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SPACE SYSTEMS



# FROG EGG EXPERIMENTAL HARDWARE

FOR

APOLLO APPLICATION PROGRAM

FINAL REPORT FOR PROTOTYPE PHASE

OCTOBER 22, 1968

by

Life Support Systems Engineering

Space Systems Organization

Missile and Space Division

General Electric Company

for

National Aeronautics and Space Administration

Ames Research Center

Moffet Field, California

Contract NAS 2-4641



GENERAL ELECTRIC

TABLE OF CONTENTS

## SECTION 1.0

## SUMMARY

This report describes the work effort performed in the design and development of prototype hardware for a Frog Egg Experiment for the Apollo Applications Program. The purpose of the experiment is to determine the effects of zero gravity upon fertilization and germination of frog eggs; therefore, this experiment requires fertilization of the eggs while in orbit under a zero gravity environment. In previous orbiting frog egg experiments, fertilization was accomplished in the laboratory before launch.

The complete experiment package consists of four modules, each containing three biological units. Each biological unit consists of a series of chambers and valves that enable a complete cycle of growth from fertilization of the frog egg, through germination and preservation at a desired stage of growth. During the contract period, a breadboard unit and a prototype module were designed, fabricated and tested.

The feasibility of providing experiment hardware to accomplish the desired function has been successfully demonstrated where acrylic is utilized for the chambers. Encouraging results have been achieved in using prototype glass chambers; however, breakage problems must be resolved before glass will be acceptable. Reasonable solutions to these problems are available for evaluation. Additional effort is needed in this area.

This report also includes recommendations for a flight type experiment, including preliminary analysis and design.

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# SECTION 1.0

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## SECTION 2.0

## PROGRAM OBJECTIVES AND REQUIREMENTS

### 2.1 Objectives

The objective of this program is to accomplish the research, design and development of prototype hardware for support of a Frog Egg Experiment for the Apollo Application Program. The purpose of the experiment is to determine the effect of zero gravity upon the fertilization and germination of frog eggs. This experiment differs from previous orbiting frog egg experiments (Gemini 8 and 12, Biosatellite) in that the eggs will not be fertilized until in orbit and under a zero gravity environment.

### 2.2 Design Requirements

#### 2.2.1 Hardware Operation

In order to demonstrate the feasibility of the Frog Egg Experiment, prototype hardware was built. The operating requirements of this hardware, as revised during the contract, result in the following operating cycle shown graphically in Figure 2-1. All controls and actuations are manual.

There is a chamber capable of holding 20 unfertilized frog eggs saturated with DeBoer's solution. The chamber has a high relative humidity to prevent drying of the eggs. Saturated air, but not liquid, are present. A 5cc quantity of frog sperm is introduced to the egg chamber for a 15-minute exposure. The egg chamber volume is constant, with air being expelled when the sperm is introduced. Still holding constant chamber volume, the sperm is washed out with 20cc of spring water. By expanding the chamber volume, 60cc of spring water is added to provide a media for germination of the eggs. At specified times, 10cc of glutaraldehyde is added to fix (kill) and preserve the eggs at a desired stage of egg development.

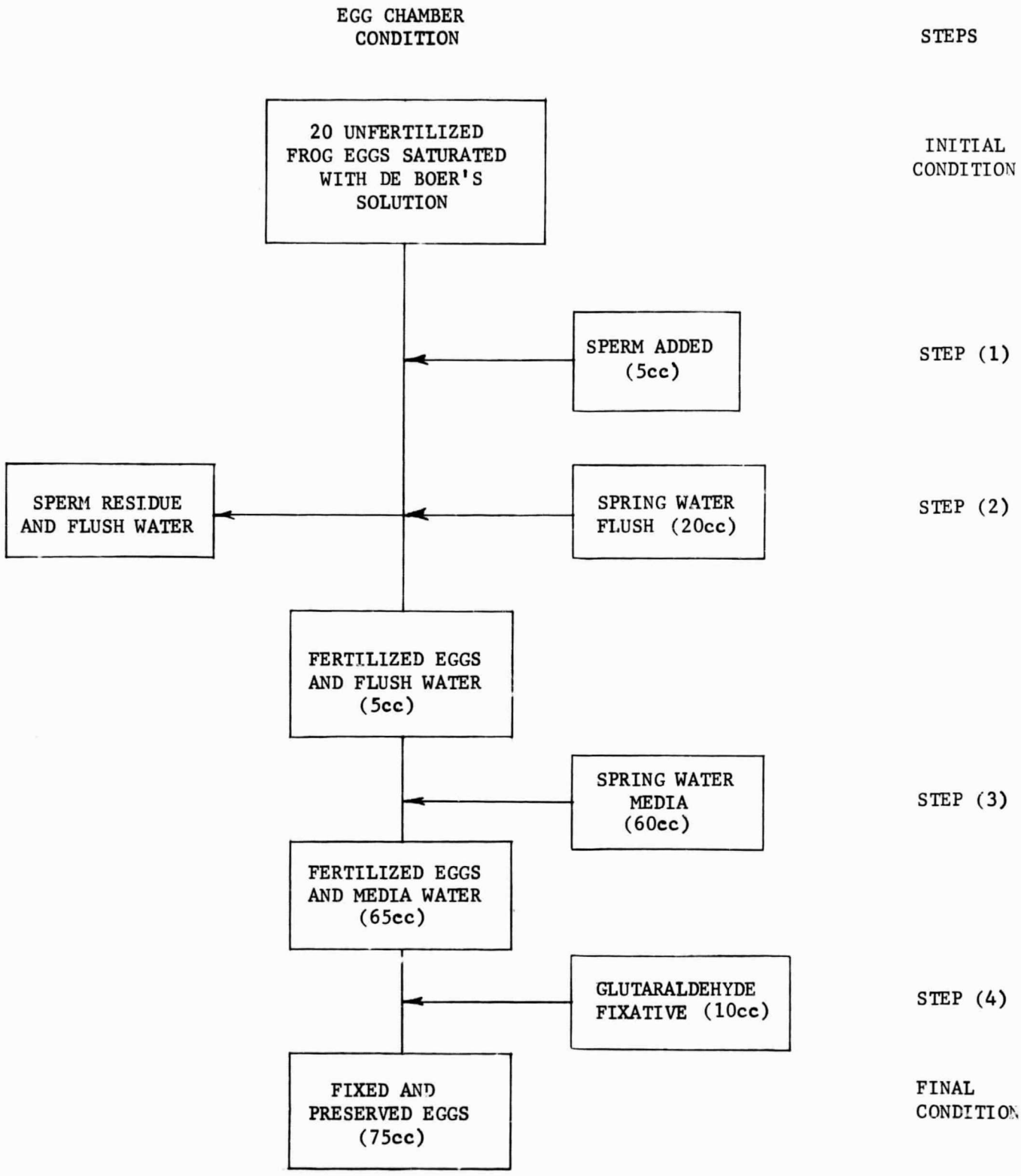



**Figure 2-1. Block Diagram of Biological Unit Operation**

2.2.2 Hardware Definition

The terminology used hereafter to identify precisely the items being discussed is listed as follows:

element - individual part

component - subassembly, e.g., 1 egg chamber

biological unit - assembly of 1 egg chamber and accompanying water, sperm and fixative components

module - assembly of 3 biological units

experiment - assembly of 4 modules

2.2.3 Material Requirements

Hardware having contact with the biologicals is to be made of glass where feasible; any seals required, however, can be made of ethylene propylene. The basic material requirement is that materials in contact with the biologicals must be compatible with egg growth requirements, as tested by NASA/Ames Research Center.

2.2.4 Temperature Requirements

Although not a design requirement for the prototype hardware, the thermal requirements for purposes of calculations are:

a. A possible 16 hour hold on the launch pad with the sperm and frog eggs maintained at 5 $\pm 1^{o}C$.

b. When in orbit, the sperm and frog eggs are to be heated to 18 $\pm 1^{o}C$ in 20 to 30 minutes.

c. An initial temperature overshoot during warmup of 2-4$^{o}C$ can be tolerated.

d. The temperature of any mixing liquid should be within 4$^{o}C$ of the egg temperature.

e. Approximately 1-2 hours will be permitted for temperature stabilization after addition of spring water.

Figure 2-2 shows the temperature cycle for a biological unit.

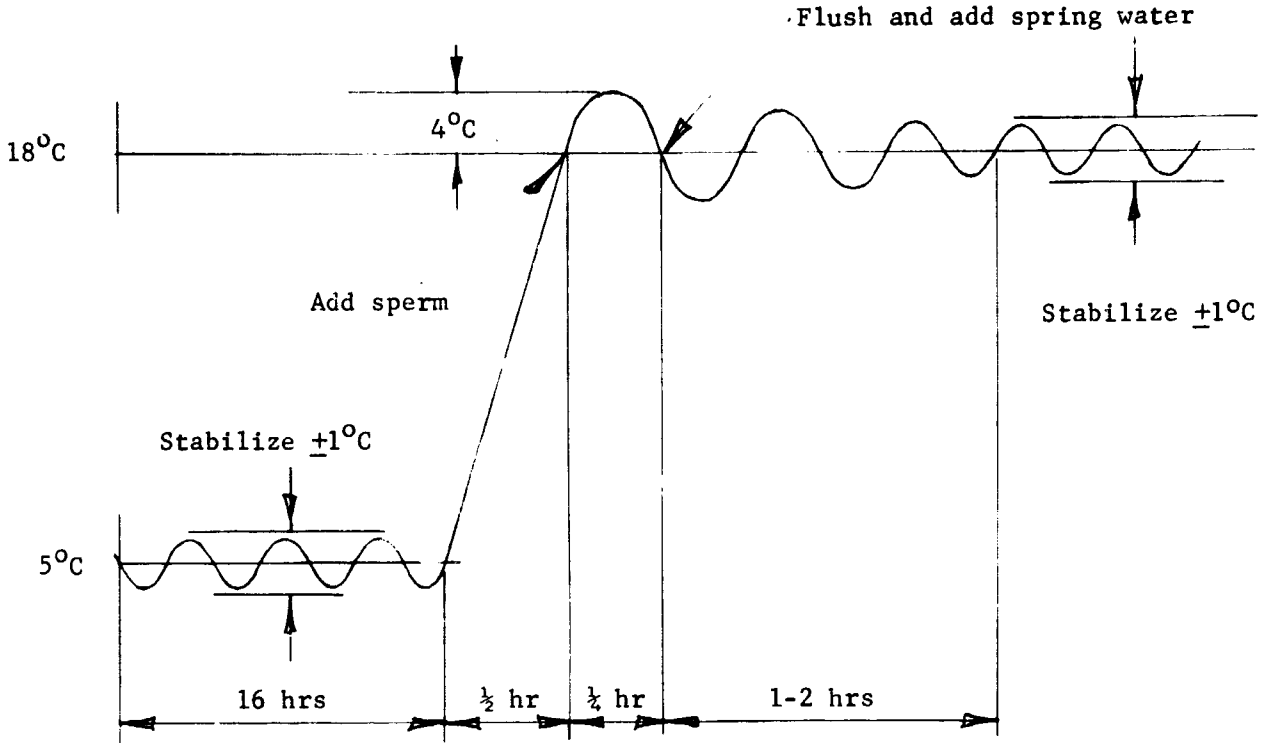



Figure 2-2. Frog Egg Temperature Profile

## 2.3 Work Effort Required

### 2.3.1 Phase I

Design, fabricate, test and deliver an engineering breadboard unit. Prepare engineering sketches and establish the design configuration of a prototype module. Conduct a status review meeting.

### 2.3.2 Phase II

Design, fabricate, test and deliver a modular prototype. Prepare preliminary assembly and operational instructions. Prepare and conduct a design review.

### 2.3.3 Phase III

Prepare preliminary drawings and specifications, and define thermal requirements for an Engineering Prototype of the Frog Egg Experiment.

### 2.3.4 Other Tasks

a. Submit a Program Plan.

b. Submit monthly reports and a final report.

SECTION 3.0

PERFORMANCE OF WORK

## 3.1 Phase I - Breadboard

### 3.1.1 Selection of Preliminary Packaging Concepts

After the program plan was issued, the Phase I effort began with a review of glass technology. Pyrex glass 7440 was selected as the best choice for chamber material because of its chemical purity, ease of fabrication and physical properties (see Appendix B). Because of the developmental nature of the program, however, the initial hardware was made from acrylic plastic with the dual intent of showing working parts to glass vendors and verifying packaging principles.

One biological unit consisting of chambers for the frog eggs, sperm, water and fixative and the associated valves was designed. Originally, individual chambers for the individual steps requiring spring water were made, but these were later combined into one large chamber.

Because of the possibility of fixative leaking or permeating past O-Rings, as was experienced in chamber designs of previous contracts, the fixative for this experiment was sealed in a glass vial with a frangible disc at one end. Operation of the breadboard fixative chamber ruptured the frangible disc without forcing glass into the fluid lines, satisfactorily demonstrating the feasibility of this design.

The various chambers and valves were located to minimize the length of connecting tubing while still providing space for future modification of the breadboard. Tubes and bored holes were kept to a minimum diameter to minimize the amount of fluid left in the lines.

### 3.1.2 Selection of Preliminary Operating Mechanism

The various chambers were fitted with pistons and sealed with O-Rings. In order to actuate the pistons and pump the chamber fluids, manually operated actuators were needed. Similarly, to prevent premature motion of the pistons,

locking devices were designed. Both of these functions are accomplished by hand-turned screws that bear on the piston stem.

Cam actuation levers were also investigated as an alternate, but were discarded because the screw mechanism offered more flexibility to change piston movement for this development phase.

3.1.3 Breadboard Unit and Design Review

During Phase I, the initial operations were based on handling an egg chamber filled with eggs in an aqueous DeBoer's solution. The first steps of operation were to expel the DeBoer's solution, wash the eggs, then add sperm. The NASA experimenter found that a better percentage of fertilization could be obtained with eggs saturated with DeBoer's solution, but initially stored in a humid air chamber; thus, the expulsion of DeBoer's solution and washing of the eggs were eliminated, a change which simplified the design.

As a result, the steps for a complete cycle of operation for a biological unit were established for the Phase II effort. These steps are given in conjunction with the block diagram of Figure 3-1.

Step 1 - Egg chamber locked, dump valve open. Expel 5cc of sperm to egg chamber, with air exiting at dump valve.

Step 2 - Egg chamber locked, dump valve open. Flush egg chamber with 20cc spring water. Excess forced to dump reservoir.

Step 3 - Egg chamber unlocked, dump valve closed. Add 60cc spring water to egg chamber, increasing egg chamber volume.

Step 4 & 5 - Optional to extend growth period of eggs by adding oxygenated spring water.

Step 4 - Dump valve open. Expel 20cc of water from egg chamber.

Step 5 - Unlock egg chamber, close dump valve. Add 20cc spring water to egg chamber.

| CHAMBER | CONDITIONS AT PROCEDURAL STEPS | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | OPTIONAL | | 6 |
| | | | | 4 | 5 | |
| EGG | LOCK | LOCK | UNLOCK | EXPEL 20CC | UNLOCK | UNLOCK |
| SPRING WATER | -- | EXPEL 20CC | EXPEL 60CC | -- | EXPEL 20CC | -- |
| SPERM | EXPEL 5CC | -- | -- | -- | -- | -- |
| FIXATIVE | -- | -- | -- | -- | -- | EXPEL 10CC |
| DUMP VALVE | OPEN | OPEN | CLOSED | OPEN | CLOSED | CLOSED |

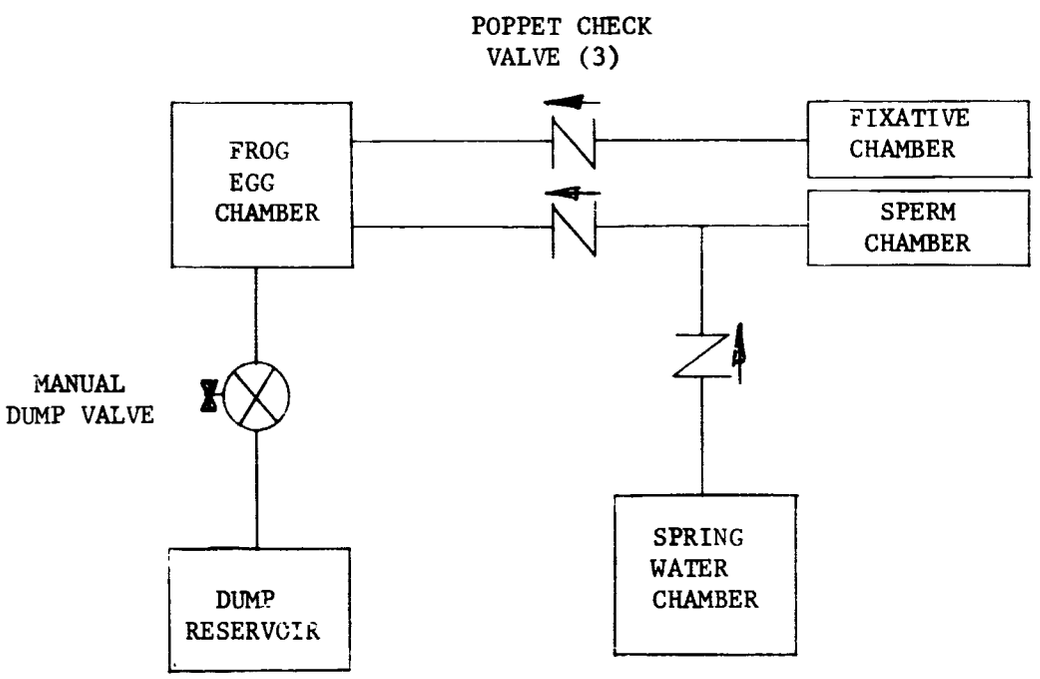



Figure 3-1. Block Diagram and Operating Sequence of Biological Unit

Step 6 - Egg chamber unlocked, dump valve closed. Actuate fixative piston to break glass vial and force 10cc fixative into egg chamber.

## 3.2 Phase II - Modular Prototype

### 3.2.1 Design Concept

The cycle developed at the end of Phase I (Figure 3-1) was used as the basic design requirement for Phase II. One module, consisting of three biological units, was to be designed and fabricated to meet this cycle. Simultaneous actuation of all units in the module was required. To do this, three identical units were stacked vertically in a frame. Manual actuation of the chamber pistons by a screw mechanism was retained as the moving force, with parallel arms designed to actuate the corresponding chambers on all three units when the screw mechanism was turned.

### 3.2.2 Operating Mechanism

To obtain parallel action on the three biological units, the mechanism designed consisted of three lever arms attached to a common shaft, which slides in linear ball bushings. The arrangement of these parts is schematically shown in Figure 3-2, a typical section through the module. The free ends of the lever arms bear on piston caps of metal which are made to prevent chipping of the end of the piston. A hand-turned screw mechanism is mounted to move the shaft. Turning the handle of the screw moves the shaft and all three arms to simultaneously actuate all three pistons.

The spring water reservoir is actuated at least twice, with an option of three times per experiment cycle. To indicate the amount of water dispensed, one end of a Negator spring with calibration marks is attached to the arm. Motion of the arm pulls the spring with its calibration marks past an indicator. The operator must watch the indicator to know that the correct amount of water is expelled.

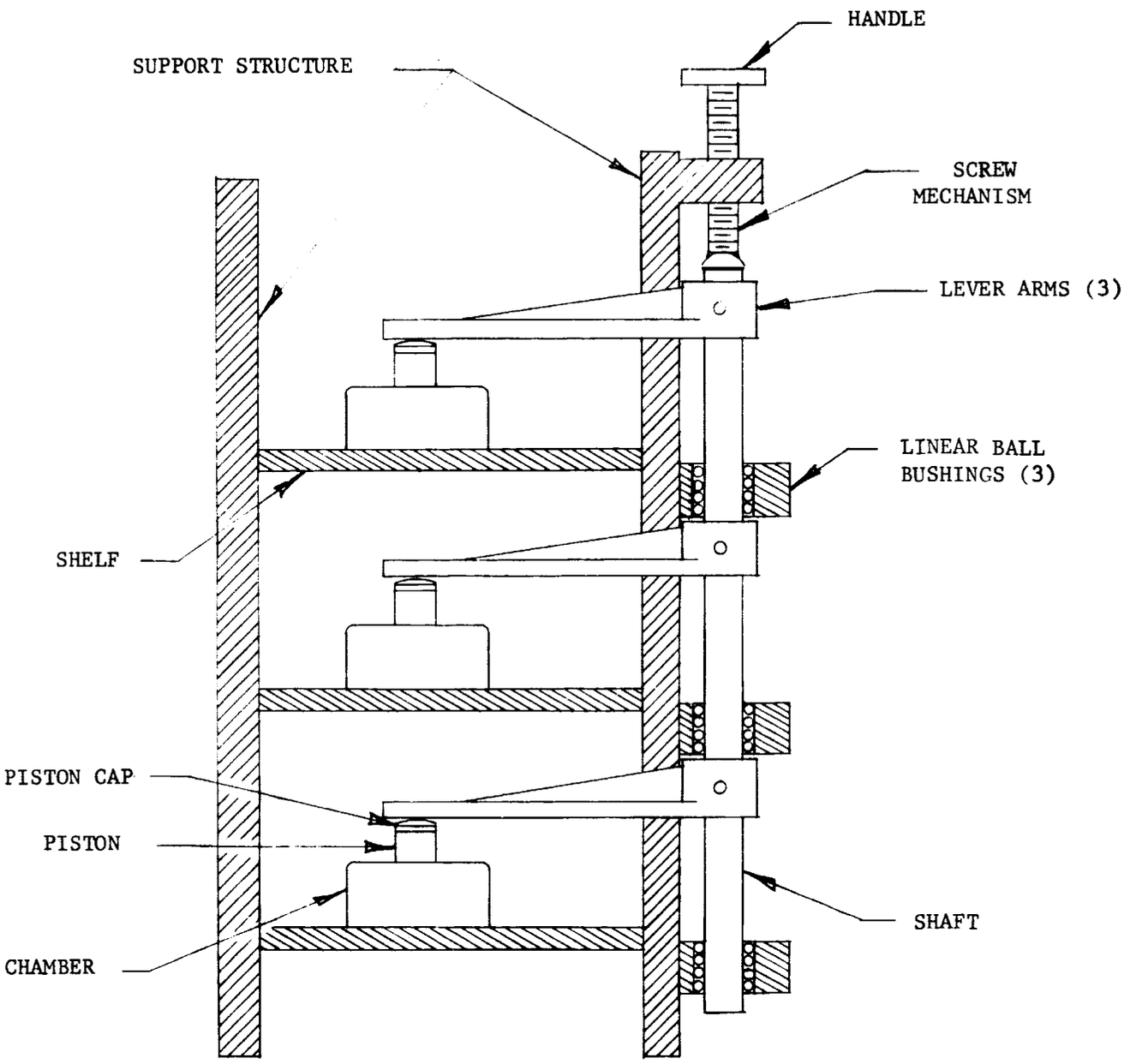



Figure 3-2. Schematic of Typical Section of Shaft-Lever Arm Actuating-Mechanism

### 3.2.3 Prototype Unit and Design Review

The prototype unit was demonstrated at the second design review. During the initial assembly and test of the modular unit, excessive bending in the mechanism shaft occurred, due to excess force requirements for the water chamber mechanism and check valves. To eliminate the bending and deflection, heavier arms and shafts were used; however, these can be lightened for a flight experiment by moving the water chamber closer to the drive shaft, shortening the lever arm and reducing the stresses. This, and other suggestions were made for future design optimization, which is discussed in Section 3.3.

The module is shown in detail in Appendix A, Assembly and Operating Procedures, which includes photographs of the hardware in various stages of assembly.

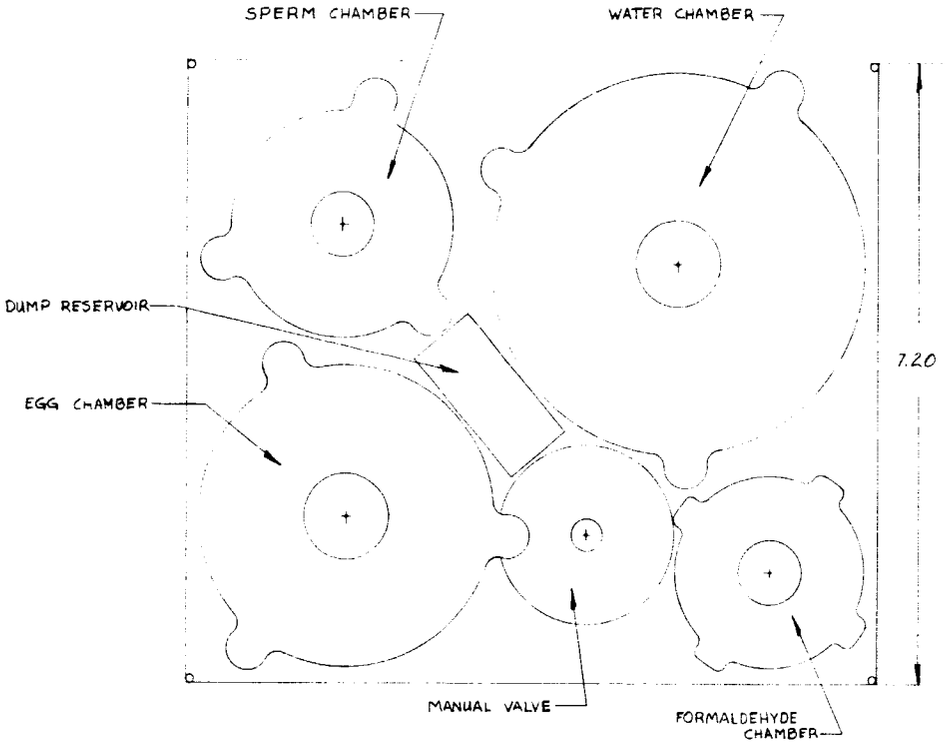
## 3.3 Phase III - Design Optimization and Recommendations

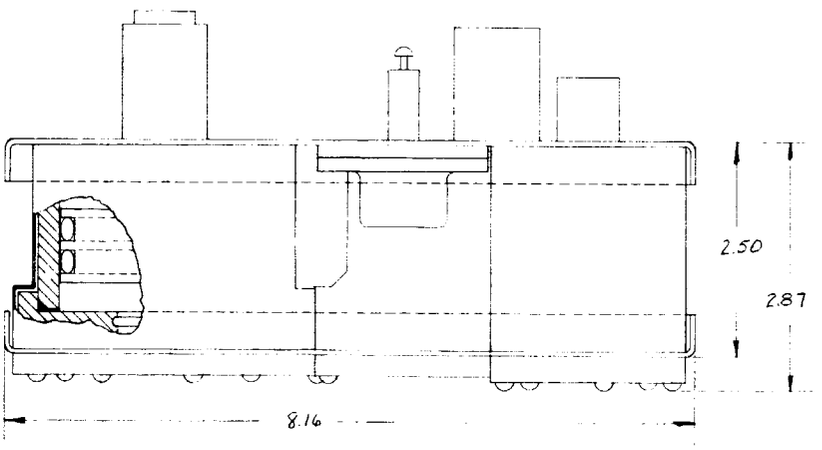
### 3.3.1 Revised Packaging Concept

The breadboard and module units were made with the prime intent of providing design feasibility. To continue toward flight hardware, several features should be incorporated to optimize the design. Figure 3-3, Biological Tray Assembly, and Figure 3-4, Experiment Assembly, show concepts that incorporate the following features.

a. A major improvement to the design would be incorporation of the poppet valves as part of the chamber. This permits locating the sperm, water and fixative chambers, closer to the egg chamber, which increases the packaging density and reduces the length of connecting tubes.

b. When relocating chambers, the actuator shafts would be relocated to reduce the length of the lever arm. The shorter arm length reduces the bending moment on the shaft, which permits lighter construction, possibly hollow shafts. Placing shafts along two of the shelf edges instead of one edge is a feasible approach.


SPERM CHAMBER
WATER CHAMBER
DUMP RESERVOIR
EGG CHAMBER
7.20
MANUAL VALVE
FORMALDEHYDE CHAMBER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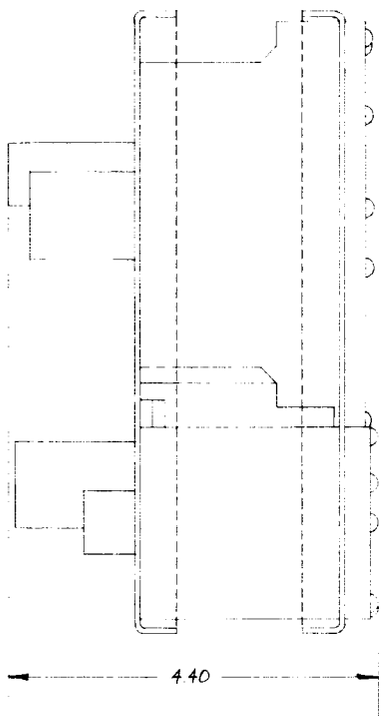


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GENERAL ELECTRIC
DEPT LOC

APOLLO FROG EGG
BIOLOGICAL TRAY ASSEMBLY

| SIZE | CODE IDENT NO. | FIGURE 3-3 |
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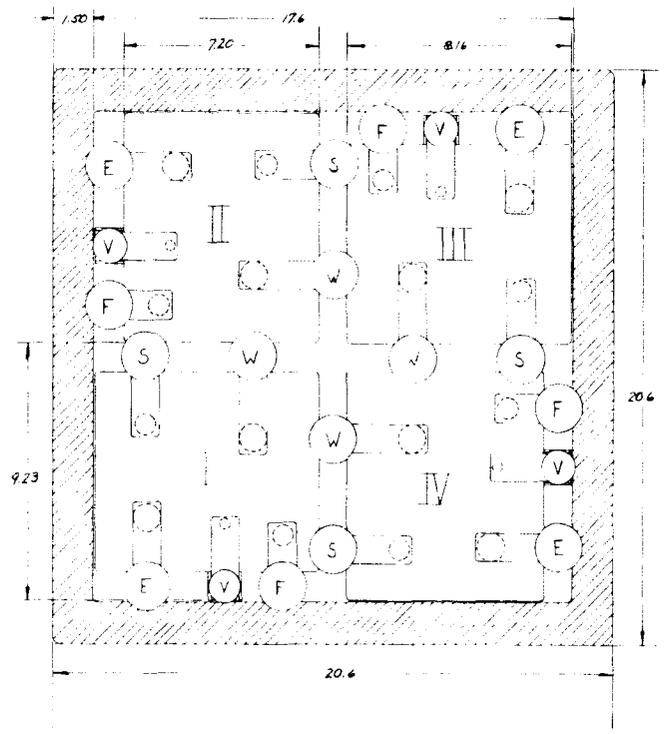
| SCALE | | SHEET |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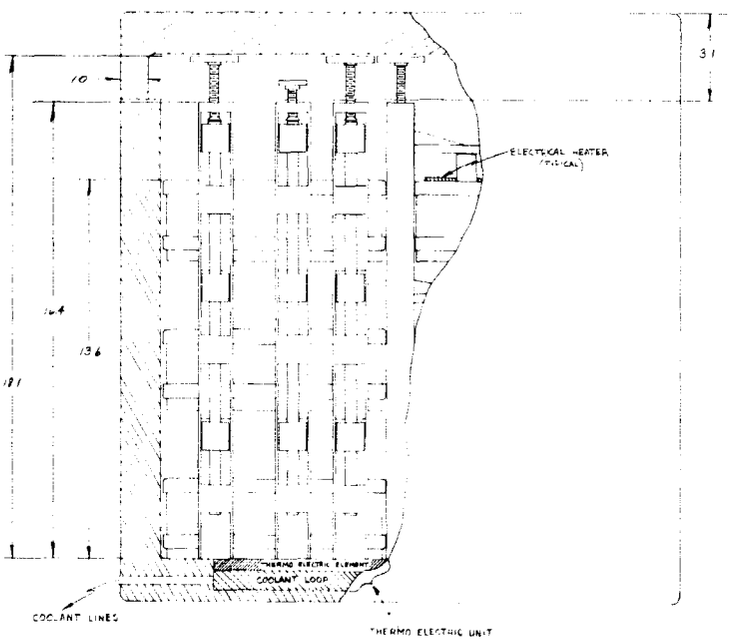
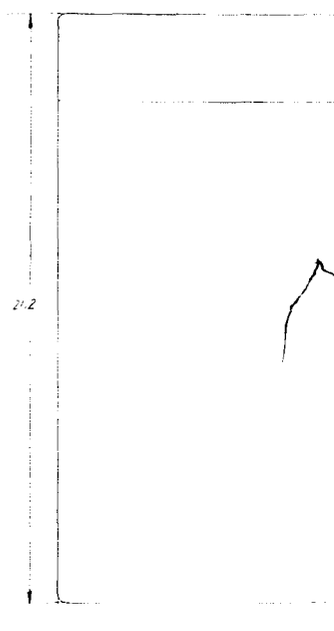

3.1
10
ELECTRICAL HEATER
(TYPICAL)
13.6
18.1
COOLANT LOOP
COOLANT LINES
THERMO ELECTRIC UNIT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GENERAL ELECTRIC

APOLLO FROG EGG
EXPERIMENT
ASSEMBLY

| SIZE | CODE IDENT NO. | FIGURE 3-4 |
|---|---|---|
| E | | |

SCALE 2:1 SHEET

1

1-13

c. Repackaging of a biological unit in a square shape instead of a long rectangle permits improved packaging density, because the space for the handles is used more efficiently. This is compatible with relocation of the shafts. The overall shape of the entire experiment (4 modules) approaches a cube, which has less surface per unit volume than a rectangular package. Smaller surface area results in lower heat losses, lower weight of insulation and case.

d. The shelf construction of the Phase II biological unit was a ½ inch thick aluminum plate, machined to retain all chambers and valves. To reduce weight and obtain improved stiffness, the shelf design for flight is conceived as a honeycomb or box-type of construction. Two parallel sheets of light gage metal will be brazed or bonded with stiffening members resulting in a high moment of inertia per unit weight. Holes will be provided in the sheets for mounting the chambers. The chambers will be of uniform height because the valves will be incorporated into the chamber. Uniformity of chamber height is necessary for packaging efficiency in this type of design. The weight of the flight shelf is estimated to be 1/3 of the prototype shelf weight.

e. A future detail to be investigated is the incorporation of slip clutches on all chamber actuators to prevent over-travel of the shaft and arm assembly. The prototype uses a slip-clutch on the dump valve actuator. An alternate is inclusion of positive stops for the arms, or indicator lights. Prevention of over-travel is necessary since a screw mechanism provides a very high mechanical advantage, with the consequent possibility of breakage of the mechanism or the glass pistons or chambers.

f. An additional concept to consider for flight hardware is automatic or semi-automatic operation instead of manual operation. The screw mechanism could be replaced by pneumatic or hydraulic actuators with power remotely controlled through solenoids. Electrically powered gear motors are also a possible driving force. Of course, adaptation of this concept requires trade-off studies of power requirements, and package size and weight.

3.3.2 Packaging for Thermal Requirements

Designing the package for thermal requirements will require careful analysis and development tests. Meeting the goal of holding the egg chambers to a pre-launch temperature of 5 $\pm 1^{o}C$ and an orbit temperature of 18 $\pm 1^{o}C$ is a problem similar to the temperature control of the Gemini and Biosatellite Frog Egg Experiments. The judicious use of insulation, heaters and coolers are tested concepts that can be adapted to this program. For example, to minimize the amount of heat leakage and to isolate the package from thermal shock, an insulated case can be used. The amount of insulation that is practical will depend on vehicle volume, weight and power limitations.

For pre-launch temperature control, cooling will be necessary. This could involve a liquid loop from the ground or vehicle environmental control system for rough control, plus a heater for fine temperature control (as in Biosatellite) or a thermoelectric unit (as in Gemini). Two proven means of minimizing the pre-launch heat load are: 1) pre-chill the entire experiment during countdown assembly, and 2) deliver the hardware to the vehicle in a transport case that is passively temperature controlled with a eutectic alloy. With these techniques the only heat to remove during pre-launch is the leakage through the insulation from the atmosphere to the experiment.

If thermoelectric cooling is chosen, there are units that have been developed with integral liquid-cooled heat sinks. The liquid coolant for the heat sink could be available from the Apollo environmental control loop, which would provide refrigeration for both pre-launch and orbit. Depending on environmental conditions, two 38 watt units would be sufficient for cooling this experiment (see Appendix D). The space required for both would be 5. x 7. x 1. (see Figure 3-4). If a liquid coolant interface between the experiment and Apollo is not feasible, an air cooled thermoelectric device can be used. These units have integral finned air cooled heat sinks instead of liquid cooled heat sinks. Ambient air blowing over the fins removes the experiment heat load; however, since air cooling is not as efficient as liquid cooling, two 38 watt finned coolers would require 5. x 9. x 2½ plus a blower. Of course, if a thermally conductive mounting surface could be provided to conduct the experiment heat to the vehicle structure, then fins and blower or liquid cooling interface can be eliminated. Comparison of the three types of heat sink, assume equivalent heat sink temperatures. If this is not the case, radically different TED sizes will be needed to obtain the same cooling. On the experiment side of the cooler, adding fins and a blower would give an oven effect inside the experiment case, surrounding all parts of the experiment in temperature controlled air.

To warm up the biologicals and water chambers in orbit, strip heaters will be used. These could be bonded to the biological shelf or possibly right on the chambers, depending on acceptable gradients and allowable time for warm-up.

### 3.3.3 Size and Weight Reduction

The approximate size of the flight package, including structure and insulation, is 20.6 x 20.6 x 21.3 high (9000 cubic inches) (see Figure 3-4). By comparison, a single Phase II module occupies a space of 16.3 x 16 x 17. Since four

modules, structure and insulation are needed for an experiment, the projected size of a Phase II design would be 20 x 34 x 21.3 high (14,500 cubic inches); hence, the volume of the flight concept design is approximately 62% of the present design.

Reducing the length of lever arms, shortening the mounting plates, and lightening the shafts all contribute to a large weight reduction. A prototype module weighs 36 pounds. As a first estimate, the weight of a Phase III module is 17 pounds. Allowing 17 pounds for the case, insulation and temperature control gives a total weight of 85 pounds for the new design versus 161 pounds by Phase II methods, a reduction of nearly 50%.

A weight reduction to 60 pounds is a desired goal; therefore, effort to minimize the weight for flight will be needed.

## APPENDIX A

## MODULAR PROTOTYPE ASSEMBLY AND OPERATIONAL INSTRUCTIONS

### A.1 Structure Disassembly

NOTE: Do not remove screws marked with red GLYPTAL paint.

Step No.

1 Start the disassembly procedure with the unit standing upright on its base plate with the holding fixture ready for use (Figure #1).

2 Remove two position indicators as follows:

a. Loosen the screw holding the tape spool to the mechanism bar.

b. Push the tape spool down and out of the slot in the mechanism bar.

c. Let the tape spool recoil up to the position indicator structure.

d. Remove the two screws holding the position indicator structure to the upper tray.

3 Remove the four screws from the base of each hand actuator assembly attached to the upper tray (four locations).

4 Locate the holding fixture so that the left top tag on the fixture and the left top tag on the assembly are at the same rear corner.

5 Use the shaft support flange (Figure #1) of the holding fixture to lift the five actuating bars while raising the fixture up and inward until it snaps over the assembly.

6 Hold the fixture and assembly together at the sides while tipping the assembly over onto the fixture horizontally.

7 Lay unit on table with fixture on the bottom (Figure #2).

8 Remove the two upper screws from the bottom of the base plate.

9 Remove the three screws from the side of front rails (right side) (Figure #2).

10 Remove the three screws from the side of the front rail (left side) (Figure #2).

11 Remove the two front rails.

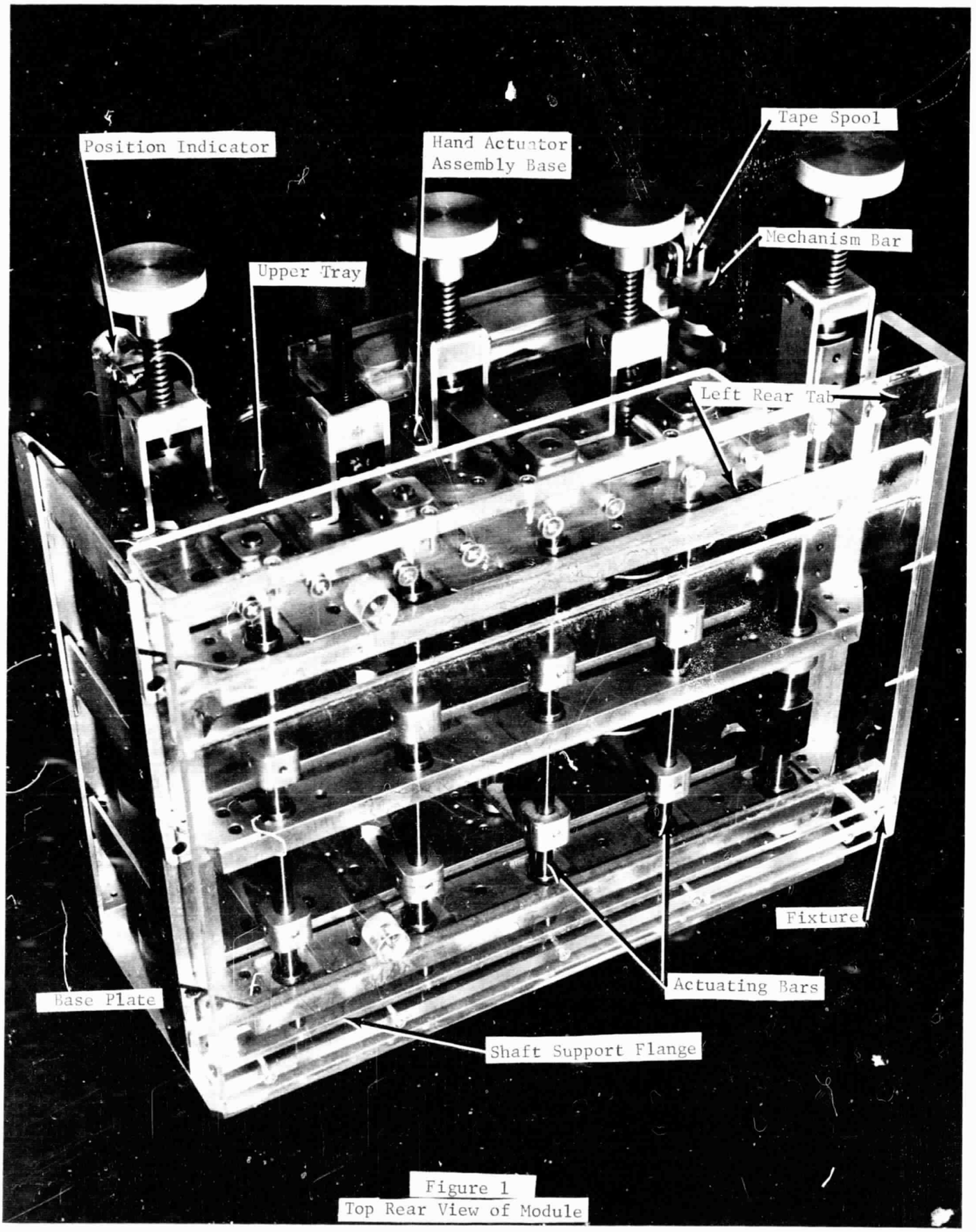


Figure 1
Top Rear View of Module

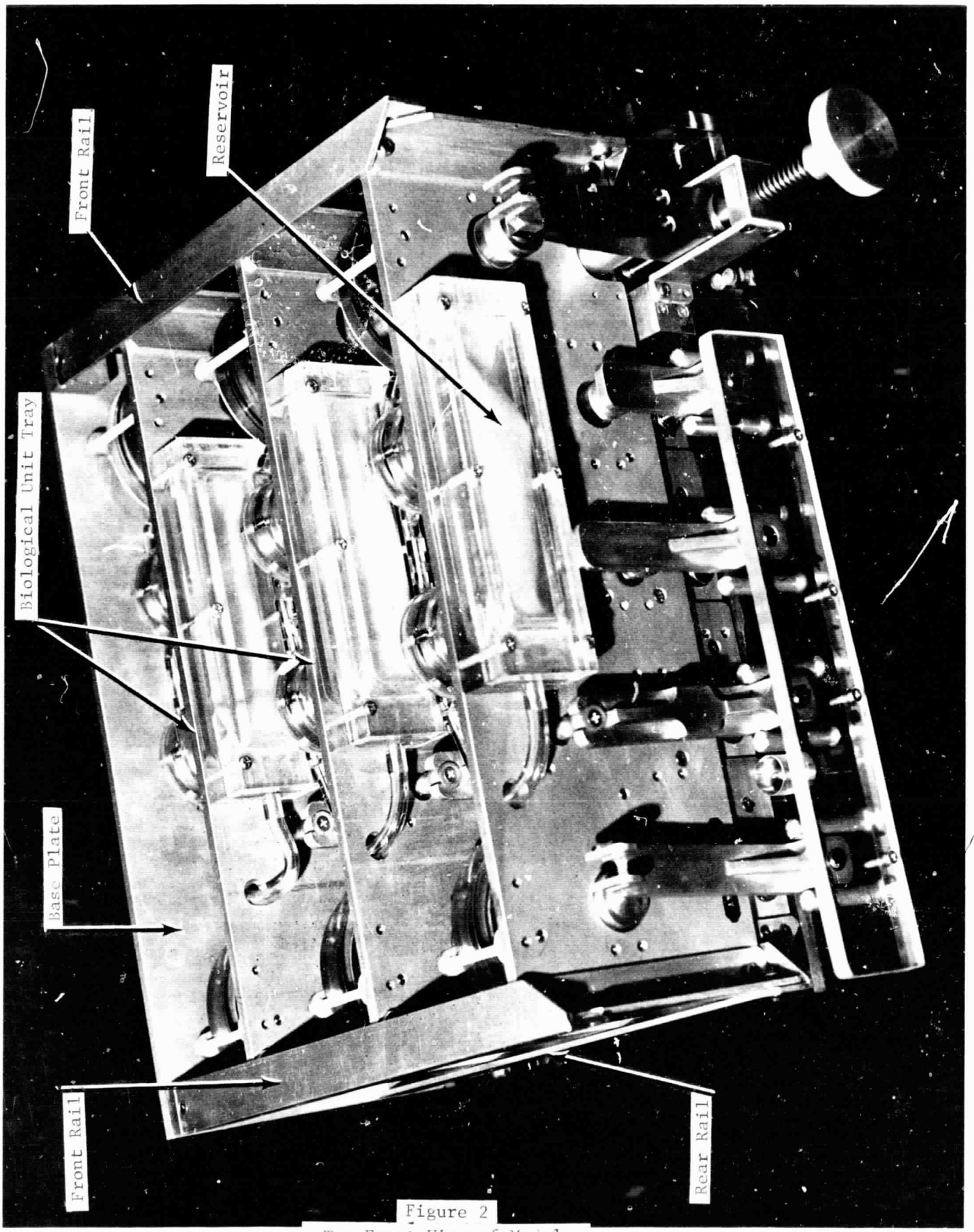


Figure 2
Top Front View of Module

12 Remove the three screws at the side of the rear rail (right side) (Figure #2).

13 Remove the three screws at the side of the rear rail (left side) (Figure #2).

14 Remove each biological tray unit and place on a table so that the chamber elements face downward.

A.2 Biological Tray Disassembly Procedure

Place tray in a position with the shafts facing up.

Step No.

1 Reservoir

a. Remove dump tubing at reservoir connection (Figure #2).

b. Remove four screws from reservoir corners.

c. Remove reservoir.

d. Invert tray and place on table with chambers facing up (Figure #3).

2 Formaldehyde Chamber

a. Remove four flathead screws from formaldehyde chamber while supporting chamber by hand from the back.

b. Turn tray so that the chambers face up with the actuating shafts down.

c. Using Tool #1 remove connecting tubing as chamber is removed from the adjacent valve inlet.

d. Remove four panhead screws from chamber and separate carefully.

e. Clean out broken glass from all parts.

3 Water Chamber

a. Remove three nuts from water chamber retainer ring.

b. Remove the chamber end plate while removing the connecting tube with Tool #1.

c. Remove the tubing from the check valve.

d. Remove the lower half of the chamber and place all related parts in a container.

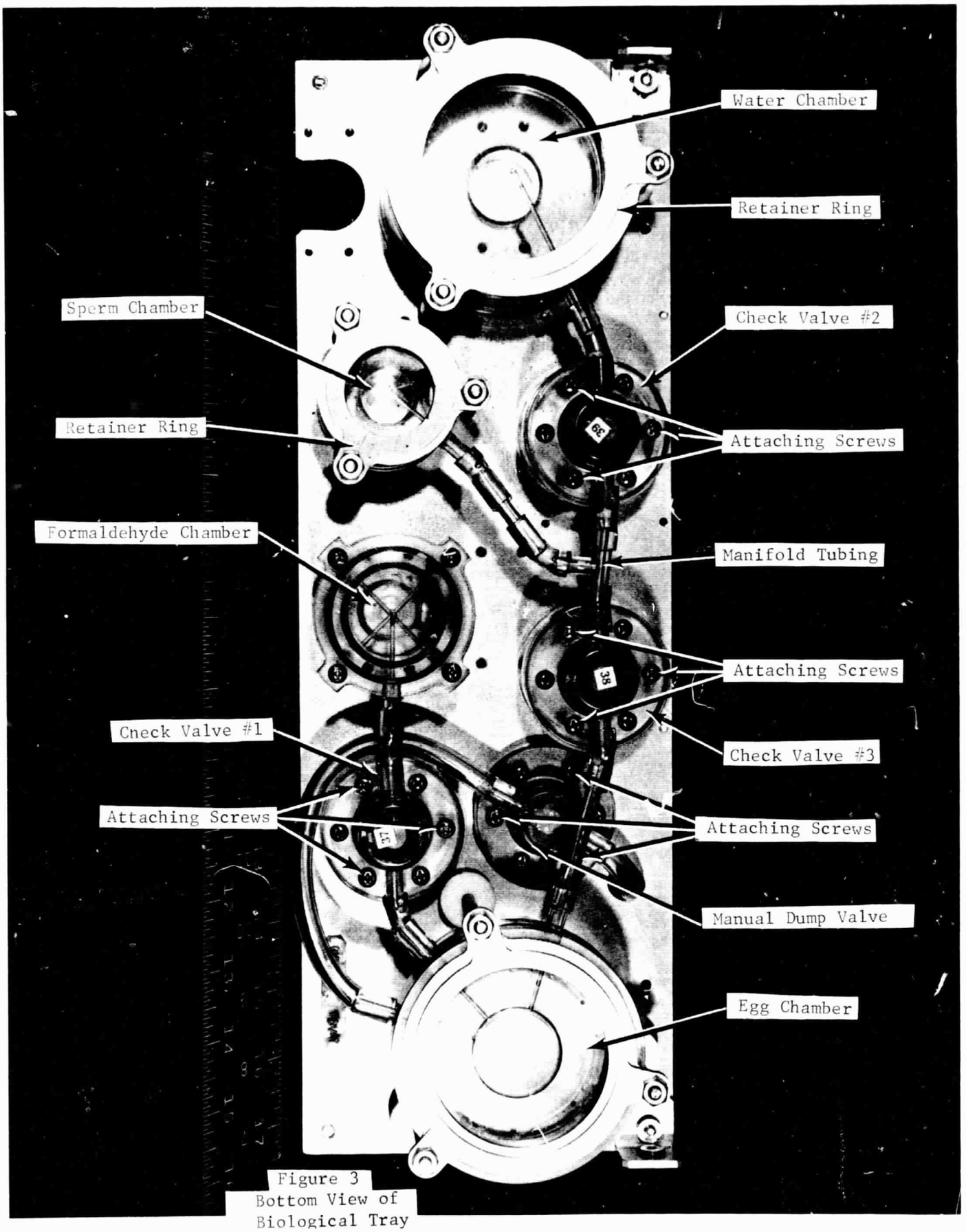


Figure 3
Bottom View of
Biological Tray

4 Sperm Chamber

a. Remove three nuts on sperm chamber retainer ring and remove the ring.

b. Remove the chamber end plate while removing the connecting tubing using Tool #1.

c. Remove the tubing from the check valve.

d. Remove the lower half of the chamber and place associated parts in a container.

5 Using Tool #1, remove the line connecting the egg chamber with the manual dump valve.

6 Remove the dump valve reservoir line using Tool #1.

7 Check Valve #1

a. Remove the three valve attaching screws from the valve assembly.

b. With the valve loose on its base and using Tool #1, slide outlet tubing off the egg chamber assembly.

c. Place valve and associated parts in a container.

8 Check Valve #2

a. Remove the three valve attaching screws.

b. With the valve loose on its base, slide the manifold tubing off the valve outlet.

c. Remove valve and place in a container.

9 Remove check valve to sperm chamber manifold tubing using Tool #1.

10 Check Valve #3

a. Remove three valve attaching screws.

b. With valve loose on its base, remove connecting tubing at the egg chamber inlet.

c. Remove valve with tube and place in a container.

11 Egg Chamber

a. Loosen three nuts and remove retainer ring.

b. Slide chamber out of support structure.

c. Place egg chamber and associated hardware in a container.

12 Manual Dump Valve

a. Remove three valve attaching screws from the dump valve.

b. Remove valve and place in a container.

A.3 Biological Tray Assembly Procedure

NOTE: Before Assembly

- biologically clean all parts
- apply silicone grease to all O-Rings and gaskets

Step No.

1 Place biological tray on table so that threaded studs face upward (Figure #4).

2 Assemble the manual valve. Assemble valve upper and lower body, poppet, spring O-Ring, diaphragm and gasket together using three screws. Mount the valve onto tray. (Note flow arrow orientation). Torque screws to 16-18 in-oz.

3 Mount manual dump valve using three valve attaching screws taking care to match valve flow arrow with tray flow diagram (Figure #5).

4 Water Chamber (Figure #5)

a. Place gasket in machined groove on base plate.

b. Remove one Teflon spacer from its stud.

c. Place chamber cylinder in groove with chamfered end up.

d. Replace Teflon spacer on stud.

e. Fit piston with O-Rings.

f. Assemble piston in cylinder bore with shaft downward.

g. Align piston face with full mark on the cylinder.

h. Fill cylinder bore with oxyginated water up to the base of the chamfer at the top of the cylinder.

i. Assemble end cap.

1) Place gasket against inside cap face.

2) Insert O-Ring against gasket.

j. Slide the tygon tubing over the outlet port (Figure #6).

k. Place end cap on the chamber. (NOTE: Water in chamber will be displaced when cap is installed onto chamber).

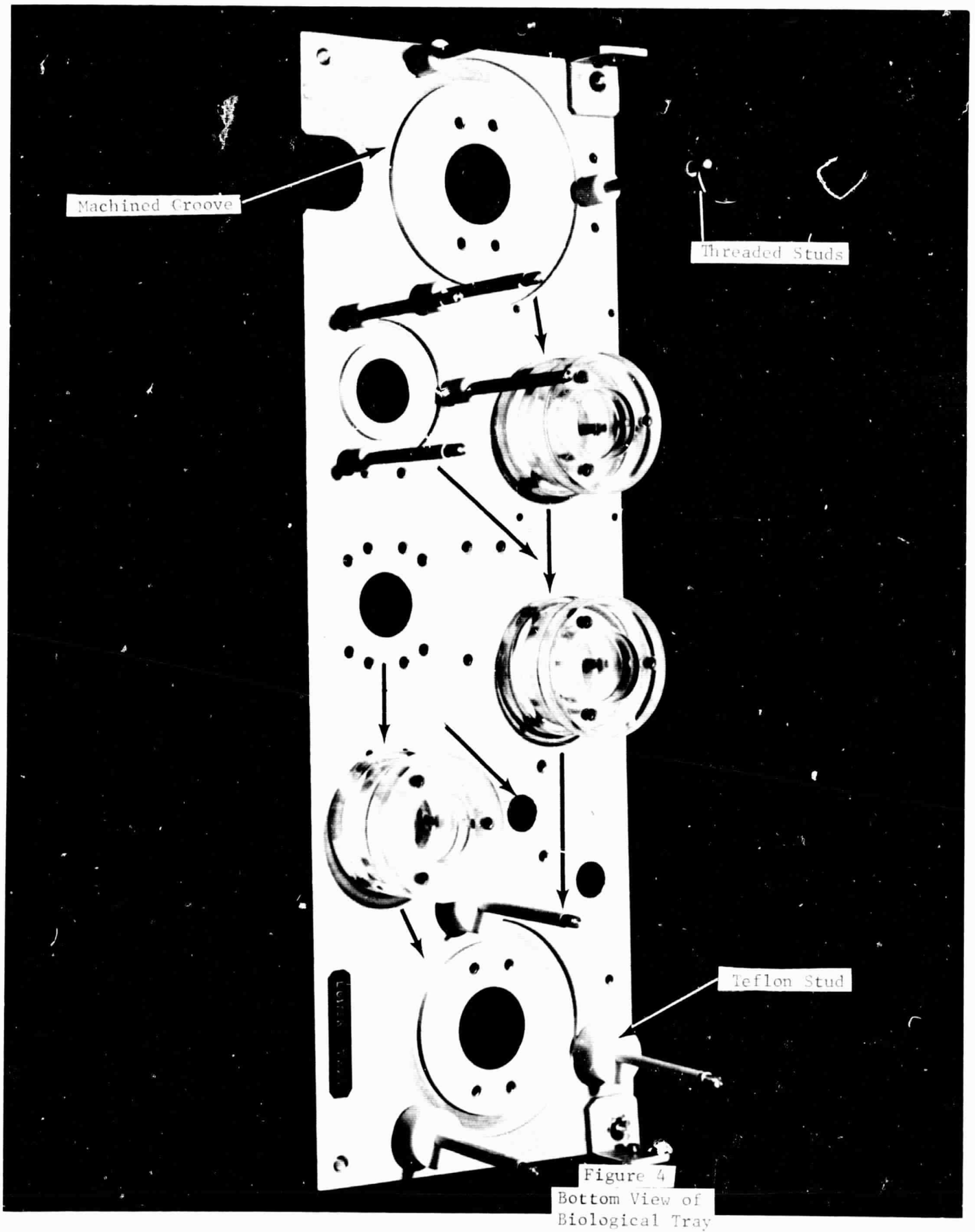


Figure 4
Bottom View of
Biological Tray

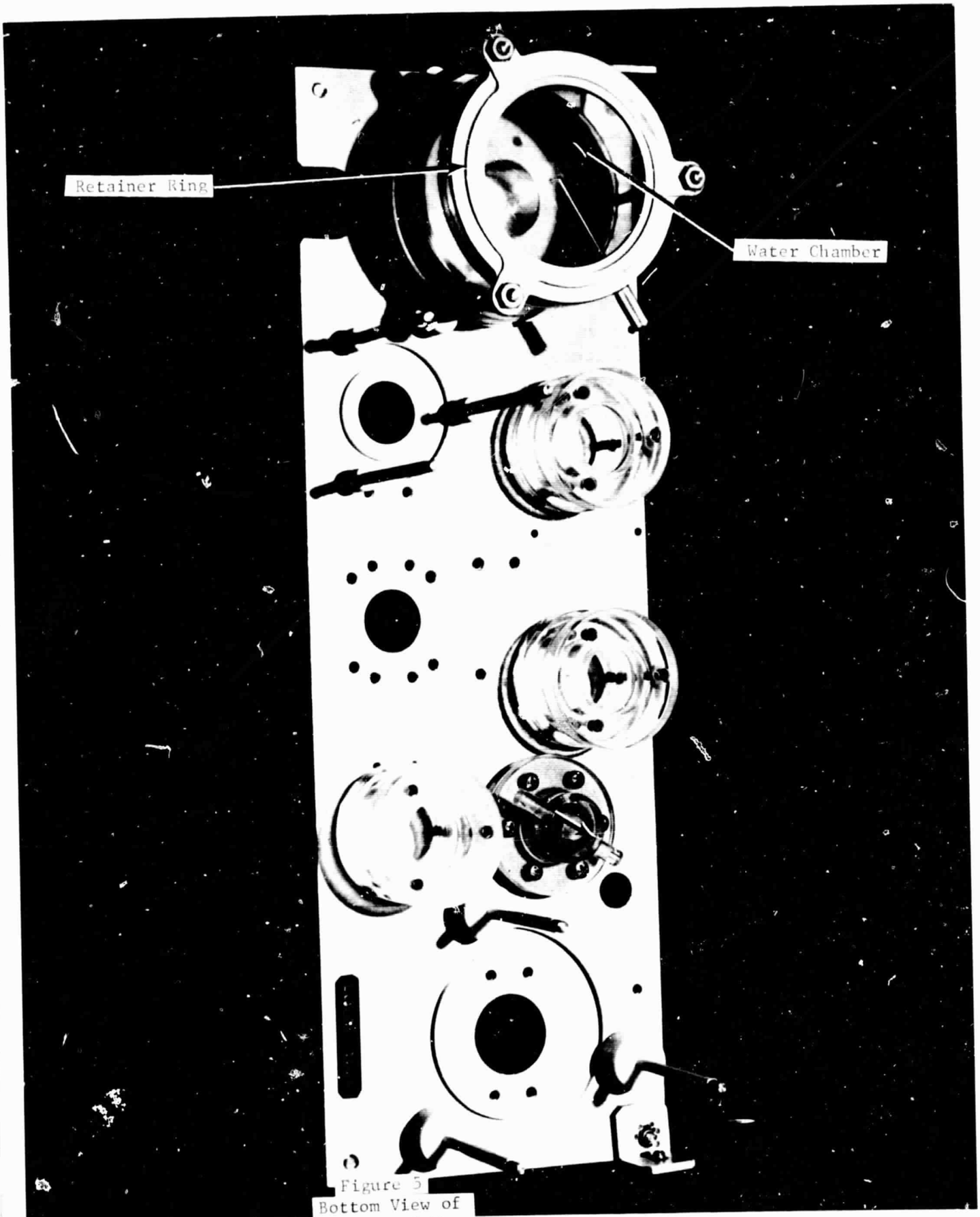


Figure 5
Bottom View of
Biological Tray

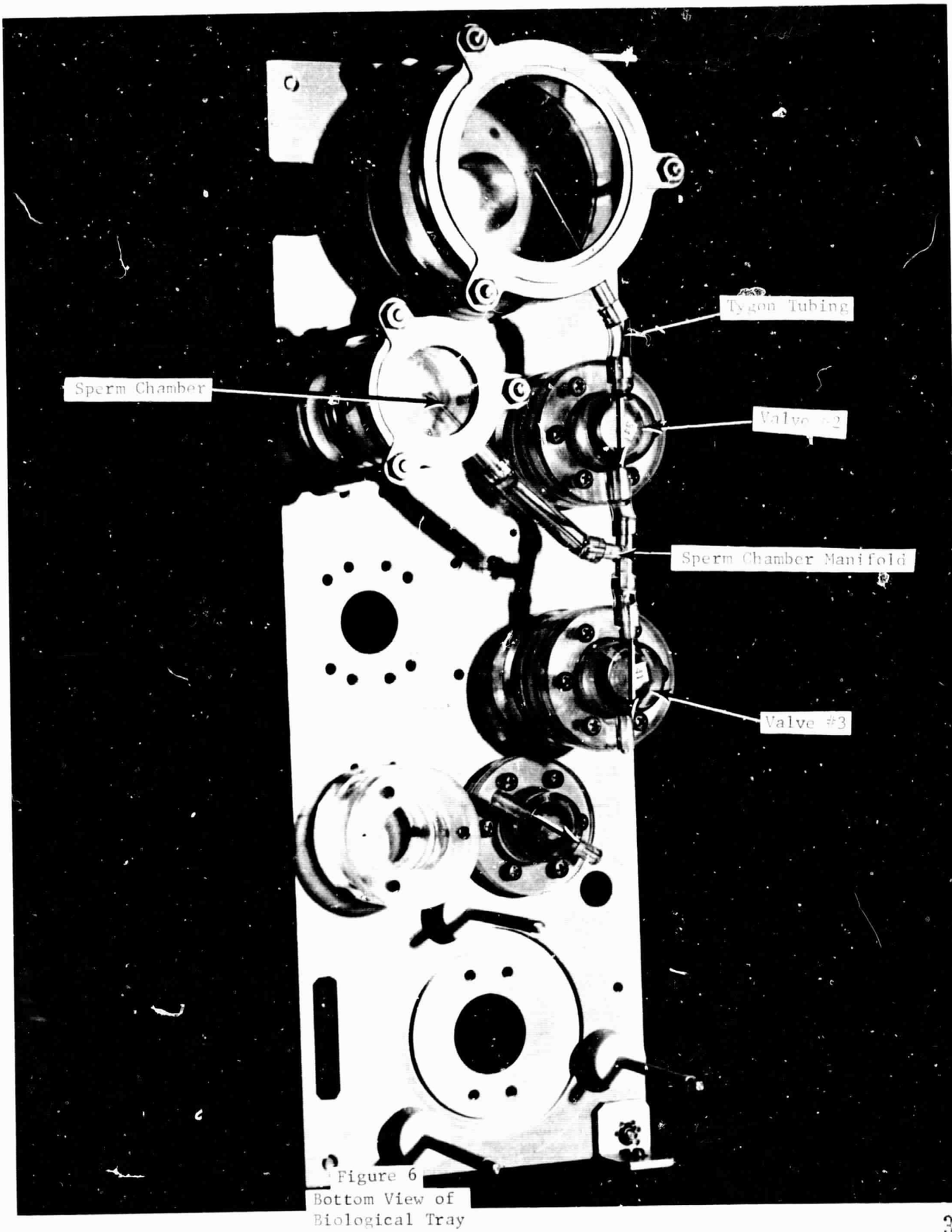


Figure 6
Bottom View of
Biological Tray

l. Place retainer ring over the assembly.

m. Alternately tighten retainer ring nuts to 7-8 in-lbs.

5 Assemble Valve #2 (Figure #6)

a. Slide the valve inlet port into the water chamber tygon.

b. Assemble valve upper and lower body, poppet, spring, O-Ring, diaphragm and gasket together using three screws (note flow arrow orientation when valve assembly is installed onto mount). Mount the valve on its base using the three screws (note flow arrow).

c. Torque screws to 16-18 in-oz.

6 Sperm Chamber (Figure #6)

a. Place gasket in machined groove on base plate.

b. Remove one Teflon spacer from its stud.

c. Place chamber cylinder in groove with chamfered end up.

d. Replace Teflon spacer on stud.

e. Fit piston with O-Rings.

f. Assemble piston in cylinder bore with shaft downward.

g. Align piston face with top edge of cylinder (chamfered end).

h. Assemble end cap.

1) Place gasket against inside cap face behind O-Ring diameter.

2) Insert O-Ring against gasket.

i. Place end cap on chamber cylinder (note flow arrow).

j. Place retainer ring over the assembly.

k. Alternately tighten retainer ring nuts to 7-8 in-lbs.

7 Fill the sperm chamber by injecting 10cc of sperm through the outlet port with a syringe.

8 Fill the valve sperm chamber manifold line with sperm and attach line to the chamber and Valve #2.

9 Assemble Valve #3

a. Assemble valve upper and lower body, poppet, spring, O-Ring, diaphragm and gasket together using three screws (note flow arrow orientation when valve assembly is installed onto mount). While placing valve in its base, attach sperm manifold tubing to valve inlet (note flow arrow).

b. Torque screws to 16-18 in-oz.

10 Formaldehyde Chamber (Figure #7)

a. Locate chamber on tray.

b. While supporting chamber, turn tray and insert four flathead screws from back side of base plate. Torque to 7-8 in-lbs.

c. Return tray assembly to an upright position (chambers facing up).

d. Assemble O-Rings to piston.

e. Place piston in bore with shaft down. Push piston down until rear of piston is flush with base plate.

f. Drop SEALED formaldehyde capsule into chamber with fill-tube protruding into the recess in the piston face.

NOTE: DO NOT APPLY PRESSURE TO THE CAPSULE

g. Place O-Ring in the groove at top of the chamber.

h. Fill chamber with water to approximately ½ inch above capsule.

i. Place end cap on chamber, insert screws and torque to 10 in-lbs.

11 Assemble Valve #1

a. Assembly valve upper and lower body, poppet, spring, O-Ring, diaphragm and gasket together using three screws (note flow arrow orientation when valve assembly is installed onto mount). Place Valve #1 in its base (note flow arrow).

b. Rotate Valve #1 outlet port while attaching valve to formaldehyde outlet.

c. Tighten valve attaching screws to 16-18 in-oz.

d. Attach outlet line.

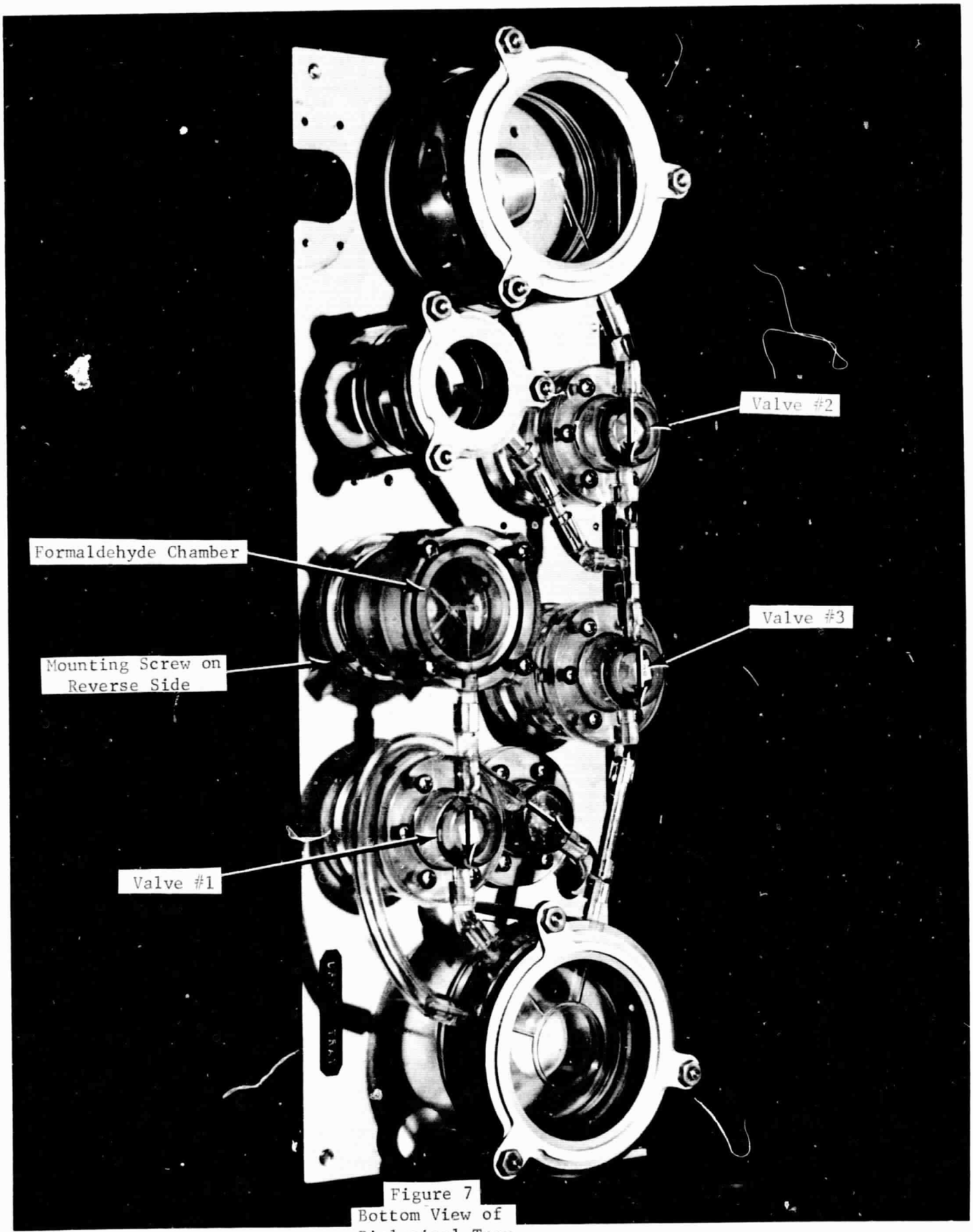


Figure 7
Bottom View of
Biological Tray

12 Egg Chamber

a. Place gasket in machined groove on tray.

b. Remove one Teflon spacer from its stud.

c. Place chamber cylinder in groove with chamfered end up.

d. Replace Teflon spacer on stud.

e. Fit egg chamber piston with O-Rings.

f. Assemble piston in cylinder bore with shaft downward.

g. Align piston face with top edge of cylinder (chamfered end).

h. Assemble end cap.

1) Place gasket against face behind O-Ring diameter.

2) Insert O-Ring in groove.

3) Insert eggs.

i. Place end cap on egg chamber cylinder by aligning outlets (Figure #7) on the tray. Attach line to Valve #1 before seating end cap.

j. Place retainer ring over assembly.

k. Alternately tighten retainer ring nuts to 7-8 in-lbs.

13 Connect appropriate tubing between egg chamber and manual dump valve using Figure #7 for routing.

14 Attach reservoir line to manual dump valve outlet port and route through the base plate as shown in Figure #7.

15 Invert tray assembly so that chamber shafts are facing up (Figure #8).

16 Assemble dump reservoir.

17 Attach reservoir to the line from the manual dump valve where it comes through the tray.

18 Locate reservoir on tray and attach using four screws. Torque to 4-5 in-lbs.

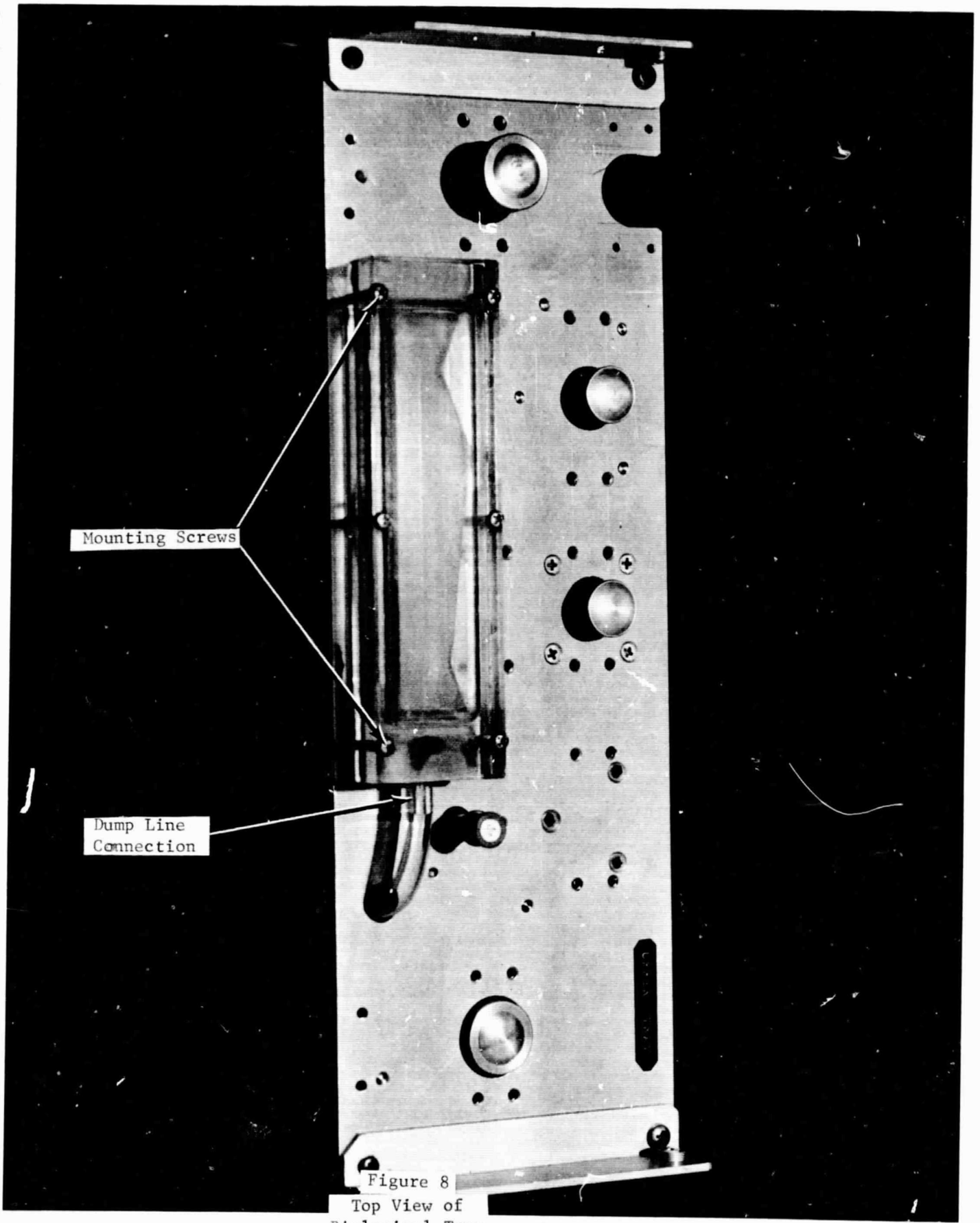


Figure 8
Top View of
Biological Tray

A.4 Structure Assembly

Step No.

1 Start the procedure with the basic structure standing upright on its base with the holding fixture ready for use.

2 Locate the holding fixture so that the left top tag on the fixture and the left top tag on the basic structure are at the same rear corner.

3 Use the bottom flange of the holding fixture to lift the five actuating bars while raising the fixture up and inward until it snaps over the structure.

4 Hold the structure and fixture together at the sides and tip over until the structure is laying on top of the fixture (Figure #9).

5 Position each of the three biological tray assemblies in the basic structure and hand tighten the left and right rear screw of each tray attaching it to the rear side rails (Figure #10).

NOTE: DO NOT TORQUE SCREWS - FOR POSITIONING PURPOSES ONLY

6 Position the front side rails taking note of the markings on the rails.

7 Insert two screws through the base plate into the base of the rails.

NOTE: DO NOT TIGHTEN SCREWS

8 Insert screws through the left and right sides of the front rails into each of the three biological trays.

NOTE: DO NOT TIGHTEN SCREWS

9 Torque screws at front of base plate to 12-13 in-lbs.

10 Torque screws on front and rear side rails to 7-8 in-lbs.

11 Return the assembly to an upright position with the structure standing on its base (Figure #11).

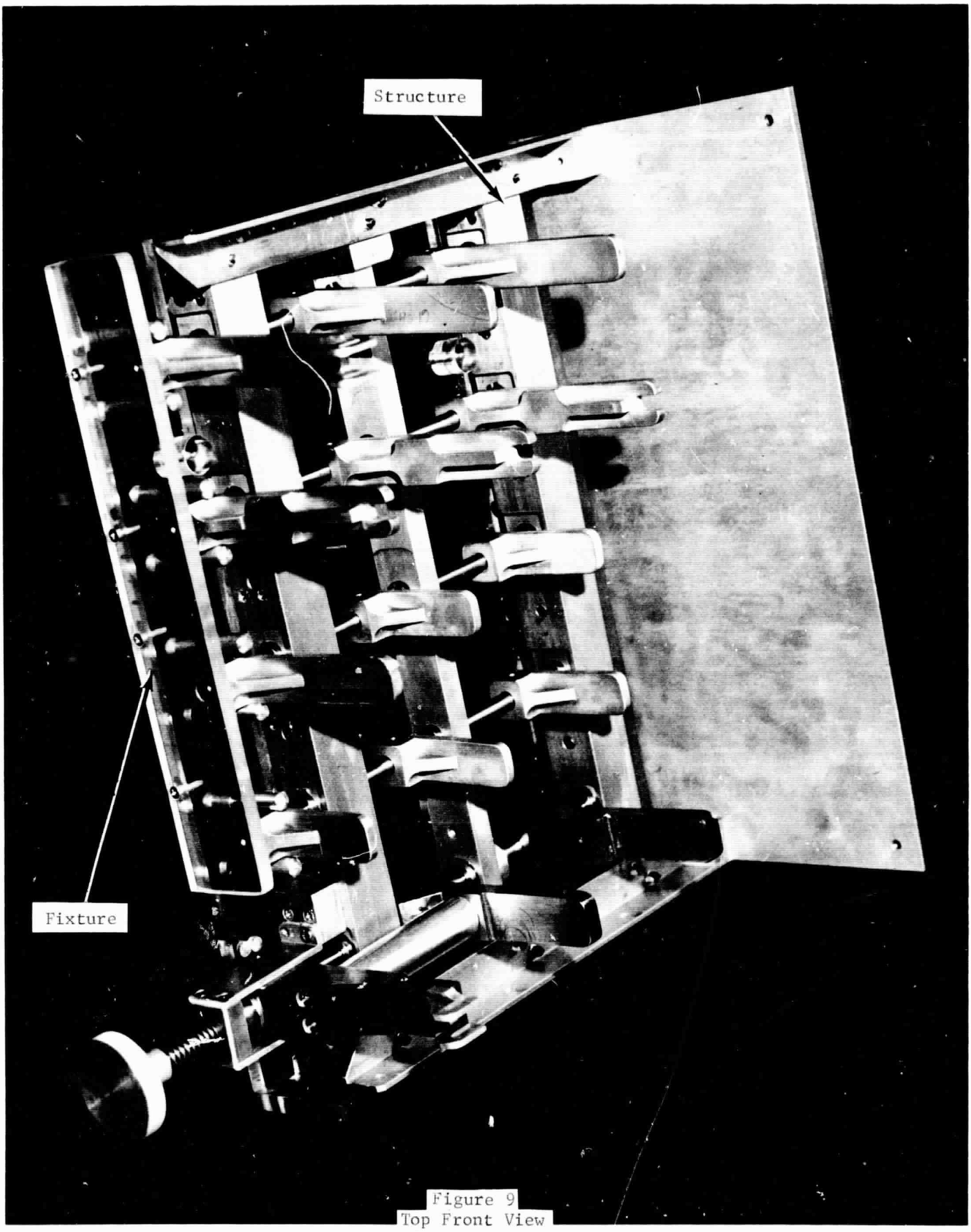


Figure 9
Top Front View
of Structure

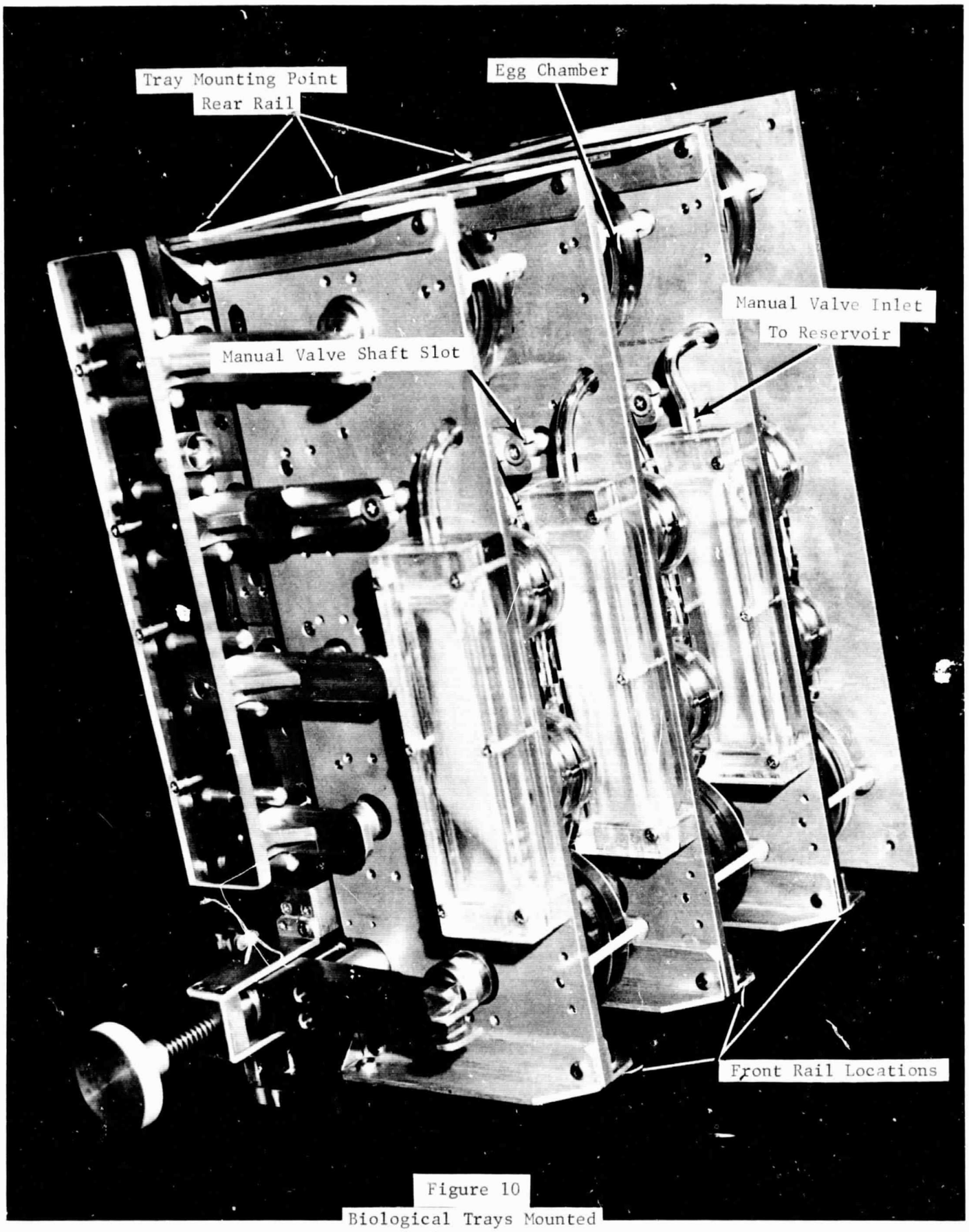


Figure 10
Biological Trays Mounted
in Structure

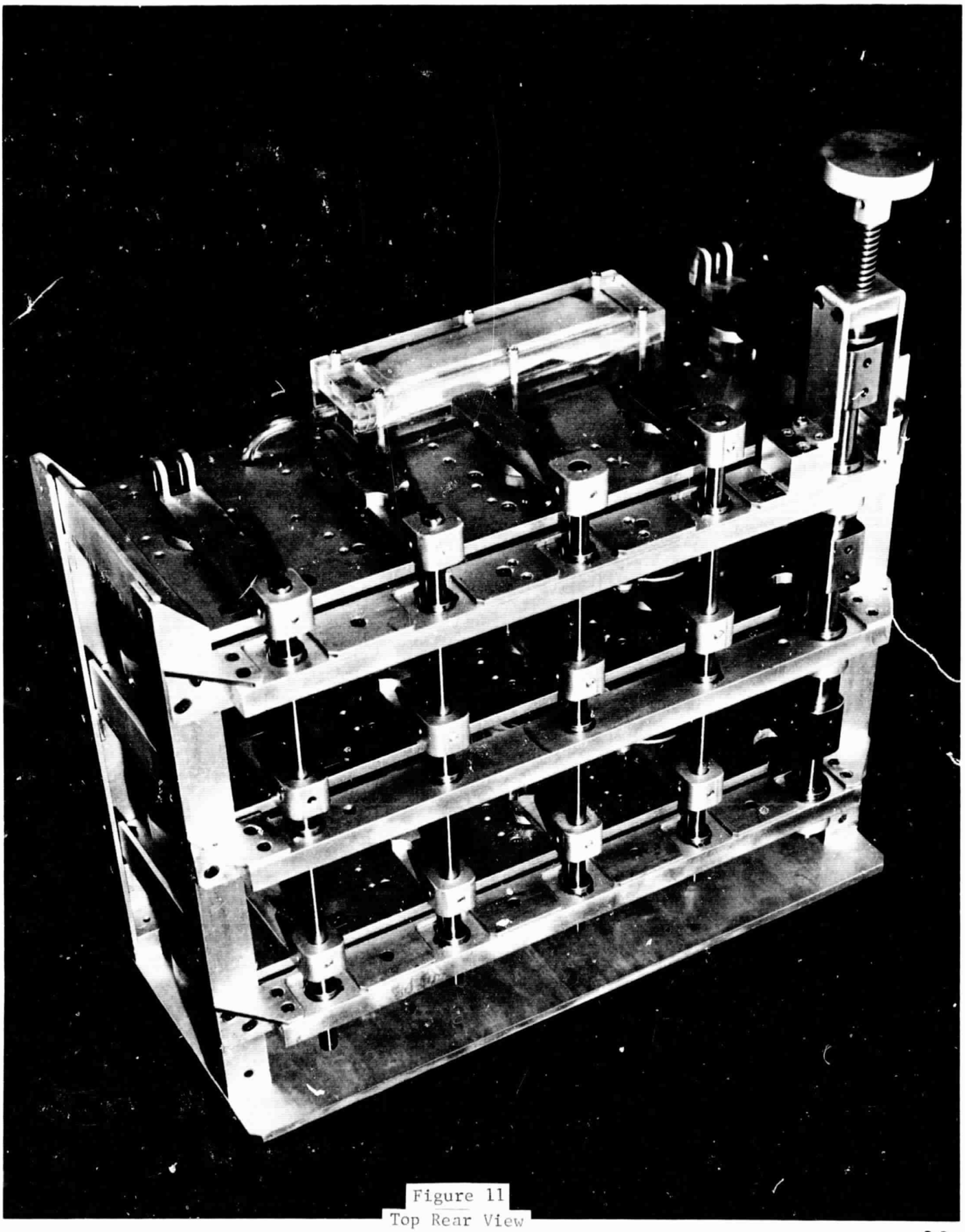

Figure 11
Top Rear View
of Module

12 Check the hand actuators to assure that the screw rams are backed up against the stops.

13 Locate the hand actuation assemblies as indicated on the upper tray (Figure #12) - insert screws and torque to 7-8 in-lbs.

14 Position the two counter mechanisms as indicated on the upper tray - insert screws and torque to 7-8 in-lbs.

15 Pull movable spool down and toward actuator arm and slide tape spool into hook at end of arm. Repeat for second counter.

16 Torque bolts on arm to 7-8 in-lbs.

NOTE: DO NOT DROP ACTUATING ARMS ONTO THE SHAFTS

17 Support holding fixture at top slide fixture away from structure at the top while continuing to support the actuating rods in the up position.

18 When the fixture clears the structural assembly, slowly lower the actuating rods until the arms contact the chamber shafts. Remove the holding fixture.

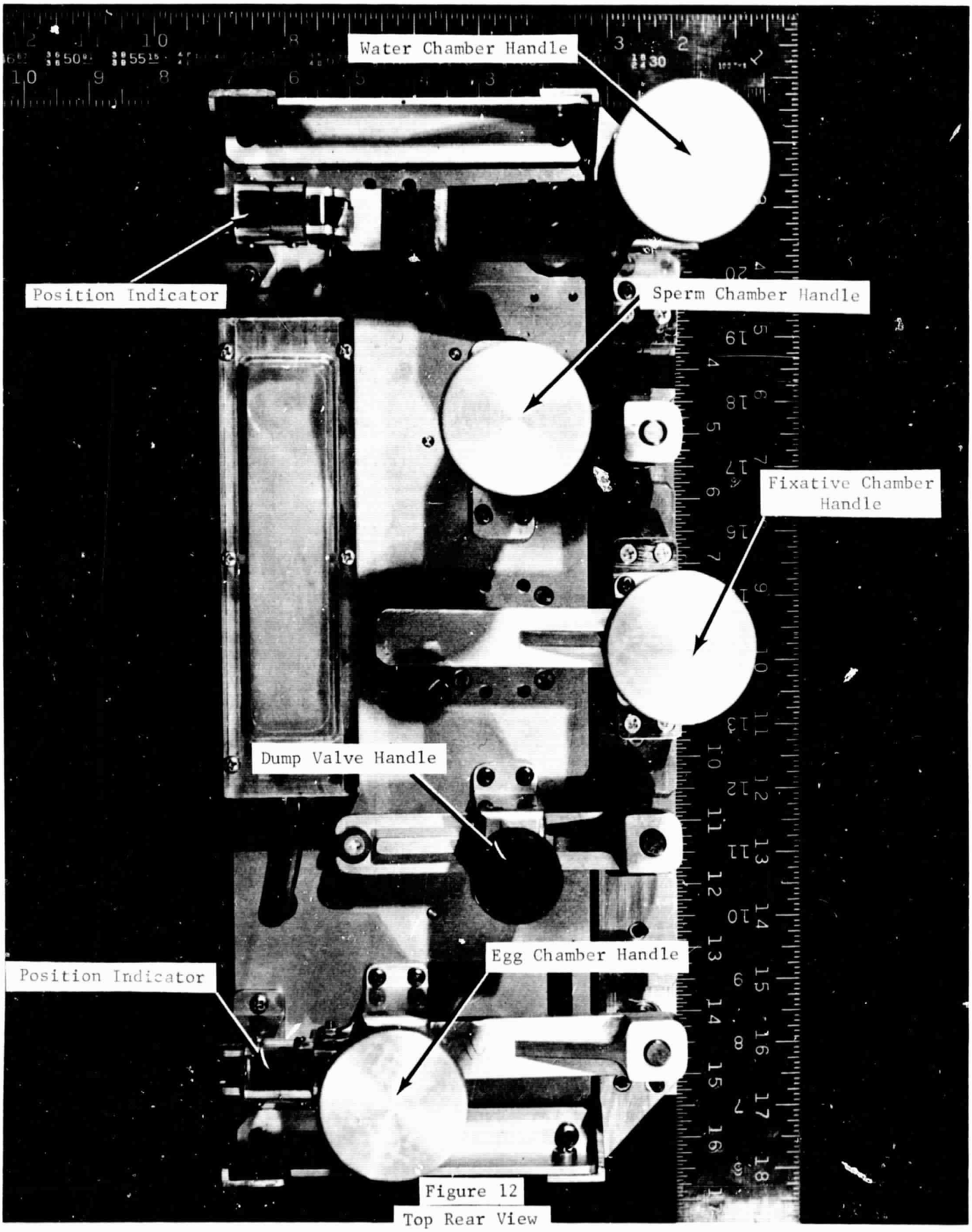


Figure 12
Top Rear View
of Module

A.5 Operational Instructions

When the module is properly assembled, the egg chambers will be locked (pistons down) and the dump valves will be closed (poppets down). The screw handles for these two chambers will be all the way in, clockwise, as viewed from the top in Figure #12. The remaining chambers will be operational, with the pistons in the "up" position lightly contacting the arms. The screws will be down lightly touching or just clearing the actuating arm or shafts.

| Operation Number | Description |
|---|---|
| | Injection of Sperm |
| 1 | Open the dump valve by turning the dump valve screw handle counter clockwise. |
| 2 | Turn the sperm chamber handle clockwise until the piston seats against the chamber bottom. |
| | Flushing of Sperm |
| 3 | Turn the handle of the water chamber clockwise until the position indicator shows that 20cc has been expelled from the water chamber. |
| | Germination of Eggs |
| 4 | Close the dump valve by turning its handle clockwise until the piston seats in the chamber and the ratchet slips. |
| 5 | Turn the egg chamber handle fully counter clockwise to unlock the egg chamber piston. |
| 6 | Turn the water chamber handle clockwise until 60cc of water is expelled to the egg chamber. Watch water position indicator for the 60cc mark. NOTE: Piston of egg chamber will rise as water enters. |

Oxygenation of Eggs

The following four operations are optional. If not followed, proceed to Operation #12.

7 Turn dump valve handle fully counter clockwise to open dump valve.

8 Turn egg chamber handle clockwise to expell 20cc of water. Observe position indicator until proper mark is reached.

9 Close dump valve by turning handle clockwise until piston seats and ratchet slips.

10 Unlock egg chamber by turning handle fully counter clockwise.

11 Tranfer 20cc of spring water from water chamber to egg chamber by turning handle of water chamber clockwise. This should empty spring water chamber, and piston will "bottom."

Fixation of Growth

12 Verify that egg chamber is unlocked and dump valve closed.

13 Turn fixative chamber handle clockwise until glass vial breaks. Continue turning handle to inject fixative into egg chamber. Egg chamber piston will rise.

# APPENDIX B

## MATERIALS INVESTIGATION AND SELECTION

### B.1 Glass Technology

#### B.1.1 Types of Glass

The initial research of the literature on the basic properties of glass resulted in a survey of the nature and composition of various types of glass in common use. Several types of glass investigated can be categorized by the oxides and fluxing agents that are added to impart particular physical and chemical characteristics. Glass formulations run into the tens of thousands. The important industrial usage, fortunately, is limited to five or six types or groups. These types are discussed in this report.

The simplest glass chemically and physically is silica glass which is nearly 100% "fused silica" ($Si\ O_2$). It resists temperatures as high as 1000°C, has low thermal expansion and good resistance to thermal shock; however, because it is very difficult to melt and fabricate, usage is limited to special products.

Glass exhibiting most of the characteristics of fused silica can be manufactured by starting with melts (batches) high in fluxing oxides. Special heat treatment and acid leaching removes practically all constituents except the silica. This glass is categorized as "96% Silica Glass," but it has a great affinity for moisture. To overcome this and eliminate porosity, the glass is heated to 950°C, causing a 35% reduction in volume, and resulting in a transparent non-porous silica glass.

In terms of tonnage, lime glasses account for 90% of the glass produced. Lime glass is basically soda silica glass to which lime (calcium oxide) is added. Alkali silicates, including soda-silica glass, are by themselves glass-like compositions that are soluble in water. The addition of lime reduces the

solubility, resulting in the lowest cost glass of good physical and optical properties. Oxides of sodium, patassium or lithium are used in combination with oxides of calcium, magnesium, zinc, or barium. To obtain specific improvements, other compounds are added to the basic lime glass formulation.

If the CaO content of lime glass is increased beyond 15%, it becomes more difficult to melt and is likely to devitrify. Replacement of the CaO by PbO leads to another group or type of glass. These are categorized as lead alkali silicate glasses. This type of glass is superior to lime glass for special use as X-ray shields, fine tableware and art objects.

Glasses which contain major amounts of Si $O_2$ and smaller amounts of $B_2$ $O_3$ or $P_2$ $O_5$ as glass forming oxides, plus 20% or more of $Al_2$ $O_3$ are categorized as Alumina-silicates. This type of glass has good resistance to deformation at high temperature and is used in high temperature and pressure applications.

Addition of 12-30% $B_2$ $O_3$ to silica glass melts has lead to a widely used category of glass known as Borosilicate Glasses. The popular "Pyrex" trademark of the Corning Glass Works is applied to many types of Borosilicate Glass. $B_2$ $O_3$ is a glass forming material and also serves as a fluxing agent for Si $O_2$. Compared with the lime glasses, this glass permits a drastic reduction in alkali content with consequent improvement in chemical and electrical properties, with greatly decreased coefficient of expansion. The melting temperature is not greatly increased in this type of glass so that fabrication is not impaired. The desirable engineering properties of this type of glass are heat-shock resistance, chemical stability, and low coefficient of expansion.

B.1.2 Properties of Glass

Physical and chemical properties of different types of glass will vary depending on the chemical composition. By selecting a specific composition, the desirable properties can be controlled. This report will present the desirable physical properties of Pyrex because this is the glassware selected for the modular prototype.

The coefficient of expansion is an important physical property of glass since the thermal shock resistance depends on this property more than any other physical property. For Pyrex with 13% $B_2 O_3$, the coefficient of expansion in the temperature range of 0-300°C is 32 x $10^{-7}$ in/in°C.

The mean specific heat for Pyrex in the range of 25 to 400°C is 0.20 BTU/lb-°F. Other mechanical properties for Pyrex type glass are tensile strength of 9900 lbs/in$^2$, compressive strength of 131,000 lbs/in$^2$ and modulus of elasticity of 9.4 x $10^6$ lbs/in$^2$.

These mechanical properties are dependent on the surface quality of the glass and will be lower if flaws or cracks are present.

B.1.3 Fabrication of Glass

A brief discussion of fabricating methods will indicate the dependence of the mechanical properties on careful manufacturing techniques. Glass blowing is the simplest method for fabricating shapes in glassware. The advantages of this technique are the surface quality of the finished item will be uniform and relatively free of flaws if the molds are polished, and residual stresses in the finished item will be evenly distributed if the part is uniformly cooled. The disadvantage of this technique is that uniformity of sections are difficult to maintain since the glass tends to thin out at corners and over large flat areas. Intricate precision items are impossible to fabricate without costly molds and numerous manufacturing operations.

A more precise method of glass fabrication is to handle glass similar to metal fabrication, with the exception that diamond cutting tools are needed for glass, and manufacture items by turning, grinding, and drilling. Raw glass material in the shape of plates, rods, and tubing can then be fabricated by normal machining operations. The use of ultrasonic apparatus facilitates drilling small, long, precision holes. Glass surfaces produced by machining may retain tool marks that can reduce the mechanical properties slightly. The literature survey does not clearly indicate this since the major subject treated is the molding processes for mass production. Hydrofloric acid etching and flame polishing treatment can be used to repair or refinish obvious surface flaws.

Either technique for fabricating glassware for the prototype module is costly and time consuming because of the limited production involved.

B.1.4 References for Glass Technology

The following references were used in preparation of Appendix B.1:


1. Phillips, C. J., Glass Its Industrial Applications, Reinhold Publishing Corporation, New York, New York, 1960.
2. Morey, G. W., The Properties of Glass, Reinhold Publishing Corporation, New York, New York, 1954.
3. Tooley, F. V., Handbook of Glass Manufacture, Vol. I, Ogden Publishing Company, New York, New York, 1953.
4. Shand, E. B., Glass Engineering Handbook, McGraw-Hill Book Company, Inc., New York, New York, 1958.


B.2 Material Selection and List

The selection of materials for use on this program was guided primarily by experience gained on the Gemini Frog Egg Experiments. The materials that come in contact with the internal fluids of the assembly were selected after biological testing

by Dr. John Tremor, NASA/ARC, to insure compatibility. The prime factor for selection of candidate materials for use in biological systems is knowledge of the materials' chemical composition. If a complete definition of the material composition is available, the materials containing known toxic elements or compounds may be eliminated immediately without further testing. Materials that contain small amounts of impurities may become usable after further processing by cleaning, heat and vacuum outgassing and by limiting quantities to safe levels.

Wherever possible, the use of materials in contact with biologicals of one element or compound category is preferred. When use of complex compounded materials are necessary, the best way to insure compatible hardware is to test with the biologicals under actual conditions.

To eliminate toxicity problems entirely, all substances that contact the hardware prior to use with biologicals must be identified. These include cleaning compounds, machining compounds, material processing additives, mold release compounds and storage facilities.

The following list identified the materials in the modular prototype that contact the biological fluids:

List of Materials

Pyrex 7740 glass - Corning Glass Works

*Tygon tubing - U.S. Stoneware

Acrylic plastic LP 391 - Rohm and Haas

Medical grade silastic rubber - Dow Corning Company

Latex rubber - Davol Rubber Company

Ethylene propylene E 515 - Parker O-Ring Company

High vacuum silicone grease - Dow Corning Company

RTV 102 silicone sealer - General Electric Company

Glass machining compound GTC 59 - Beaver Laboratories, Incorporated

*NOTE: Tygon may be unsuitable for space use because of outgassing. Alternate elastomeric materials are available, subject to biological compatability tests.

## APPENDIX C

## OBJECTIVES AND SPECIFICATIONS

The engineering objectives and specifications in designing the hardware for the Frog Egg Experiment for the Advanced Apollo Program are:

1. The hardware is to provide the performance sequence as outlined by Figure 3-1, effectively and reliably.
2. Materials are to be compatible with the biologicals and the Apollo vehicle.
3. The hardware shall be readily assembled for flight.
4. The hardware shall require minimum interface with the Apollo vehicle.
5. The size, weight, and power shall be minimized. Present estimates are:
   a) Size 21 x 21 x 21 inches
   *b) Weight 85 pounds
   c) Power 100 watts

   *Desired weight 60 pounds
6. Temperature requirements of experiment are:
   a) Pre-launch - (hold for 16 hours) $5^{o}C \pm 1^{o}C$
   b) Orbit - $18^{o}C \pm 1^{o}C$
   c) Warm-up Time - ½ hour
   d) Initial Warm-up Overshoot - $4^{o}C$ maximum
   e) Stabilization Time - 2 hours maximum
7. Environmental conditions
   a) Temperature, pressure, vibration, shock, etc., compatible with Apollo vehicle.

## APPENDIX D

## THERMAL ANALYSIS

### D.1 Pre-launch Cooling

The estimated envelope of the flight experiment is a cube 18 inches (1.5 feet) on a side. Adding insulation on all faces would increase the size of the package, the final size being a function of the thickness of insulation. The affect of the insulation thickness on the amount of heat transferred can be shown with a few calculations. For a hollow cube, the total heat transfer is the sum of the heat that passes through the six faces, twelve edges, and eight corners. The basic equation for steady state heat conduction is:

$$q = sk \triangle t$$

where $q$ = heat transfer Btu/hr

$s$ = shape factor

$k$ = thermal conductivity (Btu) (ft)/(hr) ($ft^2$) ($^oF$)

$\triangle t$ = thermal gradient, $^oF$

The shape factor, s, is a function of the length, 1, face area, $1^2$, or insulation thickness, x.

$s = 1^2/x$ for the faces

$s = [illegible]41$ for the edges

$s = 0.15x$ for the corners

Assumptions:

a) Pre-launch experiment temperature $41^oF$ ($5^oC$)

b) Surrounding atmosphere temperature $91^oF$ ($32.8^oC$) and $\Delta t = 50^oF$

c) Insulation material, fire retardant freon filled polyurethane foam, k = 0.0125

d) Inside length, 1 = 1.5

Calculations:

Heat transfer through 6 faces

$$q = 6\ (1^2/x)\ k\ \Delta\ t$$

$$= 6\ (2.25/x)\ (.0125)\ (50)$$

$$= 8.45/x$$

Heat transfer through 12 edges

$$q = 12\ (.541)\ k\ \Delta\ t$$

$$= 12\ (.54)\ (1.5)\ (.0125)\ (50)$$

$$= 6.08$$

Heat transfer through 8 corners

$$q = 8\ (.15x)\ k\ \Delta\ t$$

$$= 8\ (.15x)\ (.0125)\ (50)$$

$$= 0.75x$$

Examination of the equations show that for insulation thicknesses that are fractions of a foot, corner heat transfer is negligible and the edge heat transfer is constant; therefore, the major heat exchange occurs at the faces of the cube, as shown in Table D-1.

Table D-1

| Insulation Thickness | | Heat Transfer | | | |
|---|---|---|---|---|---|
| | | Face | Edge | Total | |
| Inches | Feet | Btu/hr | Btu/hr | Btu/hr | Watts |
| 1/2 | 1/24 | 202 | 6 | 208 | 61 |
| 1 | 1/12 | 101 | 6 | 107 | 31.4 |
| 1-1/2 | 1/8 | 67.5 | 6 | 73.5 | 21.6 |
| 2 | 1/6 | 50.5 | 6 | 56.5 | 16.6 |
| 2-1/2 | 5/24 | 40.5 | 6 | 46.5 | 13.6 |

Final selection of insulation thickness will involve a trade-off of insulation weight and volume versus electrical power for cooling (and warm-up heating). As a starting point, 1½ inches of thickness should be considered making a 21 inch cube.

Thermoelectric devices are built with fittings for a liquid coolant to maintain sink temperatures. A typical unit capable of removing a maximum of 38 watts at 0°C temperature difference will measure 3.5 x 5.0 x 1.0 inches, and weigh 1¼ pounds. At rated current, it will draw 51.6 watts of dc power. To remove 21.6 watts of heat, the temperature gradient will be 19°C. If two such units are used, the temperature gradient from cold to hot side of the TED will be 34°F, at a power input of 103 watts. Using less current and input power, smaller gradients will result with improved coefficient of performance (less power input for the amount of heat dissipated). Again, a trade-off analysis of insulation, power and the available heat sink temperature is needed for selection of flight cooling.

D.2 Warm-up Heating

The temperature required for the experiment in orbit is 18°C (64.4°F). From a pre-launch temperature of 5°C (41°F) the temperature rise required is 13°C (23.4°F). As a very rough first estimate, the total package of 85 pounds estimated weight, will be assumed as having a mean specific heat of 0.2. (For aluminum, plastic and glass, this is fairly good. For water, however, the specific heat is 1.0, but the weight is only 3½ pounds). The heating required is:

$$q = wc \Delta t/T$$

where

q = heat transfer, Btu/hr

w = weight, lb.

c = specific heat, Btu/lb°F

$\Delta t$ = temperature change, °F

T = time, hr.

substituting $q = (85)\ (.2)\ (23.4)/0.5$

$= 795$ Btu/hr or 233 watts

A heating requirement of 233 watts is probably too much for the vehicle to supply to an experiment. The power can greatly be reduced by applying heat directly to the eggs, water and fixative chambers for ½ hour warm-up and letting the remaining package heat more slowly.

To heat the sperm or egg chamber, the biologicals require negligible heat. The glass, however, is significant, and water heating requires significant power.

a. Egg Chamber

$w = 0.663$ lb, $c = 0.19$ for glass

$$q = (0.663)\ (.19)\ \left(\frac{23.4}{0.5}\right)$$

$= 5.9$ Btu/hr

$= 1.73$ watts

b. Sperm Chamber

$w = 0.32$ lb, $c = 0.19$

$$q = (.32)\ (.19)\ \left(\frac{23.4}{0.5}\right)$$

$= 2.85$ Btu/hr

$= 0.84$ watts

c. Water Chamber

Same q for glass egg chamber = 1.73 watts. For 0.22 lb water,

$$q = (0.22)\ (1)\ \left(\frac{23.4}{0.5}\right)$$

$= 10.3$ Btu/hr

$= 3.05$ watts for a total of 4.78 watts for the water chamber

d. Total Power to Heat Biologicals

$q = 1.73 + 0.84 + 4.78$

$= 7.35$ watts/tray

For 12 biological trays per experiment

$q = 12 \times 7.35 = 83$ watts

Because there is adjoining structure, the power provided should be higher than 83, probably 100 watts. Since this is in line with the magnitude of thermoelectric cooler power, the power drain on the vehicle would be relatively constant.

## APPENDIX E

## SYNOPSIS OF WORK HISTORY

Performance on this contract, dated January 22, 1968, was started February 1, 1968, with the issuing of a Program Plan dated February 9, 1968. The Program Plan and baseline information for the preliminary design was discussed with Dr. J. Tremor during his visit at VFSTC on February 22, 1968. A review of the state-of-art in glass technology as it pertains to this program indicated that Pyrex glass 7740 should be considered for hardware material. The proposed design concept was revised. Breadboard hardware was fabricated of plexiglas in our lab. (Reported March 12, 1968).

Layout and fabrication of one biological unit in acrylic plastic was completed. Special attention to the design of the fixative chamber resulted in breadboard hardware that demonstrates a workable method of sealing the fixative in a vial with a frangible disc on one end. Contact was made with the Lurex Manufacturing Company, Vineland, New Jersey. (Reported April 5, 1968).

Modification of the design layout and detail drawings incorporating fabrication features discussed with glass fabricators were completed. Drawings were released to purchasing to obtain cost and delivery quotations. A parallel effort of fabricating hardware for one biological unit in acrylic plastic in house was completed. Dr. John Tremor notified General Electric Company, Life Support, that biological compatibility tests of frog eggs sealed in Pyrex 7740 glass proved satisfactory. (Reported May 6, 1968).

A status review meeting was held at General Electric on May 9, 1968. A most important item, presented by Dr. John Tremor during the meeting, was the fact that the frog eggs will be installed in the egg chamber on litmus paper saturated with DeBoer's solution then sealed in the absence of water. This technique will necessarily require the experiment hardware to handle a two phase system (Viz. water and air)

under zero gravity conditions. A glass fabricator has belatedly responded to the request for quotations on glass hardware. The glass fixative vials have been ordered. An acrylic biological breadboard of the modified design has been built and tested with satisfactory results. (Reported June 7, 1968).

Testing was completed on the engineering breadboard unit. Hardware elements made of acrylic plastic to the glassware configuration were completed for three complete biological units. Assembly of the module structure and mechanisms was completed. The module structure with the acrylic biological units in place was assembled and partially operated. The first glass fixative vials were received from the vendor. Two glass vendors have made firm price quotations on the glass hardware. (Reported July 10, 1968).

The Program Plan was revised during this period to extend the hardware delivery and final report. The hardware delivery date agreed to by NASA and GE will be August 22, 1968, and the final report including thermal analysis and preliminary drawings will be October 22, 1968. The check valves were reworked. All valves were tested successfully. The structure was reworked. A work fixture was complete to assist in module assembly. Orders were placed for the balance of the glass hardware. (Reported August 7, 1968).

The Phase II design review was held at General Electric, Valley Forge, on August 20, 1968, with Dr. John Tremor and H. Asch, NASA/Ames, present. During the meeting, the prototype module was successfully demonstrated throughout an entire cycle of operation. Design optimization for flight type hardware was begun. Incorporation of the check valve as an integral part of the chamber has resulted in lower flight weight and volume, and eliminated residual losses caused by long tubing lengths. Drawings of the flight configuration assembly was begun. (Reported September 10, 1968).