CC Carriage Lifting Extension Analysis

Engineering Note #3740.210-EN-85

Revised August 7, 1987

Revised by: Richard D. Luther

PINNED EXTENSIONS FOR CC CARRIAGE

Extensions will be pinned to the support brackets in order to provide pick-up points for lifting the CC calorimeter / carriage combination. The extension must be long enough to ensure that the lifting cables will not bear on the cryostat heads. The total weight of the CC from Multiplan (Rev N) is:

MODULES	293	TONS
INNER VESSEL	11.4	
" STRUCTURE	8.0	
OUTER VESSEL	11.7	
CARRIAGE	5.0	
	<u>329.1</u>	TONS USE 340 TONS

$$\text{IMPACT FACTOR} \left(\frac{2166}{1970} \right) = 10\%$$

CHECK CRADLE INTERFACES

$$\begin{aligned} \text{BEARING ALLOWABLE STRESS} &= 0.75 F_y \text{ (Based on limits for web} \\ &\quad \text{crippling in plate girders in} \\ &= 0.75(30) \text{ AISC Specification for Bldgs)} \\ &= 22.5 \text{ ksi} \end{aligned}$$

$$\frac{P}{A} < 22.5$$

$$A > \frac{303.3}{22.5}$$

$$A > 13.5 \text{ in}^2$$

for 1 1/2" Plate

$$A = 1 \frac{1}{2} \times L$$

$$L = \frac{13.5}{1.5} = 9"$$

∴ USE 10" WIDE TOP PLATE
ON EXTENSION. THICKNESS (SAY 2")
AND ANGLE TO BE
SUFFICIENT TO COVER
FULL THICKNESS OF CARRIAGE
PLATE;

PIN JOINT BEARING

$$F_p = 0.9 F_y \text{ (AISC 1.5.1.5.1)} \\ = 0.9(30) = 27 \text{ ksi}$$

$$f_p = \frac{P}{A} = \frac{348}{1.5(10\frac{1}{4})} = 22.6 \text{ ksi} < 27 \text{ OK}$$

SHEAR OUT

$$F_s = 0.4 F_y \text{ (AISC)} \\ = 0.4(30) \\ = 12 \text{ ksi}$$

$$f_s = \frac{348}{(1.85 + 2.7)(10\frac{1}{4})} = 7.46 \text{ ksi} \quad \underline{\underline{\text{OK}}}$$

HORIZONTAL

$$f_s = \frac{303.3}{2(2)(10\frac{1}{4})} = 7.40 \text{ ksi} \quad \underline{\underline{\text{OK}}}$$

PIN

$$\text{Shear: } F_v = 0.22 F_u$$

$$\tau = \frac{P}{A} = \frac{348}{\frac{\pi(1.5)^2}{4} \times n} \quad ; \quad n = \text{number of shear planes.}$$

$$n = 6$$

$$\tau = \frac{348}{1.767(6)} = 32.8 < F_v$$

$$0.22 F_u > 32.8$$

$$F_u = 150 \text{ ksi TOOTH H.K.H.}$$

$$n = 8$$

$$\tau = \frac{348}{1.768(8)} = 24.6 \text{ ksi}$$

$$0.22 F_u > 24.6$$

$$\underline{\underline{F_u > 112 \text{ ksi}}}$$

$\therefore$ USE MATERIAL HAVING TENSILE STRENGTH IN EXCESS OF 112 ksi.

SHEAR

$$\tau = \frac{P}{A} < 0.4 F_y = 12 \text{ ksi}$$

$$\tau = \frac{170}{4(10\frac{1}{4})} = 4.15 \text{ ksi} \quad \underline{\underline{\text{OK}}}$$

TENSION

$$f_t = \frac{P}{A} < F_u = 0.6 F_y = 18 \text{ ksi}$$

$$f_t = \frac{303.3}{(4 - \frac{1.5}{2})(10\frac{1}{4})} = 12.1 \text{ ksi} \quad \underline{\underline{\text{OK}}}$$

EXTENSION

MATERIAL: ASSUME A-36 OR BETTER

$$F_y = 36 \text{ ksi MIN.}$$

PIN JOINTBearing

$$F_p = 0.9 F_y = 32.4 \text{ ksi}$$

FIND REQ LENGTH

$$\frac{P}{A} < 32.4 \text{ ksi}$$

$$1.5l > \frac{348}{32.4}$$

$$l > 7.16''$$

$$2a + 3(1.875) > 7.16$$

$$a > 0.77''$$

$$\text{let } a = 1''$$

$$l = 2(1) + 3(1.875) \\ = 7.625''$$

$$w = 16\frac{1}{4} + 2(1\frac{1}{8}) + 2(1) \\ = 18\frac{1}{2}''$$

Shear

$$A_1 = (1\frac{3}{8} + 2\frac{1}{4})(7.625) = 27.64 \text{ in}^2$$

$$A_u = 2(1.625)(7.625) = 24.78 \text{ in}^2$$

$$\frac{P}{A} < F_s = 0.4(36) = 14.4 \text{ ksi}$$

$$P_{MAX} = 14.4(24.78)$$

$$P_{MAX} = 357 \text{ K} < 348 \text{ OK}$$

(conservative!)

VERTICAL SHEAR

$$f_s = \frac{170}{4(7.625)} = 5.6 \text{ ksi} < 14.4 \text{ OK}$$

TENSION

$$f_a = \frac{303.3}{(4 - 1\frac{9}{16})(7.625)} = 14.32 \text{ ksi}$$

$$F_a = 0.6 F_y = 0.6(36) \\ = 21.6 \text{ OK}$$

SHACKLE CONNECTION

USE CROSBY # S-2130
85^T SHACKLES

SIZE WELD

WELD

$$f = 0.3 F_y A$$

$$= 0.3 (60 \text{ ksi}) (0.707)$$

$$= \underline{\underline{12.7 \text{ K/in}}}$$

E60XX WELD WIRE
ON 1" FILLET

BASE METAL

$$f = 0.4 F_y A$$

$$= 0.4 (36) (1.0)$$

$$= 14.4 \text{ K/in}$$

∴ WELD WIRE CONTROLS.

$$W = \frac{170/2}{\pi (7)} = 3.87 \text{ K/in}$$

$$\omega = \frac{3.87}{12.7} = 0.304 \Rightarrow \text{USE } 1/2" \text{ FILLETS (CONSERVATIVE)}$$

BEARING

$$F_p = 0.9 F_y = .9(36) = 32.4 \text{ ksi}$$

$$f_b = \frac{170}{2(3/4)(1)} = 26.2 \text{ ksi} \quad \underline{\underline{OK}}$$

SHEAR

$$F_s = 0.4 F_y = 14.4 \text{ ksi}$$

$$\begin{aligned} A_s &= 2(4.2)(1.0) + 4(3.1)(1) \\ &= 8.4 + 12.4 \\ &= 20.8 \text{ in}^2 \end{aligned}$$

$$f_s = \frac{170}{20.8} = 8.17 \text{ ksi} \quad \underline{\underline{OK}}$$

TENSION

@ A

$$f_a = \frac{(170/2)}{(1)(4.5)} = 18.9 \text{ ksi}$$

$$F_a = 0.6 F_y = 0.6(36) = 21.6 \text{ OK}$$

BENDING MOMENTS

SECTION @ B-B

$$W = 12 + 2 \left(\frac{6 \frac{1}{8}}{2 \frac{1}{4}} \right) (4)$$

$$= 14.29'' \Rightarrow 14 \frac{1}{4}''$$

	A	y	A _y	Ad ²	I _o
①	57	$\frac{y}{2}$	114	44.8	76
②	9	8 1/2	76.5	283.6	41
	66		190.5	I = 465.4	

$$\bar{y} = 2.884$$

$$S_{top} = 10.11 \times 10^3 \quad S_{bot} = 161.1$$

Check web shear @ hole.

$$A_w = 1 \times (9 - 3\frac{1}{2} + 4) \\ = 9.75$$

$$f_s = \frac{170}{9.75} = 17.4 \text{ ksi}$$

$$F_s = 0.4 F_y = 14.4$$

CONSIDER REINFORCING PADS

$$A_w = 9.75 + 2(1 \times 7 - 3\frac{1}{2}) \\ = 9.75 + 7.5 \\ = 17.25$$

$$f_s = \frac{170}{17.25} = 9.86 < 14.4 \text{ OK}$$

Check web away from hole

$$A_w = 1(9 + 4) = 13$$

$$f_s = \frac{170}{13} = 13.1 \text{ ksi} < 14.4 \text{ OK}$$

Bending - Compression Controls

AISC 1.5, 1.4.5.2

$$l = 22\frac{3}{4} + 8 = 30\frac{3}{4}$$

$$r_T = \sqrt{\frac{(1/2 \times 3)(1)^3}{(1)(3)}} = 0.289"$$

$$l/r_T = 106.5$$

$$C_b = 1.0$$

$$\sqrt{\frac{(510 \times 10^3)(1.0)}{F_y}} = 119 > l/r_T$$

$$F_b = \left[\frac{2}{3} - \frac{F_y (l/r_T)^2}{1530 \times 10^3 C_b} \right] F_y$$

$$= \left[\frac{2}{3} - \frac{36(106.5)^2}{1.53 \times 10^6} \right] F_y$$

$$= 0.4 F_y$$

$$= 0.4(36)$$

$$= 14.4 \text{ ksi}$$

$$F_b = \frac{M_{max}}{S}$$

$$M_{max} = 14.4(10.11) \\ = 146 \text{ in-k}$$

OBVIOUSLY UNACCEPTABLE, THEREFORE, TOP FLANGE MUST BE CONSIDERED. CHECK SECTION B-B FOR YIELDING:

$$F_b = 0.6 F_y$$

$$0.6(36) = \frac{M_{max}}{10.11}$$

$$M_{max} = 218.4 \text{ in-k}$$

$$l \approx \frac{218.4}{170} = 1.28"$$

Note that consideration of full web height (9 1/2") and reinforcing pads will reduce this stress. Bring top flange to within 1 3/4" of centerline of hole.

	A	y	Ay	Ad^2	I_o
①	20	14	280	1455	6.7
②	9	8 1/2	76.5	83	61
③	57	2	114	687	76
	86		470.5		

$$I = 236.8$$

$$\bar{y} = 5.471''$$

$$S_{top} = 248.5 \quad S_{bot} = 432.9$$

$$M_{max} = 170 \text{ K} \times 22.75 = 3868 \text{ in} \cdot \text{K}$$

$$f_b = \frac{M}{S} = \frac{3868}{248.5} = 15.57 \text{ ksi}$$

Comp. Section:

$$I_{AA} = \frac{1}{12} (10^3)(2) + \frac{1}{12} (1)^3(3) = 166.9$$

$$A = 20 + 3 = 23$$

$$\frac{L}{r} = \frac{30.75}{2.69} = 11.4$$

$$r = \sqrt{\frac{I}{A}} = 2.69$$

$$\sqrt{\frac{108 \times 10^3 C_b}{36}} = 53.2 > \frac{L}{r}$$

$$\therefore F_b = 0.6 F_y = 21.6 > f_b$$

OK

Shear Welds

$$f = 12.7 \text{ K/in}$$

TOP

$$W_g = \frac{VQ}{nI} = \frac{170(20)(14 - 5.471)}{2(236.8)} = 6.123 \text{ K/in}$$

$$w = \frac{6.123}{12.7} = 0.482 \Rightarrow \text{use } \frac{1}{2}'' \text{ fillets or full groove weld}$$

BOTTOM

$$W_g = \frac{VQ}{nI} = \frac{170(57)(5.471 - 2)}{2(236.8)} = 7.102 ; w = \frac{7.102}{12.7} = 0.56'' \quad \text{No Good}$$

$$\text{Use 70 KSI Electrode (E70XX); } f = 0.3(70)(.707) = 14.8 \text{ K/in}$$

$$w = \frac{7.102}{14.4 \text{ (Base metal)}} = 0.49'' \text{ use full groove weld}$$

C-C

(Note: 2 required as shown, 2 with opposite slope.)