Engineering Analysis

Subject: Stud Fixer

ATI Report 55128.01-122-34

Rendered to:

Greenfield Manufacturing Company
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Scope

Architectural Testing, Inc. was contracted to perform an engineering analysis of a two-part metal stud fixer based on structural performance testing (see ATI Report 54795.01-106-31) and the *National Design Specification for Wood Construction, NDS-1997* (AFPA/AWC, 1997). For this evaluation, the allowable design capacity of the stud fixer was established as the lesser of ultimate test loads with applied factors of safety, average test loads at 0.125" movement between the stud and stud fixer, or allowable wood member or fastener capacities as determined by NDS-1997.

The following reference standards are used:

National Design Specification for Wood Construction, NDS -1997 (AFPA/AWC, 1997)

Acceptance Criteria for Joist Hangers and Similar Devices (AC 13), ICC Evaluation Services, Inc., October 2003

Cold-Formed Steel Design Manual, American Iron and Steel Institute (AISI), 1996 Edition

Metal Curtain Wall Fasteners, AAMA TIR-A9-1991 American Architectural Manufacturer's Association (AAMA)

Product Description

Production drawings and samples were submitted by Greenfield Manufacturing Company of a nominal 3-1/2" by 7-1/2" stud fixer manufactured from 0.074" thick steel. A 2-1/16" diameter hole for passing conduit or piping was located in the center of the product and four 17/32" diameter holes, two per each end, were provided for securing the product to the timber studs with SAE grade 2 bolts. The steel was assumed to be cold-formed with a minimum ultimate strength of 45 ksi. Timber studs were assumed to be Douglas Fir-Larch with a specific gravity of 0.49. Two stud fixers per stud are used (see attached drawings).

Analyses

Direct Load Capacity Tests

Structural performance tests were conducted by ATI and reported in ATI Report 54795.01-106-31. Analysis of the test results confirms the testing meets the requirements of Section 3.2 *Test and Performance Requirements* of AC13 (see page 5). Therefore it is appropriate to use the reported results to establish a working load limit for the stud fixer.

For compression loading, ultimate strengths were achieved after 0.125" vertical movement (slip) of the joist with respect to the header occurred or the lowest peak load with the appropriate safety factor applied. The results are detailed in the following table.

Installation Description	Average Load[1] at 0.125" movement	Lowest Peak Load[1] ÷ 3
Single Timber Stud with 2-1/4" hole	15,547 lbs	4,725 lbs
Double Timber Stud with 2-1/4" hole	30,767 lbs	10,183 lbs
Single Timber Stud with 2-1/4" space	3,133 lbs	2,601 lbs
Double Timber Stud with 2-1/4" space	3,470 lbs	3,521 lbs

[1] *Stud Fixer assemblies were tested in compression only*

NDS Analysis

Section 3.2.11.3 of AC 13 states the device shall have a direct load capacity rating no greater than the allowable design load determined in accordance with the NDS for the wood members forming the connection. The bolted connection of the stud fixer to the stud is evaluated on pages 6 through 12 and considers bearing strength of the timber stud, bearing strength of the metal connecting plates (stud fixer) and fastener bending.

Installation Description	NDS-1997 Calculated Load Capacity Rating
Single Timber Stud with 2-1/4" hole	4,463 lbs
Double Timber Stud with 2-1/4" hole	8,925 lbs
Single Timber Stud with 2-1/4" space	± 2062 lbs
Double Timber Stud with 2-1/4" space	± 4124 lbs

Summary

For this evaluation, the allowable design capacity of the stud fixer was established as the lesser of ultimate test loads with applied factors of safety, average test loads at 0.125" movement between the stud and stud fixer, or allowable wood member or fastener capacities as determined by NDS-1997. The results are presented in the following table.

Installation Description	Load Capacity Rating, Compression Only	Limited By
Single Timber Stud with 2-1/4" hole	4,463 lbs	NDS Calculations
Double Timber Stud with 2-1/4" hole	8,925 lbs	NDS Calculations
Single Timber Stud with 2-1/4" space	2,062 lbs	NDS Calculations
Double Timber Stud with 2-1/4" space	3,470 lbs	Load at 0.125" deflection

Reference Drawings (attached)

Stud Fixer, Greenfield Manufacturing Company, October 26, 2004
Stud Fixer Single, Greenfield Manufacturing Company, October 29, 2004
Stud Fixer Double, Greenfield Manufacturing Company, October 29, 2004

Calculations

PER AC13 [3.2.11.1.1] : MEASURED TEST LOADS BASED ON LOWEST ULTIMATE VERTICAL LOAD

	DESCRIPTION	LOWEST PEAK LOAD (COMPRESSION)
①	SINGLE 2x4 STUD WITH 2¼" HOLE ∉ STUD FIXER	14175 lbs
②	DOUBLE 2x4 STUD WITH 2¼" HOLE ∉ STUD FIXER	30549 lbs
③	SINGLE 2x4 STUD WITH 2¼" SPACE ∉ STUD FIXER	7802 lbs
④	DOUBLE 2x4 STUD WITH 2¼" SPACE ∉ STUD FIXER	10564 lbs

$$\text{DEVIATION} = 100 - \frac{\text{TEST LOW}}{\text{TEST AVERAGE}} \times 100$$

① $= 100 - \left(\frac{14175 \text{ lbs}}{15675 \text{ lbs}} \times 100\right) = 9.57\%$ O.K.

② $= 100 - \left(\frac{30549 \text{ lbs}}{32872 \text{ lbs}} \times 100\right) = 7.07\%$ O.K.

③ $= 100 - \left(\frac{7802 \text{ lbs}}{8215 \text{ lbs}} \times 100\right) = 5.03\%$ O.K.

④ $= 100 - \left(\frac{10564 \text{ lbs}}{11677 \text{ lbs}} \times 100\right) = 9.53\%$ O.K.

LOWEST ULTIMATE VERTICAL LOAD ÷ 3

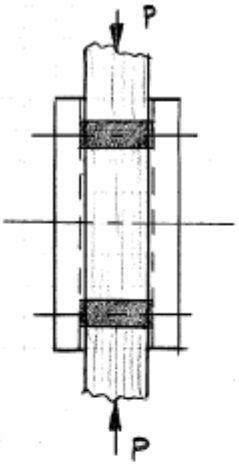
① 14175 lbs ÷ 3 = 4725 lbs

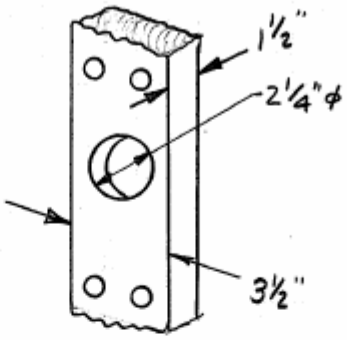
② 30549 lbs ÷ 3 = 10183 lbs

③ 7802 lbs ÷ 3 = 2601 lbs

④ 10564 lbs ÷ 3 = 3521 lbs

STUD FIXER WITH 2-1/4" HOLE IN STUD

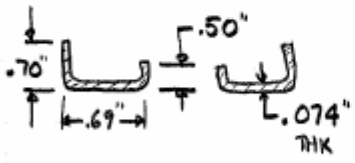




COMPRESSIVE STRESSES

AREA OF STUD @ HOLE = $(3\frac{1}{2} - 2\frac{1}{4}")(1\frac{1}{2}") = 1.875\ in^2$

AREA OF STUD FIXER @ HOLE



FROM AUTOCAD
AREA = .238 in^2 PER (1) FIXER

ASSUMING STUD STRESS WILL REACH MAXIMUM BEFORE FIXER

$\sigma_{ALLOWABLE}$ = 850psi DOUGLAS FIR (TABLE 4A N.D.S. - 1997)

$$\sigma_{BUCKLING\ ALLOWABLE\ IN\ FIXER} = \frac{\pi^2 E}{KL/r^2} = \frac{(3.14159)^2(29\times10^6)}{(1)(6.2")/(1.0118)^2} = 4.726\times10^7\ psi$$

KL/r^2 ← AISI C.F. STEEL SECTION C4.1

$\therefore$ BUCKLING NOT A FACTOR

– MAXIMUM LOAD A SINGLE STUD WOULD SUPPORT

$$P_{TOTAL} = \sigma_{ALLOWABLE} \times A_{STUD} = 850\ psi\ (1\tfrac{1}{2}" \times 3\tfrac{1}{2}") = 4463\ lbs.$$

↳ NDS TABLE 4A

$$P_{STUD} + P_{STUD\ FIXER} = \underline{4463\ lbs}$$

$$\gamma_{STUD} = \frac{P_{STUD} L_{STUD}}{A_{STUD} E_{STUD}} \quad \& \quad \gamma_{FIXER} = \frac{P_{FIXER} L_{FIXER}}{A_{FIXER} E_{FIXER}}$$

$$\gamma_{STUD} = \gamma_{FIXER}$$

$$\frac{P_{STUD} L_{STUD}}{A_{STUD} E_{STUD}} = \frac{P_{FIXER} L_{FIXER}}{A_{FIXER} E_{FIXER}}$$

AND SINCE

$P_{STUD} = 4463\ lbs - P_{FIXER}$

$$\frac{(4463\ lbs - P_{FIXER})}{(1.875\ in^2)(1.4 \times 10^6\ psi)} = \frac{P_{FIXER}}{(2 \times 0.238\ in^2)(29 \times 10^6\ psi)}$$

$$1.7 \times 10^{-3} - 3.81 \times 10^{-7} P_{FIXER} = 7.24 \times 10^{-8} P_{FIXER}$$

$P_{FIXER} = \underline{3749\ lbs}$

$P_{STUD} = 4463\ lbs - 3749\ lbs = \underline{714\ lbs}$

} THESE LOADS ARE LOWER THAN SEPARATED STUD SO BEARING PRESSURE IS NOT A FACTOR

$$\sigma_{FIXER} = \frac{P}{A} = \frac{3749\ lbs}{2 \times 0.238\ in^2} = \boxed{7876\ psi}$$ O.K.

$$\sigma_{STUD} = \frac{P}{A} = \frac{714\ lbs}{1.875\ in^2} = \boxed{381\ psi}$$ O.K. ALLOWABLE IS 850 psi

– MAXIMUM LOAD A DOUBLE STUD WOULD SUPPORT

$$P_{TOTAL} = \sigma_{ALLOWABLE} \times A_{STUD} = \underset{1 \text{ STUD TABLE 4A}}{850 \text{ psi}} \times (1\tfrac{1}{2} \times 3\tfrac{1}{2}'') \times 2 = 8925 \text{ lbs}$$

$$P_{STUD} + P_{\substack{STUD \\ FIXER}} = 8925 \text{ lbs}$$

$$\delta_{STUD} = \delta_{FIXER} \quad \text{AND} \quad P_{STUD} = 8925 \text{ lbs} - P_{FIXER}$$

$$\frac{(8925 \text{ lbs} - P_{FIXER})}{2(1.875 \text{ in}^2)(1.4 \times 10^6 \text{ psi})} = \frac{P_{FIXER}}{(2 \times 0.238 \text{ in}^2)(29 \times 10^6 \text{ psi})}$$

$$.0017 - 1.905 \times 10^{-7} P_{FIXER} = 7.24 \times 10^{-8} P_{FIXER}$$

$$P_{FIXER} = 6465 \text{ lbs}$$

$$\therefore P_{STUD} = 8925 \text{ lbs} - 6465 \text{ lbs} = 2460 \text{ lbs}$$

$$\sigma_{FIXER} = P/A = \frac{6465 \text{ lbs}}{2 \times 0.238 \text{ in}^2} = \boxed{13581 \text{ psi}} \quad \text{O.K.}$$

$$\sigma_{STUD} = P/A = \frac{2460 \text{ lbs}}{2 \times 1.875 \text{ in}^2} = \boxed{656 \text{ psi}} \quad \text{O.K.} \quad \text{ALLOWABLE IS } 850 \text{ psi}$$

STUD FIXER WITH 2-¼" SEPARATION BETWEEN STUDS

$R_e = \frac{F_{em}}{F_{es}} = \frac{5500\ psi}{31050\ psi} = .177$

$t_m = 1\frac{1}{2}"$

$t_s = 0.074"$

$F_{em} = 5500\ psi$ (TABLE 8A)

$F_{es} = \cancel{45000\ psi}$ (AISI TABLE IV-6a) $\Omega = 2.22$

$F_{yb} = 57000\ psi$ AAMA TIR-A9-1991

$D = \frac{1}{2}"$

$K_\theta = 1 + (\theta_{max}/360°) = 1$

$\theta = 0°$

$$K_3 = -1 + \sqrt{\frac{2(1+R_e)}{R_e} + \frac{2F_{yb}(2+R_e)D^2}{3F_{em}t_s^2}}$$

$$K_3 = -1 + \sqrt{\frac{2(1+0.177)}{0.177} + \frac{2(57000psi)(2+0.177)(\frac{1}{2}")^2}{3(5500psi)(0.074in)^2}}$$

$K_3 = 25.46$

SINCE STUD FIXER DOES NOT SATISFY THE EDGE DISTANCE REQUIREMENTS OF AISC ($1\frac{1}{2} \times D$) (J3-3)

$F_{es} = \frac{L_e F_u}{2D} = \frac{0.69"(45000\ psi)}{2(\frac{1}{2}")} = 31050\ psi$

OK SINCE $\leq 1.2\ F_u$

DESIGN VALUES FOR DOUBLE SHEAR CONNECTIONS (NDS 8.3.2)

$$Z = \frac{Dt_m F_{em}}{4K_\theta} \qquad (8.3.1)$$

$$Z = \frac{(\frac{1}{2}")(1\frac{1}{2}")(5500\ psi)}{4(1)} = 1031\ lbs$$

$$Z = \frac{K_3 D t_s F_{em}}{1.6(2+R_e)K_\theta} \qquad (8.3.3)$$

$$Z = \frac{(25.46)(1\frac{1}{2}")(.074")(5500\ psi)}{1.6(2+0.177)(1)} = 4462\ lbs$$

$$Z = \frac{D^2}{1.6K_\theta}\sqrt{\frac{2F_{em}F_{yb}}{3(1+R_e)}}$$

$$Z = \frac{(\frac{1}{2}")^2}{1.6(1)}\sqrt{\frac{2(5500\ psi)(57000\ psi)}{3(1+0.177)}} = 2082\ lbs$$

ADJUSTMENT FACTORS (TABLE 7.3.1)

$C_D = 1$

$C_m = 1$ ASSUMING NOT USED IN WET CONDITIONS

$C_t = 1$ ASSUME $T \leq 100°F$

$C_g = 1$ SINCE BOLTS ARE NOT IN ADJACENT ROWS

$C_\Delta =$

END DISTANCE IS $\frac{7\frac{1}{2}"}{2} - \frac{2.13"}{2} = 2.69"$

RATIO $= \frac{2.69"}{\frac{1}{2}"\phi} = 5.37$ ∴ CAN USE FULL DESIGN VALUE

$C_\Delta = \frac{2.69"}{4(\frac{1}{2}")} = 1.35 \rightarrow$ USE 1.0

$Z' = C_D C_m C_t C_g C_\Delta Z$

$= (1)(1)(1)(1)(1)(1031 \text{ lbs}) \times 2$ BOLTS

$Z' = 2062$ lbs

- FOR DOUBLE STUD, YIELD MODE I_m GOVERNS DESIGN

$Z = \frac{(\frac{1}{2}")(1\frac{1}{2}" \times 2)(5500 \text{ psi})}{4(1)} = 2062 \text{ lbs}$ (8.3.1)

∴ $Z' = (1)(1)(1)(1)(1)(2062 \text{ lbs}) \times 2$ BOLTS

$Z' = 4124$ lbs

stud fixer section.mpr

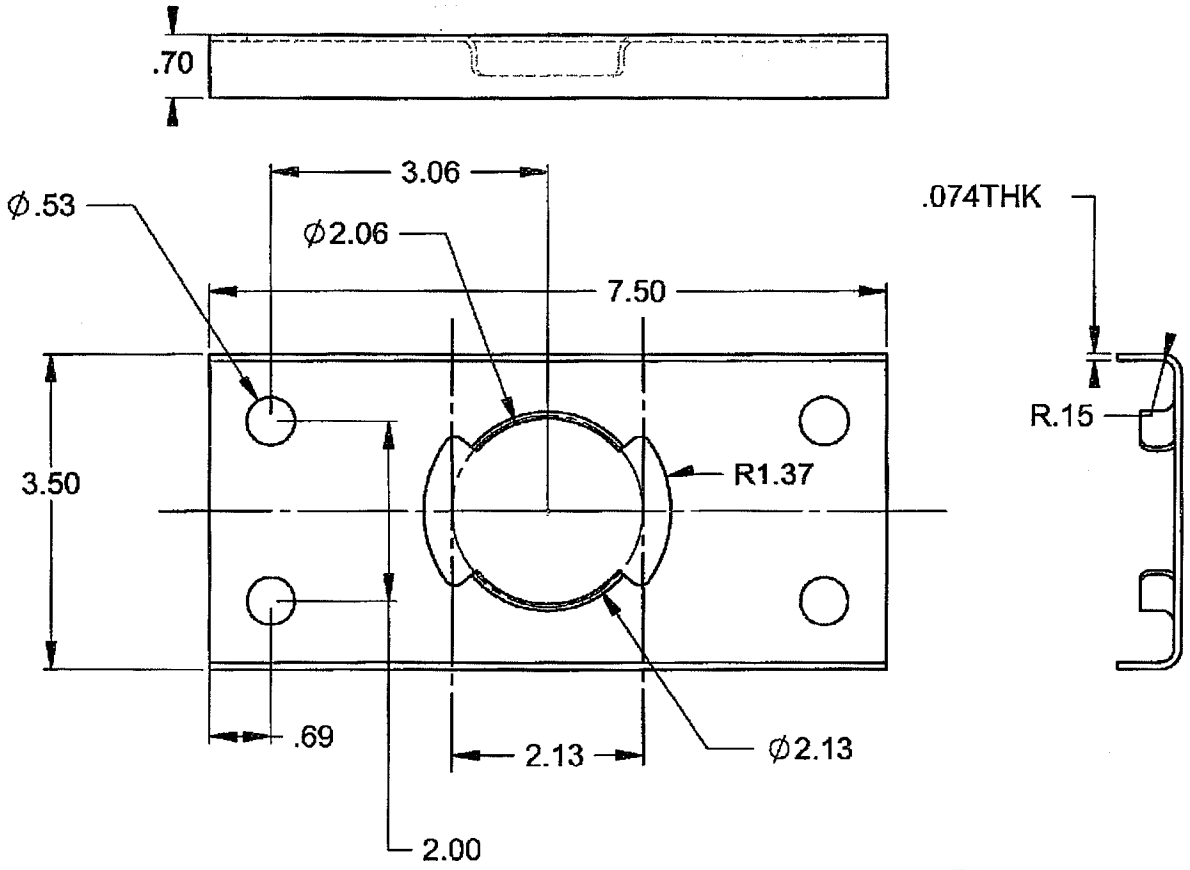
---------- REGIONS ----------

Area:	0.4770		
Perimeter:	13.4838		
Bounding box:	X: -1.7500	--	1.7500
	Y: -1.4500	--	1.4500
Centroid:	X: 0.0000		
	Y: 0.0000		
Moments of inertia:	X: 0.4883		
	Y: 1.0107		
Product of inertia:	XY: 0.0000		
Radii of gyration:	X: 1.0118		
	Y: 1.4556		

Principal moments and X-Y directions about centroid:
I: 0.4883 along [1.0000 0.0000]
J: 1.0107 along [0.0000 1.0000]

Revision Log

Rev. #	Date	Page(s)	Revision(s)
0	12/17/04	N/A	Original report issue



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS DECIMALS ANGLES ± .XX+ .XX + 1 .XXX+.XXX	CAD GENERATED DRAWING. DO NOT MANUALLY UPDATE	GREENFIELD MFG CO
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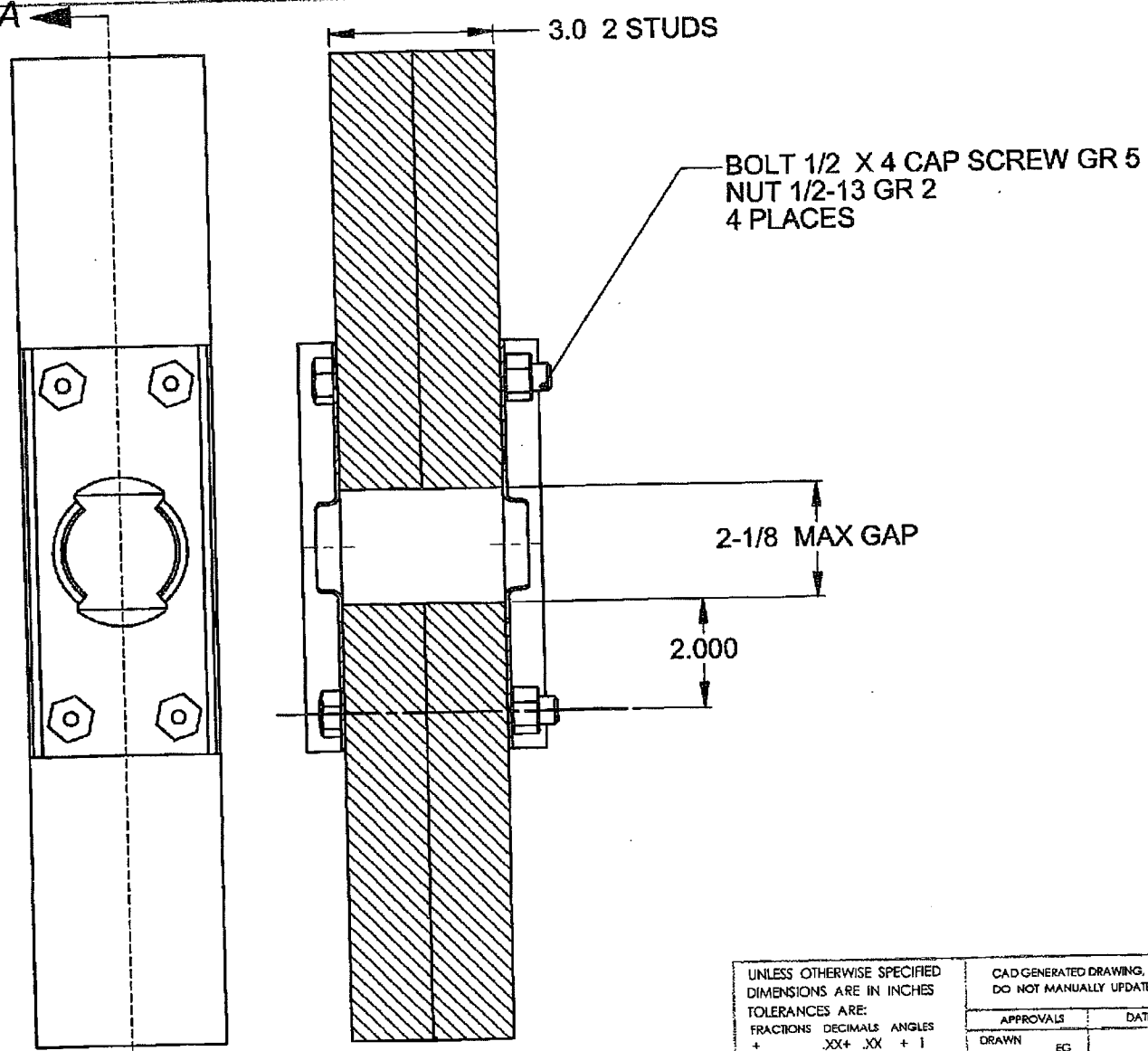

SECTION A-A

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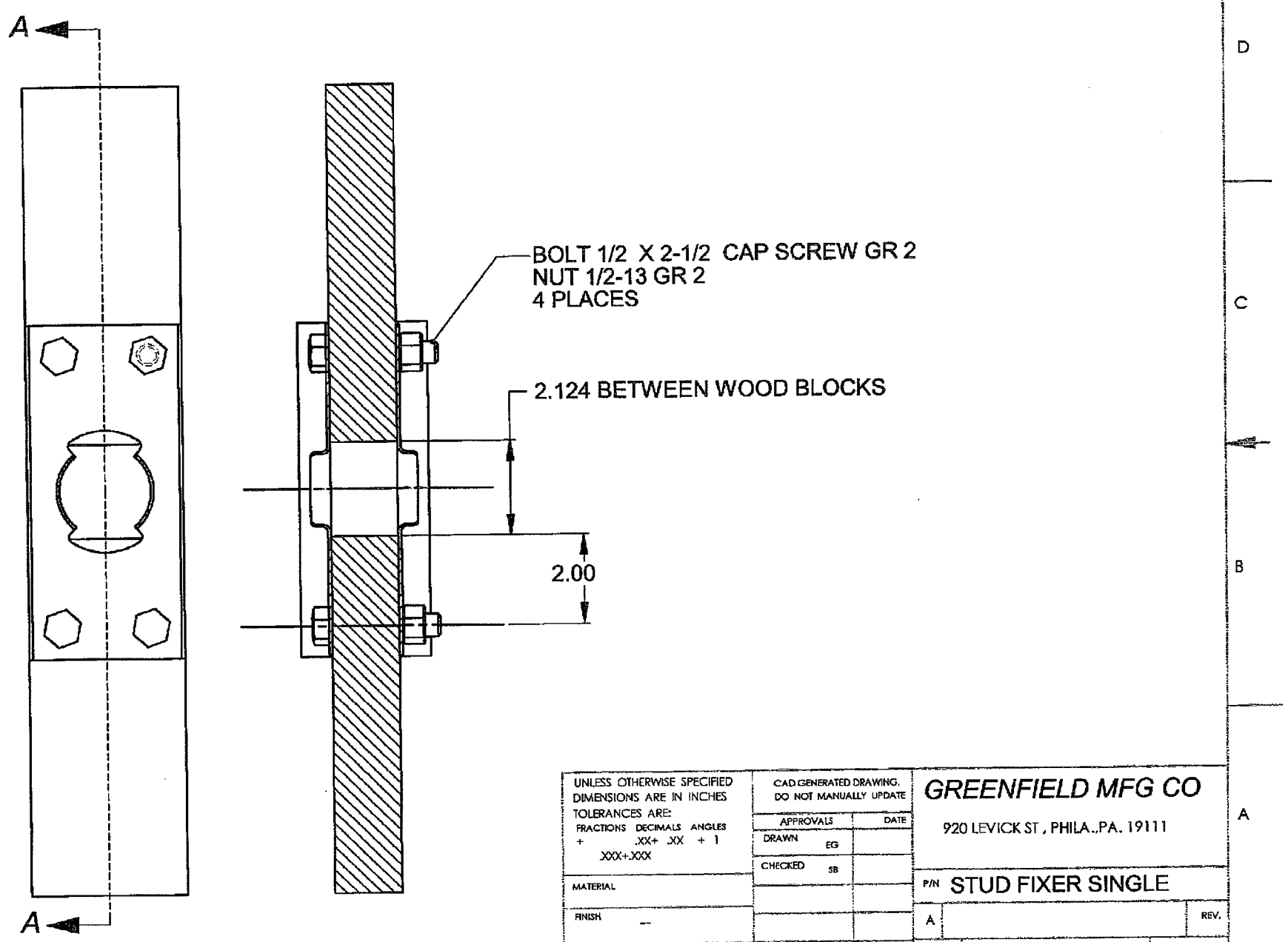

SECTION A-A

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS DECIMALS ANGLES + .XX+ .XX + 1 .XXX+.XXX	CAD GENERATED DRAWING. DO NOT MANUALLY UPDATE	GREENFIELD MFG CO
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