener

Bearing Strength

| FASTENER PART NUMBERS | BACB30DX
BACB30LJ
BACB30LK
BACB30LM
BACB30LN
BACB30MB
BACB30MR | BACB30NE
BACB30NF
BACB30NM
BACB30NR
BACB30NT
BACB30NX
BACB30PF | BACB30PU
BACB30PW
MS20004-24
NAS623
NAS673-678
NAS1218
NAS1223-1235 | NAS1303-1320
NAS1465-1472
NAS6965-6972 | | | | |

three failure modes in multiple fastener joint:

net tension bearing tear out (shear out)

FASTENER DIAMETER		3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8
SINGLE SHEAR (LB)		2690	4650	7250	10400	14200	18600	23600	29150
SINGLE SHEAR BEARING STRENGTH (LB) / MATERIAL GAGE	0.063	1390	1830	2280					
	0.071	1560	2060	2570	3090				
	0.080	1760	2320	2900	3480	4060			
	0.090	1980	2610	3260	3910	4570			
	0.100	2200	2900	3620	4350	5050	5800		
	0.112	2470	3250	4060	4870	5700	6500		
	0.125	2690	3620	4530	5450	6350	7250	8150	9050
	0.140		4060	5050	6100	7100	8100	9150	10100
	0.160		4640	5800	6950	8100	9300	10400	11600
	0.180		4650	6500	7850	9150	10400	11700	13000
	0.200			7250	8900	10400	11900	13400	14900
	0.224				10000	11700	13300	15000	16700
	0.250				10400	12500	14200	16000	17800
	0.312					14200	17800	20000	22200
	0.375						18600	23600	26700
	0.500								29150
	0.562								
	0.625								
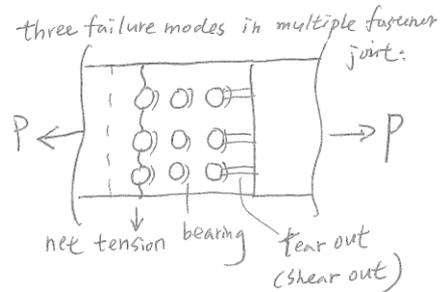
NO VALUES GIVEN (NOT ALLOWED, TRANSIONAL FAILURE MAY OCCUR)

(keep in bearing area)
MATERIAL BEARING FAILURE AREA

(optimized design to allow bearing before fastener single shear, easy for inspection)

FASTENER SHEAR FAILURE AREA
for load re-distribution

TENSION PROTRUDING HEAD BOLTS, LOCKBOLTS AND HEX-DRIVE BOLTS IN: ← *FASTENER TYPE*

7075-T6 CLAD OR BARE, SHEET OR PLATE

7075-T6, -T6510, -T6511 EXTRUSION (LESS THAN 0.185 THICK)

JOINT MATERIALS (TABLE VALUES ARE FOR FIRST ONE LISTED)

95 KSI SHEAR STRENGTH ← *FSU OF FASTENER MATERIAL*

JOINTS - FASTENER ALLOWABLE TABLES (*in SKM*)

27 Joint Allowable Table

( ) (Joint Analysis)

(Joint Analysis)

28, 29

SINGLE SHEAR JOINTS
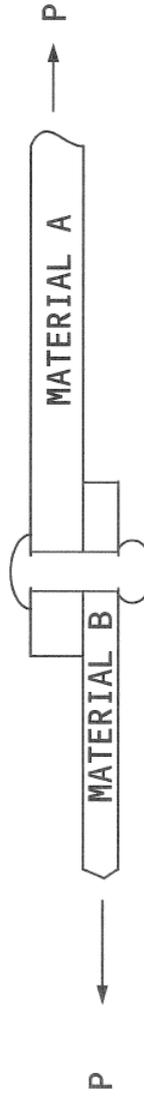
P_A = MATERIAL A SINGLE SHEAR JOINT ALLOWABLE

P_B = MATERIAL B SINGLE SHEAR JOINT ALLOWABLE

P = TOTAL JOINT ALLOWABLE = LESSER OF P_A OR P_B

P_{SRM} = SINGLE SHEAR JOINT ALLOWABLE FROM THE SRM JOINT ALLOWABLE TABLES
FOR A SIMILAR TEMPER OR PRODUCT FORM OF THE SAME ALLOY AS MATERIAL A OR B.

F_{BRG} = LESSER OF (F_{BRU}) OR (1.5 X F_{BRY})

SINGLE SHEAR JOINT ALLOWABLES

IF P_A OR P_B IS AVAILABLE IN THE TABLES, USE THE TABLES

IF P_A OR P_B IS NOT AVAILABLE IN THE TABLES:

$$P_A = P_{SRM} \times \frac{F_{BRG(MATERIAL\ A,\ E/D=1.7,\ B-BASIS)}}{F_{BRG(MATERIAL\ THAT\ P_{SRM}\ IS\ BASED\ UPON,\ E/D=1.7,\ B-BASIS)}}$$

$$P_B = P_{SRM} \times \frac{F_{BRG(MATERIAL\ B,\ E/D=1.7,\ B-BASIS)}}{F_{BRG(MATERIAL\ THAT\ P_{SRM}\ IS\ BASED\ UPON,\ E/D=1.7,\ B-BASIS)}}$$

NOTE: P_A AND P_B SHOULD NOT EXCEED THE FASTENER SHEAR CAPABILITY

JOINTS - USING FASTENER ALLOWABLE TABLES

28   (Single Shear Joint Analysis)

DOUBLE SHEAR JOINTS
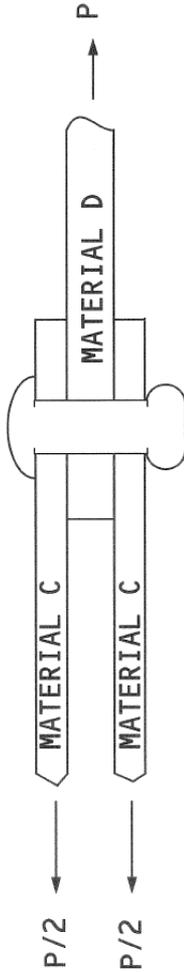
P_C = MATERIAL C SINGLE SHEAR JOINT ALLOWABLE (sheet)

P_D = MATERIAL D DOUBLE SHEAR JOINT ALLOWABLE (two side of material c)

P = TOTAL JOINT ALLOWABLE = LESSER OF $(2 \times P_C)$ OR $(1 \times P_D)$

P_{SRM} = SINGLE SHEAR JOINT ALLOWABLE FROM THE SRM JOINT ALLOWABLE TABLES FOR A SIMILAR TEMPER OR PRODUCT FORM OF THE SAME ALLOY AS MATERIAL C.

F_{BRG} = LESSER OF (F_{BRU}) OR $(1.5 \times F_{BRY})$ (Bearing)

SINGLE SHEAR JOINT ALLOWABLES (MATERIAL C)

IF P_C IS AVAILABLE IN TABLES, USE THE TABLES

IF P_C IS NOT AVAILABLE IN TABLES:

$$P_C = P_{SRM} \times \frac{F_{BRG}(\text{MATERIAL C, E/D = 1.7, B-BASIS})}{F_{BRG}(\text{MATERIAL that } P_{SRM} \text{ IS BASED UPON, E/D = 1.7, B-BASIS})}$$

(Bearing)

DOUBLE SHEAR JOINT ALLOWABLES (MATERIAL D)

IF P_D IS AVAILABLE IN THE TABLES, USE THE TABLES (Rivet D.S. values are available in the tables)

IF P_D IS NOT AVAILABLE IN TABLES:

$P_D = F_{BRG}(\text{MATERIAL D, E/D = 1.7, B-BASIS}) \times D \times T$

(min. edge margin)

NOTE: P_C AND P_D SHOULD NOT EXCEED THE FASTENER SHEAR CAPABILITY

JOINTS – USING FASTENER ALLOWABLE TABLES

(Also check the double-shear fastener capability = 2X fastener shear strength)

29

(Double Shear Joint Analysis)

(Single Shear Joint) Bearing

Load Capability SRM Joint Allowable Tables

Bearing Capability

Bearing Load Capability

(Double Shear Joint) Bearing

Load Capability Bearing Capability

Bearing Capability

Bearing Load Capability

Joint Allowable Tables Bearing

Strength Joint Allowable Tables (

(-T6 -T651) (e/D))

Bearing Strength

(Yield Strength) (Ultimate Strength)

(Extrapolation) Bearing Failure

Bearing Strength Ratioing 30 Ratioing

( ) (Running Loads)

Web

(Running Loads) 31

Example of Ratioing Joint Allowables

Example: From Problem 7

- **Material A:** 7075-T6 extrusion, t = 0.15 inch

- **What is** P_{cap}?

- No table value for XCZ in 7075-T6 ext.

- Closest is Fig. 5, Table III, for 7075-T6 sheet

  - Same alloy, different form

  - To ratio from test values, must use tested material

  - Tested material is listed first in the table

  - Table III is based on clad sheet

7075-T6 ext.
t = 0.15"

XCZ
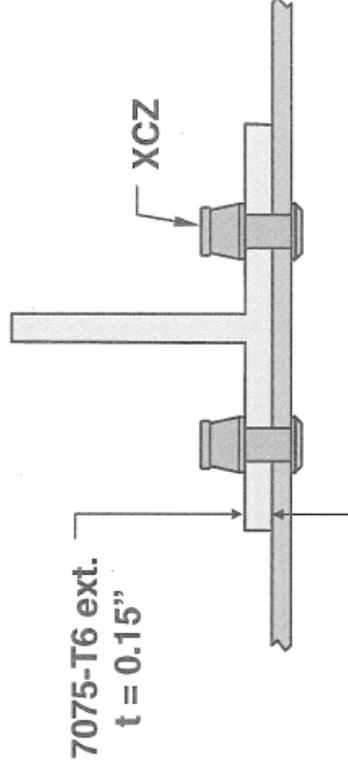
$$P_A = P_{joint\ table} \times \frac{F_{brg\ -\ A}}{F_{brg\ -\ A\ table\ matl.}}$$

$$P_{7075-T6\ ext} = P_{fig.\ 5,\ tbl.\ III} \times \frac{F_{brg\ -\ 7075-T6\ ext.}}{F_{brg\ -\ 7075-T6\ clad}}$$

30   Joint   Bearing Strength   (Extrapolation, Ratioing)

44

Caution
Countersunk

ROW 1
ROW 2
ROW 3

P stop for stress
analysis

P

RS
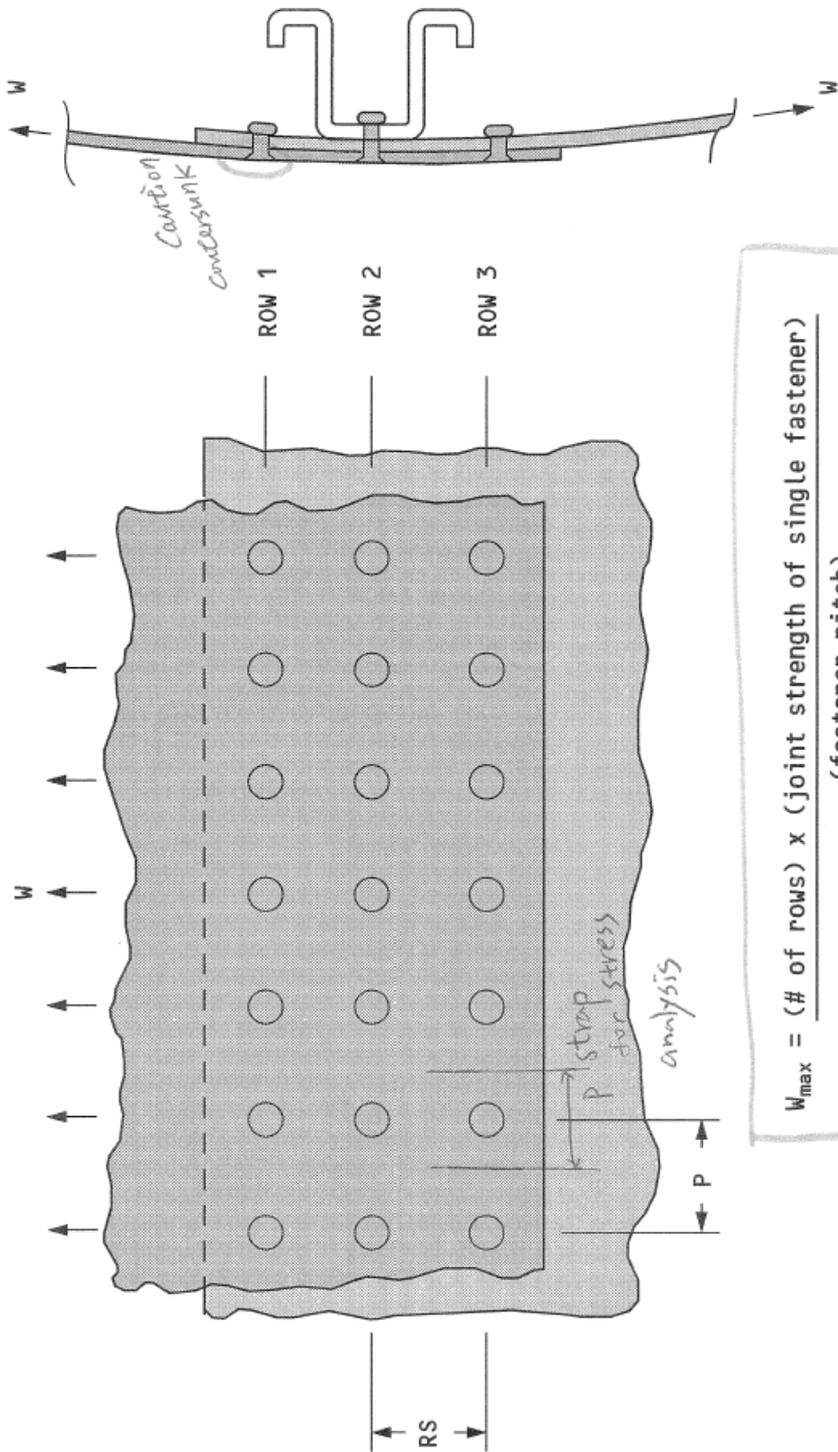
$$W_{max} = \frac{(\text{\# of rows}) \times (\text{joint strength of single fastener})}{(\text{fastener pitch})}$$ W = RUNNING LOAD, LBS/INCH

P = FASTENER PITCH $\left(\begin{array}{c}\text{longitudinal}\\ \text{spacing}\end{array}\right)$

RS = FASTENER ROW SPACING

TYPICAL FUSELAGE LONGITUDINAL LAP SPLICE
(Running Loads)

31

( )   (Edge Margin)   (Row Spacing/Pitch)

(Edge Margin)

Shear Out Failure   (Row Spacing/Pitch)

Shear Out Failure/Tear Out Failure

(Inter-Fastener Shearout)

2D ± 0.05 inch   SRM

(Note)

(2D)

(Average Diameter)(Davg)

2D ± 0.05 inch

(Short Edge Margin, SEM)

SEM   32

SEM

(Net Tension or Shearout Check)

Edge margins (EM) normal to the primary load path.

Joints that typically carry tension loads:

- EM≥1.5D: Acceptable provided the part is shot peened.
- EM<1.5D: Not acceptable. The hole must be trimmed out and a doubler installed.
- Perform net tension checks on all parts less than 4D in width.

Joints that do not typically carry tension loads:

- EM≥1.5D: Acceptable.
- 1D≤EM<1.5D: Acceptable when not more than two fasteners are affected and two fasteners on each side can be oversized. In all other instances, a doubler must be added.
- EM<1D: Not acceptable. The hole must be trimmed out and a doubler installed.
- Perform net tension checks on all parts less than 4D in width.

Edge margins parallel to the primary load path.

All joints:

- EM≥1.7D: Use joint allowable tables directly.
- 1.5D≤EM<1.7D: Ratio joint allowable by $F_{brg}(e/D=actual) / F_{brg}(e/D=1.7D)$. For bolts in double shear use $F_{brg}(e/D=actual)$ x D x t, where F_{brg} = lesser of $1.5F_{bry}$ or F_{bru}.
- 1.0D≤EM<1.5D: Use tearout check.
- EM<1.0D: Not acceptable. The hole must be trimmed out and a doubler added.
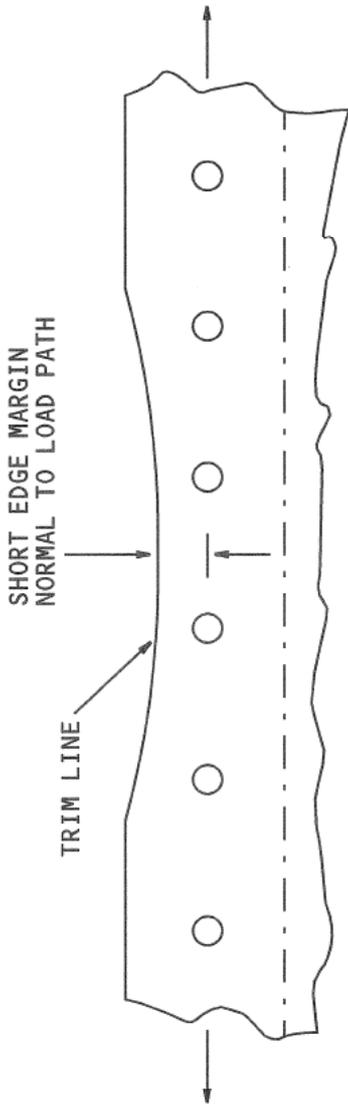
ACCEPTABLE

EM ≥ 1.5D [1]

NOT ACCEPTABLE

EM < 1.5D [2]

ACCEPTABLE

EM ≥ 1.7D [3]
1.5D ≤ EM < 1.7D [4]
1.0D ≤ EM < 1.5D [5]

NOT ACCEPTABLE

EM < 1.0D [2]

[1] Shot peen part
[2] Trim out hole and repair
[3] Use joint table load
[4] Ratio load by relative F_{brg}
[5] Use tearout load

SHORT EDGE MARGIN
NORMAL TO LOAD PATH

TRIM LINE

TYPICAL SHORT EDGE MARGIN NORMAL
TO PRIMARY LOAD PATH

SHORT EDGE MARGIN PARALLEL TO LOAD PATH

TYPICAL SHORT EDGE MARGIN
PARALLEL TO PRIMARY LOAD PATH

$$P_{allow,\ e/D=1.6} = P_{allow\ table\ (e/D=1.7)} \times \frac{F_{brg\ e/D=1.6}}{F_{brg,\ e/D=1.7}}$$

32

4D ~ 6D

(   )

(Pull-Up Gap)

Buckling   0.01 inch

Pull-Up Stress   50%   Stress

Corrosion Threshold

(Staggering)

33

(Staggering)

2.5D MIN

L

diagonal spacing
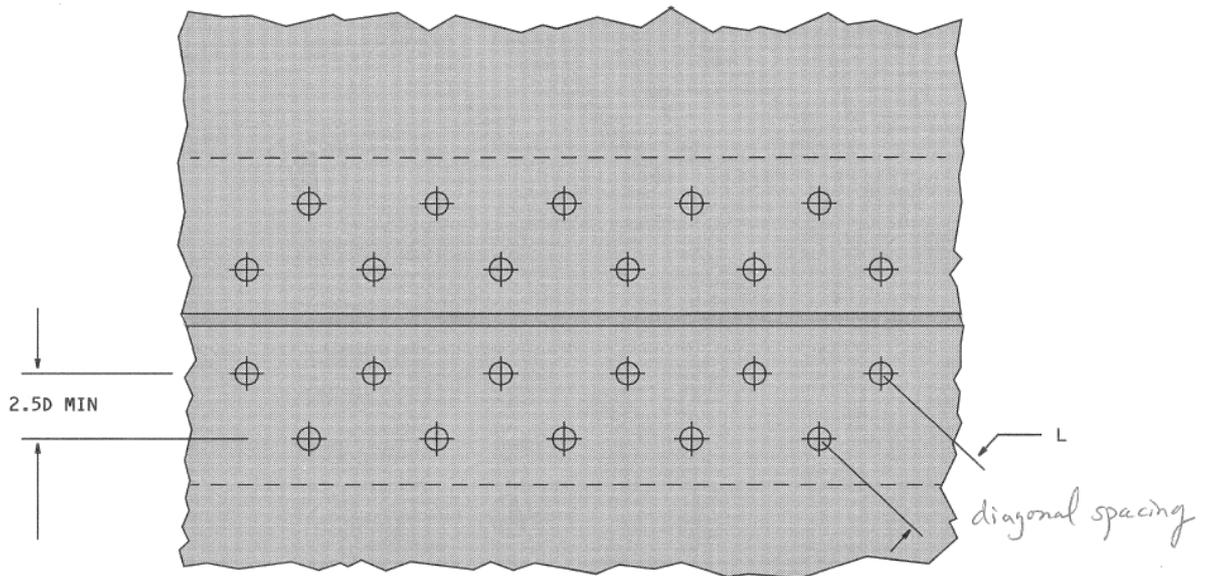
Staggered Rivets: $L_{rivets} \leq 3.75 \times D_{shank}$

Staggered Bolts: $L_{bolts} \leq 4.50 \times D_{shank}$

All Fastener Types: $L_{fasteners} \leq 10 \times t_{thinnest}$

33   (Staggering)

（　）　　　　　　　　　　（Eccentric Load）

（Fastener　Pattern）

（Centroid）　　　　　　　　　　　　　（Moment）

Shear Tie

（　　Frame　　Floor　Beam）

（Hoop Stress）　　　　　　　　（Frame）

34
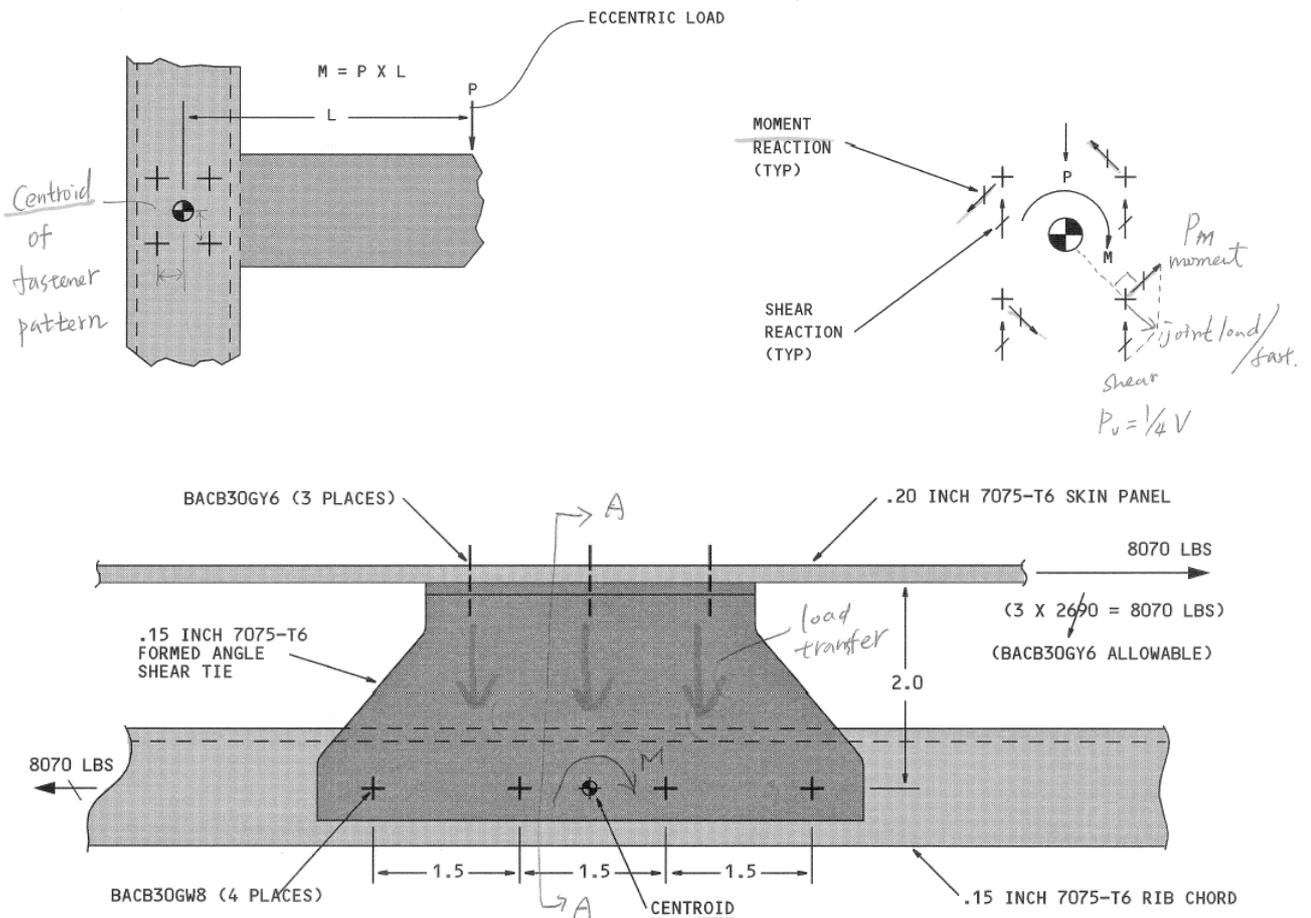
34　　　　　　　　（Eccentric Load）　　　Shear Tie

(Eccentric Load Chart)
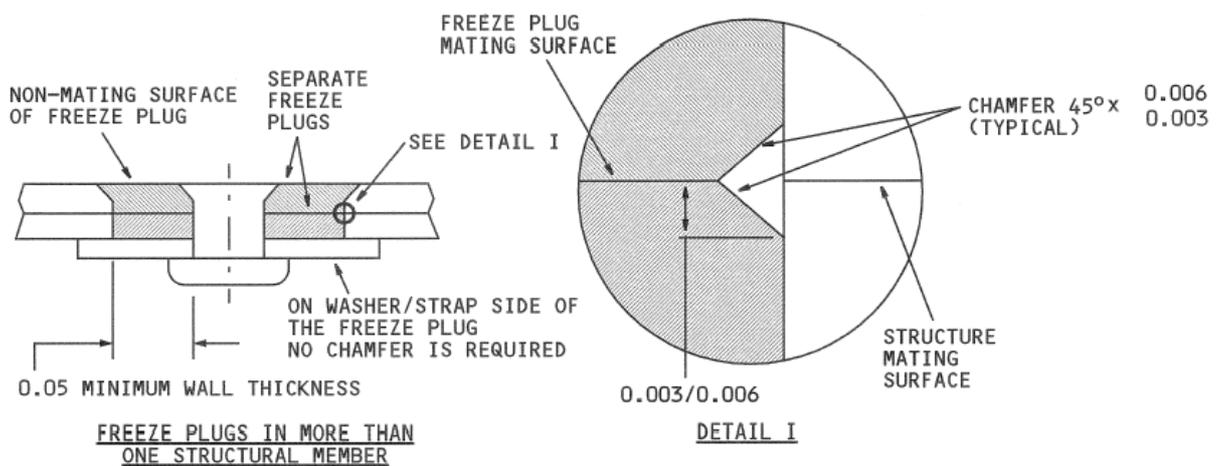
/

$P_{end} = (\%) V$

JOINTS — ECCENTRIC LOAD CHART

WHERE:
V = Applied shear load
a = Distance between end fasteners
b = Distance between shear load and fastener lines
n = Number of fasteners

$RS = \dfrac{a}{n-1}$

63-06-00-131.fm

35 (Eccentric Load Chart)

50
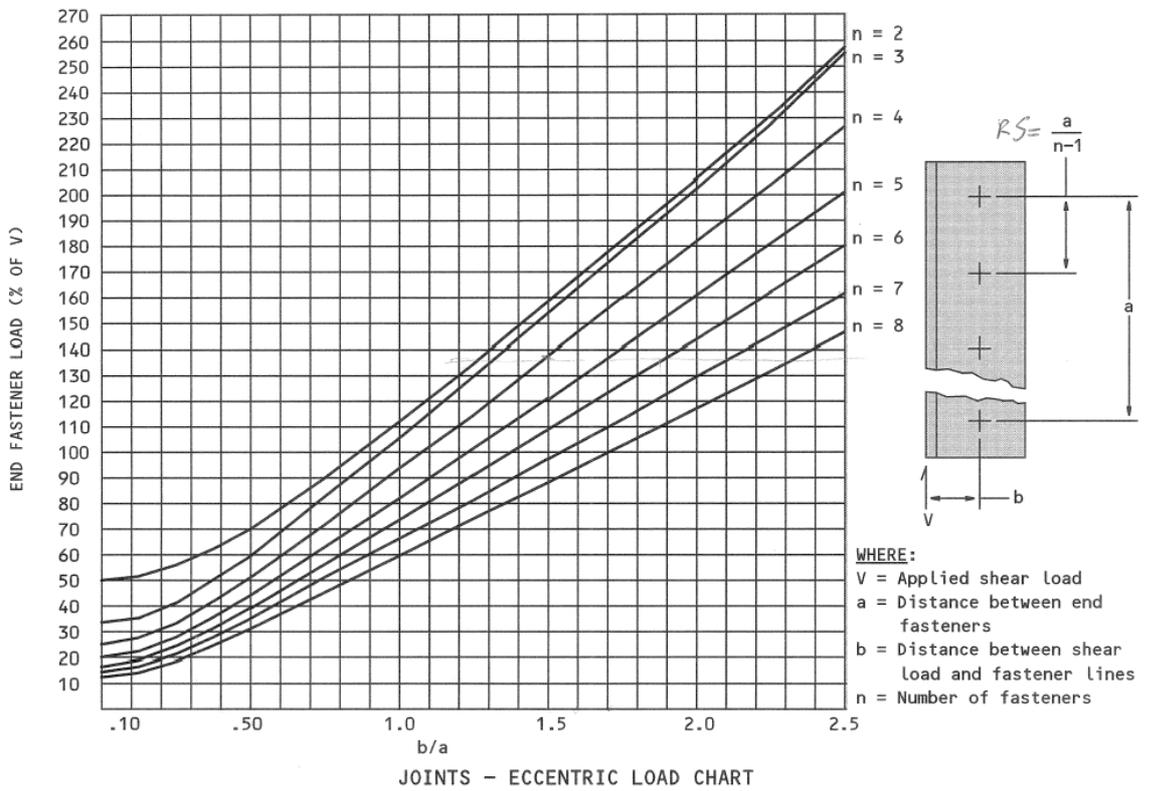
( ) (Freeze Plug)

(Freeze Plug) 36

(Freeze Plug)

(Freeze Plug)

Net Tension Failure

FREEZE PLUG
MATING SURFACE

NON-MATING SURFACE   SEPARATE
OF FREEZE PLUG   FREEZE
                     PLUGS
                              SEE DETAIL I

CHAMFER 45°x   0.006
(TYPICAL)   0.003

ON WASHER/STRAP SIDE OF
THE FREEZE PLUG
NO CHAMFER IS REQUIRED

STRUCTURE
MATING
SURFACE

0.05 MINIMUM WALL THICKNESS

0.003/0.006

FREEZE PLUGS IN MORE THAN
ONE STRUCTURAL MEMBER

DETAIL I

The following guidelines apply to the installation of
aluminum freeze plugs in aluminum.

- The repaired material must be a minimum of 0.063
  inch thick.
- Make freeze plugs in aluminum parts from 7075-T6.
- Make the shank diameter 1.0035 to 1.0040 times
  larger than the diameter of the hole.
- The freeze plug diameter must be less than or equal
  to 10 times the plate thickness.
- Maintain a minimum wall thickness of 0.05 inch
  between the freeze plug and the fastener hole.
- If a freeze plug is used to transfer load keep the
  plug concentric with the fastener going through
  plug.

- Maintain an edge margin of (1.7 x D_{plug}) for freeze
  plugs.
- Maintain a spacing of (2 x D_{plug}) between freeze
  plugs and adjacent fasteners for a single freeze
  plug. Maintain a spacing of (2.5 x D_{plug}) for up to
  5 freeze plugs in a part.
- Make separate freeze plugs for each material in a
  stack up.
- Retain freeze plug with a countersink, washer, or
  strap.
- Make the countersink freeze plug so it and the
  fastener have a 100 degree countersink.
- Make the countersink depth of the freeze plug less
  than or equal to 50% of the material thickness.
- Maintain 0.05 inch minimum measurable material
  between the fastener countersink and the freeze
  plug countersink.

36   (Freeze Plug)

( )　　　　　(Shim)

0.005 ~ 0.01

inch

(Structural　Shim)　　　　　(Non-Structural

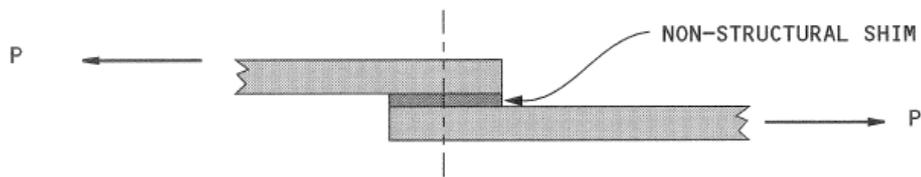Shim)　　　　　(Load Path)

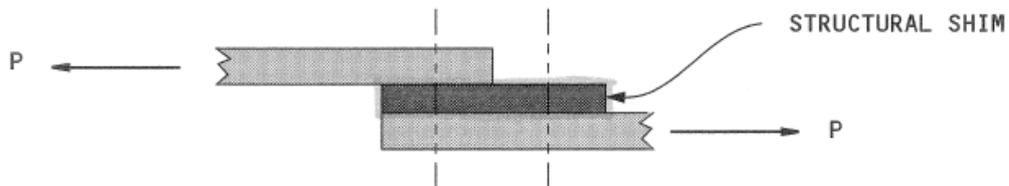Laminated　Solid Shim　Laminated

Shim　　　0.05 inches　　　　0.05 inches

Solid Shim　　　Laminated Shim

NON-STRUCTURAL SHIM

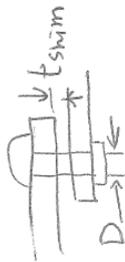— ASSUME NO LOADS IN SHIM
— SOLID OR LAMINATED
— TAKE UP GAP

STRUCTURAL SHIM

— LOADS CARRIED IN SHIM
— SOLID
— TAKE UP GAP
— PREVENT FASTENER BENDING

37　　　　(Shim)

SHIM THICKNESS AS A PERCENTAGE OF THE FASTENER DIAMETER	FASTENER TYPE AND MATERIAL	NON-STRUCTURAL SHIM [B]	STRUCTURAL SHIM [A]
LESS THAN 16%	RIVETS (ALUMINUM)	X	
16% AND GREATER			X
LESS THAN 21%	SHEAR LOCK OR HI-LOKS BOLTS (STEEL OR TITANIUM)	X	
21% AND GREATER			X
LESS THAN 26%	TENSION LOCKBOLTS BOLTS OR HI-LOKS (STEEL OR TITANIUM)	X	
26% AND GREATER			X

777 SRM DATA

NOTES:

- EXAMPLE CALCULATION:
  FOR A 0.040 INCH THICK SHIM AND A 3/16
  (0.1875) INCH DIAMETER TITANIUM SHEAR HI-LOK,
  THE SHIM THICKNESS AS A PERCENTAGE OF THE
  FASTENER DIAMETER:

  $$= \frac{\text{SHIM GAGE}}{\text{FASTENER DIAMETER}} \times 100$$

  $$= \frac{0.040 \text{ INCH}}{0.1875 \text{ INCH}} \times 100$$

  $$= 21.3\%$$

A NON-STRUCTURAL SHIM IS ALLOWED ONLY IF
THE SHIM THICKNESS IS LESS THAN 21%,
THUS, A STRUCTURAL SHIM IS NECESSARY. → or change diameter or change fastener type to allow to use non-structural Shim.

[A] THE SHIM MUST BE FASTENED TO THE REPAIR
PART OR THE INITIAL PART. THE STRUCTURAL
SHIM IS USED TO PREVENT MOVEMENT THAT COULD
POSSIBLY BEND THE FASTENER.

[B] THE SHIM CAN BE BONDED WITH ADHESIVE
BMS 5-95 OR BAC5010, TYPE 70 TO THE REPAIR
PART FOR CONVENIENCE OF INSTALLATION.

38   (Shim)

JOINTS - SHIMMING GUIDELINES

(Durability)

(Fatigue Resistance)   (Corrosion Resistance)

(Wet Installation)

(Fatigue Resistance)

( )   –

(Wet Installation)   39

1. BMS 5-45

Microballoon

(Specific Gravity)

BMS 5-26   20%

2. BMS 5-95

3. BMS 5-63

Silicone

4. PR1826   PR1828

BMS 5-45   BMS 5-26

ITEM NO.	SPEC	APPLICATION CLASS	BASE	COLOR	DESCRIPTION OF USE
1	5-26	B,C,D	POLYSULFIDE	DARK GRAY	CORROSION PROTECTION AND FUEL SEAL IN FUEL TANK [1]
2	5-45	A,B,C	POLYSULFIDE	BROWN/GRAY	CORROSION PROTECTION AND FUEL SEAL IN FUEL TANK(LOW DENSITY)
3	5-63	B	SILICONE	GRAY	FIREWALL, SKYDROL RESISTANT
4	5-95	B,C,E,F,G	POLYSULFIDE	GRAY	CORROSION PROTECTION, FASTENER INSTALLATION, AERODYNAMIC
5	5-142	B	POLYSULFIDE	DARK GRAY	CORROSION PROTECTION, AERODYNAMIC (LOW DENSITY) [2]
6	PR-1826	B	POLYTHIO ETHER	DARK GRAY	FUEL TANK REPAIR SEALANT
7	PR-1828	B	POLYTHIO ETHER	WHITE	FUEL TANK REPAIR SEALANT

VENDOR EQUIVALENTS

BMS 5-45	BMS 5-63	BMS 5-95	BMS 5-142 [2]
PR 1776	DAPCO 18-4	PR 1436	PR 875
PRO SEAL 890	DAPCO 2200	PR 1432	PR 1772
	DAPCO 2100	PRO-SEAL 870	

[1] BMS 5-26 HAS BEEN SUPERCEDED BY BMS 5-45

[2] BMS 5-142 IS NOT PERMITTED FOR MATING SURFACE SEAL, PRE-PACK SEALING, AND WET FASTENER INSTALLATION PROCEDURES.

[3] PR1826 HAS A PRIMER THAT MUST ALSO BE USED

PERMISSIBLE OPTION

SEALANT CALLED OUT ON DRAWING OR DOCUMENT	2	3	4	5	6	7
1	YES	NO	NO	NO	YES	YES
2	NO	NO	NO	NO	YES	NO
3	NO	—	NO	NO	NO	NO
4	YES	NO	—	YES	YES	YES
5	YES	NO	YES	—	YES	YES

39

( )　　　　　　–

(Anodizing)　　　　　　Alodine

1. BMS 10-11

2. BMS 10-79

(filiform Corrosion)
3. BMS 10-20

BMS 10-100　　　　　　　　　　BMS 10-60

( )　　　　　　–

(Corrosion Inhibitor Compound, CIC)

CIC

CIC

1. BMS 3-23

(Mating Structures)

2. BMS 3-26

3. BMS 3-29

(High

Moisture Surface) Bilge Area

4. BMS 3-35

(Tack Free Surface) (Touch-Up)

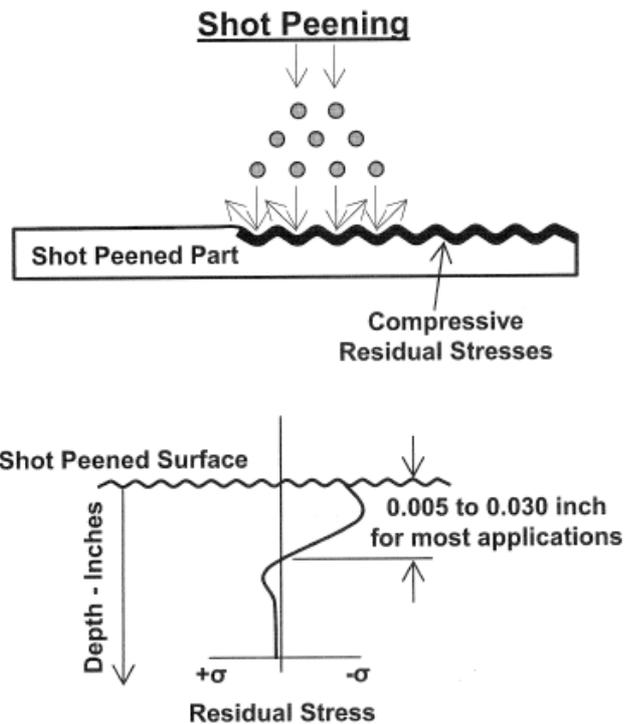( ) (Fatigue Resistant Repair)

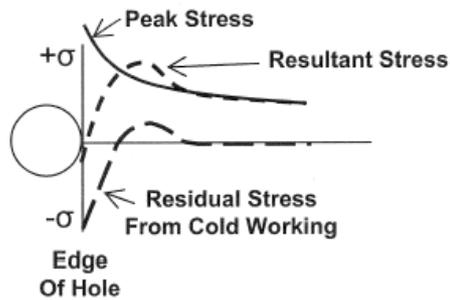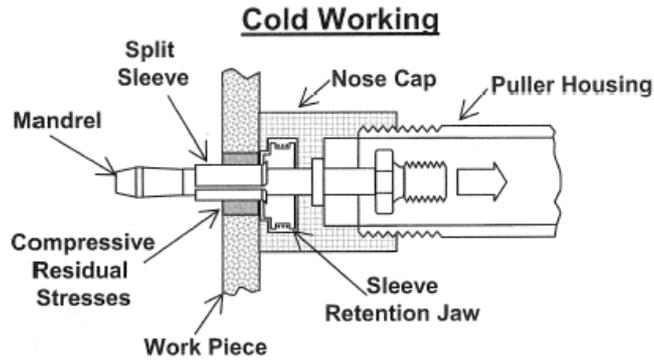1. (Shot Peening) (Cold Work) 2024

7075

Compressive Layer Peak Stress

Shot Peening

Shot Peened Part

Compressive
Residual Stresses

Shot Peened Surface

Depth - Inches

0.005 to 0.030 inch
for most applications

+σ   -σ
Residual Stress

Relative Life Increase ~75%
for shot peened 7050-T7451 plate

40 Shot Peening Surface Peak Stress

Cold Working

Relative Life Increase ~280%
for cold working in 7050-T7451 plate

41 Cold Work   Peak Stress

2.   Fatigue Resistance Fastener (Rivet, Hex-Drive Bolt,
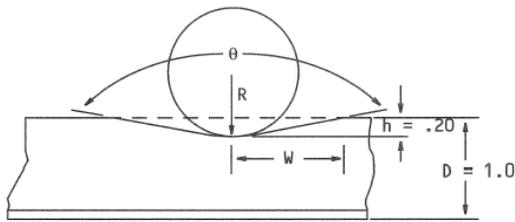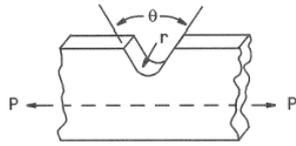
Lockbolt   )   (Interference Fit)

                     Compressive Layer

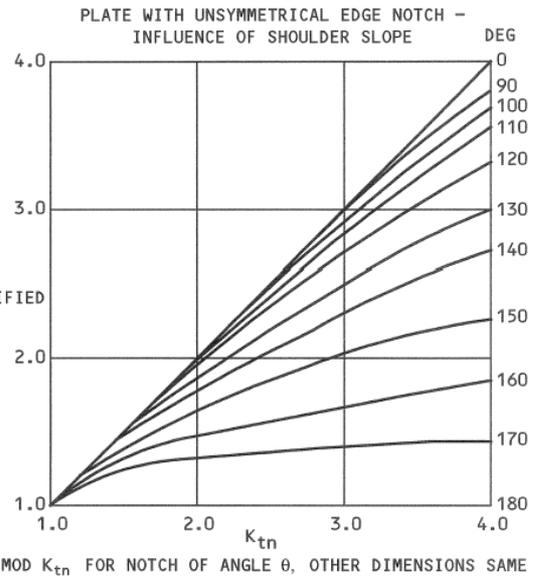( )   (Blendout Slope)

       SRM

       42

       30:1

20:1

STRINGR FLANGE WITH BLENDED NOTCH

SLOPE = $\frac{W}{h}$	FOR THE 1.0 WIDE STGR. FLANGE		
RADIUS	.25	.50	1.0
5:1 SLOPE θ = 157°	1.42	1.28	1.18
10:1 SLOPE θ = 168°	1.32	1.22	1.15
20:1 SLOPE θ = 174°	1.15	1.10	1.06
30:1 SLOPE θ = 176°	1.15	1.10	1.04

MODIFIED NOTCH K_{TN}

no substantial benefit, therefore use 20:1 is sufficient!

* <u>trim</u> the notch out ⟹ to reduce stress concent.

PLATE WITH UNSYMMETRICAL EDGE NOTCH – INFLUENCE OF SHOULDER SLOPE

K_{tn} MODIFIED

reduced K_{tn} after trim out

MOD K_{tn} FOR NOTCH OF ANGLE θ, OTHER DIMENSIONS SAME

Ref 3: Peterson's Stress Concentration Factors

DURABILITY — NOTCH REMOVALS

42

59

FAR

(Ultimate Load)

(Patches/Doublers)   (Repair Angles)

(Load Capability Calculations)

(Ultimate Load

Capability)   SRM   (Durability)

(FAR 25.301   FAR 25.571   )

●

●

●

●

(Ultimate Load Capability)

●

●

●   SRM   (   )

–

Part I

Mr. Montgomery (Monty) H. Morgan

Everret

B777, B767, B747-400   B787,

B747-8

(GEMCOR   )

AMECO

6