Written Design Review— Group 6 October 19, 1998

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Team 6's goal is to produce a digital bathroom scale that accurately measures weight from any point on its weighing surface, while meeting all specified requirements (see Table 1). This design review describes Team 6's scale and discusses project advancement.

CHARACTERISTIC	SPECIFICATION
capacity	250 pounds force
resolution	5 pounds force
accuracy	5% (25-100 pounds) 2% (100-250 pounds)
readability	up to 6 feet
weighing surface size	holds (2) 13EEE shoes
power	(2) 9 Volt batteries
kit size	copy paper box
assembly time	50 minutes
disassembly time	15 minutes

Table 1-- Design Requirements

Team 6's scale is divided into four major subsystems: 1) platform; 2) piston and cylinder; 3) strain bar; 4) electronics.

The first subsystem, the platform, collects the weight of the object set upon it. This subsystem is important because all the weight of an object must be collected so that it can be transferred to other subsystems. The platform (see Figure 1) is box-shaped with an open bottom end. The box shape houses all other systems, and adds rigidity because of its joints. Also, a ¼ inch aluminum plate is welded to the underside of the top of the platform to increase rigidity. The platform will be made of aesthetically-pleasing, ¼ inch aluminum diamond plate which is welded at the seams. The size of the platform (see Figure 1) accommodates size 13EEE shoes, while it is small enough to fit in a copy paper box. Problems encountered with the platform include need for aluminum welding, and complexity. After researching Reno Salvage's aluminum prices, $10.00 has been set aside for the platform.

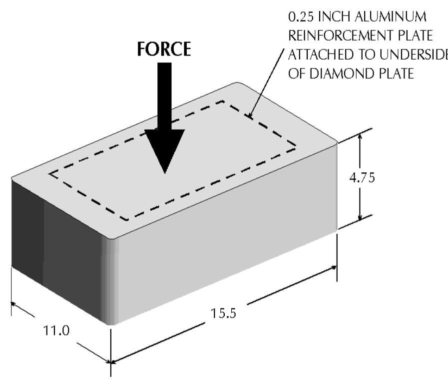

Figure 1-- Platform Detail (all dimensions in inches)

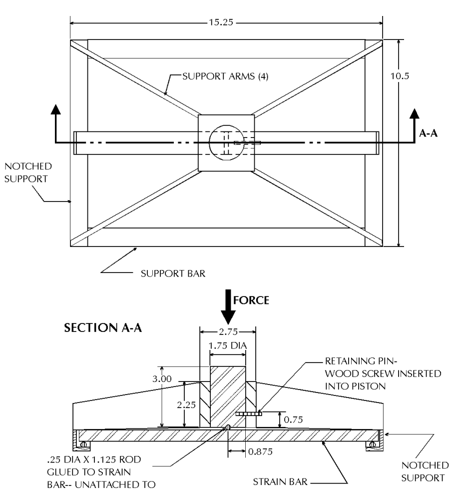

Figure 2—Piston & Cylinder Detail (all dimensions in inches)

Next, the piston and cylinder subsystem solves the problem of transfer of weight from any point on the platform to a lateral point (in other words, a line) on the strain bar. Because the strain bar encompasses three-point bending, weight must be applied to it at one lateral point, and the platform cannot do this alone. The piston and cylinder (see Figure 2) interfaces with the platform via a weld between the piston top and the platform reinforcement plate. This subsystem will also interface with the strain bar via the bottom of the piston. As weight is applied to the platform, the piston moves downward through the cylinder, and the piston's bottom end applies weight to a rod attached laterally to the strain bar. This causes weight to be applied laterally at one point on the strain bar—the purpose of the piston and cylinder. The cylinder is supported by four support arms (see Figure 2) that are mounted on support bars attached to a 3/8 inch plywood base. The piston has great enough diameter to cause it not to bend if weight is not balanced on the platform to which it is attached. The diameter and height of the piston increases friction dispersion between it and the cylinder, while a lubricant will decrease friction to allow piston movement if weight is not balanced on the platform. Also, the piston is taller than the cylinder to allow it room to move downward as the strain bar bends. This subsystem is constructed of aluminum to reduce total scale weight. Problems encountered with this subsystem include possible high cost, complexity, need for aluminum welding, and how to keep the piston from coming out of the cylinder when the scale is picked up. In order to solve the last problem, a retaining pin (see Figure 2) secures the piston. $35.00 is budgeted for the piston and cylinder to cope with possible high cost.

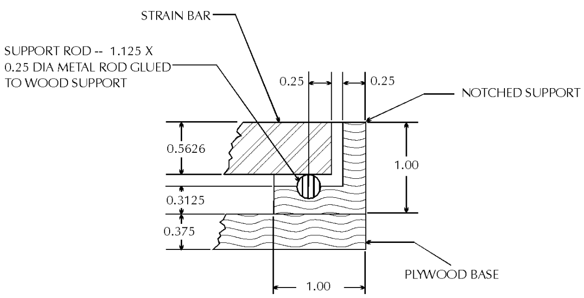

Figure 3-- Cross-section of Strain Gage-Notched Support Interface (all dimensions in inches)

The third subsystem, the strain bar, changes applied weight into strain. It embodies three-point bending because it is supported at two lateral points while weight is applied by the cylinder at one lateral point. The bar is supported by a wooden notched support at either end of its span. The ends of the strain bar fit inside the notch of each notched support and sit upon one lateral rod within each notch (see Figure 3). Atop the mid-point of the strain bar is a lateral rod that the piston pushes on (see Figure 2). This system of lateral rods allows for true three point bending. The strain bar is made of aluminum 6061-T6 because it is light-weight and common. The span of the strain bar is 14 ½ inches because that size easily fits inside the platform which encases it, but only 14 inches of the bar are strained. With the span and material selected, analysis of various bases and heights for the bar found that a base of 1 ¼ inches and height of ½ inches gave a strain of .001680 at 250 pounds (see Table 2). This strain value is most acceptable because the strain gage can handle such strain, and the sizing of the strain bar is common. Also, as a safety factor, this bar only stresses 20,160 psi at 300 pounds applied force, and aluminum 6061-T6 yields at 40000 psi.

	HEIGHT (in.)		
WEIGHT (lbs)	7/16	**1/2**	9/16
0	0	**0**	0
25	0.002194	**0.001680**	0.001327
300	0.002633	**0.002016**	0.001593

Table 2— Bar strain at various heights (Span = 14 in. & Base = 1 ¼ in.)

Problems encountered with the strain bar are possible difficulties in finding the correctly sized aluminum 6061-T6 bar, and fabrication of the notched supports. The notched support problem was solved by choosing wood as the material since it is easy to machine. $10.00 was budgeted toward this subsystem after researching Reno Salvage's aluminum prices.

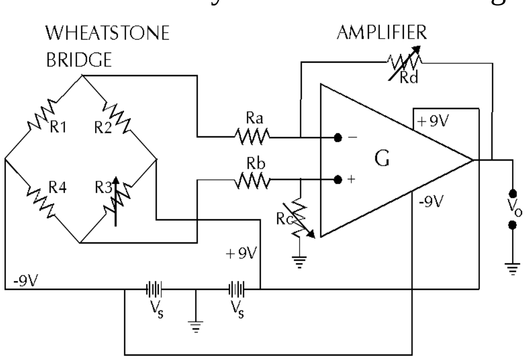

Figure 4-- Electronics Schematic

The last subsystem of Team 6's scale is the electronic system, which converts strain bar strain into a digital readout of weight. To make the conversion, first, a strain gage converts strain of the strain bar to resistance. The gage is glued to the bottom of the strain bar directly below the lateral point where weight is applied by the piston. The Micro-Measurements CEA series strain gage with a gage factor of 2.05, a resistance of 120 ohms, and a Self-Temperature-

Compensation of 13 (recommended for use with aluminum) is used because it is meant for general purpose use. This strain gage acts as a variable resistor in position R1 of a Wheatstone bridge (see Figure 4). The Wheatstone bridge converts the small change in resistance of the strain gage to voltage. To make such a change, four 120 ohm resistors are used in the Wheatstone bridge, one being the strain gage. No voltage leaves the bridge as long as R1*R3 equals R2*R4, but as the strain gage (R1) changes resistance the bridge outputs voltage. R3 is a potentiometer that zeroes the scale by making R1*R3 equal to R2*R4 if the strain gage does not equal 120 ohm. When 250 pounds are applied to Team 6's scale, the Wheatstone bridge outputs only 15.50 mV. This voltage must be amplified, so it is conditioned through a non-inverting amplifier. The amplifier includes a LM741 opamp (see Figure 4- opamp is labeled G) and four resistors—Ra, Rb, Rc, and Rd. The ratio of Rd to Ra, or Rc to Rb equals the gain of the voltage conditioned by the amplifier. Team 6's amplifier gain is about 161 because Rd and Rc are approximately 3,548,845 ohms while Ra and Rb are 22000 ohms, a standard value. This causes an amplifier output voltage of 2.5 V when 250 pounds are on the scale. Since there are no resistors with a value of 3,548,845 ohms, Rd and Rc will be potentiometers that include that value. These potentiometers can be used to adjust gain. The amplifier output voltage will be fed into a digital voltmeter that includes an A-D converter, and a display. By modifying decimal point position on the display, an input of 2.5 V can be displayed as 250.0, which corresponds to the weight on the scale. The supply voltage of the Wheatstone bridge and amplifier are both 18 V, so 9 V batteries supply each. After researching Sandy's Electronics prices, a generous $50.00 was budgeted toward electronics to cope with high prices, especially display prices.

The parts list of the Team 6 scale includes 16 parts (see Table 3). Team 6 estimates that the lateral rods, strain bar, notched support, and base will be relatively easy to fabricate. The On/Off switch, strain gage, and retaining pin require no fabrication. The other parts will be moderately to highly difficult to fabricate.

PARTS LIST		
Name	*Description*	*Qty.*
Platform	Al Box	1
Reinforcement Plate	1/4 in. Al Plate	1
Piston	1 3/4 in. Dia x 3 in. Al Rod	1
Cylinder	Bored 2 3/4 in. x 2 1/4 in. Block	1
Support Arm	1/4 in. Al Plate	4
Retaining Pin	Wood Screw	1
Lateral Rod	1/4 in. dia x 1 1/4 in. metal rod	3
Strain Bar	Al 6061-T6 Bar	1
Notched Support	Wood Bar with notch	2
Support Bar	Wood Bar	2
Base	3/8 in. plywood	1
Circuitry	Opamp, board, wires, resistors	1
Display	Digital voltmeter	1
On/Off Switch	Toggle switch	1
Zero	Rotating knob	1
Strain Gage	CEA-13-240UW-120	1

Table 3-- Parts List

Now that the scale is described, project progress will be discussed. At this point, Team 6 has met all previous deadlines because the team meets twice to three times a week. Future scheduling is as follows: 10/19-10/25- Finalize plans; 10/19-11/1- Acquire material and fabricate the prototype; 11/2-11/8- Test prototype; 11/9-11/16- Prepare prototype presentation and test results; 11/16-12/7- Prepare final presentation. Also, at present, Team 6 has spent $20.00 on research by buying a scale, and $10.00 for all platform and cylinder metal, which leads us slightly below budget. Team 6 has also found Reno Salvage to be a good source of aluminum necessary for the prototype, and Sandy's Electronics to be a good source of all electronic components except the strain gages. The main operational issue at this point is fabrication of the parts estimated to be difficult to fabricate because of their need for welding or metal cutting. Tools to do such fabrication work must be found.