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REPORT NO T4-88

AN IMPROVED PORTABLE HYDROSTATIC WEIGHING SYSTEM FOR BODY COMPOSITION

U S ARMY RESEARCH INSTITUTE
OF
ENVIRONMENTAL MEDICINE
Natick, Massachusetts

NOVEMBER 1987

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UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

TECHNICAL REPORT
No. T4-88

AN IMPROVED PORTABLE HYDROSTATIC WEIGHING SYSTEM FOR BODY COMPOSITION

by

P.I. FITZGERALD, J.A. VOGEL, J MILETTI AND J. M. FOSTER

US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE
NATICK MA

OCTOBER 1987

HUMAN RESEARCH

Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

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This report describes a total underwater weighing system for the determination of body density to estimate body composition. It was designed specifically to be suitable for transport to field sites to quickly weigh large groups of subjects accurately and reproducibly. The tank itself is made of 1/4 inch welded aluminum, weighs 141 pounds and is 4x3x4 feet in dimension. The subject to be weighed is suspended in the water on an aluminum chair and exhales to a residual lung volume through a snorkel device. Weights are registered with an electronic load cell, converted to a digital signal and fed into a desk top computer and software program which assists in the selection of stable readings and the computation of density, body fat and fat free mass. Heating and filtration of the water are accomplished with attached commercial Jacuzzi components. The system has been tested both in the laboratory and at four field locations and found to be both rugged and dependable. Repeated trials over days have shown a very high degree of reproducibility.

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FOREWORD

In 1982, the Exercise Physiology Division received a tasking from the Army Surgeon General to conduct a major research study with which to revise the Army's Weight Control Program described in Army Regulation 600-9. The objectives of the resulting study required the hydrostatic weighing of approximately 1500 soldiers at sites remote from the Institute. It was therefore necessary to develop a portable hydrostatic weighing system that would be durable and reliable, as well as, a weighing procedure that would be rapid, reproducible and accurate. The resulting system is described in this report.

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ABSTRACT

This report describes a complete underwater weighing system for the determination of body density to estimate body composition. It was designed specifically to be suitable for transport to field sites to quickly weigh large groups of subjects accurately and reproducibly. The tank itself is made of 1/4 inch welded aluminum, weighs 141 pounds and is 4x3x4 feet in dimension. The subject to be weighed is suspended in the water on an aluminum chair and, while completely submerged, exhales to a residual lung volume through a snorkel device. Underwater weights are registered with an electronic load cell, converted to a digital signal and fed into a desk top computer, a software program which assists in the selection of stable readings and the computation of density, body fat and fat free mass. Heating and filtration of the water are accomplished with attached commercial Jaccuzzi® components. The system has been tested both in the laboratory and at four field locations and found to be both rugged and dependable. Repeated trials over days have shown a very high degree of reproducibility.

I INTRODUCTION

Research involving the assessment of physical fitness of military personnel often includes the estimation of body composition. Although many methods for body composition assessment are available to investigators e.g., anthropometric, radiographic, densitometric, volumetric, gas dilution and K^{40}, densitometry or hydrostatic weighing is the most popular (1). However, given that this method requires specialized equipment, trained personnel and a large time commitment, its use is generally confined to research and as a reference standard for less sensitive indirect methods.

Prior to 1982 the Exercise Physiology Division met the research requirements for the estimation of percent body fat and lean body mass using the four site skinfold technique of Durnin and Womersley (2). This was considered the best practical field method, as the Division did not have an underwater weighing system that was field deployable. In 1982 the Division received a tasking which requested validation of the height-weight and body fat standards and methodology specified in AR 600-9, the Army Weight Control Program.

Since the required reference or "gold" standard for AR 600-9 is hydrostatic weighing, it was necessary to develop a weighing system suitable for such a study that required weighing 1500 soldiers. Some of the original specifications required of the system included: a) tank should be durable but light enough to be man-handled for transport to remote Army posts, b) sensitivity and accuracy of an electronic force transducer rather than a spring loaded weight balance, c) operator bias should be minimized by an on-line computer analysis of the output signal of the electronic force transducer and d) heating and filtering system should be readily transportable and provide maximum safety for the subject.

The purposes of this technical report are to describe the design, components and mechanical operation of the resulting system, describe the computer program and operating procedure used, provide detailed instructions for the total operating procedure and finally, provide data which validates its reliability and reproducibility.

II BACKGROUND

In body composition studies related to physical fitness and physical performance, we are most concerned with the body's content of fat and muscle mass. Estimates of these components are facilitated by the fact that their densities are quite different. The density (at 36 degrees C) of fat is 0.9007 while protein is 1.34 and bone (mineral and non-osseous material) averages 3.15 (3). The density of fat free mass can be deduced from its components to be 1.100. Thus by determining the body's density, one can calculate the proportion of fat and fat free mass (primarily muscle and bone). Body density (weight/volume), in turn, can be determined by the difference in the weight of the body in air and while submerged in water, as first employed systematically humans by Behnke, et al (4) and described more recently by Goldman and Buskirk (5).

The procedure requires that the underwater weight be taken during maximum exhalation, that the temperature and density of water is known, and the residual lung volume and gastrointestinal gas volume is known. Residual lung volume can be measured and gastrointestinal gas is assumed to be 100 ml. The resulting equation is:

$$\text{Body density} = \frac{Wa}{((Wa - Ww)/Dw) - RV - 100ml}$$

where Wa = weight in air, Ww = weight in water, Dw = density of water at observed temperature, RV = residual lung volume. Percent of the body weight that is fat can be calculated according to the Siri equation(8):

$$\%\ \text{body fat} = ((4.95\ /\ \text{body density}) - 4.519) \times 100$$

Thus a hydrostatic weighing system requires two major components: a means of determining underwater weight at maximum expiration and a means of measuring residual lung volume. The latter may be estimated from body size but should be directly measured in research applications. Methodology for residual lung volume is reported elsewhere (6).

III WEIGHING SYSTEM DESIGN AND COMPONENTS

A. Design Considerations

The following design criteria need to be taken into consideration when designing a hydrostatic weighing system. First, the sensitivity of the weighing mechanism needs to be 10 grams in order to measure body fat to an accuracy of one-half percent. Also, as specific gravity changes with temperature, automatic temperature control is imperative to insure consistent readings and thermal comfort of the subject so that shivering and body movement that add artifacts to the scale readings are avoided. Trade-offs are needed to minimize cold water heating time while keeping the size of the electrical service small enough for practical use. Electrical safety is a major concern because of the high power voltages used in close proximity to a wet location. Because the tank needs to be portable and set up in various field laboratories, it was necessary to utilize a lightweight, high strength and corrosion resistant material.

B. Design and Components

The hydrostatic weighing system consists of the tank, a base plate with casters, load cell and subject support bracket, chair, ladder, and heater/filtration system. Figure I depicts a perspective of the system. The individual mechanical structures are shown in Drawings 1 through 7 in Appendix A.

The tank as shown in Drawing I has inside dimensions of approximately: height - 48 in., width - 36 in., length - 48 in. This was the minimum volume that allowed for ease of subject submersion while still maintaining portability and having acceptable load forces once the tank was filled with water. The weight of the tank is 141 pounds and when filled with water weighs approximately 3000 pounds. The tank is constructed of aluminum 5052-H32 1/4 in. thick plates welded together. In order to maintain rigidity and give support to a filled tank, three 2 x 2 x 1/8 in. square aluminum tubes are welded and equally spaced 24 in. apart on the bottom of the tank. An aluminum

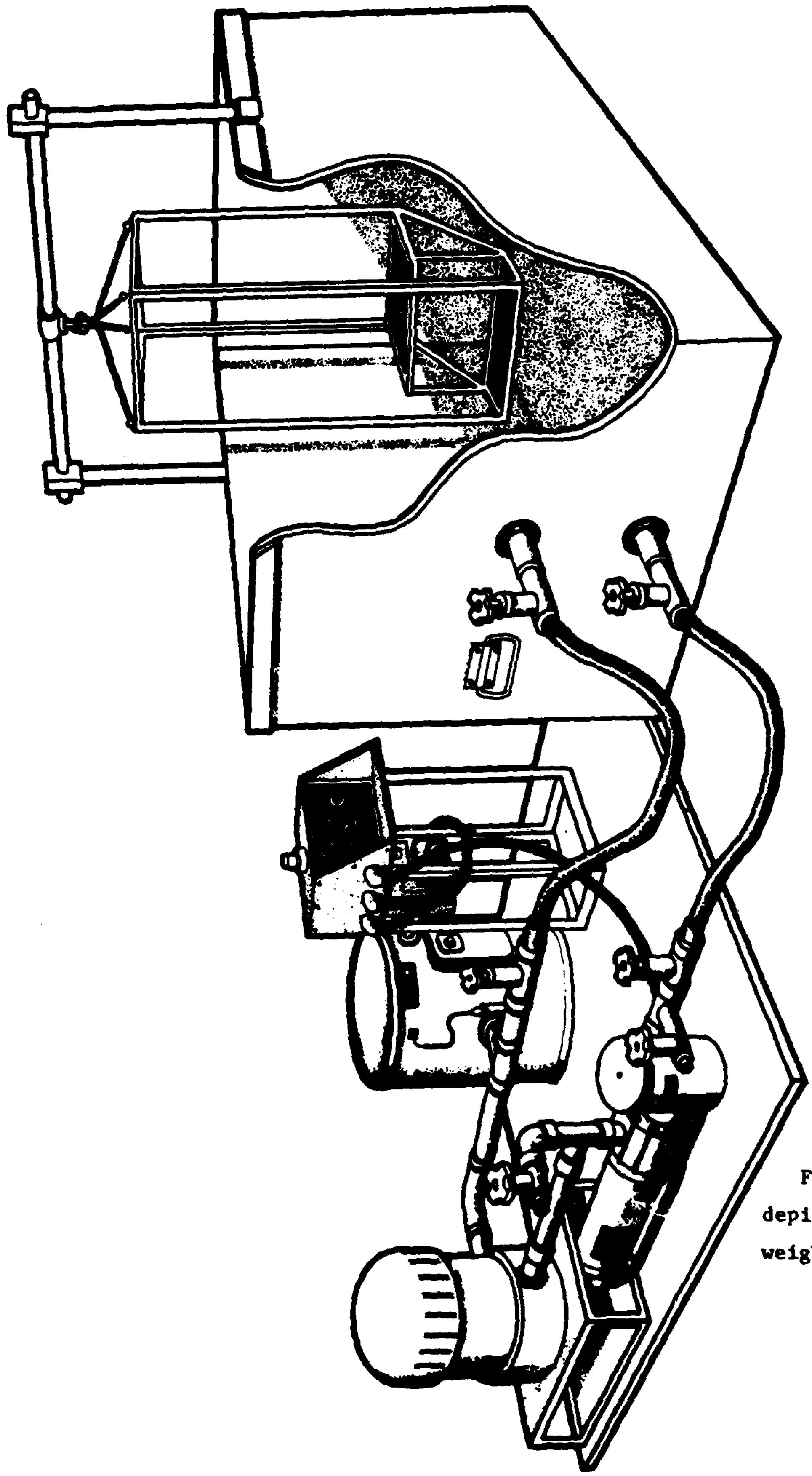

Figure 1. Schematic depiction of underwater weighing system.

flange 3 x 3 x 5/16 in. is welded to the top of the tank for additional rigidity. Aluminum handles are placed on all four sides, 24 in. from the bottom and 8 in. from each vertical corner.

The transducer mount detail and the transducer suspension system clamp detail are shown in Drawing 2. The support assembly is made from stainless steel pipe (1 1/4 in. schedule 80 type 304). The load cell suspension material and design were selected to reduce oscillations resulting from non-axial forces and subject movement.

The load cell, AMETEK model CA 100LB-T-S-L25, is rated for 100 pounds maximum. The transducer excitation voltage is +15 volts DC and the output is rated for 3 mv/volt excitation and is fed to an AMETEK model 6001-A-A-A signal conditioner whose output in turn is fed to an analog to digital converter (Hewlett-Packard model 59313).

The heating and filtration schematic is shown in Drawing 6. Once the tank is filled, water is circulated by a 0.5 horsepower pool pump (Century model 1081) through a commercially available Jaccuzzi[R] pool filter with a CFT cartridge filter. The heater is a 6000 watt, 240 VAC unit having thermostatic control. Together, the heating and the filtration system requires a 208 VAC, 30 ampere, single phase electrical service. A wiring diagram for the heater and filtration system is shown in Drawing 7.

The system as developed has incorporated several safety features. The heater has a built-in thermal sensor that shuts off power to the heater when the temperature exceeds 115°F with a redundant sensor set at 120°F. Because human volunteers are immersed in a water bath, the safety of the test subject must be ensured and leakage currents need to be minimized in accordance with Department of the Army Technical Bulletin TB MED 286(Ref. 7). A ground fault interrupter circuit that is built into the control/switch panel is set to trip at 6 milliamps of leakage current. An emergency power reset switch located on top of the control box provides redundant power cut-off capabilities.

A picture of two systems ready for operation is shown in Figure 2.

IV OPERATION OF THE WEIGHING SYSTEM

A. Set up and filling procedures.

Before beginning the filling process, the drain hole in the bottom of the tank must be plugged and valves must be mounted on the two front ports. The port is prepared by wrapping teflon tape in a clockwise direction over the threads several times. A PVC gate valve is threaded on in a clockwise direction until it is firmly seated with the knob in an upright position. The tank may have to be elevated to thread the bottom valve. Once the valves are mounted, a filter/heating hose is connected to each valve with the opposite end of the top hose connected to the heater and the bottom hose to the pump side of the filter/heating system. The flow of the system travels from the bottom port to the pump to the filter, then to the heater and back out through the top port.

Once the valves and hoses are in place, a standard garden hose can be used to fill the tank. When the water level is four inches above the height of the lower gate valve, the filtering and heating system system may be engaged as described in Section B. While hot or cold water can be used, the lower the

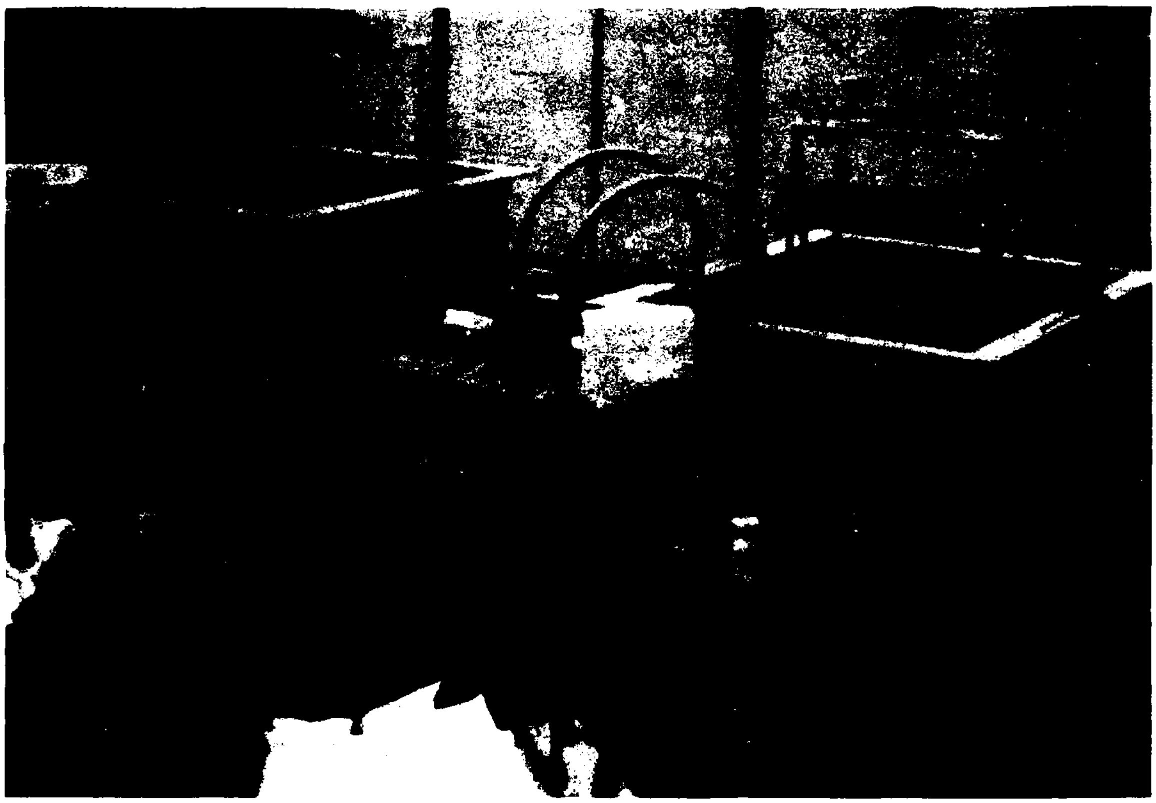

Figure 2. Underwater weighing system ready for operation.

initial water temperature, the longer the duration will be between fill and actual underwater weighing. For example, if the initial water temperature was 26° C, to raise it to 35° C will take 4 hours; if the initial temperature is 22° C it will require 6 hours to reach 35° C; if the initial temperature is 28.5° C it will take 2.75 hours to reach 35° C. The water temperature should be 37° C at the time of the underwater weighing. The water temperature should not exceed 39° C nor drop below 35° C. The water level should be approximately 6 inches from the top of the tank, with the chair submerged. The level is primarily dependent upon the height and size of the subject to be measured, for example, the water level in the tank would be lower for a large person. While filling the tank, it is desirable to inspect the valves, filter and heating apparatus and hoses for leaks.

B. Operation of Filtering and Heating Systems.

The platform that houses the filter and heating system should be positioned a safe and convenient distance behind the tank within the limits set by the length of the filter and heater hoses. All exposed metal surfaces should be grounded to the electrical service ground. (NOTE: The water pipe may have plastic tubing leading to it. Also the water pipe may be at a different ground potential than the electrical service which is not desirable). All electrical connections must conform to the National Electrical Code and any local codes. Ensure that the power switch at the control console is in the OFF position. Power connections to the control console and heater can then be made. The control console plugs into a 120 VAC, 15 A household receptacle and the heater to a 208 VAC, 30 A, single phase NEMA L6-30R receptacle. One should check the ground fault interrupters by pressing the TEST buttons.

Once it has been determined that there are no leaks in the system, and there is a sufficient amount of water, the gate valves on the tank and at the inlet and outlet ports of the filter and heating system are opened. The small vent plug on the top of the filter should be opened to vent trapped air, and closed quickly at the first indication that the water has reached the top of the filter, that is, when the water starts to leak out. The lint trap on the pump side of the assembly should be filled to the top with water. The system can then be turned ON at the power console and the system again checked for leaks. If leak free, the HEATER START button can be pressed. The heater will not engage for several minutes due to a built in time delay interlocked with the circulation pump circuit. The heater will not operate unless the circulation pump is running. The thermostat on the side of the heater should be adjusted in accordance with the initial temperature of the water in the tank to allow the temperature to increase to the desired level. Once the desired temperature has been reached the thermostat should be adjusted to maintain the temperature within comfortable limits.

C. Preparation of the Load Cell, A/D Converter, and HP 85.

1. The load cell and its indicator are plugged into the A/D converter.

2. The A/D converter is connected to the HP 85 computer via a HP-IB interface; the HP 85 must also have a ROM drawer and a 16k memory module.

3. The HP 85, Ametek indicator and A/D converter are plugged in and turned on.

4. The "UWW 2" software program (Appendix B) is loaded into the HP 85 and run in the calibration mode through menu driven instructions.

5. To zero the load cell and indicator, the load cell should be loadless and set the indicator ZERO with the ZERO ADJUST while in the GROSS MODE.

6. To ZERO the readings that appear on the HP 85 screen, the A/D converter CHANNEL 1 is adjusted to ZERO.

7. To CALIBRATE the high end of the LOAD CELL, a calibrated weight is hung from the load cell; and the readings adjusted on the A/D converter CHANNEL 1 GAIN setting until the calibration weight is achieved.

8. The calibration weight and hanger are removed and the ZERO is checked as in steps 5 and 6. If the ZERO is off by more than 0.025 (the minimum sensitivity of the load cell) then recalibration procedures should be repeated.

9. EXIT the CALIBRATION mode and ENTER the PROGRAM mode.

D. Subject weighing procedure.

Comment: We found that if we initiated the weighing procedure with the pump running, the turbulence created within the tank did not allow the recording of accurate readings. Thus, during the actual subject weighings, the pump was turned off.

1. The aluminum seat is suspended from the load cell assembly. The snorkel apparatus and weight belt should be placed on the seat.

2. Subject descriptive data, vital capacity and residual lung volume are entered.

3. The seat weight is taken with the test subject either fully submerged or submerged to the chin. Full submersion is more accurate, but requires more time to let the water settle. The snorkel must be closed, and the snorkel hose full of air. One must ensure that the subject is not touching the seat while

it is being weighed. To start the seat weight determination, key #1 is depressed and it will automatically stop sampling after 5 seconds. DO NOT try to stop it manually.

4. The seat weight should be taken twice and should not vary more than 0.150 kg (a difference of 0.150 or more requires that you recalibrate the load cell.

5. The test subject should sit on the seat and put the weight belt around their waist. Caution the subject not to pull the weight too snugly around their waist, as this will make exhalation and breathing underwater uncomfortable. The subject is instructed to insert the mouthpiece and put on the noseclip (Figure 3); also check that they are able to breath comfortably before they submerge.

6. The subject, while holding the snorkel apparatus in one hand and the chair with the other hand, should slowly bend forward while continuing to breath through the snorkel until they are fully submerged.

7. The computer technician should make the PERSON'S WEIGHT selection on the HP 85 and enter the water temperature.

8. A system of operator initiated signals should be worked out that will indicate to the submerged subject when they are to inhale and maximally exhale before they submerge.

9. When the subject feels comfortable and secure in the tank, instruct them to take a maximal inhalation followed by a maximal exhalation. They should be verbally encouraged to exhale fully.

10. Once the subject is fully submerged and exhaled, the computer operator should engage the sampling procedure, and continue sampling for 10-15 seconds.

Figure 3. Subject seated prior to submersion and weighing.

11. When the sampling is completed, the subject is instructed to resume breathing, and at this point the subject can stay submerged or come to the surface until the next trial.

12. The weights on the screen are now edited using the following instructions to recognize spurious scores which should be thrown out using the edit option:

a. Obvious Aberrant Scores: for example, if sampling is initiated while the subject is still exhaling, or if the subject comes out of the water before the sampling is terminated, or if the subject takes a breath while the sampling is in progress. Data accumulated during these situations should be discarded.

b. Bounces: for example, when 2 consecutive scores are more than 0.5 kg apart.

Examples:			
	12.2	13.4	
	12.3	13.4	
	12.9*	14.9*	
	12.1*	13.2*	
	12.3	13.4	
	12.4	13.5	
	12.5	13.6	*remove these scores

c. As readings are taken, the scores are accumulated and displayed in columns on the computer screen (usually three columns). If the scores in the first column are on the average several tenths less than the last 2 columns, discard the data in the first column. You do not want to average all of the numbers if the heaviest are in the last 2 columns or in the middle column. Obtain a representative group of weights that are stable, and have not been influenced by inhalation or exhalation.

d. Generally, if there is no pattern, for example, if the last columns were the heaviest, and all the scores are within 0.5 kg of each other, keep all of the scores. If the last columns were the heaviest, even though they differed less than 0.5 kg from the first columns, you would still edit out the first columns because of the trend (see c).

13. When the computer operator has completed editing the weights, engage the QUIT mode and the computer will print out the relevant body composition information and the computer operator will be ready to begin another trial.

14. A total of 7-10 trials should be conducted for each subject.

15. After the final trial, the NEW SUBJECT option is selected and the computer will print out STORE.

E. Tank Draining Procedures

1. Turn off the power at the main console.

2. Close all gate valves leading to and coming from the tank.

3. Remove the blue hose from the top gate valve and connect it to an extension hose and place the end securely into the drain source.

4. Leaving the top gate valve closed, open all other gate valves, turn the power on at the console and press the PUMP START.

5. Adjust the water flow with the gate valve at the filter.

6. Water will drain within 4 inches of the bottom of the tank. Finish draining with the wet/dry vacuum cleaner or use the drain plug at the bottom of the tank.

V VALIDATION DATA

To establish the variability and reproducibility of the system, 35 laboratory personnel (26 men and 9 women) were weighed 10 times on each of 5 successive days. The subjects averaged 33.4 (SD=9.0) years of age. Table 1 presents the mean ± SD density by trial, averaged from 5 days. Table 2 presents the mean density by day, an average of 10 trials per day. Using a repeated measures ANOVA with gender as a grouping factor, there was no difference in density over trials ($F= 2.54$) or days ($F=0.63$).

Table 1. Reproducibility of body density over days. Each day is an average of 10 trials. Units in grams per cubic centimeter, Mean ± SD.

	Males	Females
n	26	9
Day 1	1.054 ± .0170	1.035 ± .0117
2	1.054 ± .0162	1.035 ± .0105
3	1.055 ± .0164	1.034 ± .0108
4	1.055 ± .0163	1.033 ± .0110
5	1.055 ± .0164	1.034 ± .0103

Table 2. Variability within trials of body density performed on a single day. Data from 5 days combined. Units in grams per cubic centimeter, Mean ± SD.

	Males	Females
n	26	9
Trial 1	1.054 ± .0164	1.034 ± .0111
2	1.054 ± .0165	1.034 ± .0104
3	1.054 ± .0164	1.034 ± .0109
4	1.055 ± .0165	1.034 ± .0111
5	1.055 ± .0165	1.034 ± .0110
6	1.055 ± .0165	1.034 ± .0112
7	1.055 ± .0165	1.034 ± .0111
8	1.055 ± .0167	1.034 ± .0111
9	1.054 ± .0166	1.034 ± .0110
10	1.055 ± .0166	1.034 ± .0110

VI DISCUSSION

The system described in this report has been used and evaluated in an excess of 2500 subjects to date. Its most important and unique features are ease of transport and durability. One problem that was encountered was the crating and protection of the heater-filtration unit during shipping. Because of the large dimensions of this portion of the system, mounted on a 4 1/2 foot square base plate, 3 1/2 ft high, it was necessary to construct a strongly reinforced wooden crate for this purpose.

The system has met all expectations and design considerations. Its aluminum construction is rugged and easily maintained and has been found to facilitate its transportability to the field. Because of the corrosive nature of the chlorine disinfectant used in the water, it was necessary to apply a baked-on marine enamel after the surface was roughed to promote adhesion of the paint.

The electronic load cell and computer software used in this system have proven exceptionally worthwhile in terms of speed, accuracy, reproducibility and minimizing human bias. We have found no disadvantages in using this system as opposed to the traditional Chatillon spring loaded scale other than the initial cost of the components and training of the operator.

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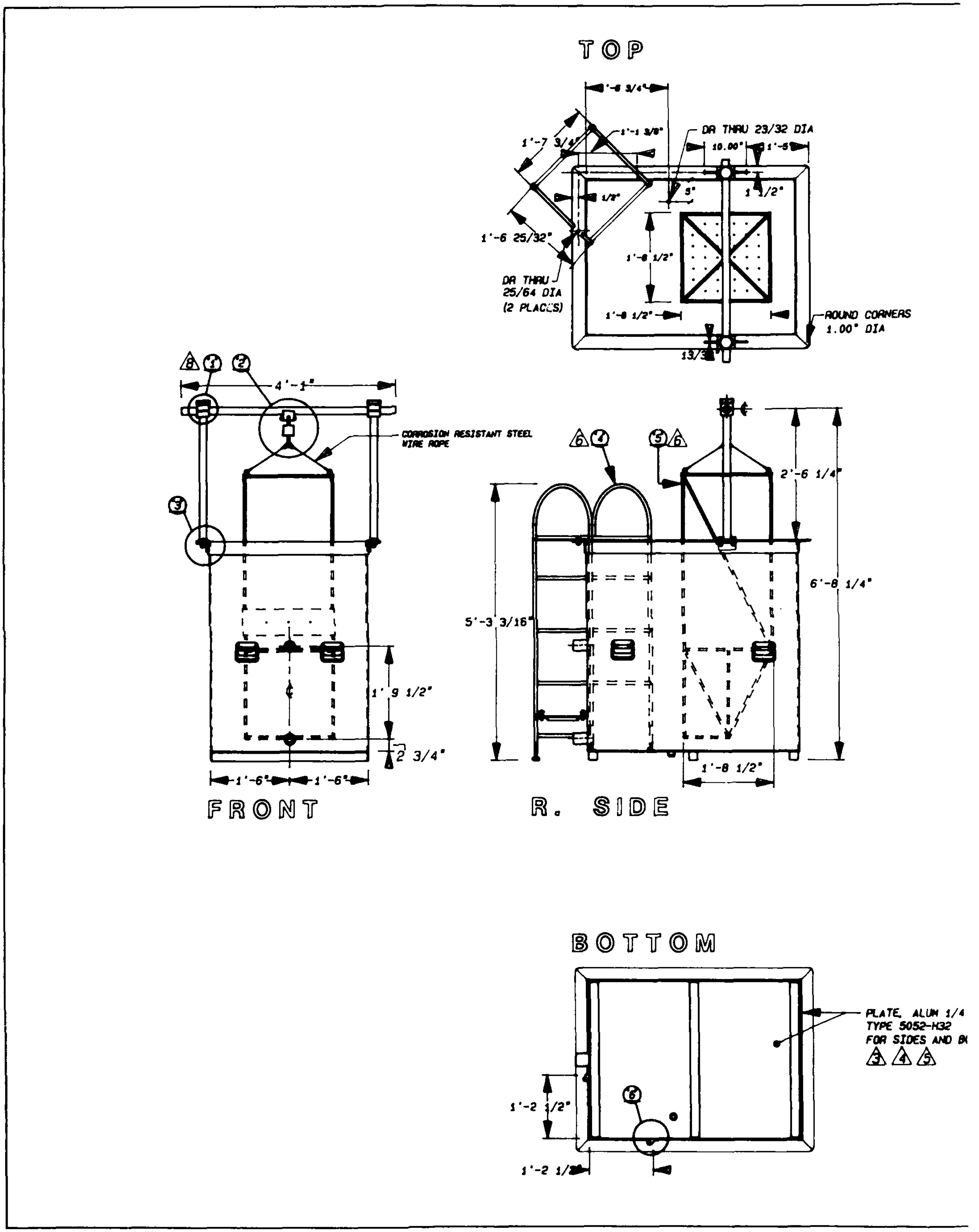
APPENDIX A



TOP
DR THRU 23/32 DIA
10.00"
1'-5"
1'-7 3/4"
1'-1 3/8"
1/2"
5"
1' 1/2"
1'-6 25/32"
1'-8 1/2"
DR THRU 25/64 DIA (2 PLACES)
ROUND CORNERS 1.00" DIA
13/32"
4'-1"
CORROSION RESISTANT STEEL WIRE ROPE
1' 9 1/2"
2 3/4"
1'-6"
FRONT
2'-6 1/4"
6'-8 1/4"
5'-3 3/16"
1'-8 1/2"
R. SIDE
BOTTOM
PLATE, ALUM 1/4
TYPE 5052-H32
FOR SIDES AND B
1'-2 1/2"

NOTES

1 ALL JOINTS SHALL BE WELDED UNLESS OTHERWISE INDICATED

2 TUNGSTEN INERT GAS ARC WELDING

3 SURFACE SHALL BE PREPARED BY SANDBLASTING (OR SANDING) THOROUGHLY WASHED AND DRIED

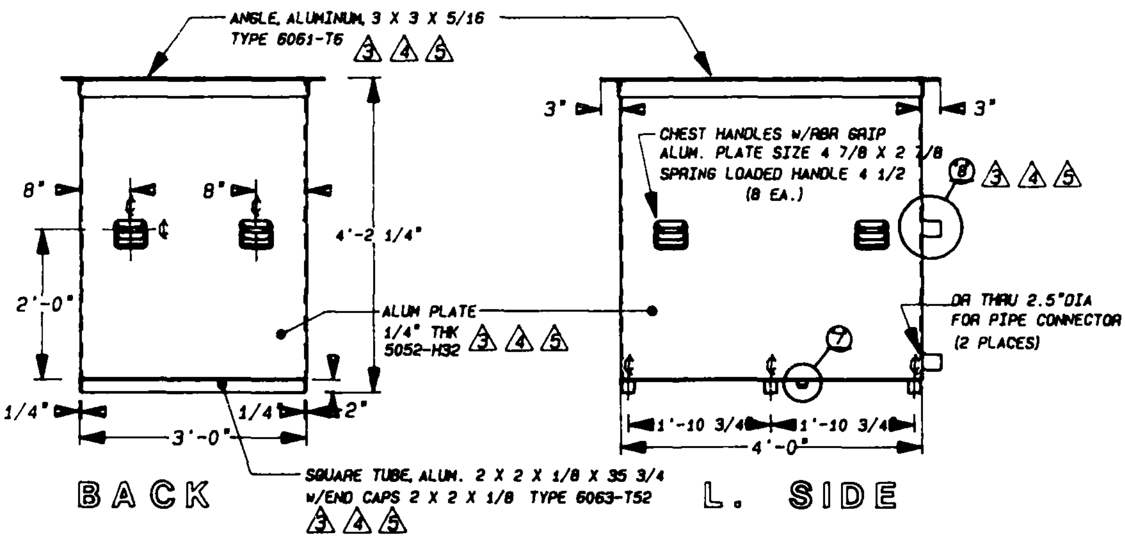
4 PHENOLIC EPOXY FINISH (ie. 'PHENOLFLEX'), approx thk-6 mils A BAKED-ON, TWO PART SYSTEM; PRIMER BASE & CLEAR FINISH

5 THE TANK LADDER AND SUSPENSION SEAT SHALL BE PREPARED IN THE PREVIOUS MANNER

6 IN GENERAL REMOVE BURRS AND SMOOTH EDGES

7 STAINLESS STEEL PARTS & ASSEMBLIES SHALL NOT BE FINISHED IN THE PRECRIBED MANNER

CORNERS
DIA



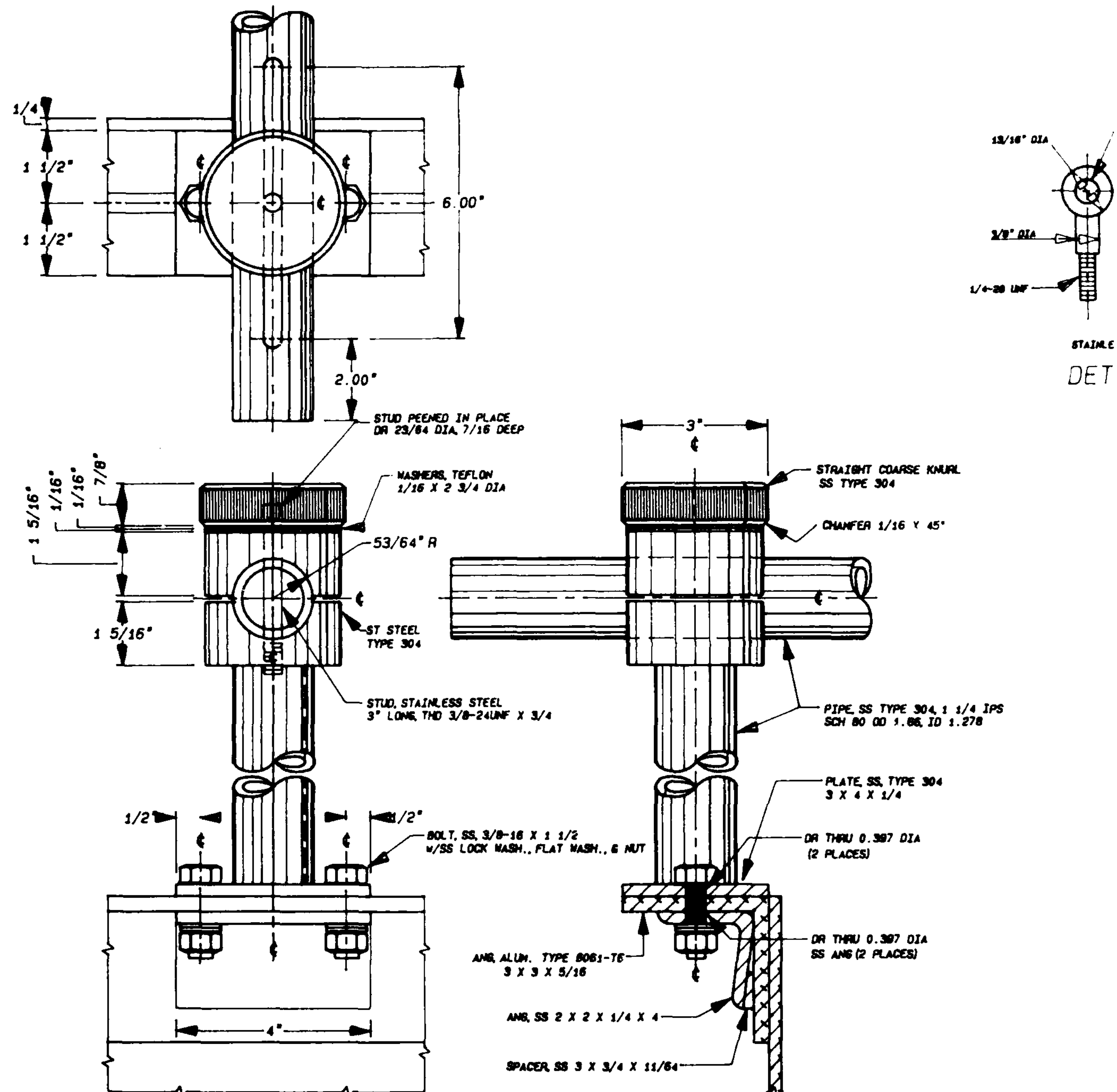
PLATE, ALUM 1/4 THK
TYPE 5052-H32
FOR SIDES AND BOTTOM OF TANK

DETAIL	1	2	3	4	5	6	7	8
SHEET	2	2	2	4	3	4	5	5

BIOENGINEERING BRANCH
USARIEM Natick, MA

HYDROSTATIC WEIGHING TANK

DESIGNER JOSE MILETTI | D | MECHANICAL | DWG NO. BB648401
DRAFTER WM A SAWYER | SCALE NONE | 26 JULY 1984 | SHEET 1 OF 7



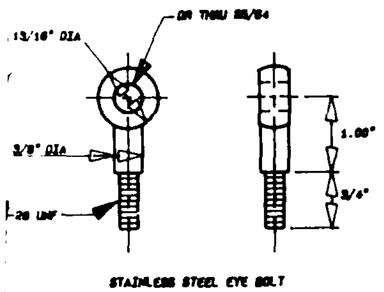
NOTES

1 IN GEN

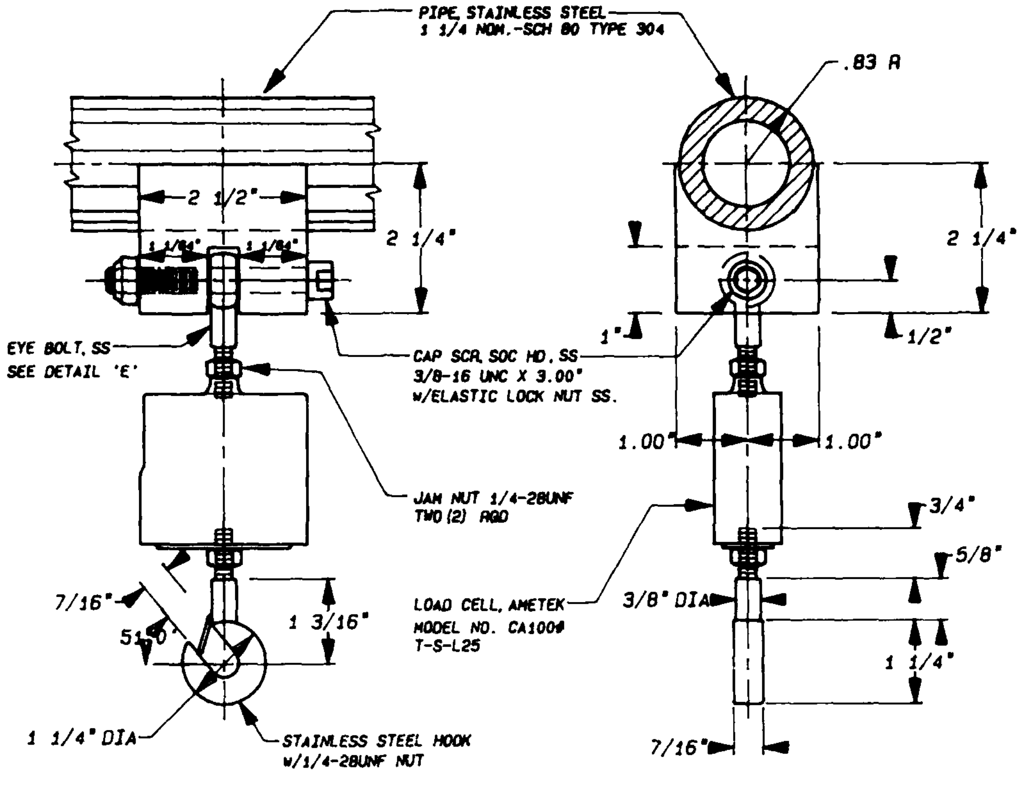
2 TUNGST

3 FOR GE

(1) & (3) SUSPENSION SYSTEM CLAMP AND BASE DETAIL



DETAIL 'E'

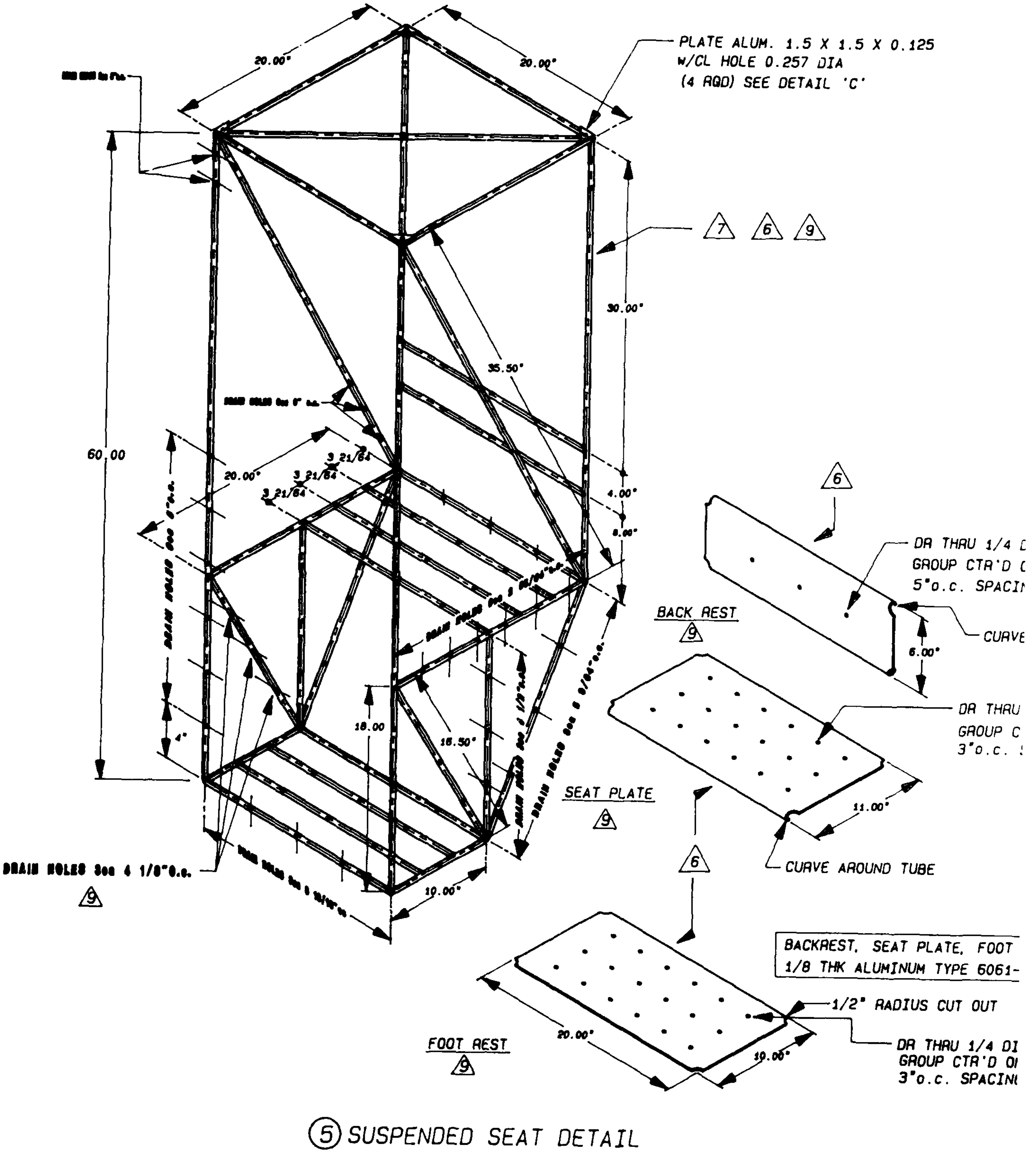


(2) TRANSDUCER MOUNT DETAIL

NOTES

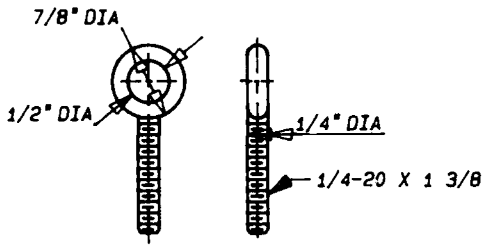
1 IN GENERAL REMOVE BURRS AND SMOOTH EDGES
2 TUNGSTEN INERT GAS ARC WELDING
3 FOR GENERAL ARRANGEMENT . SEE DWG 1

BIOENGINEERING BRANCH USARIEM Natick, MA	
HYDROSTATIC WEIGHING TANK	
DESIGNER JOSE MILETTI	D MECHANICAL DWG NO. BB648402
DRAFTER WM A SAWYER	SCALE NONE 27 JULY 1984 SHEET 2 OF 7



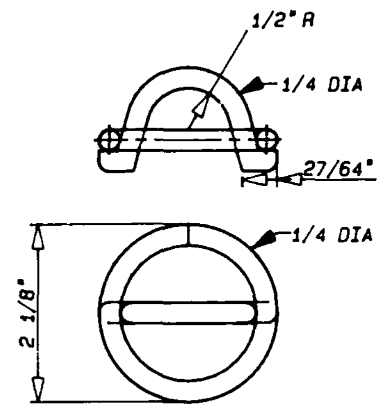
⑤ SUSPENDED SEAT DETAIL

125



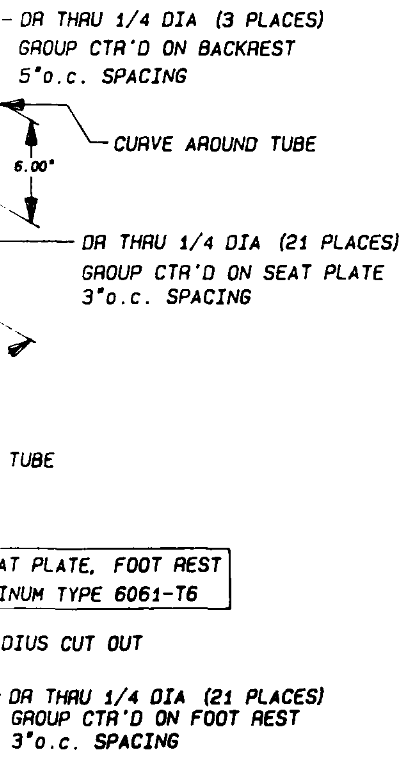
STAINLESS STEEL EYE BOLT
FOUR (4) RQD w/FLAT WASH, LOCK WASH, & NUT EA

DETAIL 'C'



STAINLESS STEEL SUSPENSION RING 9

DETAIL 'D'



NOTES

1 IN GENERAL REMOVE BURRS AND SMOOTH EDGES

2 TUNGSTEN INERT GAS ARC WELDING

3 SURFACE SHALL BE PREPARED BY SANDBLASTING (OR SANDING) THOROUGHLY WASHED AND DRIED

4 PHENOLIC EPOXY FINISH (ie. 'PHENOLFLEX'), approx thk-6 mils BAKED-ON-TWO-PART SYSTEM; PRIMER BASE & CLEAR FINISH

5 THE TANK LADDER AND SUSPENSION SEAT SHALL BE PREPARED IN THE PRESCRIBED MANNER

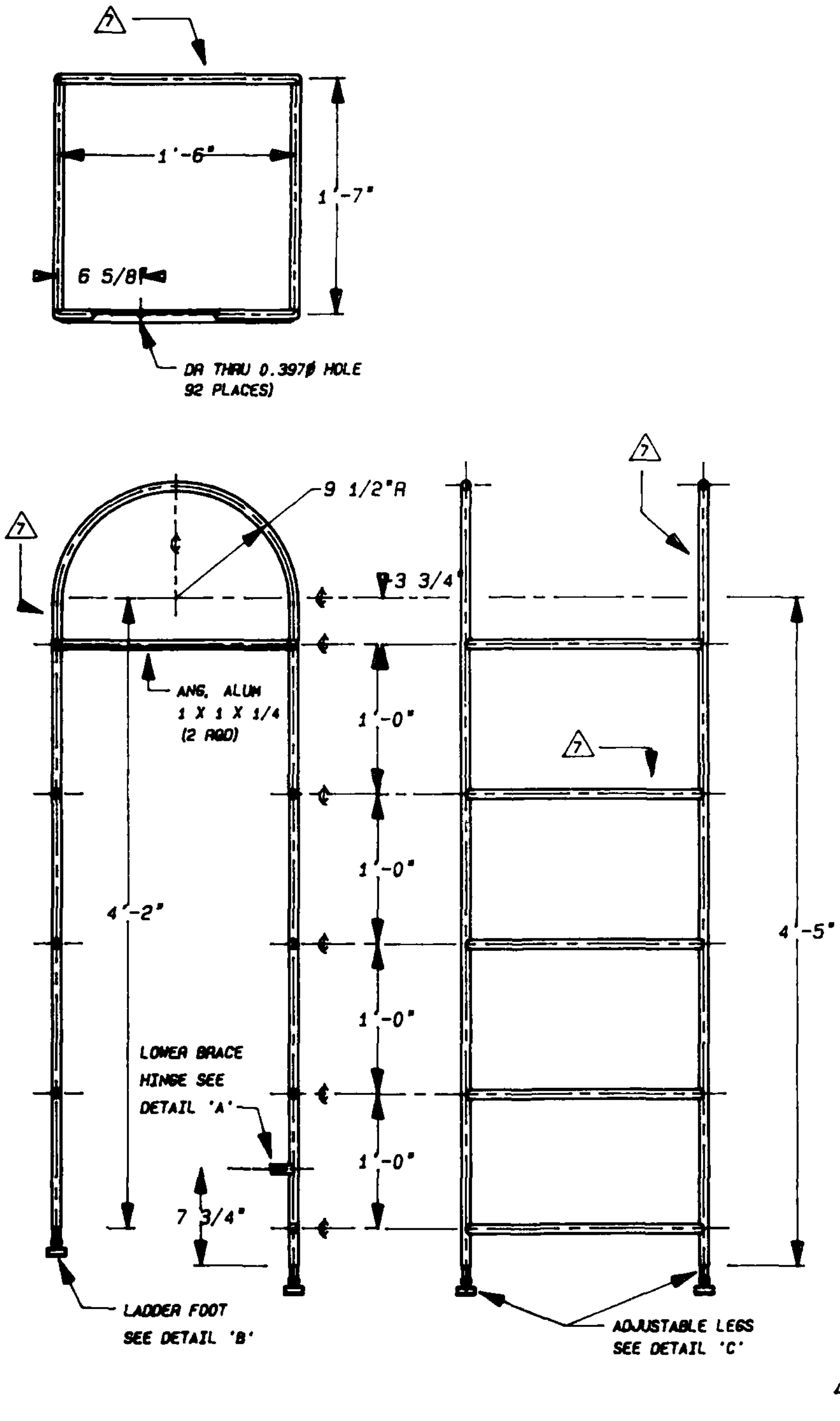
6 FRAME MATERIAL: RND PIPE, ALUM, TYPE: 6061-T6, 1/2" NOM-SCH 40

7 STAINLESS STEEL PARTS & ASSEMBLIES SHALL NOT BE FINISHED IN THE PRECRIBED MANNER

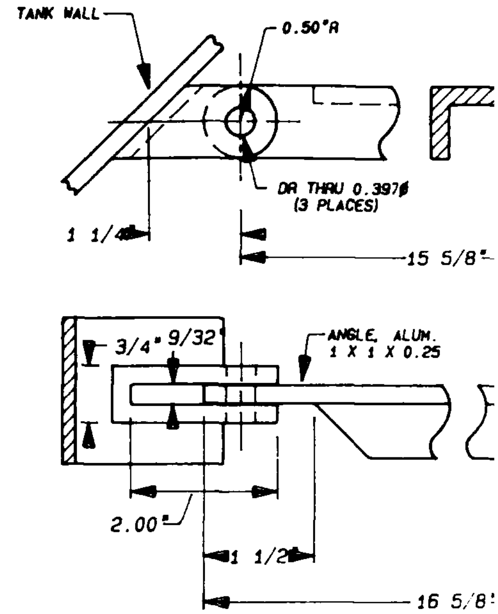
8 FOR GENERAL ARRANGEMENT SEE DWG 1

9 DRAIN HOLES 1/4" DIA

BIOENGINEERING BRANCH USARIEM Natick, MA	
HYDROSTATIC WEIGHING TANK	
DESIGNER JOSE MILETTI	D MECHANICAL DWG NO. BB648403
DRAFTER WM A SAWYER	SCALE NONE 30 JULY 1984 SHEET 3 OF 6



⑤ TANK LADDER ⚠6 ⚠9

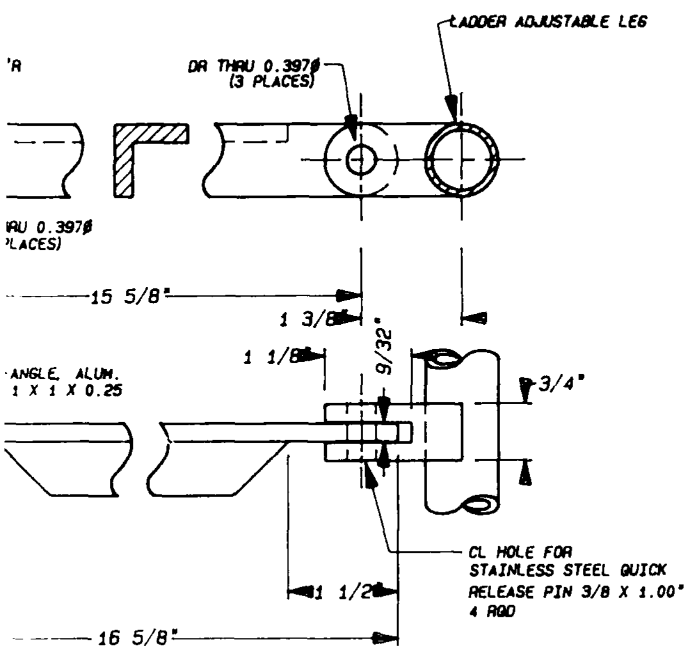


LOWER LADDER BR

DETAIL

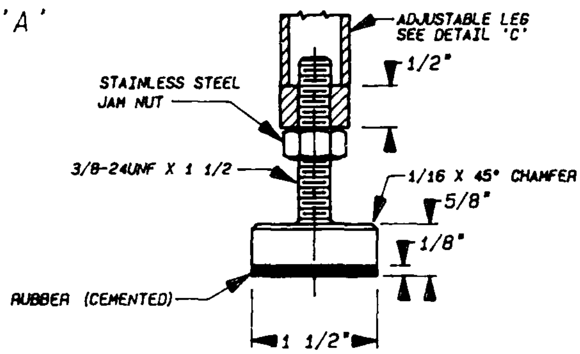
NOTES

1 IN GENERAL REMOVE BURRS AND SMOOTH E
2 TUNGSTEN INERT GAS ARC WELDING
3 SURFACE SHALL BE PREPARED BY SANDBLA THOROUGHLY WASHED AND DRIED
4 PHENOLIC EPOXY FINISH (ie. 'PHENOLFL BAKED-ON-TWO-PART SYSTEM; PRIMER BASI
⚠5 THE TANK LADDER AND SUSPENSION SEAT MANNER
⚠6 FRAME MATERIAL: RND PIPE, ALUM, TYPE;
7 STAINLESS STEEL PARTS & ASSEMBLIES PRECRIBED MANNER
⚠8 FOR GENERAL ARRANGEMENT SEE DWG 1



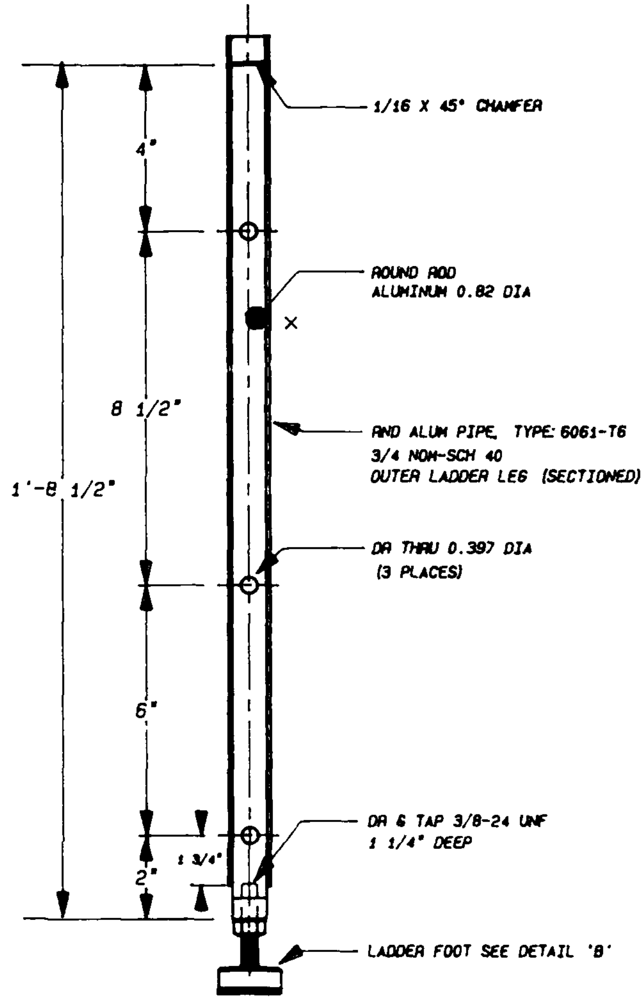
LOWER LADDER BRACE 9 6

DETAIL 'A'



STAINLESS STEEL LADDER FOOT (4 RQD)

DETAIL 'B'



ADJUSTABLE LEG (2 RQD)

DETAIL 'C'

S AND SMOOTH EDGES

WELDING

RED BY SANDBLASTING (OR SANDING)

DRIED

(ie. 'PHENOLFLEX'), approx thk-6 mils

EM; PRIMER BASE & CLEAR FINISH

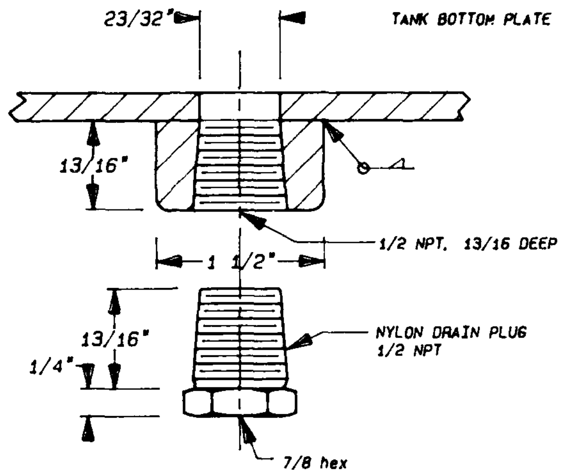
SPENSION SEAT SHALL BE PREPARED IN THE PRESCRIBED

PE, ALUM, TYPE: 6061-T6, 1/2" NOM-SCH 40

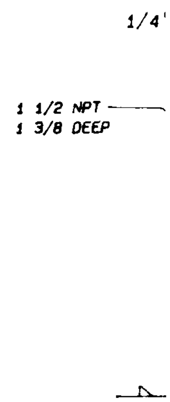
& ASSEMBLIES SHALL NOT BE FINISHED IN THE

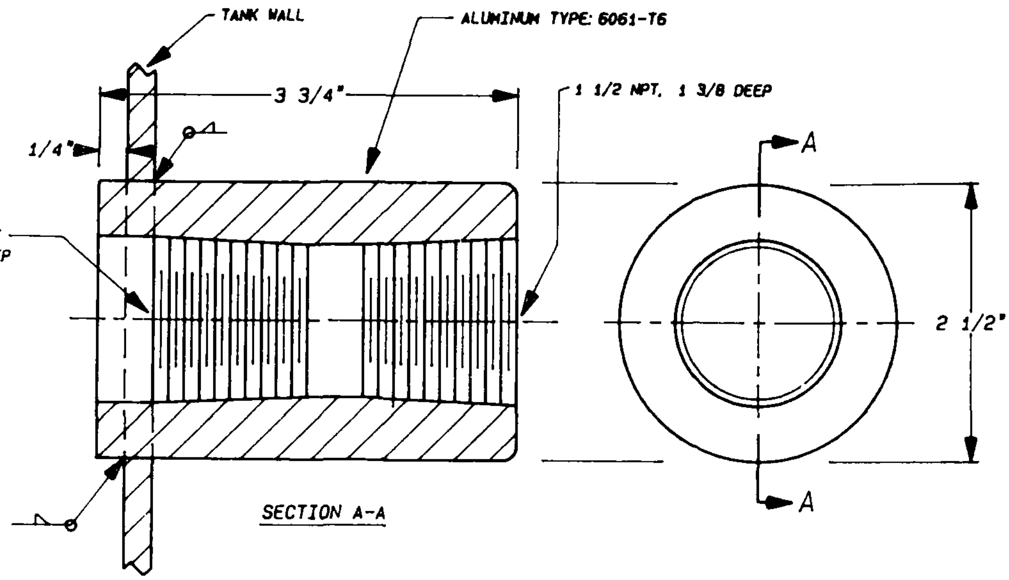
SEE DWG 1

BIOENGINEERING BRANCH USARIEM Natick, MA		
HYDROSTATIC WEIGHING TANK		
DESIGNER JOSE MILETTI	D MECHANICAL	DWG NO. BB648404
DRAFTER WM A SAWYER	SCALE NONE 4 AUGUST 1984	SHEET 4 OF 7



(7) DRAIN PLUG & BOSS

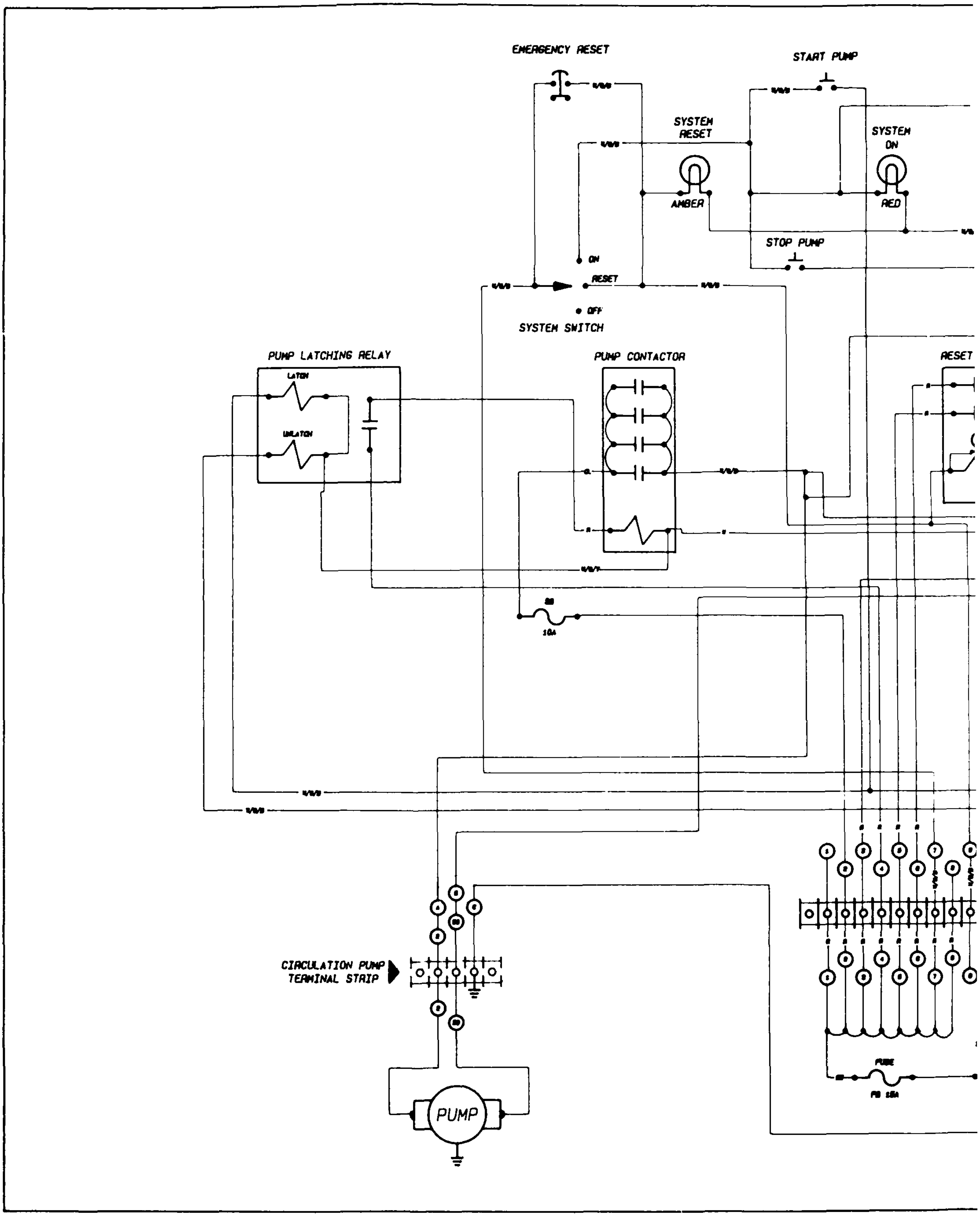




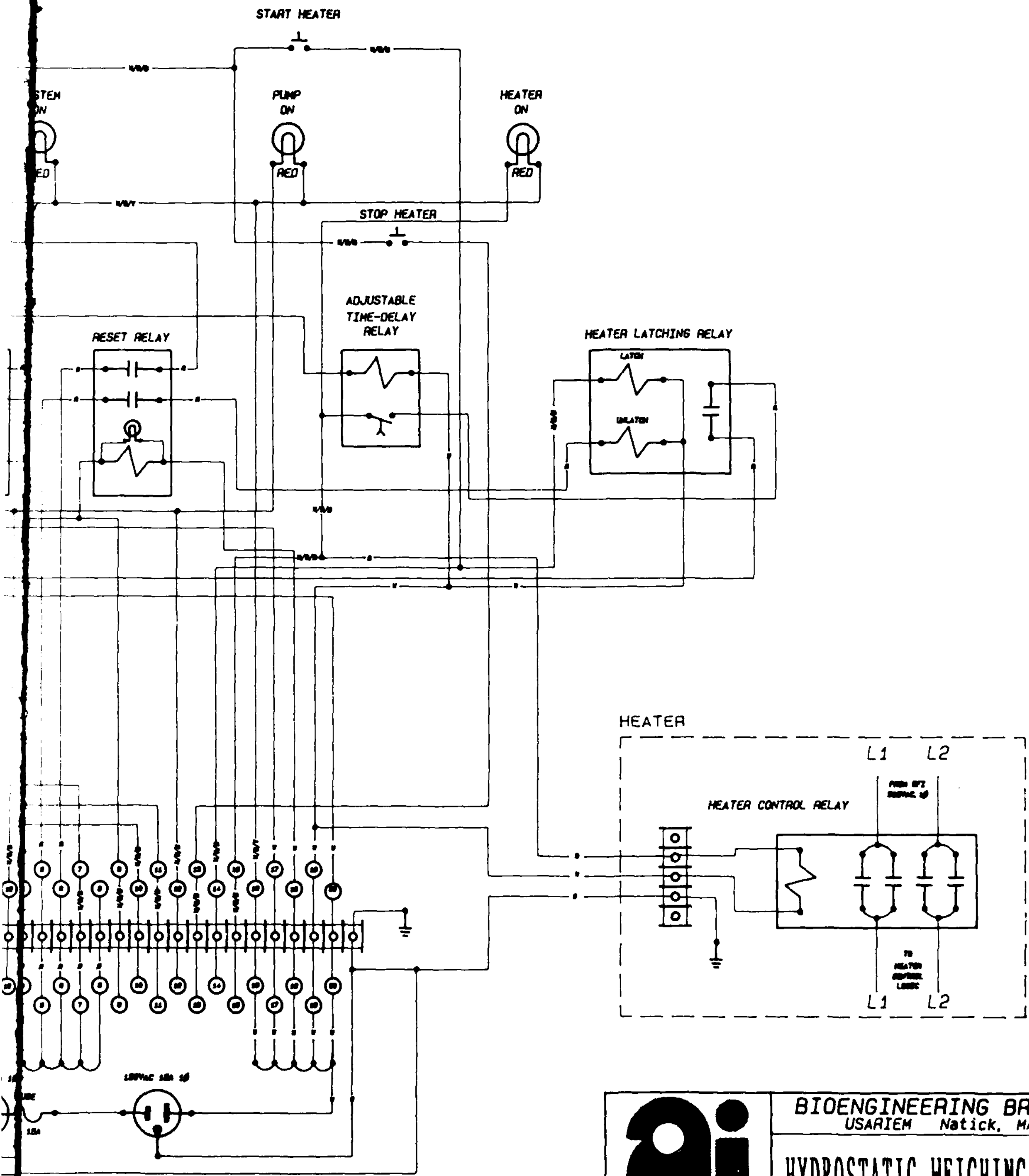
(8) HOSE CONNECTION

(2 RQD)

BIOENGINEERING BRANCH USARIEM Natick, MA			
HYDROSTATIC WEIGHING TANK			
DESIGNER JOSE MILETTI	D	MECHANICAL	DWG NO. BB648405
DRAFTER WM A SAWYER	SCALE NONE	8 AUGUST 1984	SHEET 5 OF 7



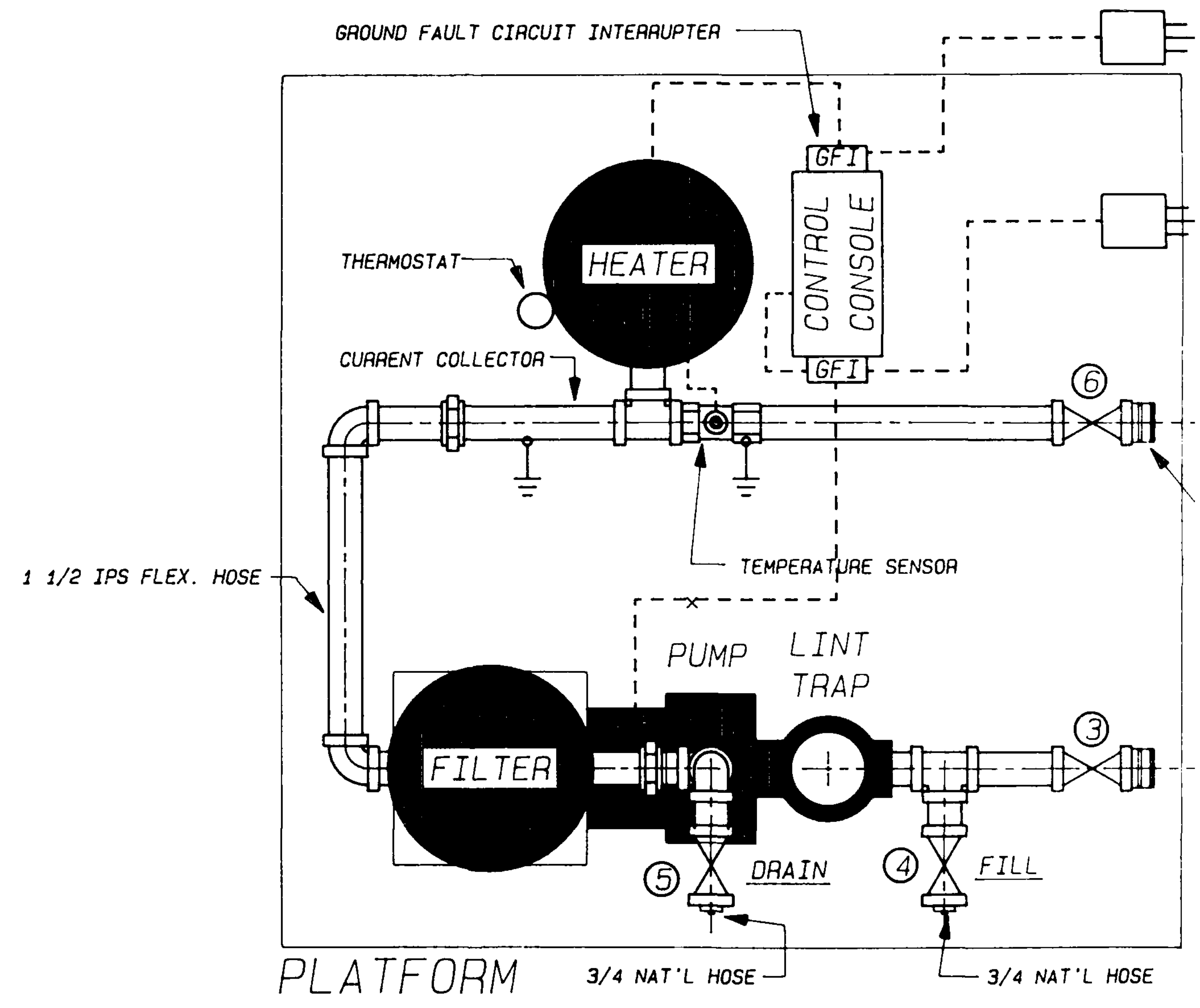
EMERGENCY RESET
START PUMP
SYSTEM RESET
AMBER
SYSTEM ON
RED
STOP PUMP
ON
RESET
OFF
SYSTEM SWITCH
PUMP LATCHING RELAY
LATCH
UNLATCH
PUMP CONTACTOR
RESET
10A
CIRCULATION PUMP TERMINAL STRIP
PUMP
FUSE

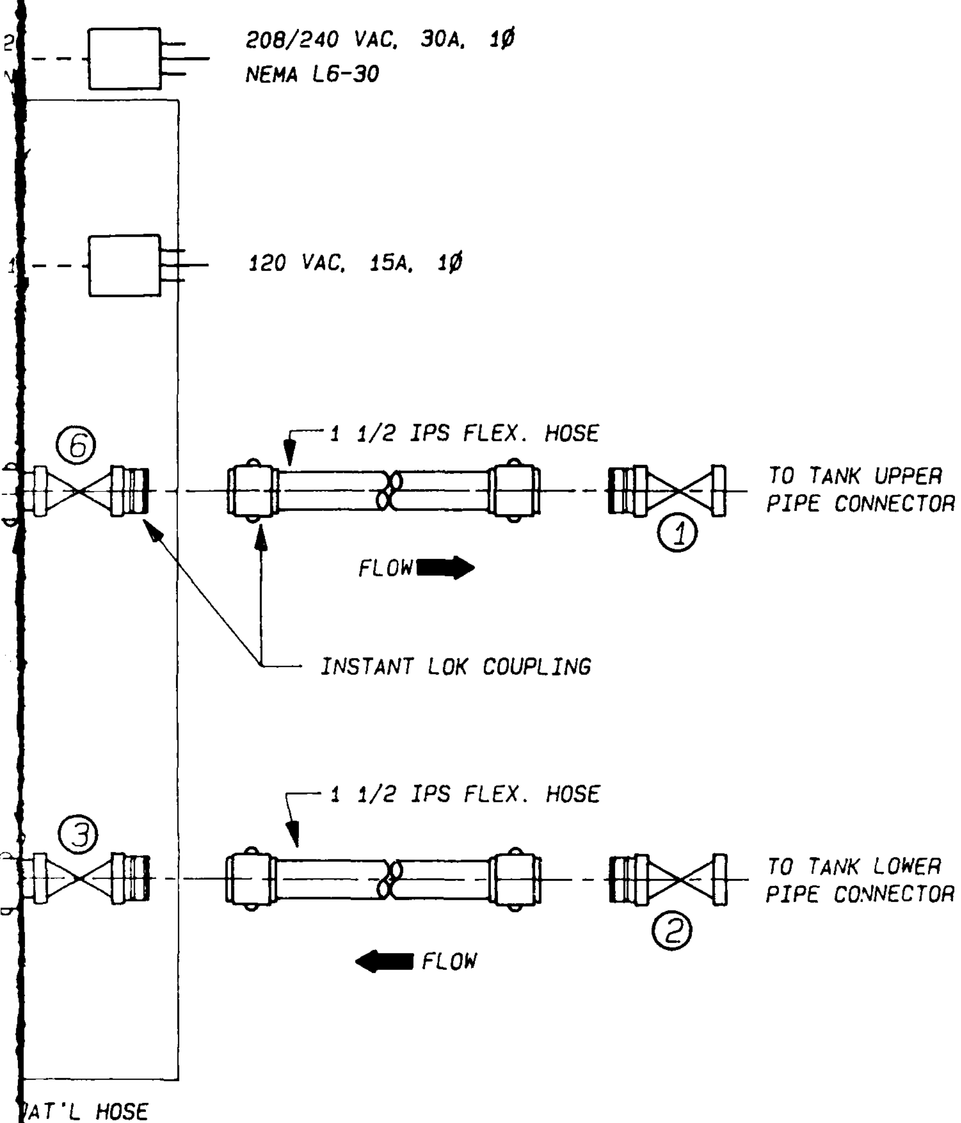


BIOENGINEERING BRANCH
USARIEM Natick, MA

HYDROSTATIC WEIGHING TANK

JOSE MILETTI	D	MECHANICAL	DWG NO. BB648406
WM A SAWYER	NONE	13 AUGUST 1984	6 OF 7


GROUND FAULT CIRCUIT INTERRUPTER
GFI
CONTROL CONSOLE
GFI
THERMOSTAT
HEATER
CURRENT COLLECTOR
6
TEMPERATURE SENSOR
1 1/2 IPS FLEX. HOSE
PUMP
LINT TRAP
FILTER
3
5
DRAIN
4
FILL
PLATFORM
3/4 NAT'L HOSE
3/4 NAT'L HOSE



BIOENGINEERING BRANCH
USARIEM Natick, MA

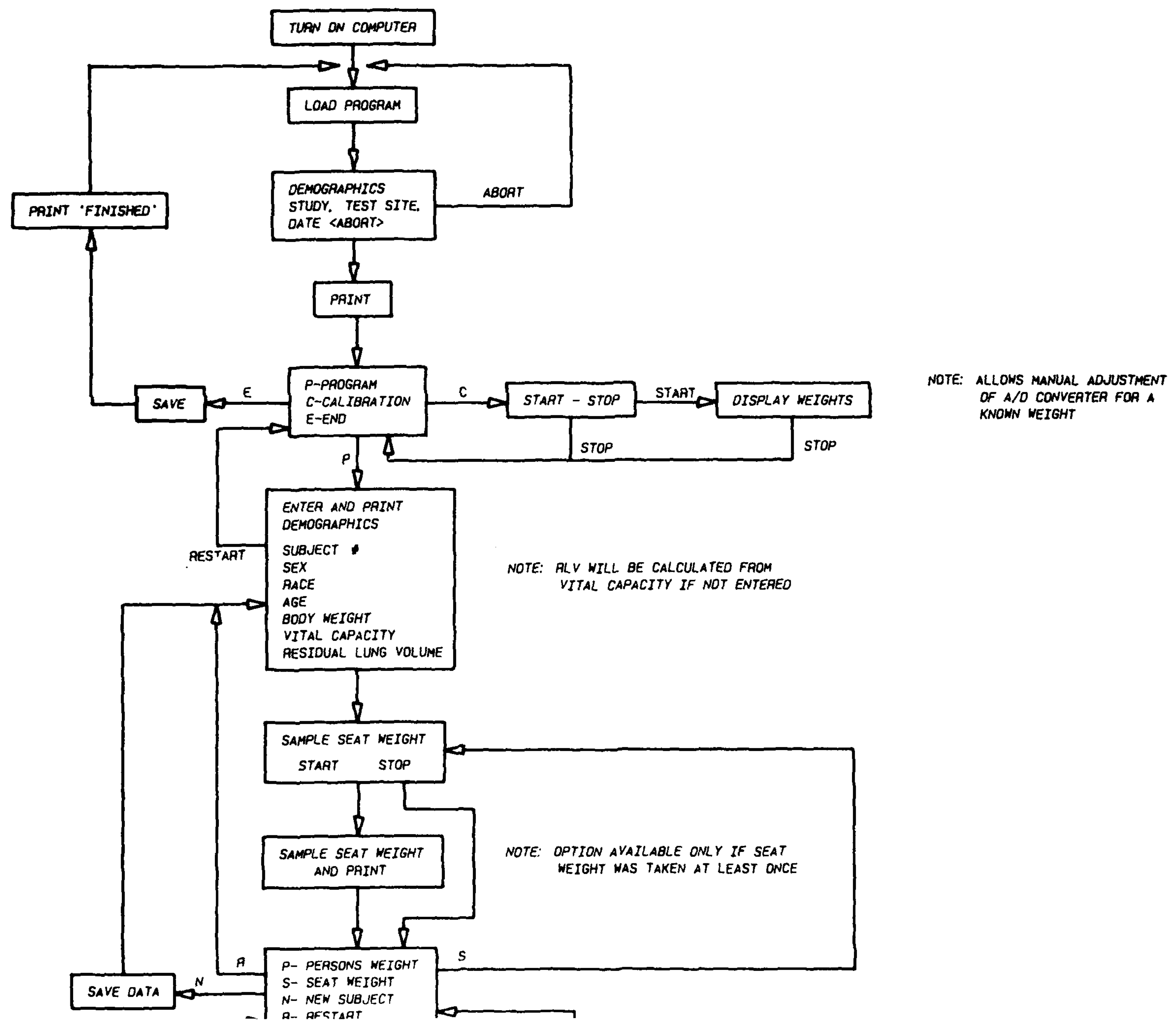
HYDROSTATIC WEIGHING TANK

JOSE MILETTI
WM A SAWYER

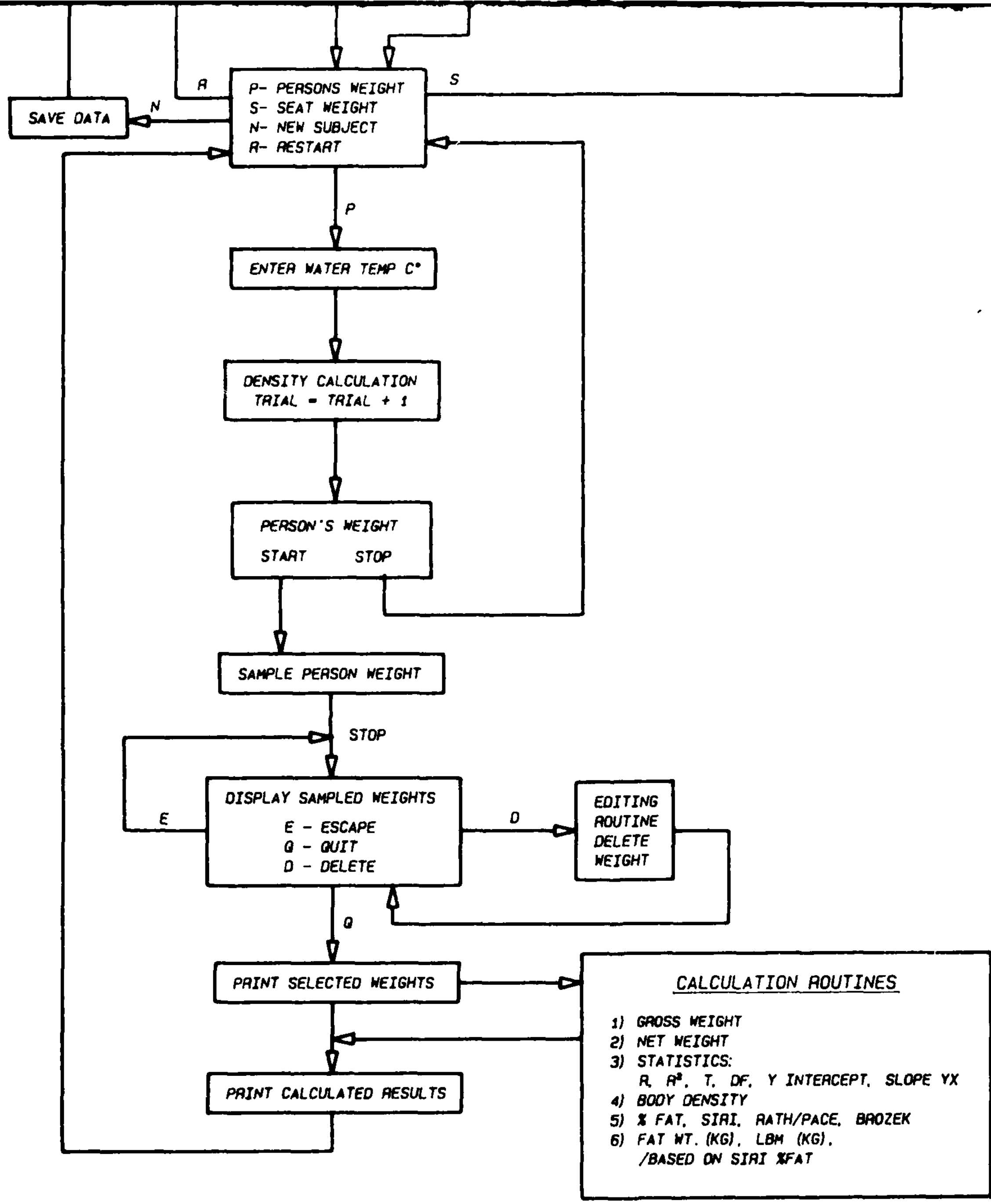
D | MECHANICAL | DWG NO. BB648407

NONE | 15 JULY 1983 | 7 OF 7

APPENDIX B



TURN ON COMPUTER
LOAD PROGRAM
DEMOGRAPHICS STUDY, TEST SITE, DATE <ABORT>
ABORT
PRINT
PRINT 'FINISHED'
P-PROGRAM
C-CALIBRATION
E-END
E
SAVE
C
START - STOP
START
DISPLAY WEIGHTS
STOP
STOP
NOTE: ALLOWS MANUAL ADJUSTMENT OF A/D CONVERTER FOR A KNOWN WEIGHT
P
ENTER AND PRINT DEMOGRAPHICS
SUBJECT #
SEX
RACE
AGE
BODY WEIGHT
VITAL CAPACITY
RESIDUAL LUNG VOLUME
RESTART
NOTE: RLV WILL BE CALCULATED FROM VITAL CAPACITY IF NOT ENTERED
SAMPLE SEAT WEIGHT
START
STOP
SAMPLE SEAT WEIGHT AND PRINT
NOTE: OPTION AVAILABLE ONLY IF SEAT WEIGHT WAS TAKEN AT LEAST ONCE
P- PERSONS WEIGHT
S- SEAT WEIGHT
N- NEW SUBJECT
R- RESTART
S
R
N
SAVE DATA


P- PERSONS WEIGHT
S- SEAT WEIGHT
N- NEW SUBJECT
R- RESTART
R
S
N
SAVE DATA
P
ENTER WATER TEMP C°
DENSITY CALCULATION
TRIAL = TRIAL + 1
PERSON'S WEIGHT
START STOP
SAMPLE PERSON WEIGHT
STOP
E
DISPLAY SAMPLED WEIGHTS
E - ESCAPE
Q - QUIT
D - DELETE
D
EDITING
ROUTINE
DELETE
WEIGHT
Q
PRINT SELECTED WEIGHTS
PRINT CALCULATED RESULTS
CALCULATION ROUTINES
1) GROSS WEIGHT
2) NET WEIGHT
3) STATISTICS:
R, R², T, DF, Y INTERCEPT, SLOPE YX
4) BODY DENSITY
5) % FAT, SIRI, RATH/PACE, BROZEK
6) FAT WT. (KG), LBM (KG),
/BASED ON SIRI %FAT