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TECHNICAL MEMORANDUM, NEDU TM 01-03

From: CAPT Knafelc, MC, USN
To: Commanding Officer 6/8
Via: (1) Senior Project Officer
(2) Executive Officer rcvd 6/7

Subj: U. S. SPECIAL OPERATIONS FORCES UNDERWATER BREATHING APPARATUS: STEAM MACHINES, INC., PRISM

Ref: (a) Navy Experimental Diving Unit Test Plan Number: 01-04, February 2001
(b) U. S Navy Unmanned Test Methods and Performance Goals. Navy Experimental Diving Unit Technical Manual No. 01-94, June 1994.
(c) Sources Sought (Procurements) N0463A-01-Q-0001, Navy Experimental Diving Unit, Panama City, FL
(d) Sources Sought N61331-01-Q-JJ02, Naval Surface Warfare Center, Coastal Systems Station, Panama City, FL

Encl: (1) Attachment to NEDU TM01-03, Prism UBA Unmanned Evaluation Remarks and Observations.

DISTRIBUTION STATEMENT F: Further dissemination only as directed by NEDU Commanding Officer or higher DoD authority. This technical memorandum contains manufacturer's proprietary information.

1. Introduction: The Advanced SEAL Delivery System (ASDS) program currently needs an Underwater Breathing Apparatus (UBA) to support a wide range of operational scenarios and depths. The current LAR V and MK 16 MOD 0 used by U.S. Special Operations Forces (SOF) do not meet ASDS requirements because of their size, depth restriction, and operational reliability. Concurrently, Naval Sea Systems Command PMS325J desires to find a replacement for the MK 16 MOD 0 that SEAL Delivery Vehicle (SDV) Teams can use.

The purpose of this project is to identify a commercially available UBA that meets or exceeds ASDS/SDV operational requirements. The final objective is to identify for the SOF community a reliable, operator friendly UBA that meets all operational scenarios of the ASDS/SDV and can suitably replace the MK 16 MOD 0.

The objective of this testing was to evaluate the operational performance of the Steam Machines, Inc., Prism and demonstrate whether it can be dived safely in controlled (test pool and pier-side) environments as part of the UBA selection process.

2. Methods: Four functional tests were performed:

Hydrostatic load
Breathing resistance
Canister duration
Oxygen control (oxygen-consumption simulation)

The procedures for conducting these tests are recorded in reference (a). We reviewed the engineering design of the UBA to evaluate the apparatus' ease of operations and maintenance of the UBA in conjunction with the manufacturer's Operations and Maintenance Manual. The Performance Goals, reference (b), were used as the criteria for judging the acceptability of hydrostatic load and breathing performance. The acceptability of canister performance and oxygen control acceptability was judged according to the SPECWAR Letter of Requirements, as per PMS325J, and the ASDS Medical Advisory Panel.

3. Results:

Breathing Performance

When the UBA is upright or prone, the hydrostatic load meets the nominal goal of 1.0 kPa, Table 1.

Table 1. Hydrostatic Load

	UPRIGHT (0°)	PRONE (90°)	INVERTED (180°)	SUPINE (270°)
Test #1	-0.10 kPa	0.46 kPa	-1.45 kPa	-1.36 kPa
Test #2	-0.08 kPa	0.46 kPa	-1.60 kPa	-1.41 kPa
Test #3	-0.08 kPa	0.48 kPa	-1.72 kPa	-1.41 kPa

Breathing performance evaluations were conducted with the UBA in a swimmer's (prone) position. The Prism meets the performance goal for a Category 4 UBA resistive load at 150 fsw with an RMV of 75 lpm. Table 2 shows the representative values obtained. Figure 1 illustrates the resistive effort and average flow resistance.

Table 2. Resistive Load

RMV	0 fsw	33 fsw	66 fsw	99 fsw	132 fsw	***Goal 150 fsw***	165 fsw	198 fsw
lpm	J/L	J/L	J/L	J/L	J/L	***J/L***	J/L	J/L
22.5	0.256	0.294	0.323	0.358	0.407	***0.170***	0.423	0.491
40	0.230	0.345	0.407	0.489	0.561	***0.509***	0.655	0.810
62.5	0.369	0.624	0.880	1.066	1.254	***1.172***	1.422	1.622
75	0.441	0.833	1.109	1.380	1.653	***1.696***	1.796	2.161
90	0.607	1.071	1.504	1.929	2.322	***2.529***	2.764	3.067

The maximum inhalation or exhalation mouth-pressure goal is 1.08 kPa. Therefore, the maximum peak-to-peak mouth-pressure expected is 2.16 kPa at 150 fsw with an RMV of 75 lpm. The Prism peak-to-peak mouth-pressures exceeded this goal. The mean values obtained are shown in Table 3.

Table 3. Peak-to-Peak Mouth-Pressure

RMV	0 fsw	33 fsw	66 fsw	99 fsw	132 fsw	***Goal 150 fsw***	165 fsw	198 fsw
lpm	kPa	kPa	kPa	kPa	kPa	***kPa***	kPa	kPa
22.5	1.25	1.16	1.15	1.21	1.47	***0.216***	1.37	1.69
40	0.82	0.89	0.95	1.08	1.23	***0.648***	1.40	1.75
62.5	0.88	1.34	1.91	2.04	2.33	***1.492***	2.40	3.00
75	1.02	1.81	1.97	2.43	2.64	***2.160***	3.03	3.54
90	1.22	1.82	2.55	3.11	3.88	***3.220***	4.53	5.09

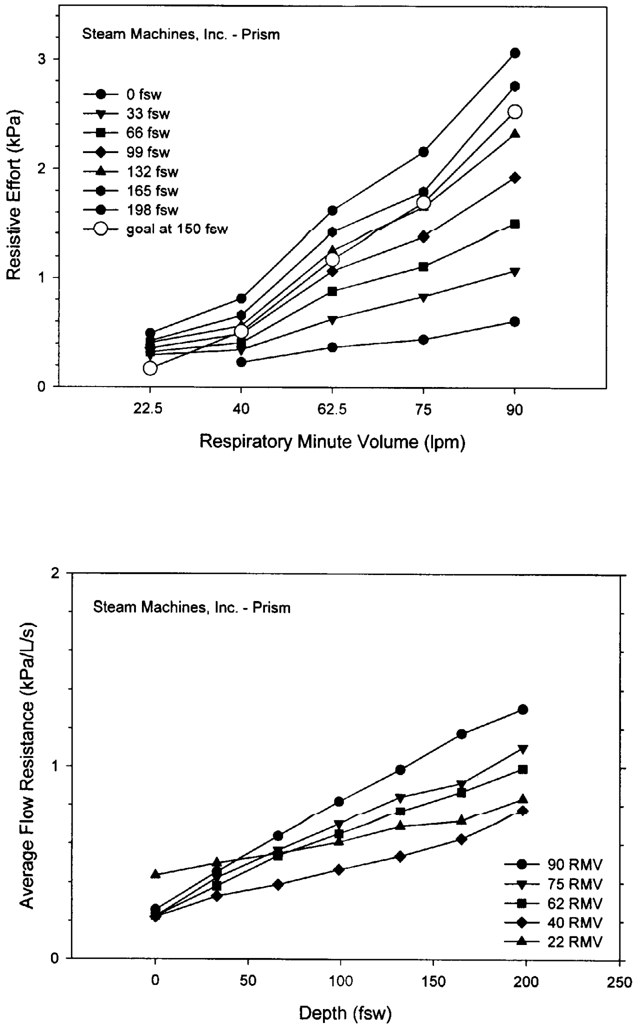

Figure 1. Breathing performance of the Prism at various depths and respiratory minute volumes (RMV).

Canister Duration

As specified in reference (c) the NEDU solicitation for the UBA requires a minimum underwater duration of 240 minutes at an oxygen consumption rate of 1.5 standard liters per minute (slpm). The Coastal Systems Station solicitation for a UBA, reference (d), requires a duration of 5 hours, with 200 minutes at an oxygen consumption rate of 1.0 slpm and 100 minutes at an oxygen consumption rate of 1.5 slpm. Therefore, the canister is required to absorb between 315 and 324 liters of CO_2 before the canister effluent CO_2 exceeds 0.5% surface equivalent value.

Because this testing was designed to ensure that the UBA can be safely dived in manned evaluations, we conducted testing using a continuous injection rate of 1.35 slpm CO_2 with a 40 lpm respiratory minute volume, emulating the ventilation rate for a diver who consumes oxygen at 1.5 slpm. The test depth was 60 fsw (18 msw) with a water temperature of 40 °F (4.5 °C).

The canister was packed with 6.0 lbs. of 8-12 Sofnolime. The average time for the canister effluent CO_2 to reach 0.5% SEV was 255 minutes. Hence, the canister was able to absorb approximately 344 liters of CO_2. The time when the canister effluent CO_2 reached various levels is shown in Table 4. Figure 2 illustrates the five runs for the Prism's canister performance.

Table 4. Elapsed Time (minutes) to Various Canister Effluent CO_2 Levels, 40°F, 60 fsw

	0.5% SEV	**1.0% SEV**	**2.0% SEV**	**3.0% SEV**	**4.0% SEV**	**5.0% SEV**
Test #1	247	277	302	316	325	332
Test #2	246	269	294	308	318	325
Test #3	264	290	311	322	329	333
Test #4	256	283	306	318	326	331
Test #5	263	295	318	329	336	341
Average	**255**	**283**	**306**	**319**	**327**	**332**
± 1 S.D.	9	10	9	7	7	6

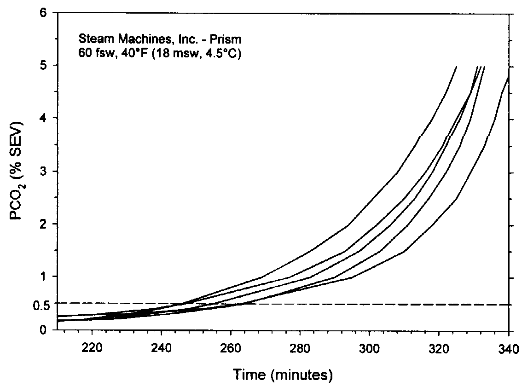

Figure 2. Canister performance of the Prism at 60 fsw, 40°F.

Oxygen Control

The Prism is an electronically controlled UBA with an adjustable oxygen set point. When operated with a 1.3 ATA oxygen set point, the UBA's switchover depth is between 15 and 18 fsw. To calibrate the UBA, we performed the low span with air. To set the high span, we purged the UBA as the manufacturer recommends, and the technician pressed the calibration button to set the high-calibration point.

We initially tested of the oxygen control at 30 fsw, with the oxygen (PO_2) set point of 0.7 and 1.3 ATA. The sampling period at each set point was 56 minutes. The breathing of an underwater swimmer was simulated using an oxygen consumption rate of 1.5 slpm with a respiratory minute ventilation rate of 50 lpm.

For the oxygen set point of 0.7 ATA, the UBA maintained 0.72 ± 0.018 ATA.
For the oxygen set point of 1.3 ATA, the UBA maintained 1.34 ± 0.005 ATA.

We tested also at 60 and 190 fsw with the 1.3 ATA set point. The sampling period was 5 minutes after the oxygen level stabilized at 60 fsw and 10 to 15 minutes after the oxygen level stabilized at 190 fsw. To simulate the breathing of an underwater swimmer, we used an oxygen consumption rate of 1.5 and 2.5 slpm for the respective respiratory ventilation rates of 50 and 62.5 lpm. These simulations were performed during 5 different pressurization cycles.

For an oxygen consumption rate of 1.5 slpm, the UBA maintained the oxygen level at:

Run #1,	60 fsw - 1.34 ± 0.003 ATA	190 fsw - 1.38 ± 0.004 ATA
Run #2,	60 fsw - 1.34 ± 0.003 ATA	190 fsw - 1.38 ± 0.003 ATA
Run #3,	60 fsw - 1.36 ± 0.005 ATA	190 fsw - 1.39 ± 0.003 ATA
Run #4,	60 fsw - 1.36 ± 0.002 ATA	190 fsw - 1.39 ± 0.003 ATA
Run #5,	60 fsw - 1.39 ± 0.003 ATA	190 fsw - 1.39 ± 0.005 ATA

For an oxygen consumption rate of 2.5 slpm, the UBA maintained the oxygen level at:

Run #1,	60 fsw - 1.36 ± 0.003 ATA	190 fsw - 1.38 ± 0.003 ATA
Run #2,	60 fsw - 1.36 ± 0.003 ATA	190 fsw - 1.39 ± 0.023 ATA
Run #3,	60 fsw - 1.36 ± 0.003 ATA	190 fsw - 1.39 ± 0.004 ATA
Run #4,	60 fsw - 1.34 ± 0.004 ATA	190 fsw - 1.37 ± 0.002 ATA
Run #5,	60 fsw - 1.35 ± 0.003 ATA	190 fsw - 1.37 ± 0.003 ATA

We attempted to determine how high the oxygen rose above the set point during a descent from 60 fsw to 190 fsw. The UBA was pressurized from the surface to a depth of 60 fsw. After the oxygen control stabilized for 5 minutes while simulating an oxygen consumption of 1.5 slpm at 60 fsw, we adjusted the oxygen consumption parameters for 190 fsw and then the chamber was pressurized to 190 fsw at a rate of 55 feet per minute. Once at the new depth we further adjusted the oxygen consumption simulation to simulate the appropriate consumption rate. We repeated this procedure using a simulated oxygen consumption rate of 2.5 slpm.

For the oxygen consumption simulation of 1.5 slpm, the maximum PO_2 observed during descent was 1.97 ATA, a level that decreased to 1.76 ATA at 190 fsw. Within 10 minutes the UBA controlled the oxygen level at 1.39 ATA. For the oxygen consumption simulation of 2.5 slpm, the maximum PO_2 observed during descent was 1.88 ATA, a level that decreased to 1.87 ATA at 190 fsw. Within 10 minutes the UBA controlled the oxygen level at 1.39 ATA. Because oxygen consumption simulations are technically challenging to perform under dynamic conditions, these values may not portend what divers will actually experience during excursions to 190 fsw.

The Prism controlled the PO_2 at a level slightly higher than the desired set point of 1.3 ATA, though the variability around the set point is very small. We discussed with the vendor the disparity between the expected oxygen control level and the measured oxygen level. Because of the vendor's experience with field operators who do not adequately purge the unit, the unit sets the high span as 98%. If the unit was meticulously purged so that a span of 100% oxygen was to result, the unit will still assume this span is 98%. Hence, the calibration may result in the slightly higher oxygen control level we observed.

Observations

The Prism was very easy to set up within 30 minutes. Overall, this UBA's modular design allows the unit to be rapidly reconfigured for varying mission needs. In addition, this design allows the vendor to make minor modifications to the UBA if the field operators request such changes. The electronic control package is digital in design, permitting rapid changes in the unit's operational parameters if any changes are required. The use of standard components in the Prism significantly simplifies the logistical support requirements. Overall, the engineering design, component and material selection, and manufacturing process are suitable to allow class certification of the existing UBA. The Operations and Maintenance Manual provides pertinent details to allow the operator to set up and operate this UBA.

4. Conclusion: The Steam Machines, Inc., Prism does meet the performance and design requirements for use with the ASDS or for use as an UBA to replace the MK 16 MOD 0. In water temperatures of 40°F and higher, the Prism can be safely dived to a maximum depth of 190 fsw. The canister duration is 240 minutes when 90% of the total duration is at 60 fsw or shallower.

5. Recommendation: Further evaluations to determine the operational suitability of Steam Machines, Inc., Prism should be performed.

M E Knafelc MD, PhD
M. E. KNAFELC
CAPT, MC, USN

COMMANDING OFFICER'S DECISION:

Forward to Program Sponsor, if requested ______
Only File in Technical Library: Gm
OTHER: Steam Machines, Inc., if requested Gm

ATTACHMENT TO NEDU TM01- 03

PRISM TOPAZ UBA UNMANNED EVALUATION REMARKS and OBSERVATIONS

A Prism Topaz electronic controlled closed circuit breathing apparatus (UBA) manufactured by Steam Machines, Inc., Hermosa, CA, was purchased by the Navy Experimental Diving Unit for evaluation in March 2001. Functional testing was conducted in accordance with Test Plan 01-04 (TA01-02).

During the course of testing, members of the 5-person test team responsible for daily UBA setup and operation recorded their remarks and observations into the daily test log.

- No discrepancies were noted.
- No mechanical, electrical, or pneumatic failures occurred during the testing.
- No rig flooding occurred during the course of testing.
- All remarked favorably on simplicity of design, ease of setup and maintenance.
- All remarked favorably on acquisition cost and projected logistic support cost.
- System design allows maintenance of a hygienic breathing loop.
- Carbon dioxide absorbent canister is easy to fill and install.
- No tools are required for normal setup and operation.
- A minimal number of components are used to construct the UBA, improving reliability.
- The UBA is well designed and well manufactured.

Remarks and Observations

- The UBA is a compact, lightweight (47 lbs.), ergonomically designed apparatus shown front view, Figure 1. All pneumatic controls (O_2 add, diluent add, exhaust) are conveniently located on the breathing bags. Integrated/detachable weight pockets are fitted to the front of the buoyancy compensator. All harness straps and closure mechanisms are well made and of heavy duty construction. The mouthpiece (dive/surface valve) is attached to the breathing hoses with brass connector rings to neutralize hose buoyancy and reduce mouth/neck fatigue.

- Figure 2, rear view, shows the simplicity of the molded electronic head with see-through scrubber assembly attached, flanked by the gas cylinders. The back mounted integral buoyancy compensator is located beneath the gas cylinder. Gas cylinders are easily accessed for filling and maintenance, as are both regulators.

- The CO_2 scrubber assembly shown in Figure 3 consists of a rugged, clear canister housing that contains an efficient radial flow scrubber basket. The scrubber basket is easy to fill properly with granulated sodalime. The clear canister housing permits visual verification of seal integrity when the canister housing is installed, to prevent. No tools are required for servicing.

- The molded electronics compartment (head, with top cover removed) is shown in Figure 4. All electronics are fully encapsulated, with access to the calibration switch and oxygen sensor potentiometers located beneath O-ring sealed caps providing redundant sealing. The power supply is an off-the-shelf 9V battery. No tools are required for opening the electronics head or access to sensor calibration/set point ports.

- Predive setup (excluding gas cylinder and canister filling) is routinely accomplished in less than 30 minutes.

- More than of 150 hours of hyperbaric testing and an estimated 20 hours of bench testing have been conducted with no failures noted. The oxygen sensors have not required recalibration.

For military use, the following modifications should be discussed:

- Replace the secondary display and cable assembly with a simple, robust GO or NO-GO type of non-illuminated indicator.

- Remove the rotary switch and cable assembly. Substitute a simple on/off switch in the existing electronics head cable connector.

R.J. Steckel - 10 May 2001
Hyperbaric Test Director
R&D Technology Services, Inc.

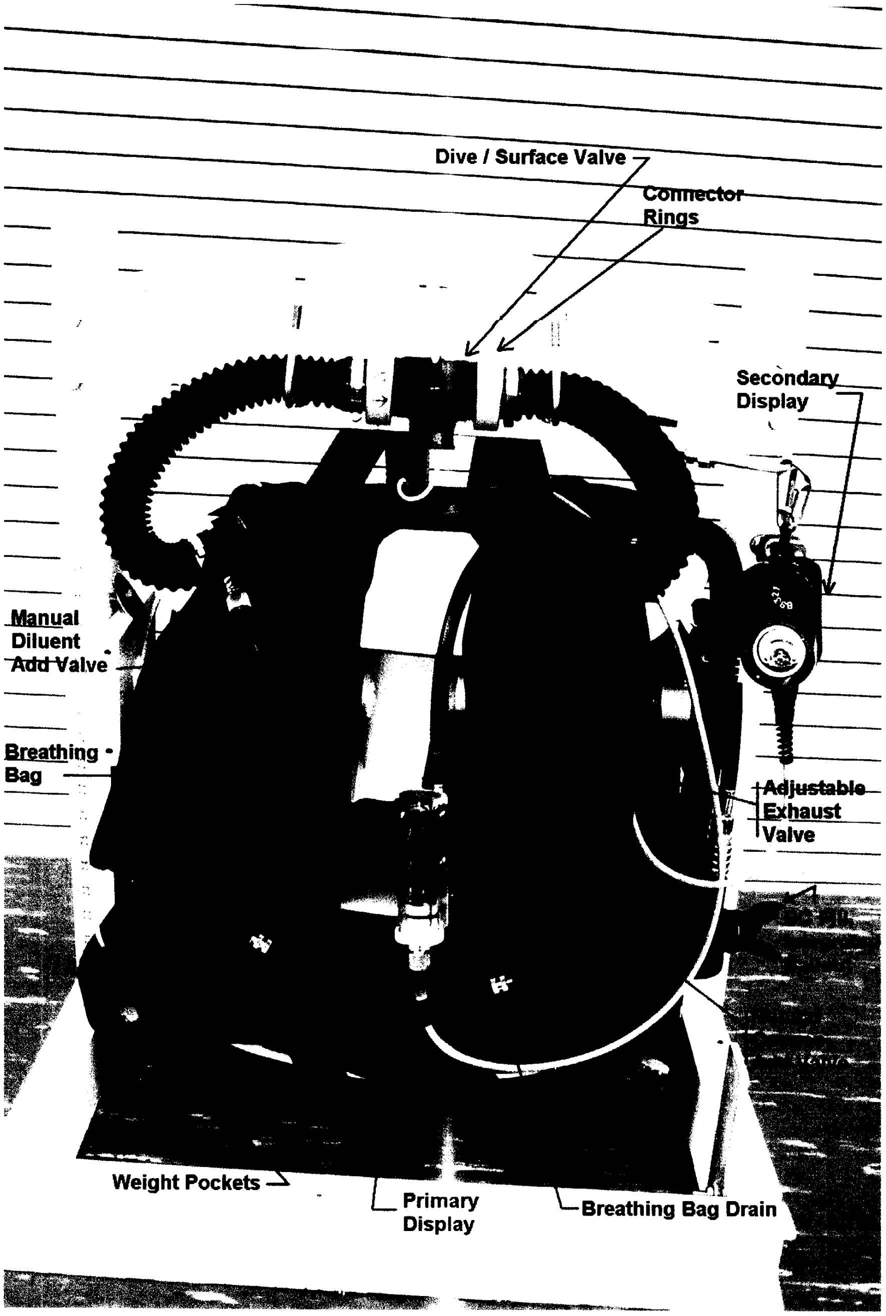

Figure 1 Steam Machine Prism – Front View

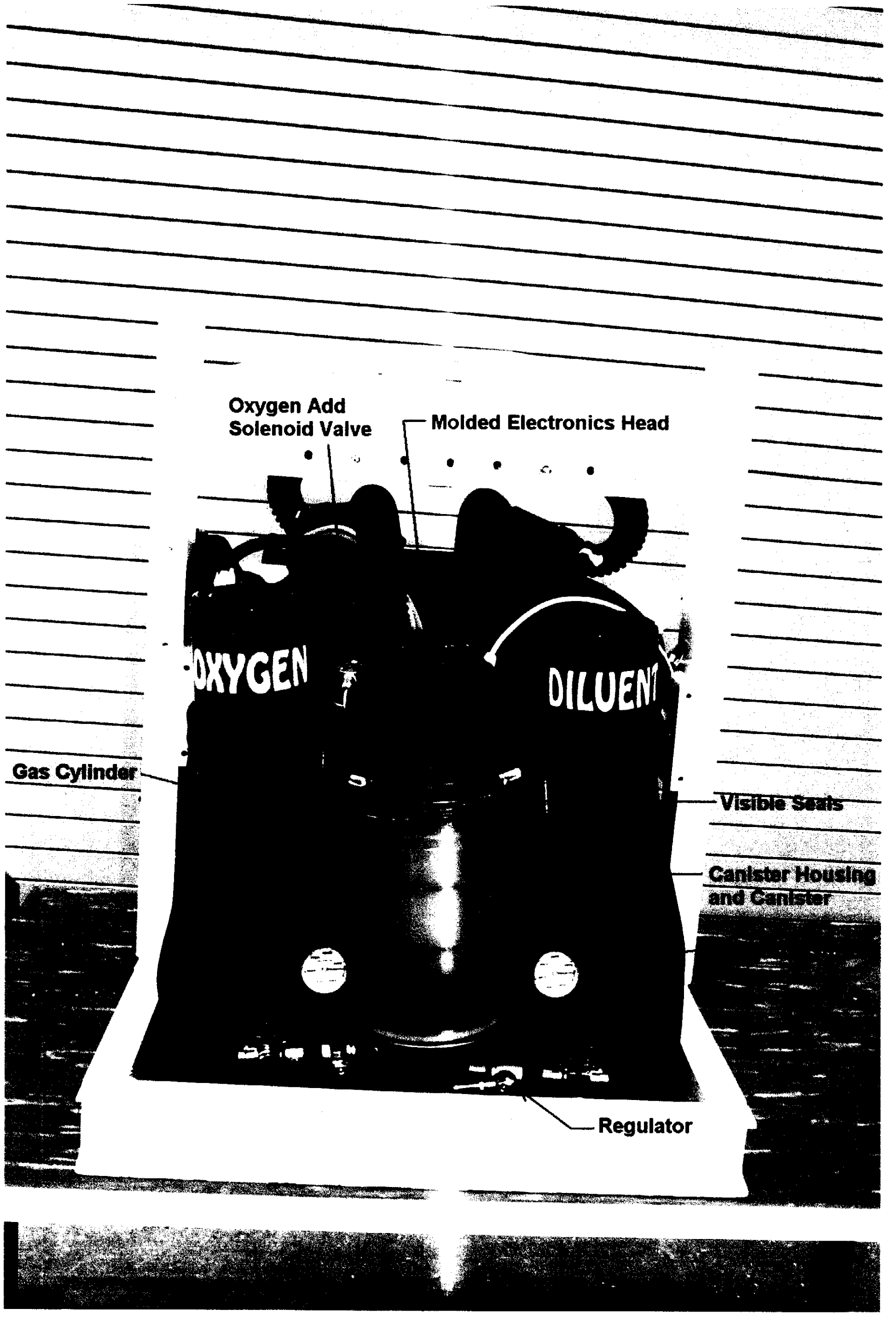

Figure 2 Steam Machine Prism – Back View

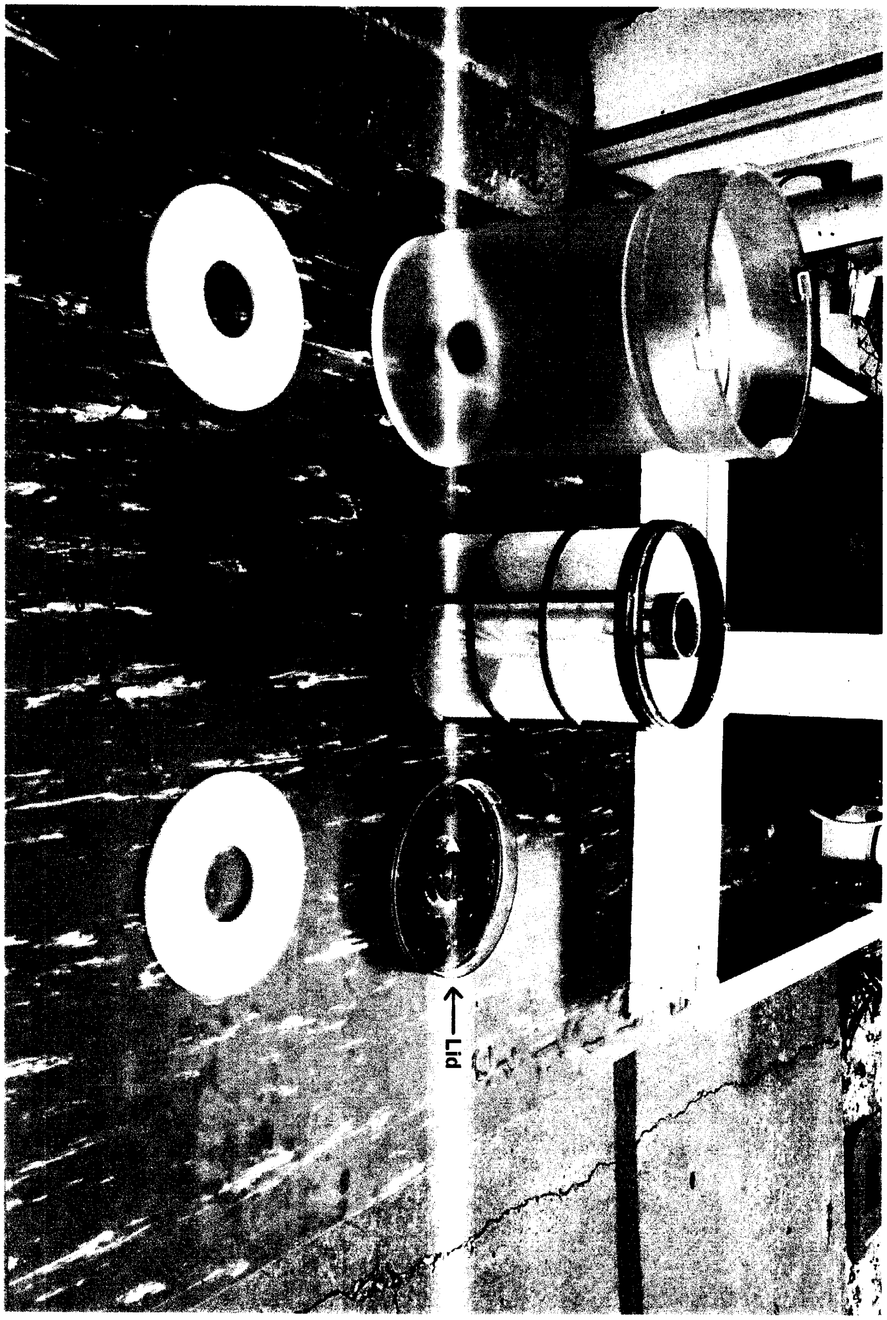

Figure 3 Steam Machine Prism – Canister Assembly

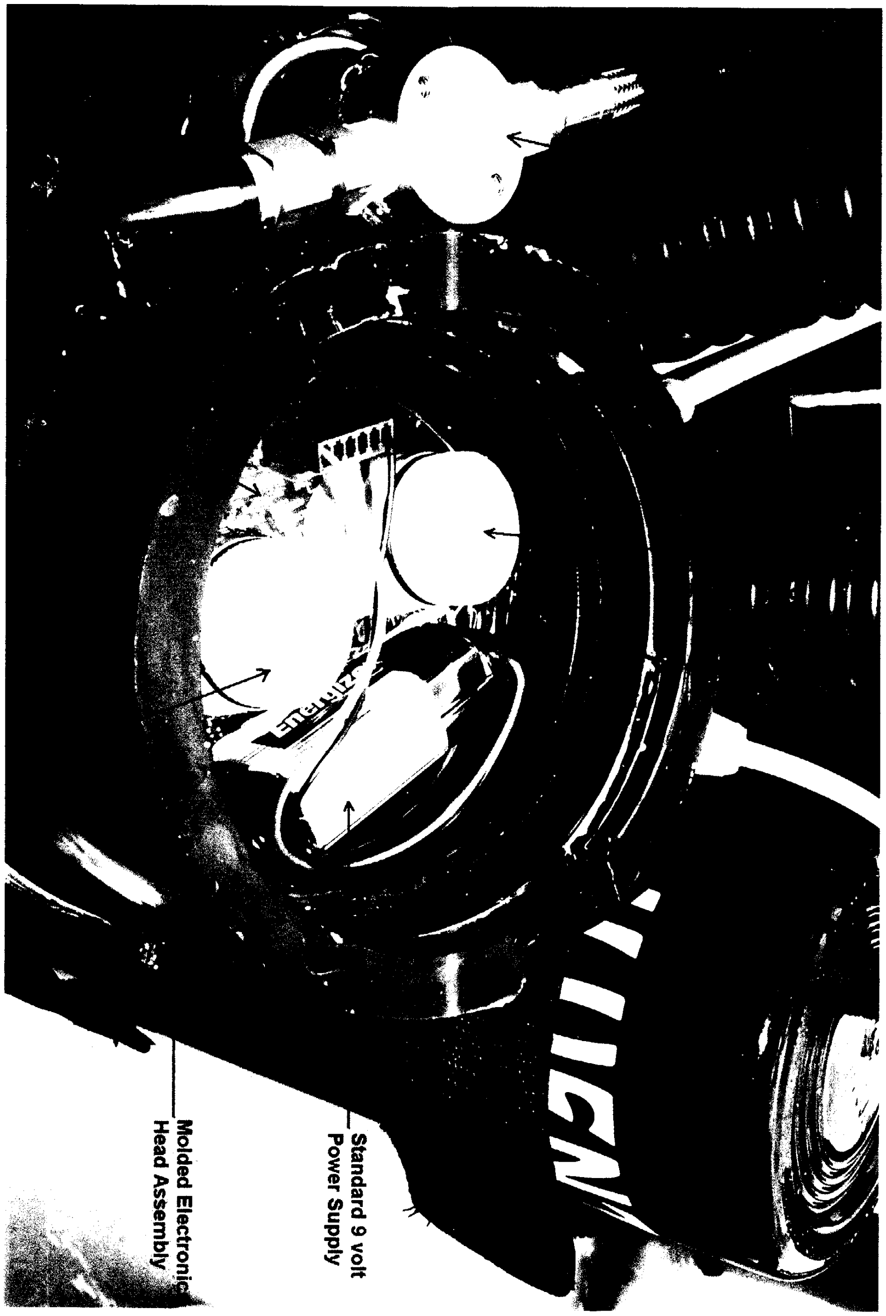

Figure 4 Steam Machine Prism – Back View, Electronics Head