O.H. MODULE VACUUM LIFTING FIXTURE

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WRITTEN BY:

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VACUUM LIFTING DEVICE:

In order to move the 800 lb. copper plates that make up the O.H. modules a vacuum lifting device has been made that will lift the plates safely. The purpose of this report is to provide documentation for the structural integrity of the system and to make sure that it passes all of the safety requirements that have been established for a system of this nature.

VACUUM LIFTING DEVICE: VACUUM SYSTEM

The vacuum system is composed of a PIAB model M125 vacuum pump that has the pumping capacity of 27 in. Hg. This pump will produce vacuum for three 8 1/2 in. diameter suction cups or pads. A pressure gauge is fixed on the unit to allow the operator to continually monitor the pressure during all lifts. An additional safety feature is a mechanical vacuum monitoring device that is set to emit a shrill tone if the system vacuum falls below 24 in. Hg. A "bleed" valve fixed on the unit will be used to let the system go to atmospheric pressure once the lift is complete. A 3 psi. check valve and a vacuum reserve of 384 in.³ is used to insure that the device will not just drop the object if the pump fails. A schematic for the pumping system is given in Figure 1.

Figure 1:

The first thing that must be done is to analyze the vacuum system to determine if we have enough lifting capacity. According to the ANSI/ASME American National Standard ¹ for vacuum lifting devices, the the ultimate pad capacity is defined as:

$$UPC = 1/2 * A * Hg \quad \text{Where: } A = \text{Total suction cup area.}$$

$$Hg = \text{Vacuum pump capacity.}$$

For our case, $UPC = 1/2 * 170.24 \text{ in.}^2 * 27 \text{ in. Hg}$

$$UPC = 2298.132 \text{ lbs.}$$

Because we will only lift horizontal loads, the rating of the vacuum lifting device can be a maximum of $1/2 * UPC$ or:

$$\text{Maximum Load Rating} = 1/2 UPC$$

$$\text{Maximum Load Rating} = 1149.066 \text{ lbs.}$$

VACUUM LIFTING DEVICE: STRUCTURAL ANALYSIS

The structure portions of the vacuum lifting device are shown in Figure 2. The structure consists of an aluminum plate to which the suction cups are fixed and a steel hooking piece which will be used to hoist the device.

Figure 2:

According to the standards mentioned above, the load bearing structure portions of the device must have a minimum design factor of two times the UPC based on the yield strength of the material. This means that the aluminum plate and the steel hooking piece must be able to withstand a force of:

$$\text{Maximum Force} = 2 \text{ UPC}$$

$$\text{Maximum Force} = 4596.264 \text{ lbs.}$$

Table 1 show the properties of interest of the two different materials used to make the device.

Table 1: Material Properties ²			
		<u>Tensile Strength</u>	<u>Yield Strength</u>
6160-T6511	Aluminum	45 ksi	40 ksi
Carbon Steel (1020 H.R.)		55 ksi	35 ksi

The analysis of the aluminum plate can be found in Appendix 1 of this report.

The hooking device can be easily analyzed. Figure 3 shows the hooking device along with the dimensions needed to analyze it. The piece is made of 1020 H.R. steel.

Figure 3:

Pull-Out shear in the hole:

$$\text{Stress} = \text{Force} / \text{Area}$$

$$\text{Stress} = 4596.264 \text{ lbs} / (2 * 2 \text{ in.} * 1/2 \text{ in.})$$

$$\text{Stress} = 2.298 \text{ ksi}$$

Tensile stress in edges:

$$\text{Stress} = \text{Force} / \text{Area}$$

$$\text{Stress} = 4596.264 \text{ lbs} / (2 * 7/8 \text{ in.} * 1/2 \text{ in.})$$

$$\text{Stress} = 5.252 \text{ ksi}$$

!!! This piece will not be stressed above the allowable limits.

Figure 4 shows a three dimensional view of the hook and the type of welds used to make the hook.

Figure 4:

Figure 5 shows a cross section of the weld and the dimensions needed to analyze it.

Figure 5:

Tensile stress in the weld:

$$\text{Stress} = \text{Force} / \text{Area}$$

$$\text{Stress} = 4596.264 / (2 * 4 * .177)$$

$$\text{Stress} = 3.246 \text{ ksi.}$$

!!! The stress in the weld will never be greater than the allowable stresses.

Four (4) 3/8"-16 standard Grade 1 bolts are used to attach the hooking piece to the aluminum base. Standard Grade 1 bolts are made from low to medium carbon steel and have a yield strength of 33 ksi in tension loading.³ The total stress in the four bolts is given by:

$$\text{Stress} = \text{Force} / \text{Area}$$

Where the area in question is the minimum section area of the bolt which in this case is .0678 in².⁴

$$\text{Stress} = 4596.264 / (4 * .0678)$$

$$\text{Stress} = 16.947 \text{ ksi.}$$

It is easy to see that the stress in this part of the device falls safely within the allowable limits.

!!! The bolts will not be stressed above the allowable limits.

VACUUM LIFTING DEVICE: LOAD TESTING

The vacuum lifting device should be rated at the maximum capacity of 1100 lbs. In order to do this, the device must be load tested at 1.25 times the rated load or 1375 lbs.⁵ All structural aspects of the device have been shown to be sound.

An accepted procedure for the testing of the vacuum lifting device is included in Appendix 2 of this report.

REFERENCES:

- 1 ANSI/ASME B30.20-1985, AN AMERICAN NATIONAL STANDARD: Below-the-Hook Lifting Devices, The American Society of Mechanical Engineers, 1986, p. 25.
- 2 Central Steel & Wire Company 1986-87 Product Catalog, pp. 253, 285.
- 3 ASTM, SEA and ISO GRADE MARKINGS AND MECHANICAL PROPERTIES FOR STEEL FASTENERS, p. N-20.
- 4 Marks' Standard for Mechanical Engineers, 8th Edition, McGraw Hill 1969, p. 8-10.
- 5 ANSI/ASME B30.20-1985, AN AMERICAN NATIONAL STANDARD: Below-the-Hook Lifting Devices, The American Society of Mechanical Engineers, 1986, p. 27.

APPENDIX 1

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O.H. MODULE VACUUM LIFTING FIXTURE

APPENDIX 1

THE ALUMINUM PLATE WILL EXPERIENCE THE FORCES SHOWN BELOW.

VIEWING THIS PIECE AS A SIMPLY SUPPORTED BEAM:

FINDING F_1 & F_2 : $\Sigma F: F_1 + F_2 = 4596.264$

$$\Sigma M: 6F_1 = 9F_2$$

$$F_1 = \frac{3}{2}F_2$$

$$\frac{3}{2}F_2 + F_2 = 4596.264$$

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$$\frac{5}{2} F_z = 4596.264$$

$$F_1 = 2757.726 \text{ lbs}$$

$$F_z = 1838.504 \text{ lbs}$$

FORCE DIAGRAM:

MOMENT DIAGRAM:

$$1838.509 \times 9" = 16546.536 \text{ m-lb}$$

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THE STRESS PRODUCED BY THIS MAXIMUM MOMENT IS OF THE GREATEST CONCERN

$$\sigma = \frac{Mc}{I}$$

Where σ = STRESS

M = MAXIMUM MOMENT AT THE PICK-UP POINT

C = DISTANCE OF MAXIMUM STRESS FROM THE NEUTRAL AXIS.

I = MOMENT OF INERTIA OF THE SECTION OF MAXIMUM MOMENT; the PICK-UP POINT

$$M = (1838.504)(9) = 16546.536 \text{ m} \cdot \text{lb}$$

$$C = \frac{3}{4} \times \frac{1}{2} = \frac{3}{8} \text{ m}$$

$$I = \frac{1}{12}bh^3 = \frac{1}{12}(14)\left(\frac{3}{4}\right)^3 = .492 \text{ m}^4$$

STRESS:
$$\sigma = \frac{(16546.536 \text{ m} \cdot \text{lb})(\frac{3}{8} \text{ m})}{.492 \text{ m}^4}$$

$$\underline{\underline{\sigma = 12.612 \text{ Ksi}}}$$

THE STRESS PRODUCED BY THE MAXIMUM BENDING MOMENT DOES NOT EXCEED THE ALLOWABLE LIMITS. !!

APPENDIX 2

APPENDIX 2

The procedure for testing this vacuum lifting device shall be as follows:

- 1) A suitable load shall be found that weighs 1.25 X the rated load of 1100 lbs. or 1375 lbs.
- 2) During the test all personnel will stay clear of the test load.
- 3) The normal operating procedures of turning on the safety alarm switch before connecting the air line to the vacuum pump, and of monitoring the vacuum gauges will be followed.
- 4) The test shall consist of the following steps followed in sequence:

Attach the vacuum fixture to the test load.

Raise the test load a minimum distance to assure that the load is supported by the vacuum lifting fixture.

Hold load for two (2) minutes.

Disconnect the air line from the vacuum pump. By monitoring the vacuum gauge, note the initial vacuum pressure and the change in pressure over four (4) minutes. The vacuum pressure with power off shall not decrease more than 10 % in four (4) minutes.

Lower the fixture and the load to the ground.

Open the ball valve and reduce the vacuum pressure just until the vacuum safety alarm begins to sound; quickly close valve.

Using the pressure gauge, visually verify that the alarm sounds at the set safety pressure, 24 in. Hg.

Raise the test load a minimum distance to assure that the load is supported by the vacuum lifting fixture.

Hold for two (2) minutes.

Lower the load for release.

Visually inspect the vacuum fixture for any defects.

If the vacuum fixture fails to pass any step in the test then the test should be terminated and the defect shall be corrected. After any defect has been corrected the entire test sequence must be repeated from the beginning.