

FINAL REPORT

AUTOMATED IODINE MONITORING SYSTEM DEVELOPMENT (AIMS)

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1.0 BACKGROUND

This Final Report discusses the further development of the Shuttle Prototype Automated Iodine Monitoring/Controller System (AIMS). AIMS has evolved from prior efforts based on the direct spectrophotometric determination of aqueous iodine:

- Feasibility demonstrated: Contract NAS9-11879 (simple, manually operated I₂ colorimeter).
- Design for an Automated Iodine Monitor/Controller System (AIMS): Contract NAS9-12769.
- A Prototype AIMS based on the design: Contract NAS9-13479.

The current effort (NAS9-14298) has been directed toward the design, fabrication, and test of a system configuration suitable for spacecraft use.

2.0 AIMS OPERATING PRINCIPLE

The operating principle of the present AIMS is the same as that of the earlier configuration (Figure 1). Light from the source (tungsten lamp) traversing a 5-cm cell, through which the sample solution flows, impinges on a beamsplitter. The transmitted light passes through a 465-nm filter to a photodiode detector. The reflected light passes through a 631-nm filter to a second detector. The detector receiving light filtered at 465 nm responds to the iodine concentration in the stream and, since aqueous iodine does not absorb light at 631 nm, any change in transmitted light at this wavelength represents interference effects (Figure 2). The electronic ratio of these two signals is used as a measure of the iodine level in the sample stream. This signal also controls the addition of iodine to a water supply to maintain the iodine concentration at a preset level.

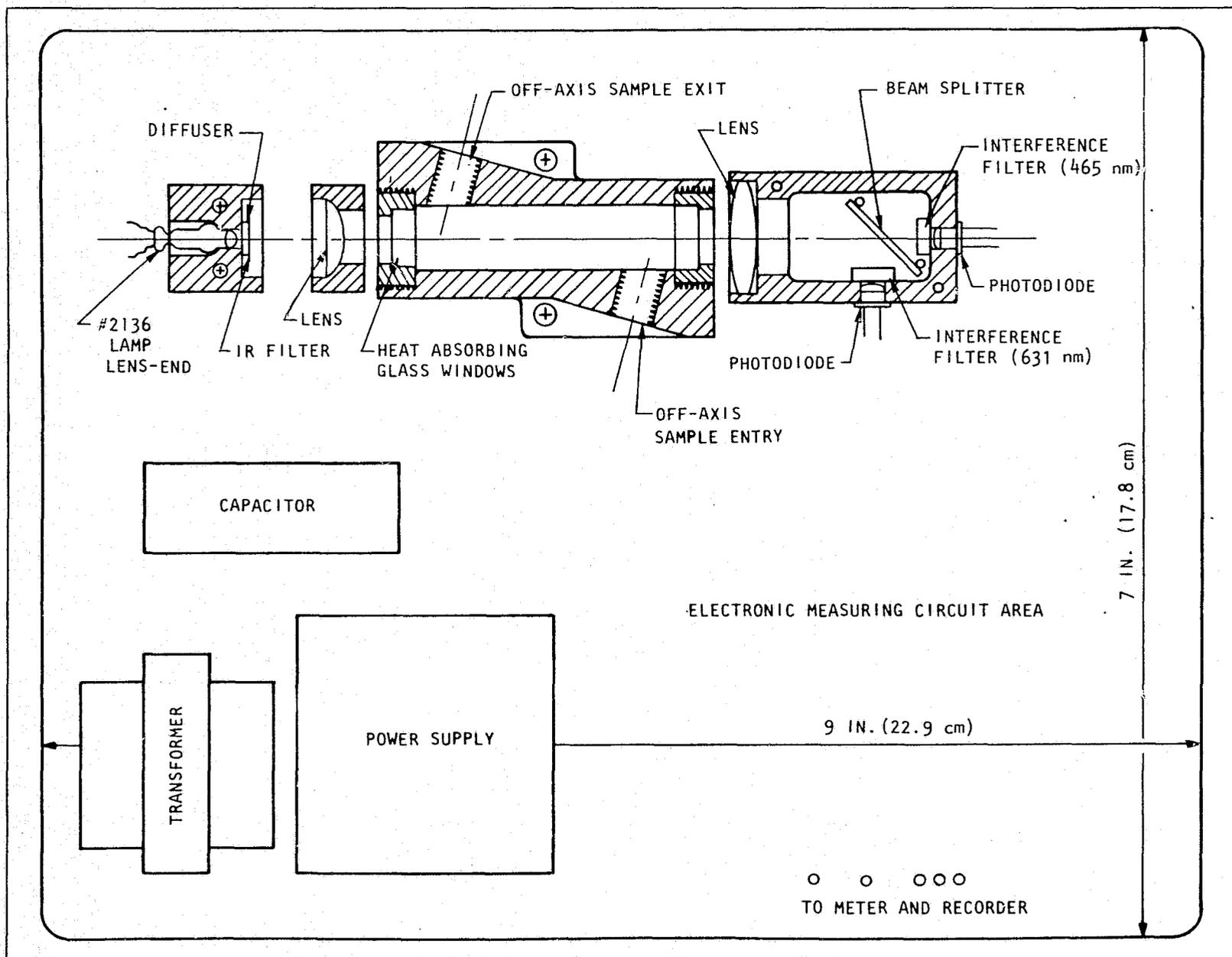


Figure 1. AIMS Colorimeter -- Earlier Configuration

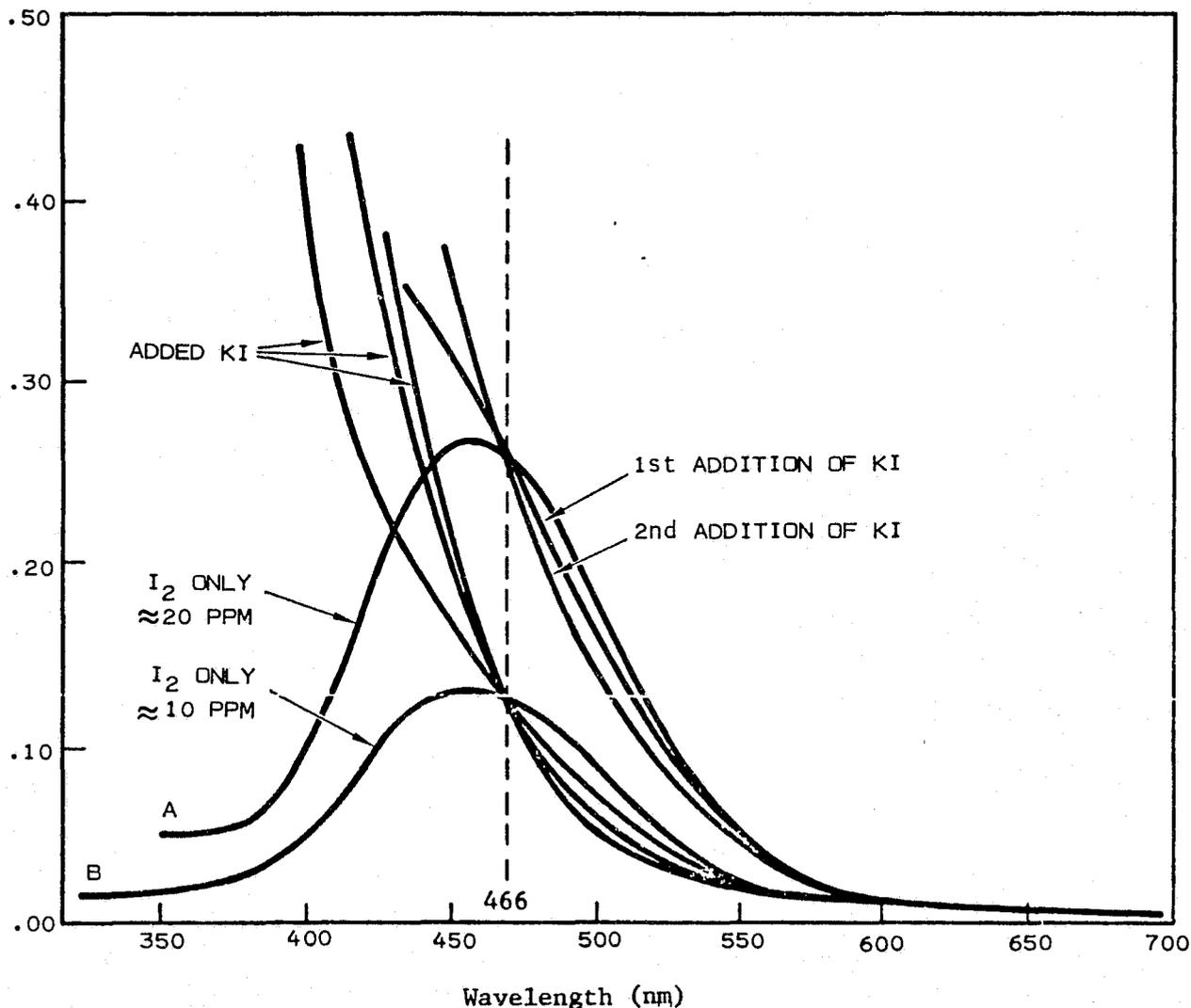


Figure 2. *Measuring Aqueous Iodine at the Isosbestic Point.* Curves A and B show the absorption spectrum of aqueous iodine at two different concentrations. The other curves show how this spectrum is altered with the addition of potassium iodide (KI) to the iodine solutions. Note the crossover point, at 466 nm, where the absorption is identical for a given concentration of iodine. This point is named the "isosbestic point." In a family of different equilibria (0-20 ppm I₂ in KI) one maximum rises and the other falls as the equilibrium shifts, but the intersection (isosbestic) remains constant. It is only here, at 466 nm, that iodine can be accurately measured without KI interference.

3.0 DESIGN MODIFICATION

Certain functional design modifications have been made to both the colorimeter (monitor) and the iodine addition system. The basic principle, however, remains the same as discussed in the previous section.

A different lamp was selected. We felt that the previous source, a No. 2136 lens-end lamp, because of its small size would require frequent replacement due to tungsten darkening of the envelope. This source was replaced with a No. 1855 (14-mm-diameter) lamp. Drawing 0.8 amperes at 6.3 volts, the expected life is 3,000 hours, but by reducing the voltage somewhat its expected life will be appreciably increased. This source provides more light and the larger envelope spreads the tungsten darkening thinner than the previous source.

To improve the stability of the source and hence its accuracy, we added a lamp monitoring circuit. A photodiode detector receives radiation from the lamp through a 465-nm filter. When the lamp brightness changes from its initial setting, the change is sensed by the photodiode and the resulting signal is acted on by the regulator circuit to restore the lamp's original intensity. The 465-nm filter was chosen because lamp filament temperature changes, and hence the brightness, are more sensitively detected at the shorter wavelengths (as evident from the blackbody curves shown in Figure 3).

The degree of control of lamp brightness by this component has proved effective. Figure 4 shows how, over a period of 70 days, the voltage to maintain the required brightness increased as the lamp aged. Notice also the voltage excursion on some days: when the ambient temperature was high (afternoons) a lower voltage maintained the filament brightness; when the ambient was low (mornings and nights) more voltage was required. This effect shows even more clearly in Figure 5 where lamp voltage appears to be directly proportional to housing temperature (controlled test chamber conditions).

The sample cell retains its 50-mm length, but the diameter has been increased so that there will be less reflected light from the cell wall. In addition,

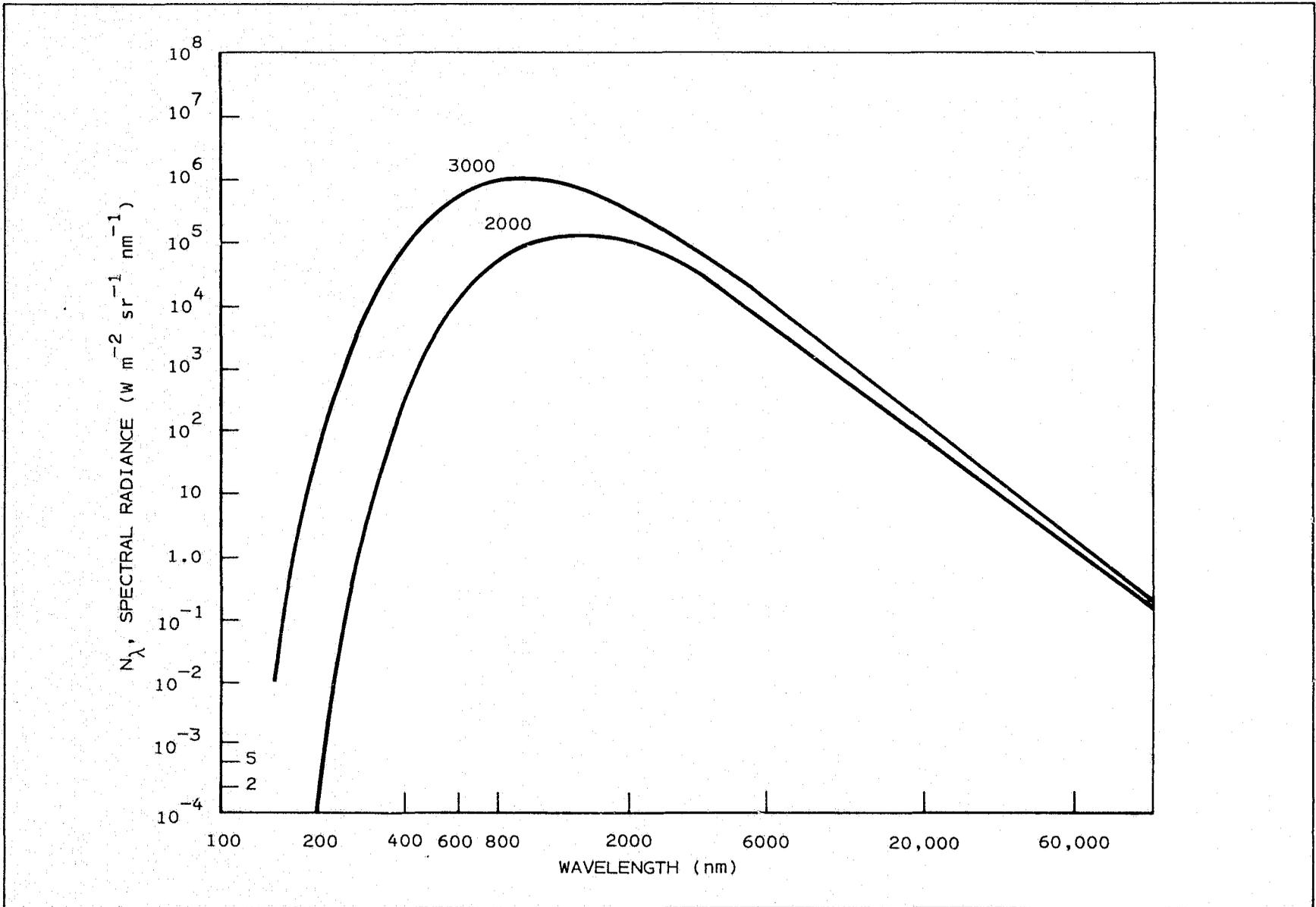


Figure 3. Spectral Radiance of a Blackbody, N_λ , at $^\circ\text{K}$ for Each Curve

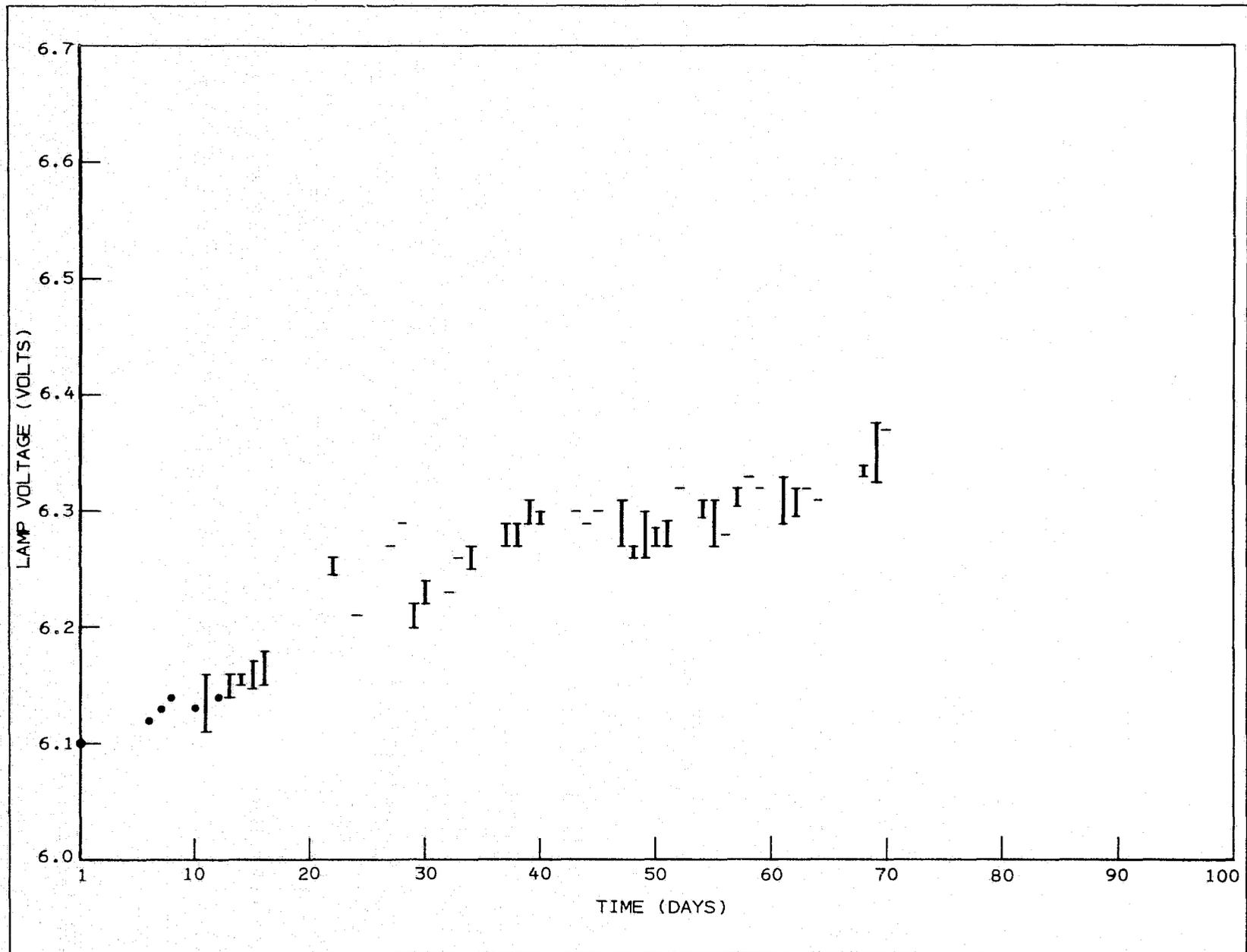


Figure 4. Lamp Brightness Varies with Time and Voltage

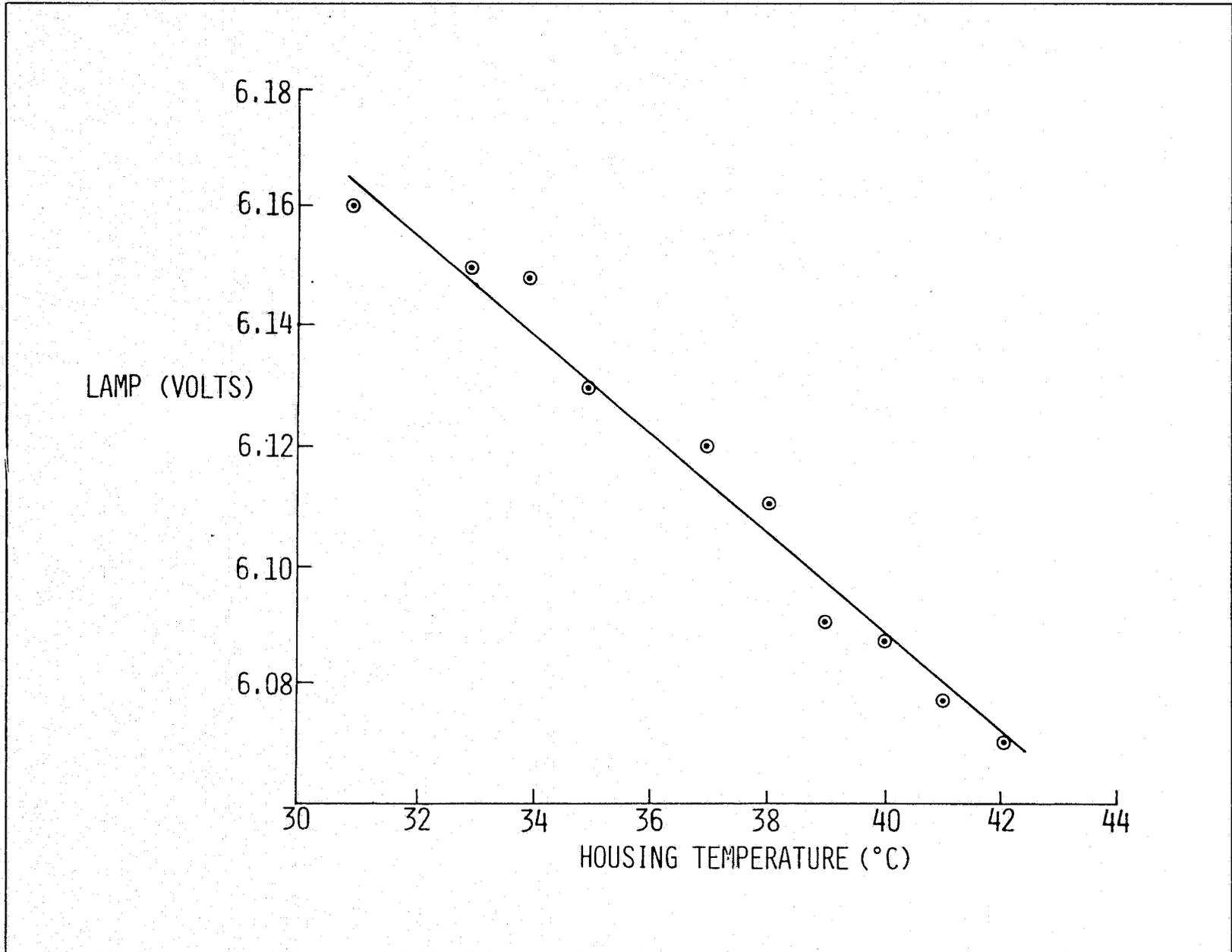


Figure 5. Lamp Voltage Versus Housing Temperature

an opaque annulus (1.5 mm) was placed on one cell window to stop down still further light beam. Figure 6 shows a sketch of the colorimeter subsystem.

The circuitry underwent several modifications. FET inputs were added as well as a comparator. Crosstalk has been largely eliminated so that zero can now be adjusted without affecting the span setting. A block diagram of the circuit is shown in Figure 7.

The housing has been redesigned (see Figure 8). Internal details appear in Figure 9.

3.1 Lamp Control

To provide an adequate source of light energy at the two required wavelengths of 465 and 631 nm, a No. 1855 (14-mm-diameter) tungsten lamp was selected. Because the lamp output varies with ambient temperature and aging, its output is maintained by a photodiode that drives the lamp power supply referenced to -15 V through R11 in series with a selected resistor (Reference: Drawing No. 674559). The amount of regulation or correction needed as the lamp ages is provided by selecting resistors in series with R10 and R12.

3.2 Signal Processing

As discussed in Section 2.0, light from the source passes through the sample and, by means of a beamsplitter, is directed through narrow bandpass filters onto two photodiode detectors. The output of each detector is proportioned to the light energy received. Each photodiode converts this energy to a voltage. The two voltages are adjusted so that they are equal when the sample contains no iodine. Aqueous iodine will cause a reduction in the light energy received through the 465-nm filter, and the reduced signal will be proportional to the iodine concentration. Light energy received through the 631-nm filter will be essentially unchanged by the iodine concentration.

The outputs from the current-to-voltage amplifiers AR1 and AR3 are applied as inputs to an electrical divider U1. The output, then, of U1 is proportional

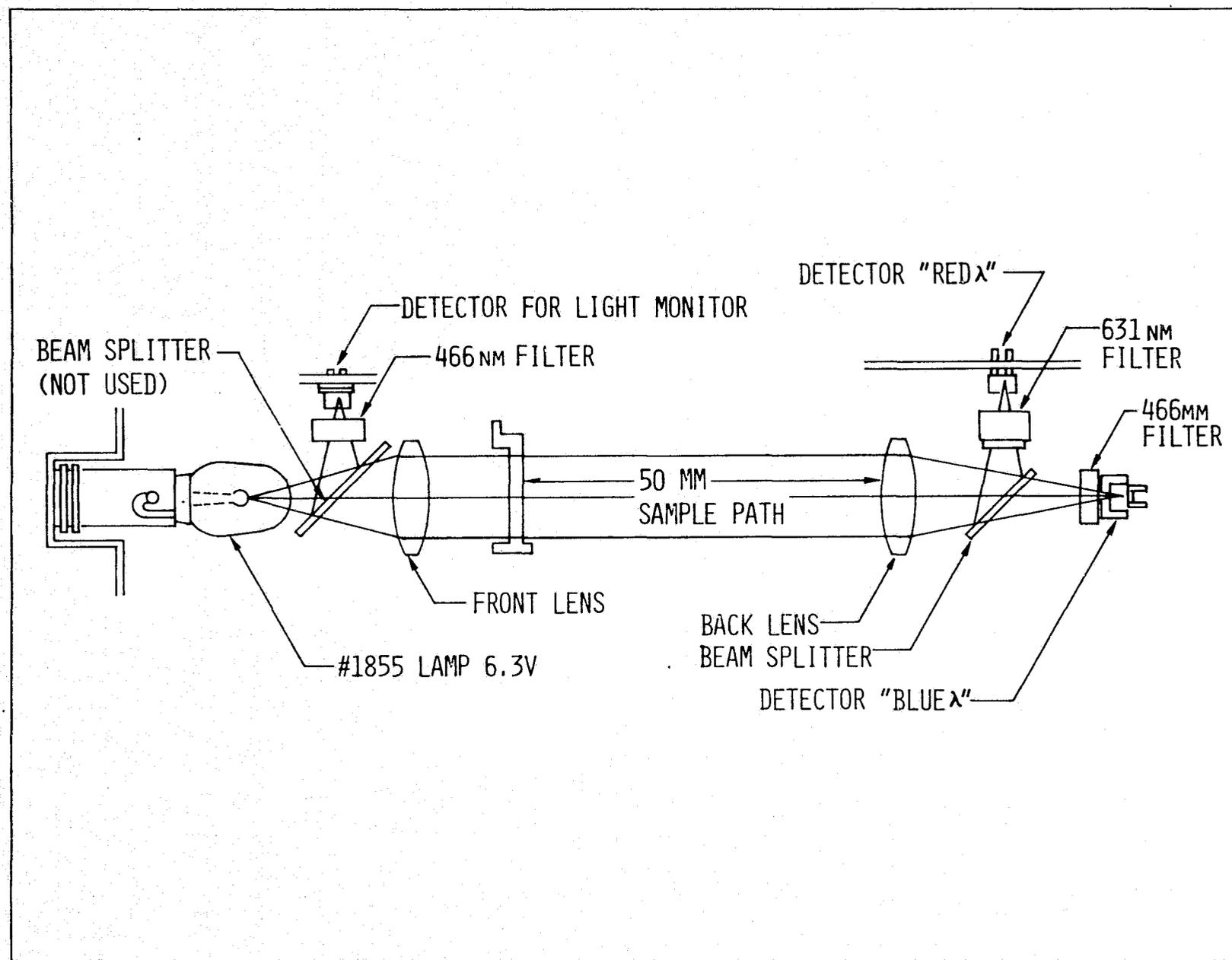


Figure 6. AIMS Optical Layout -- Present Design

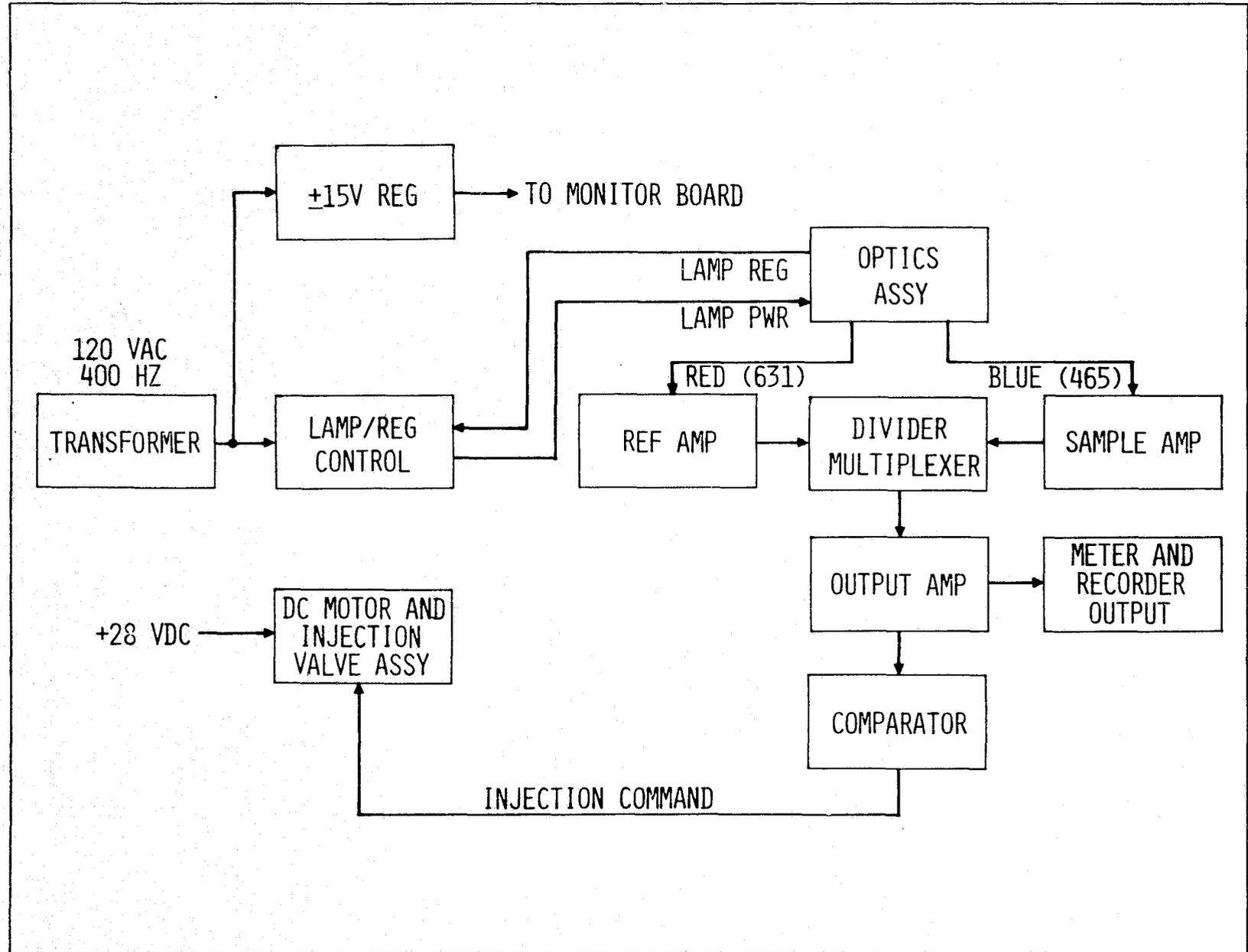


Figure 7. Electronic Block Diagram

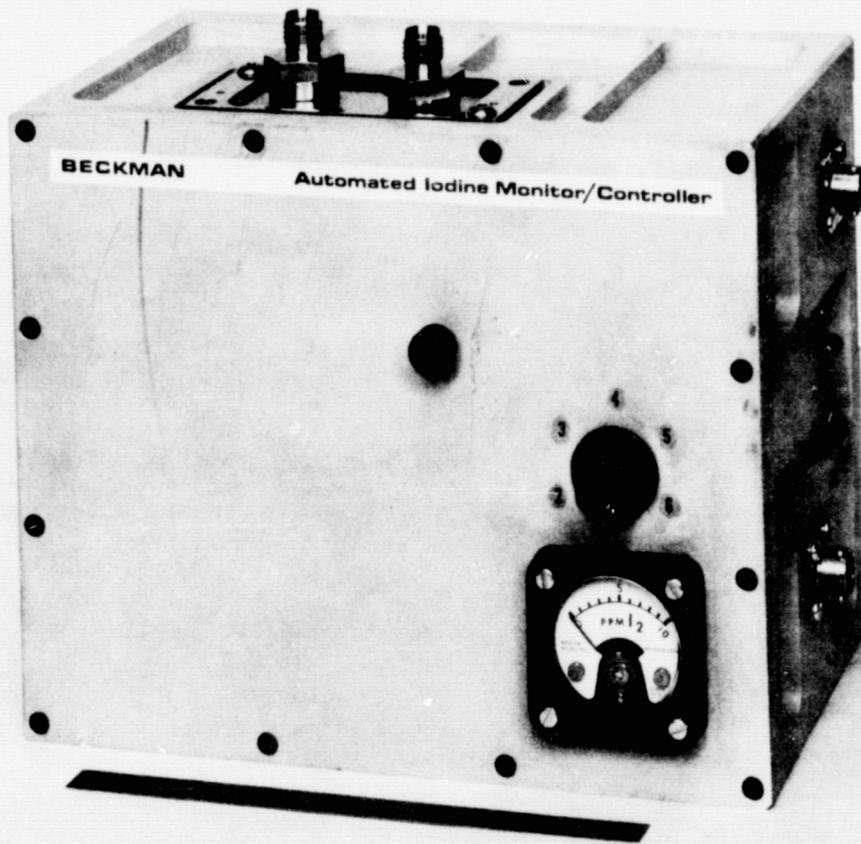


Figure 8. AIMS Iodine Monitor

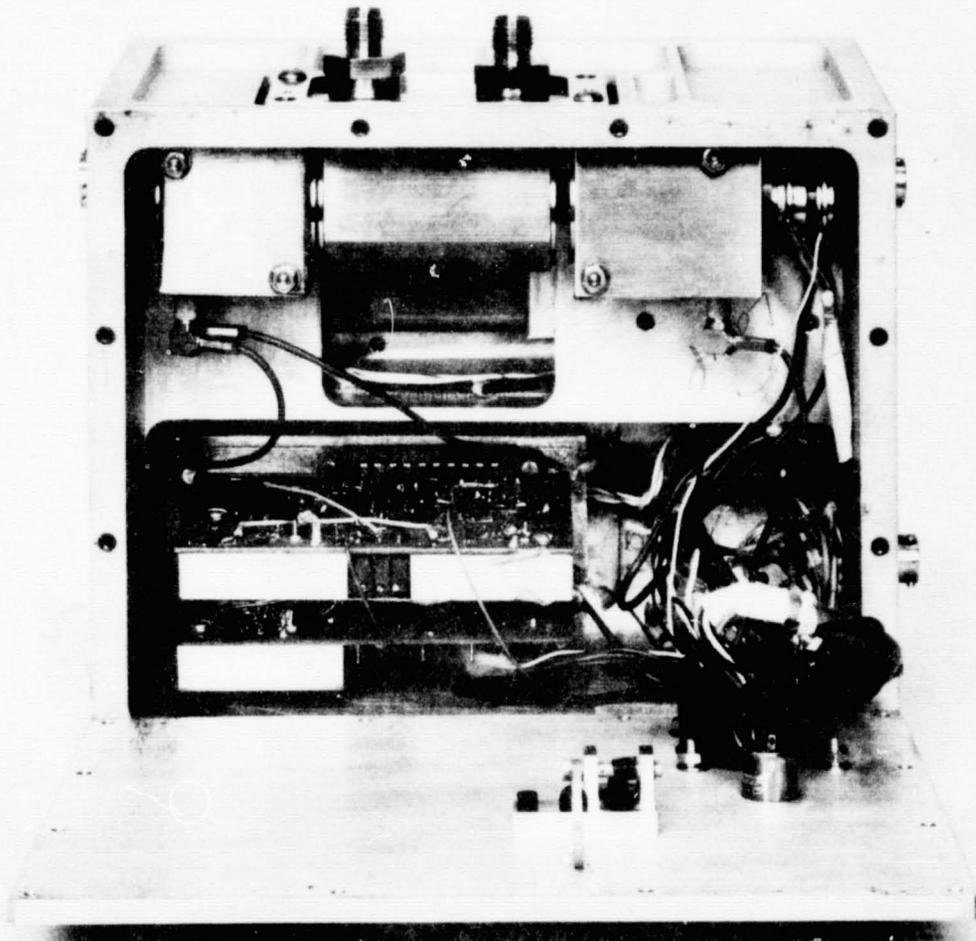


Figure 9. AIMS Monitor--Interior View

to the quotient of the 465-nm signal divided by that of the 631-nm signal (Reference: Drawing No. 674562).

The output of U1 is presented through R6 in series with R7 to the current summing inverting input of amplifier AR2. Adjustment of R6 provides any span changes required. Since the output of U1 is offset to +10 V for 0 ppm I_2 , it is necessary to suppress this zero volts as seen at the AR2 output. This is accomplished by putting R8 in series with potentiometer R9, driven from the -15 V supply.

Proper adjustment of SPAN R6 and Zero Adjust R9 will cause the output of AR2 to be - volts at 0 ppm I_2 and to go positive with increasing iodine concentration.

The output of AR2 drives amplifier AR4 as well as a meter and recorder (optional). AR4 functions as a Schmitt Trigger that has five selectable trip points, thus allowing for presetting the iodine level at 2, 3, 4, 5, or 6 ppm I_2 .

The output of AR4 drives a power transistor Qs which in turn operates a relay K1 which provides power to operate the rotary Iodine Addition Valve. This valve is enabled when the iodine level is below the preset trip point and remains inactive when the level is above the trip point. A timer in the circuit between the monitor output signal and the rotary valve prevents iodine additions more often than once in ten minutes to allow adequate mixing of iodine in the water supply.

4.0 THE IODINE ADDITION SYSTEM

The previous system employed a syringe pump (Sage) to inject small amounts of iodine concentrate into the water supply. The syringe, filled with a concentrated iodine:KI solution (30,000 ppm I_2), was activated by signals from the monitor. For the current system our first approach was to use a non-glass syringe as a pump. Iodine concentrate, under pressure, would enter the syringe through a check valve. The piston would then force a precise volume

of iodine solution into the water stream through a second check valve. The first check valves were stainless steel, which proved unsatisfactory because of excessive corrosion when their components were immersed in the concentrated iodine solution (Figure 10). All-Teflon valves (Fluorocarbon Co.) were substituted. This system again proved unsatisfactory.

An alternative approach was implemented and the results demonstrated the feasibility of using a simple rotating valve to meter the iodine concentrate. The valve is a modified Hamilton microvalve made of a polyimide to withstand iodine corrosion. This two-way valve is rotated by a small Globe motor. The volume of the bore in the valve, and the time it is open, determine the amount of iodine injected per revolution. The iodine concentrate tank (GFE) is spring loaded and when the valve is open the pressure pushes iodine into the incoming water line (Figure 11).

One component of the test setup is a timer. Once every ten minutes the timer closes a microswitch for a short time. This switch is in series with the monitor and the Globe motor. When the iodine level falls below a preset level, a signal from the monitor is transmitted through the closed microswitch to the Globe motor on the valve. A cam on this motor ensures that the motor will remain on for at least one revolution and that it will always stop in the valve-closed position. The timer cam has, in fact, been set so that the valve will rotate twice. This double revolution provides enough iodine ($200 \mu\text{l}$) to make a small change in the iodine level in the water tank (39 ℓ) of the test setup. If the tank is full, a single "injection event" (two valve rotations) will raise the iodine level about 0.15 ppm. If the iodine requirement is satisfied, then no signal is sent and the Iodine Addition System remains inactive. The effect of a single injection is shown in the tracing of a recording in Figure 12. (Note that in this case the rise in iodine level is 0.3 ppm instead of 0.15 ppm because the water tank was only half full.) By changing the valve bore diameter, or the speed of rotation, the effect of iodine additions can be tailored to fit the requirements of a given water supply. Iodine injection patterns in going from one level to another are shown in Figure 13. The Iodine Addition System is pictured in Figure 14.



x 20

Figure 10. Corrosion of Stainless Steel (316 SS)
by Concentrated Iodine (30,000 ppm I_2)

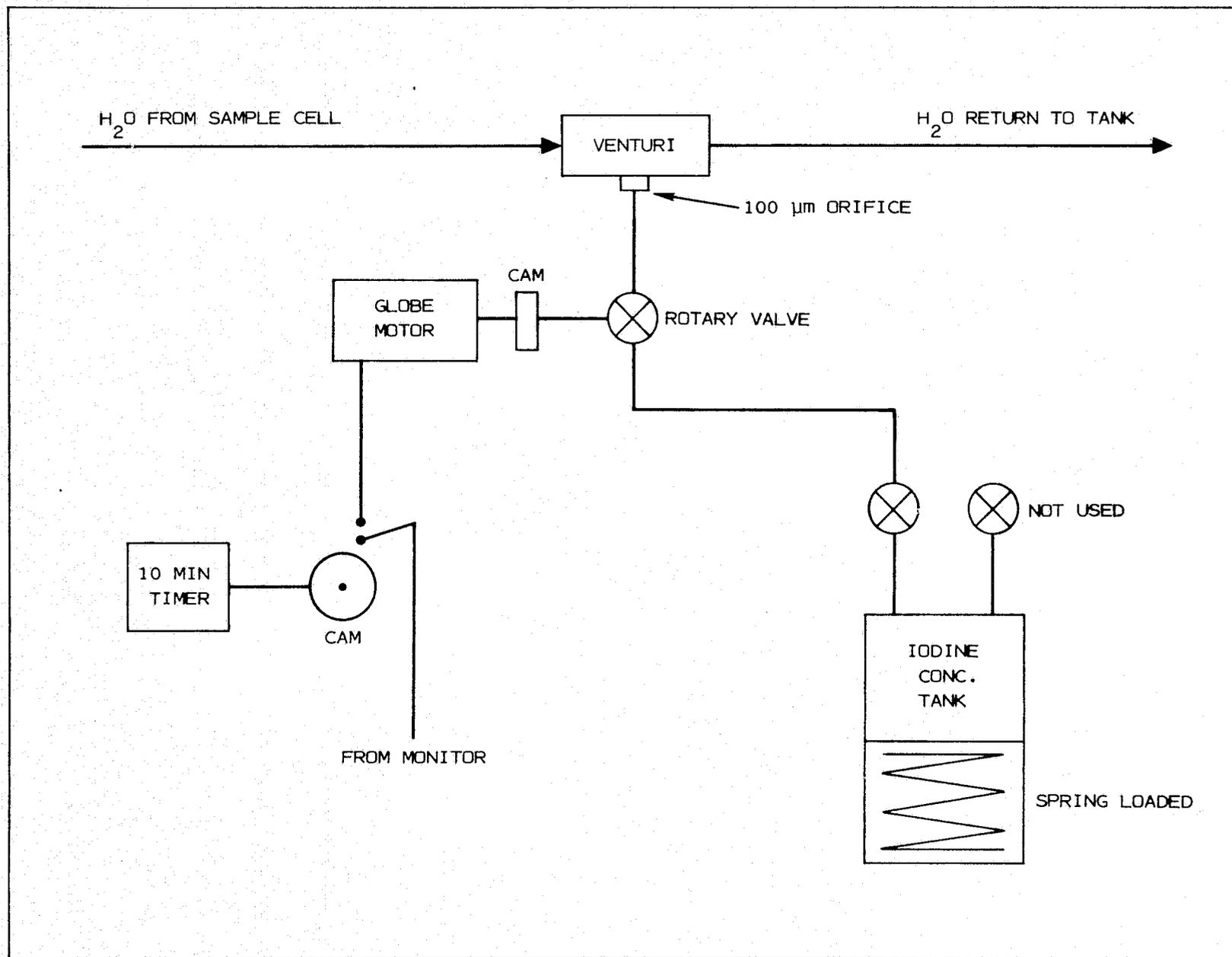


Figure 11. Iodine Addition System Schematic

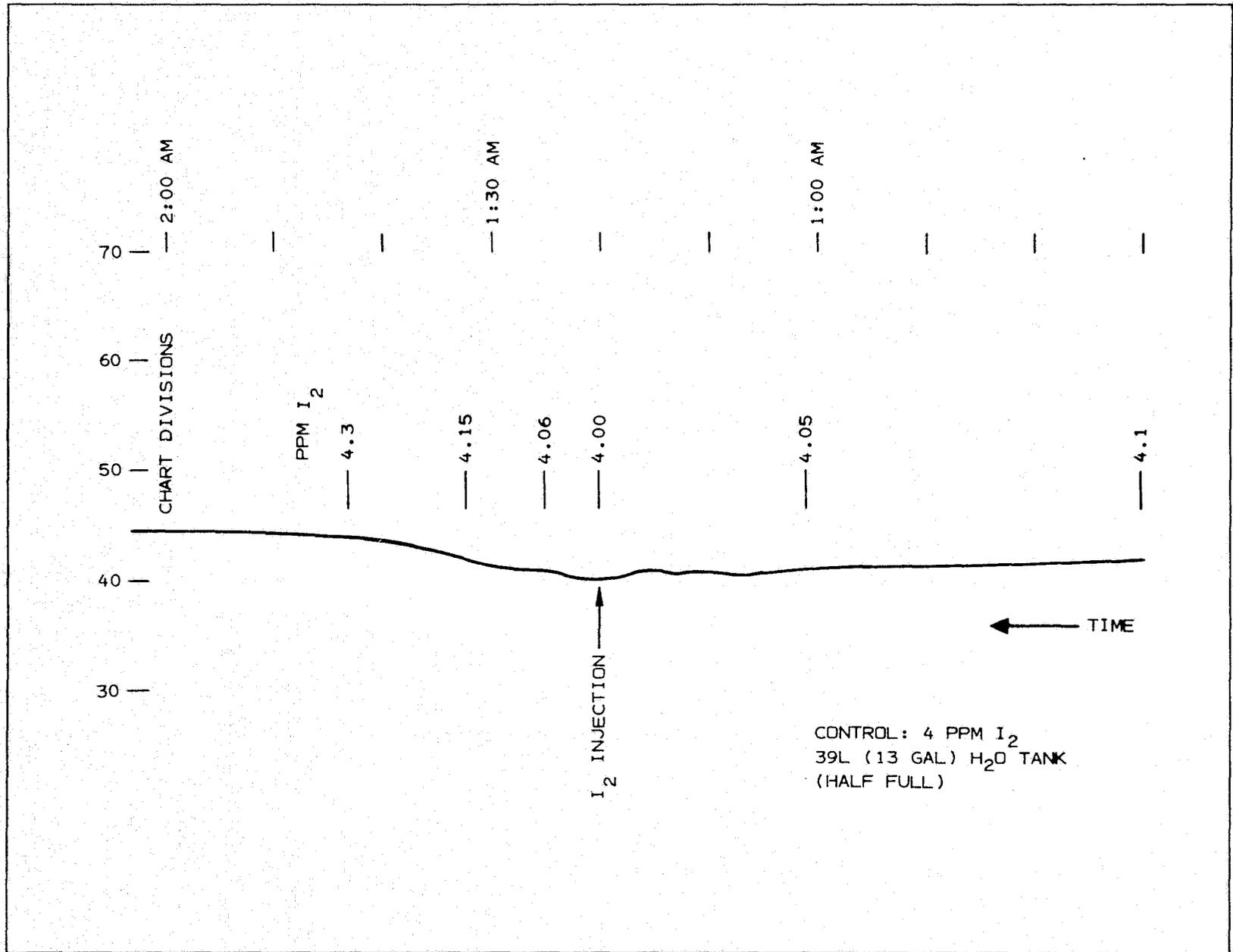


Figure 12. Iodine Addition. A Typical Single Addition to Control at 4 PPM.

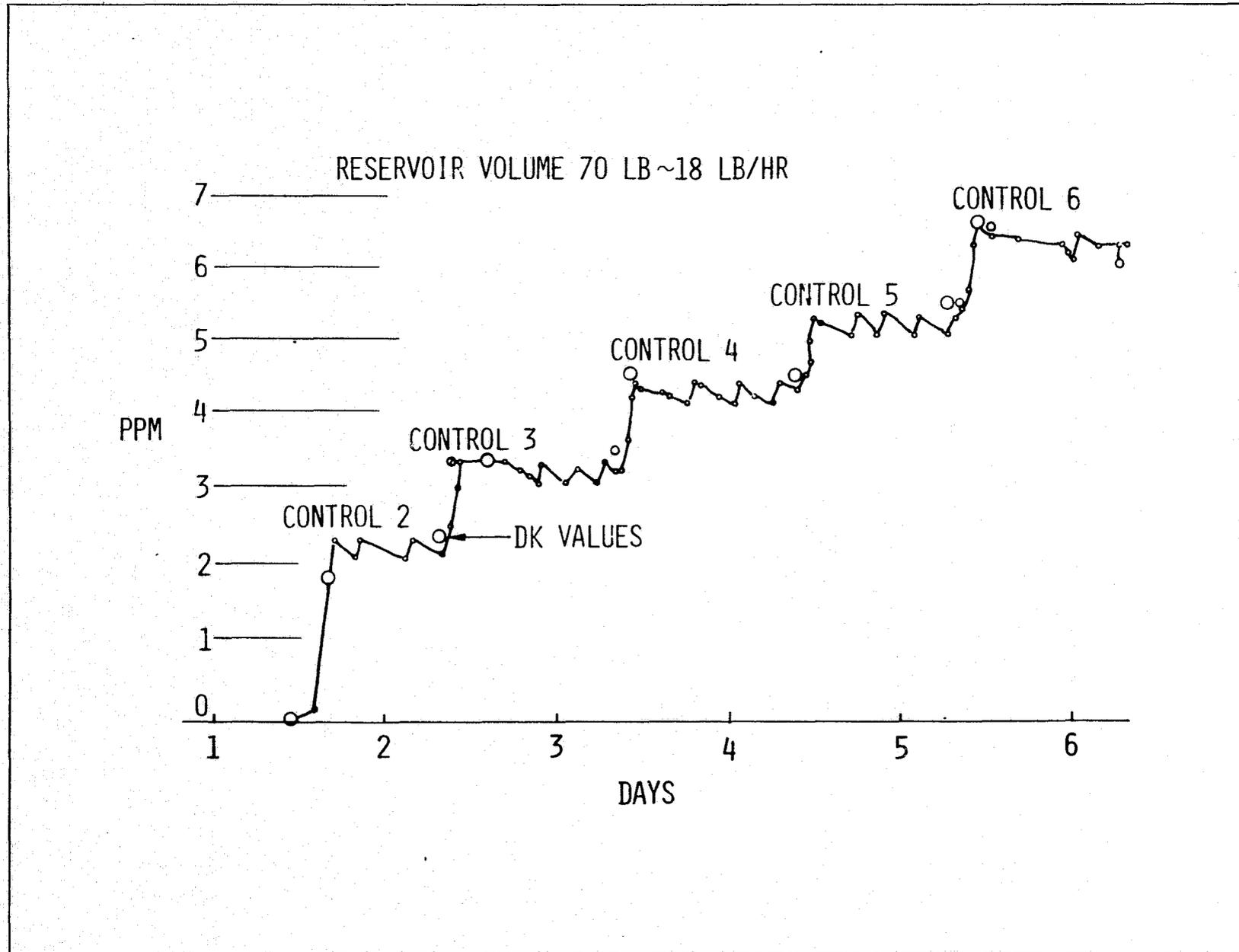


Figure 13. Iodine Additions, 2 to 6 PPM Iodine

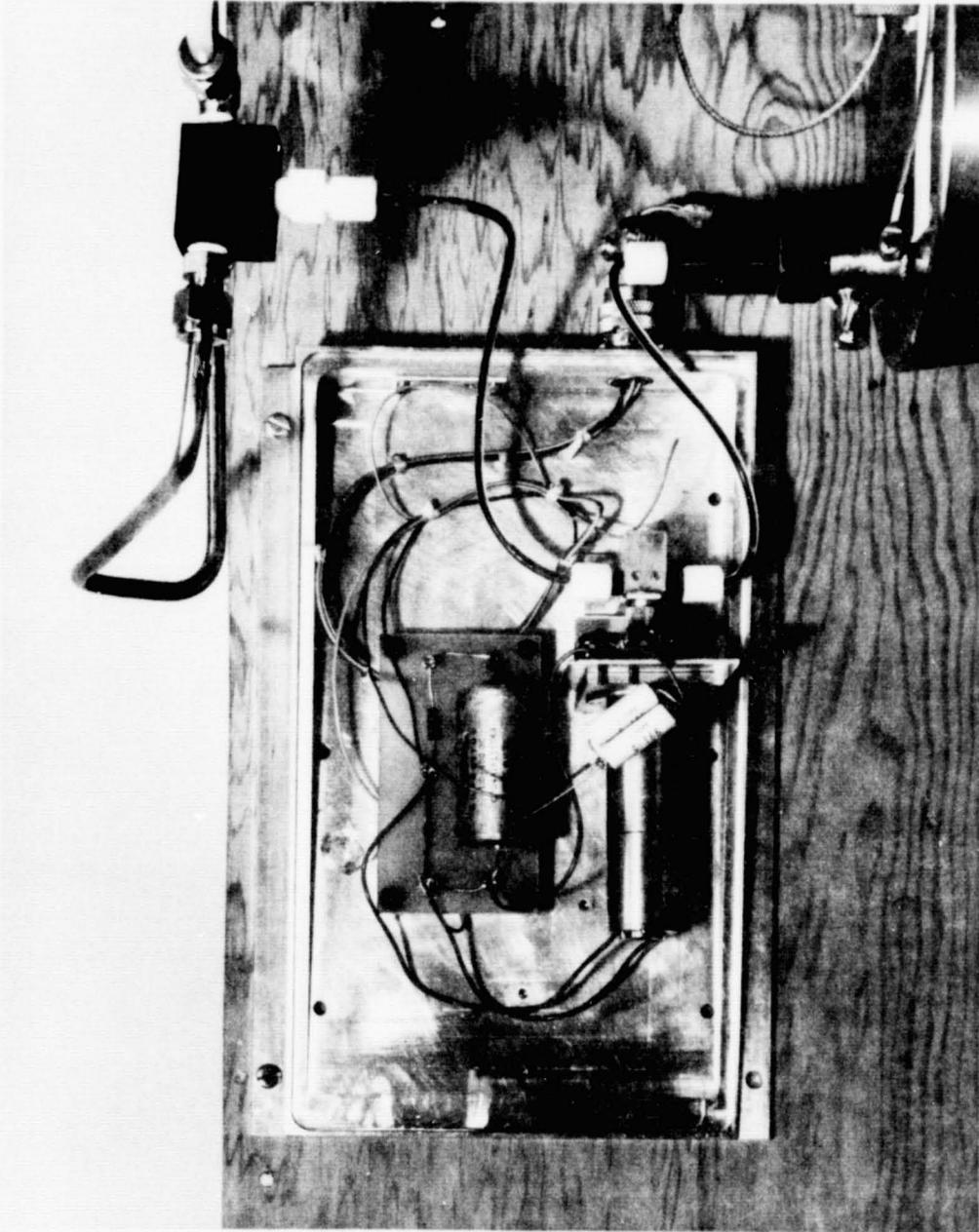


Figure 14. Iodine Addition System

Teflon tubing carries the iodine concentrate from the I₂ reservoir to the valve and from the valve to the water inlet tube. Experiments were made to determine whether iodine diffused through such tubing. Spectroscopic tests showed no diffusion during a three-month interval.

5.0 TEST SETUP

To provide a realistic test setup for AIMS, we designed and built a working mockup of essential features of the Shuttle potable water system. In particular, we incorporated the iodine storage container (GFE, Hastalloy C), .64-mm (1/4") stainless steel conduit of 3.05 m (10') length between the monitor and water tank (39 kg), and arranged for a variable water input and output.

One of the tasks was to determine whether a bubble trap was necessary in the test setup. Some tests were made without this element and the results indicated that, for reliable performance--at least in our configuration--we needed to retain the bubble eliminator. Our method of pressurizing the system was to apply compressed air (at the water tank) and subsequent outgassing was observed. This is a departure from the real case, and was used simply to demonstrate any pressure effects on performance.

The test setup is diagrammed in Figure 15. The Test Plan and Results are separately documented as Appendix A.

6.0 CALIBRATION

The calibration of the monitor was performed by adding iodine to the water supply, measuring the iodine concentration in the Beckman DK-2A Spectrophotometer, and relating these determinations to the monitor output voltage. The calibration curve is shown in Figure 16. Adherence to Beer's Law is shown in Figure 17.

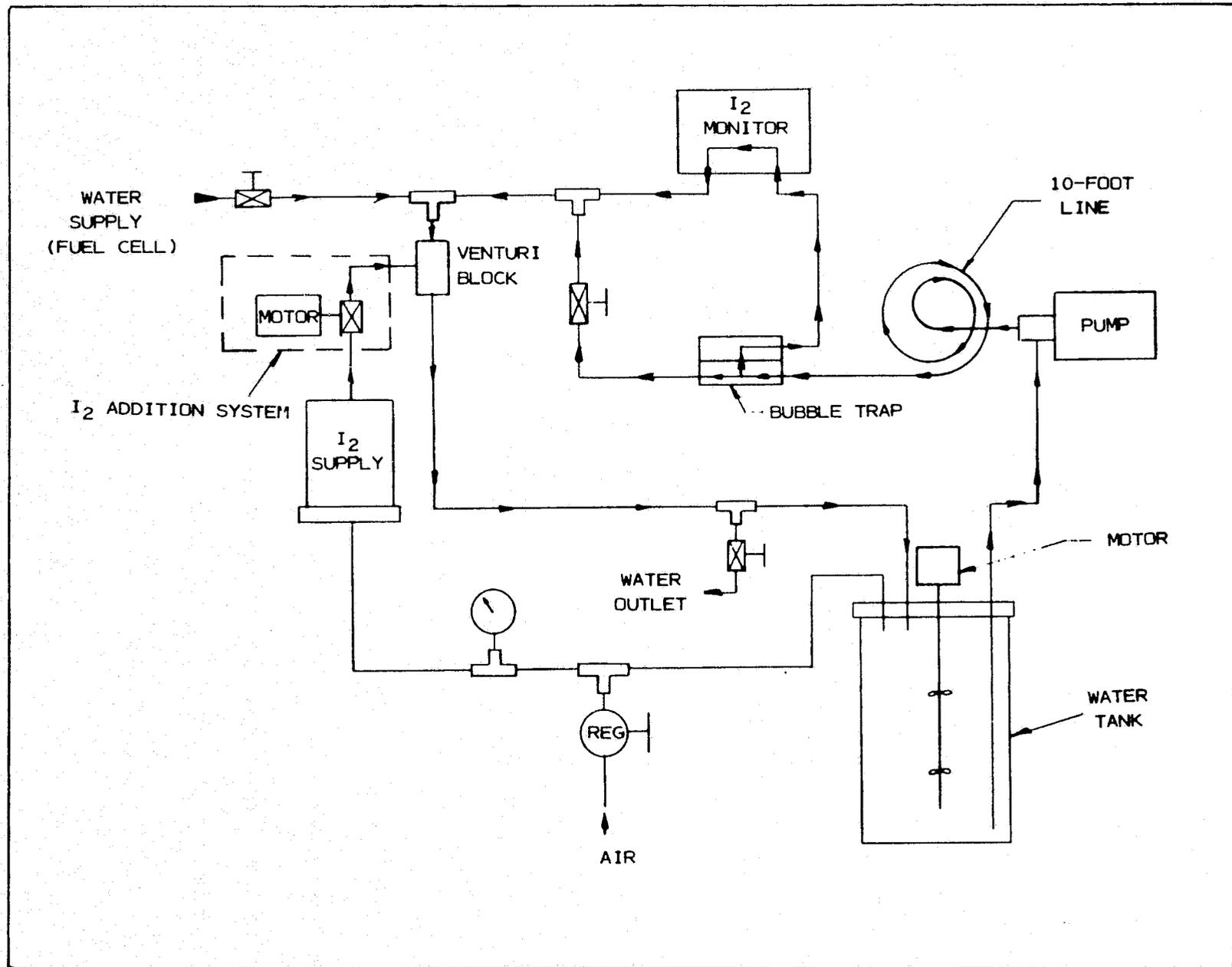


Figure 15. Test System

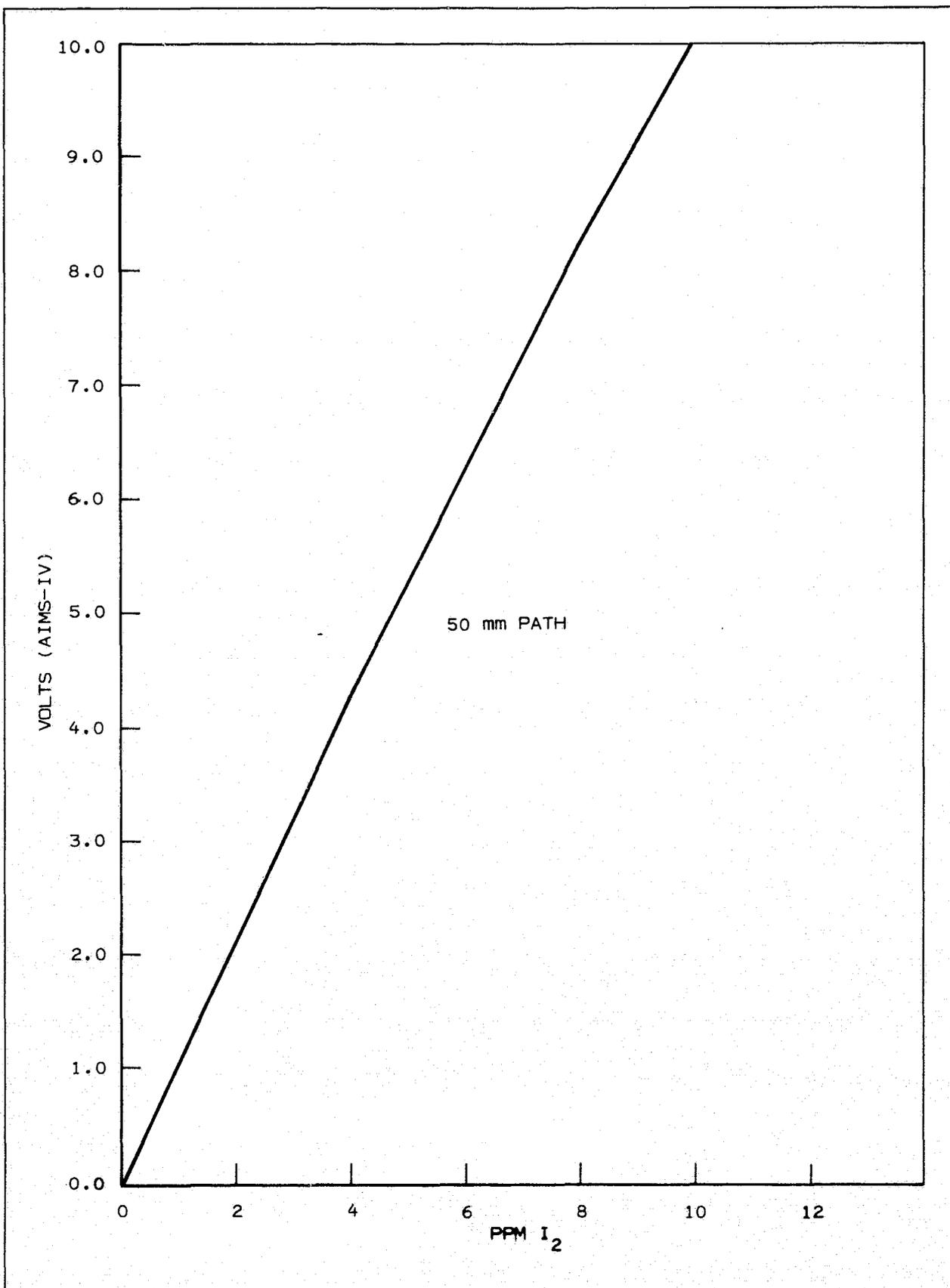


Figure 16. Calibration Curve

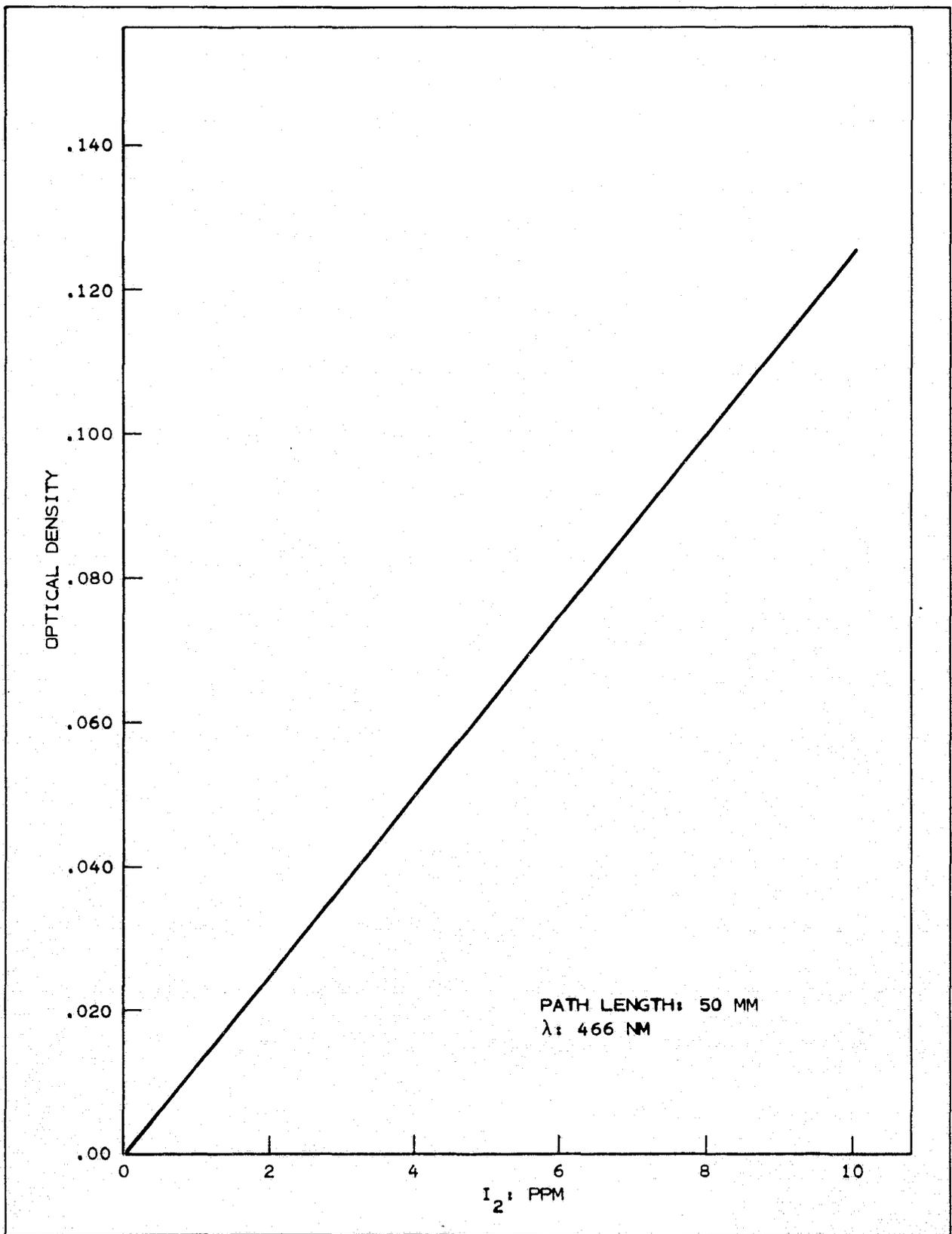


Figure 17. Iodine Concentration Versus Optical Density

7.0 AIMS FACSIMILE

The Statement of Work for the Shuttle Prototype AIMS was amended to include the fabrication and testing of a facsimile of the optical/mechanical portion of the Iodine Monitor. The facsimile consists of the Lamp Housing (including lamp and detector), the Flow-through Cell, and the Detector Housing (including beamsplitter, filters, and detectors).

The Facsimile was built without any modifications to the original specifications and integrated electronically with the AIMS, but not mounted in the AIMS housing. Additional leads were added to allow the Facsimile to be positioned outside the AIMS without disturbing the AIMS circuitry.

A calibration test showed excellent agreement with the DK-2A Spectrophotometer.

An Acceptance Test Procedure, approved by NASA-JSC, was conducted to validate conformance of the Facsimile with that of the AIMS.

The "Mechanical Integrity Test," witnessed by Beckman QA, required the pressurization of the Optical Cell to 18 psig. This pressure was maintained for one minute and there was no evidence of leakage.

Two functional tests were performed: Demonstration of Baseline Stability and Confirmation of Accuracy.

After integrating the Facsimile with the electronics of the AIMS, plain water ("Iodine Zero") was circulated from a reservoir through the Optical Cell for a period of two days at approximately 100 ml/minute.

Maximum excursion from zero should not exceed ± 0.5 ppm iodine equivalents. The maximum excursion in the test was +0.55, -0.00. However, since the system was not zeroed at the midpoint of the excursion all the deviations were on the plus side; had system zero been centered, the excursion would have been ± 0.28 .

The accuracy of iodine measurement between 2 and 6 ppm iodine was confirmed by recording the system response to successive iodine additions (30,000 ppm I₂) and comparing the AIMS values with the spectrophotometer measurements. The DK-2A and AIMS readings should agree within ±1 ppm I₂.

A previous test gave these results:

<u>Facsimile</u>	<u>DK-2A</u>
1.35 ppm I ₂	1.3 ppm I ₂
2.55	2.5
4.7	4.7
7.5	7.3
9.6	9.5

The Acceptance Test, witnessed by Beckman QA and NASA personnel, showed comparable results. One DK-2A check was made when the AIMS read 2.2 ppm I₂. The DK-2A also read 2.2 ppm I₂.

8.0 RECOMMENDATIONS

The AIMS, intensively tested for more than two months, has demonstrated more than adequate sensitivity, good stability, repeatability, and the capability to operate successfully under reasonably simulated spacecraft environmental conditions. It has proven compatible with pressure and flow requirements. Attention has been given to meeting material and component constraints for the intended application. It was to be expected that the fabrication, testing, and evaluation of the present AIMS revealed areas where further improvements can be made. It appears that appreciable reductions in weight, volume, and power can be realized, thus increasing weight-power effectiveness.

It now appears that the Monitor-Addition System weight of more than 5 kg (11-1/2 lb) can be reduced to at least 3.2 kg (7 lb) through reduction in envelope size and material selection.

The present volume of 4000 cc (247 in.³) can probably be reduced to only 2500 cc (154 in.³). Similar reductions can be applied to the Iodine Addition

System. Some nominal relaxation of environmental test constraints may be indicated in order to exploit fully these weight-volume economies.

The large 8 W lamp used in AIMS-IV does not appear to be essential--lamp darkening is not the problem we once thought it to be, and the higher radiant flux is not needed. This lamp accounts for a major part of the power requirements. Substituting a smaller lamp, such as the one used in earlier efforts, will greatly reduce the power requirements. With appropriate changes in the ancillary electronics, the power can be reduced from a steady-state level of 12 W to 6 W, and the present peaking level of 15 W can be reduced to 9 W.

APPENDIX A

SHUTTLE PROTOTYPE AUTOMATED MONITORING/CONTROLLER SYSTEM

TEST REPORT

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1.0 TEST RATIONALE

The system level test protocols were designed to uncover problems that might obtain when AIMS is used to monitor a potable water supply system having the characteristics of the Shuttle system. The design objective of the program was to develop a monitor/controller capable of measuring iodine with an accuracy of ± 1 ppm over a range of 2-6 ppm and controlling iodine levels within that same range. This capability was to be exercised in a water system with the following characteristics:

Water source flow rate	3.2 kg (7 lb)/H to 5.5 kg (12 lb)/H
Inlet pressure	117.1 \pm 13.8 kPa (17 \pm 2 psig)
Water quality	Equivalent to distilled water
Water storage	2 tanks each 75 kg (165 lb) one active and one contingency
Tank pressure	82.7 \pm 13.8 kPa (12 \pm 2 psig)
Iodine control level	Variable between 2 and 6 ppm ± 1 ppm
Iodine depletion rate	2 ppm maximum/24 hrs
Maximum mission duration	30 days
Water use rate	44 kg (97 lb)/man day, 6 man crew
Electrical power	120 Vac, 400 Hz, and 28 Vdc
Conduit between tank and monitor	3.05 m (10 ft)
Iodine containers	GFE, Hastalloy-C

1.1 Test Parameters

The following functional characteristics of the AIMS were considered appropriate as test parameters to demonstrate capability for monitoring and controlling in such a potable water system:

- Baseline stability
- Accuracy of monitoring and controlling at iodine levels between 2 and 6 ppm.
- Accuracy of monitoring and controlling at various water flow rates.
- Accuracy of monitoring and controlling at various system pressures.
- Accuracy of monitoring and controlling during simulated tank draw-down and refill conditions.
- Effect of trace interferences.
- Effect of instrument orientation.
- Requirement for bubble elimination.

2.0 TEST PROGRAM

2.1 Test System

A schematic of the test system is shown in Figure 2-1 and a photograph in Figure 2-2. Deionized water, simulating the fuel cell water supply, is routed through a venturi block into a storage tank simulating the Shuttle storage tank. This tank is constructed of stainless steel and has a capacity of 39 liters. Water is pumped from this tank through a 3.05 m (10-foot) connecting line constructed of 0.64 cm (1/4-inch) 316 stainless steel tubing. The flow passes through a bubble trap and into the AIMS monitor system. From the monitor the water passes back through a T-connection and is recirculated into the storage tank.

Iodine, contained in the GFE Hastalloy C storage tank, passes into the Hamilton valve as previously described and thence into the venturi block. The concentrated iodine solution passes down the inlet tube to the tank, diluted by the recirculating or added water.

System pressure may be varied as illustrated. The pressure of the water system and the iodine supply reservoir are maintained equal. A Δp of 34.5 kPa (5 psig) over system pressure is supplied in the Hastalloy reservoir by a spring. Mixing within the water tank is provided by a stainless steel impeller. The flow rate through the system is provided by a variable speed pump.

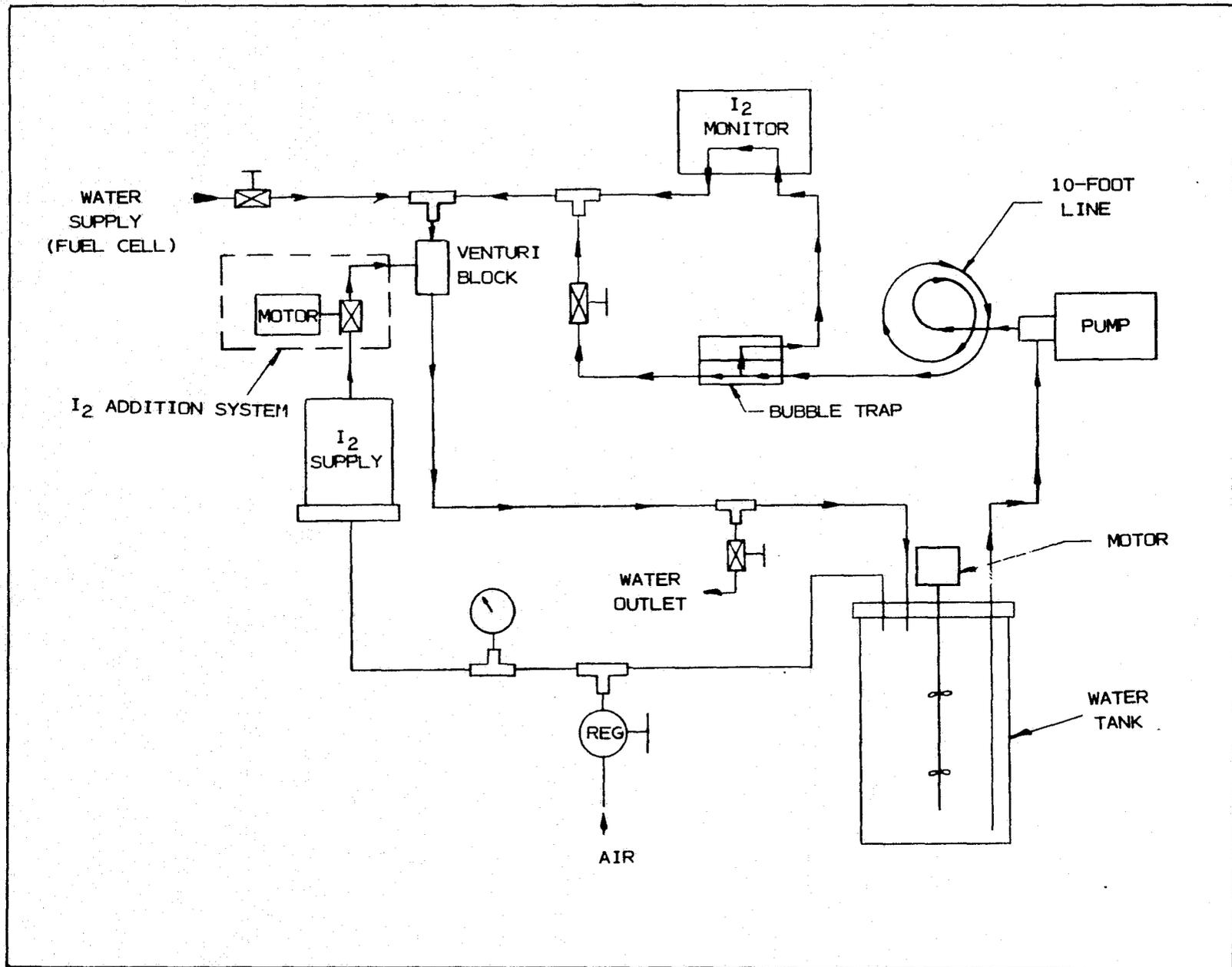


Figure 2-1. Test System

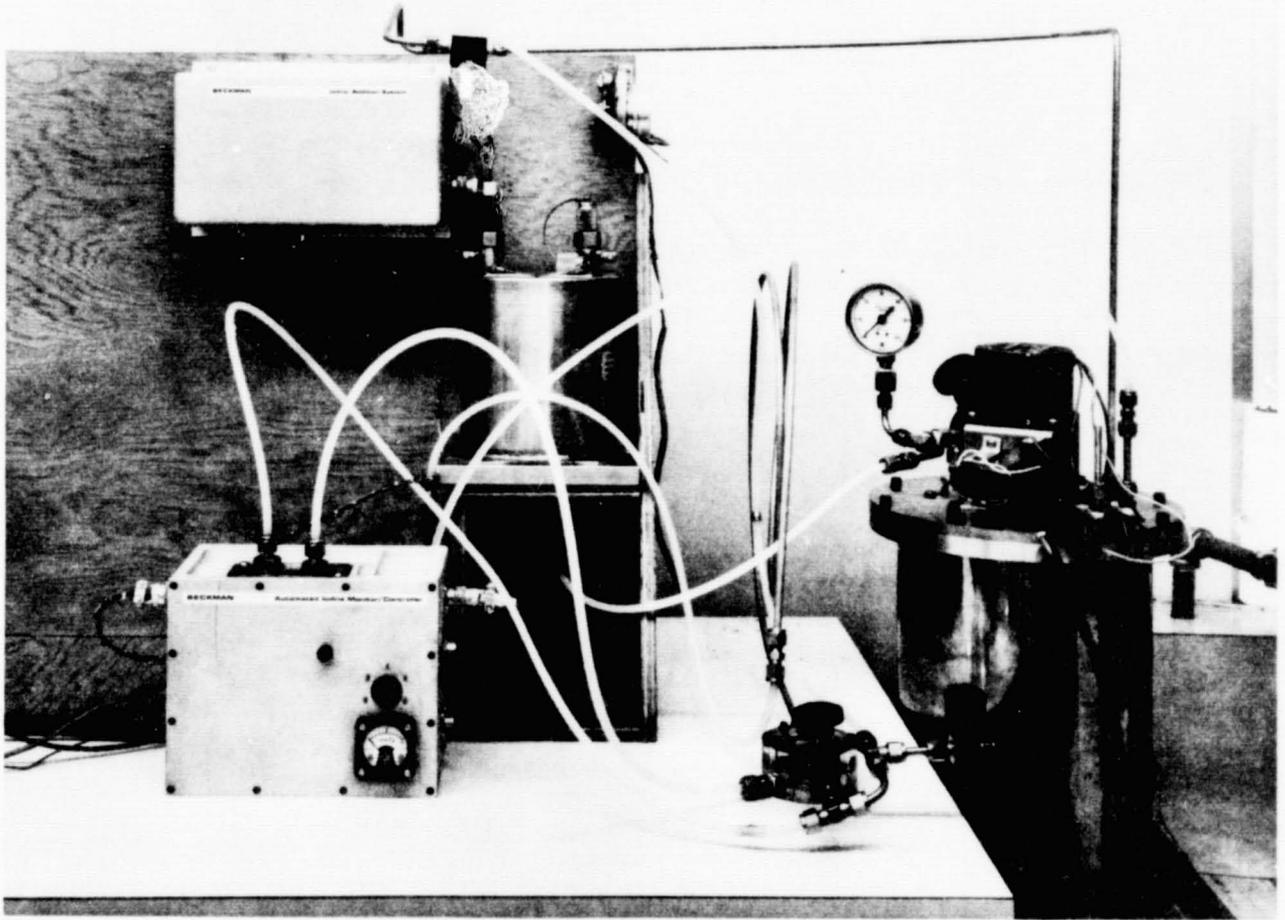


Figure 2-2. Testing Configuration

For special test situations, e.g., the effect of trace contaminants, the water tank is replaced by a smaller reservoir of approximately 3 liters volume. The iodine reservoir was filled with 30,000 ppm iodine in an I₂:KI solution.

2.2 Test Results

2.2.1 Baseline Stability

The stability of the baseline (zero drift) is important because of the effect drift would have on the accuracy of the measurement and also upon the control of iodine addition. If, for example, negative drift occurred, iodine over the amount desired would be added to the water supply system. A positive drift would result in an under-treatment of the water supply.

To determine the baseline stability (see Table I), water containing no iodine was circulated through the optical cell for a total of 16 days. During this interval, the maximum excursion from meter zero (0 ppm I₂) was equivalent to ±.40 ppm.

2.2.2 Accuracy of Monitoring and Controlling at Iodine Levels Between 2 and 6 ppm

In these tests, the setpoint for iodine addition and control was adjusted on the face of the monitor. Periodic samples were collected through the run for off-line comparison on a Beckman DK-2A Spectrophotometer.

2.2.2.1 Control at 2 ppm I₂

The water within the storage tank was adjusted to near 2 ppm I₂. At the beginning of the test the AIMS presented a reading of 1.8 ppm; the DK-2A read 1.9 ppm for the same sample. At the first injection interval, the Iodine Addition System raised this level to 2.25 ppm. No further addition occurred until 10 hours later. At this time the level had dropped to 2.05 ppm and iodine was injected. Forty minutes later, the iodine level was once again at 2.25 ppm. Four and one-half hours later, the level had again dropped to 2.05 ppm. Again iodine addition restored the 2.25 ppm level. Ten hours later, the AIMS system read 2.2 ppm I₂; the DK-2A read 2.4 ppm I₂. This test was maintained for 24 hours.

TABLE I. BASELINE STABILITY

Date (1974)	Time	Signal	
		+	-
Nov. 15	4:35 p.m.		0.10
16	7:15 a.m.	0.45	
	4:00 p.m.	.18	
17	4:00 p.m.	.36	
18	7:30 a.m.	.31	
	4:35 p.m.	.20	
19	7:30 a.m.		.30
	4:30 p.m.	.40	
20	7:30 a.m.	.10	
	6:00 p.m.	.0	.0
21	8:20 a.m.		.40
25	12:27 p.m.	.0	.0
26	7:30 a.m.		.40
	11:09 a.m.		.20
	11:30 a.m.	.0	.0
27	7:30 a.m.		.10
Dec. 2	10:00 a.m.	.10	
	5:00 p.m.	.30	
3	6:00 a.m.	.10	
	4:45 p.m.	.35	
4	7:30 a.m.	.10	
17	4:30 p.m.		.12

2.2.2.2 Control at 3 ppm I₂

At a control point of 3 ppm I₂ and starting at 2.1 ppm, seventy minutes and seven additions were required to achieve a level of 3.2 ppm I₂. At this point, the correlation reading made with the DK-2A was 3.4 ppm. With constant circulation, an iodine injection command did not occur until seven hours later when the level had dropped to 3.0 ppm. Additional injections were required at four hour intervals to maintain the level between 3.0 and 3.3 ppm. The test was continued for 24 hours.

2.2.2.3 Control at 4 ppm I₂

At a switch position equal to 4 ppm, seven iodine additions were made to increase the concentration from 3.25 ppm (DK-2A, 3.5 ppm) to 4.15. Three additions were required during a 24-hour test period to maintain the set level.

2.2.2.4 Control at 5 ppm I₂

Similar behavior was exhibited during the 24-hour test at 5 ppm. Five injections were required to maintain the level at 5 ppm during this interval.

2.2.2.5 Control at 6 ppm I₂

Similar behavior was shown at the 6 ppm level during a 24-hour period. However, only one iodine injection was required to maintain the 6 ppm level after equilibrium was achieved.

2.2.2.6 Conclusions--Accuracy of Monitoring and Control

The recorded data are much too voluminous to reproduce in this report. However, the data have been reduced as shown in Figures 2-3 and 2-4. It is apparent from these data that monitoring and control well within the ± 1 ppm requirements are achieved.

During these tests, the water tank contained 38 liters of water (93% of capacity). Theoretically, to change the iodine content of this volume of water by 1 ppm would require 1.3 ml of 2.9×10^4 ppm I₂ concentrate. During each of the incremental steps, it was noted that seven injections were required to achieve the new baseline. Each injection represents two revolutions of the valve and each revolution adds 90 microliters of iodine concentrate. Since $7 \times 90 \times 2 = 1260$ microliters, it is evident that the theoretical value (1.3 ml = 1300 μ l) and the actual value are in close agreement.

A typical single iodine injection pattern is shown in Figure 2-3, and typical patterns for the 2-6 ppm levels are shown in Figure 2-4.

2.2.3 Accuracy of Monitoring and Controlling at Various Flow Rates

The flow rate has been varied between zero and 80 ml/min. Above 75 ml/min there is no effect on noise or stability. Below 75 ml/min noise increased slightly, to about 1% (the minimum measurable flow rate was 10 ml/min). At zero flow rate a slow increase in the zero offset occurs, rising to about 1 ppm in three hours. The housing temperature increased 3°C during this

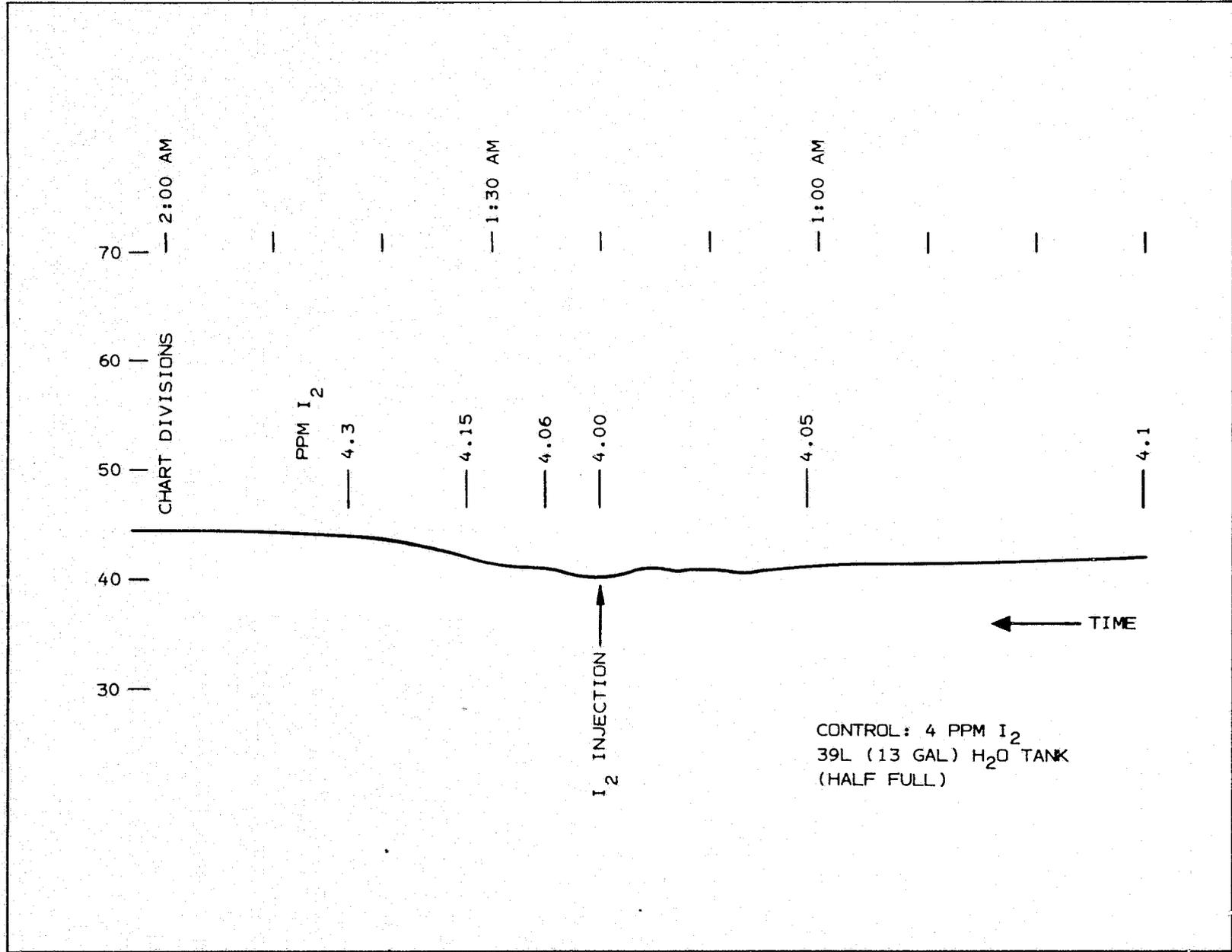


Figure 2-3. Iodine Addition. A typical single addition to control at 4 ppm.

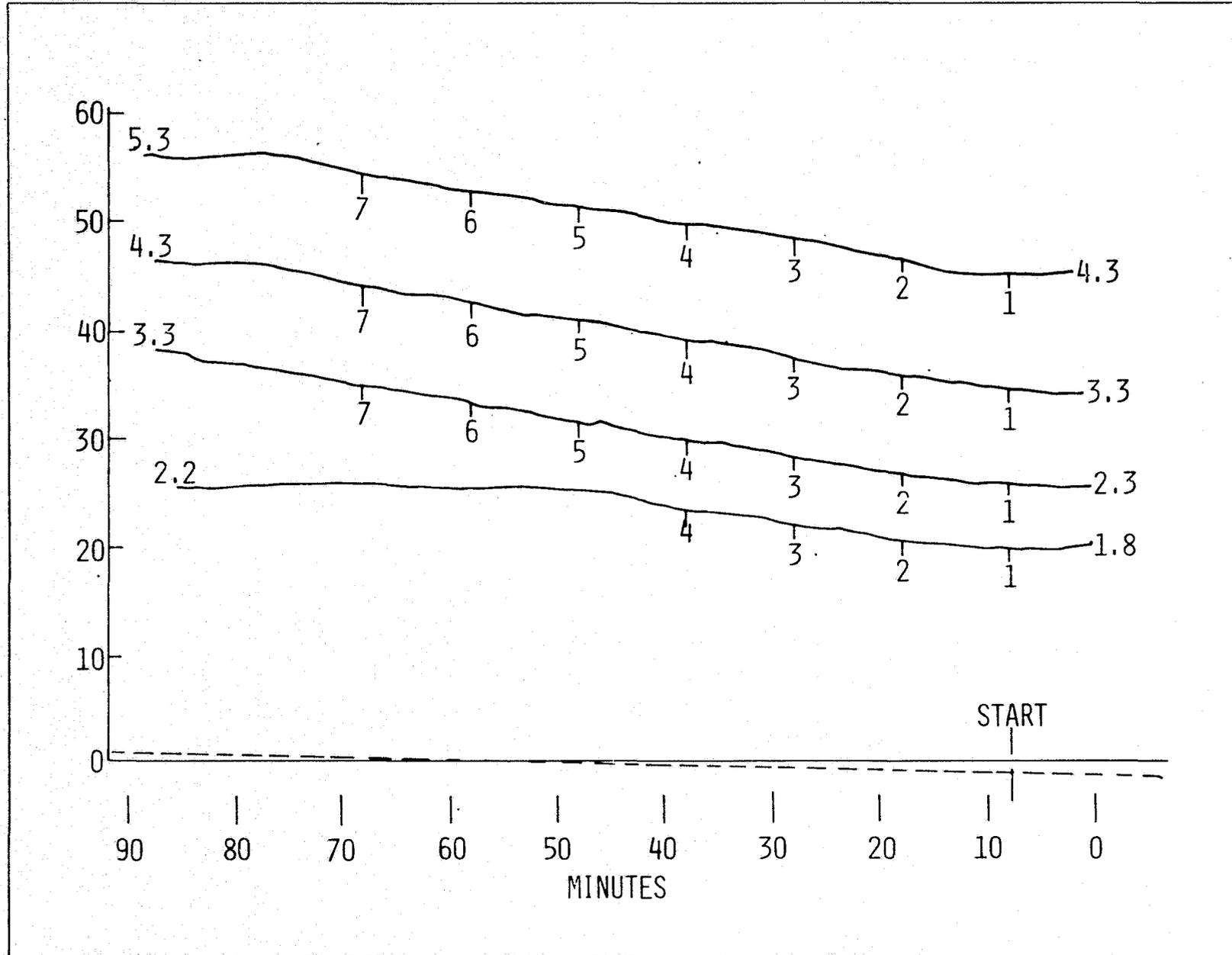


Figure 2-4. Iodine Injection Patterns

no-flow period. It is apparent that in the flow condition the sample cell is a very good heat sink.

2.2.4 Accuracy of Monitoring and Controlling at Various System Pressures

In order to pressurize our test system with compressed air it was necessary to run an air line from the regulated air pressure outlet through a sealed plate to the underside of the spring loaded iodine concentrate tank. In this way we could preserve the Δp of the tank. The pressure on the system was varied between 34.5 and 110.3 kPa (5 and 16 psig) at iodine levels ranging between 2 and 6 ppm. It was observed that iodine was added, as the system required, in a satisfactory way. The system was operated at a steady 68.9 kPa (10 psig) for several days at an iodine level of 5 ppm.

2.2.5 Accuracy of Monitoring and Controlling During Simulated Tank Draw-Down and Refill Conditions

As previously mentioned, no inaccuracies were noted under flow conditions as high as 800 mL/min. This condition might be observed during periods of maximum usage, e.g., meal time, showers, etc. If continuous flow is provided at rates above 10 mL/min (through the Shuttle flash evaporator) during periods when no usage is occurring, accurate results will also be obtained. If, however, a no flow condition exists, the monitor will continue to indicate the concentration of iodine contained in the cell at the time when flow stopped. This reading will be influenced by temperature effects and will reflect only depletion of iodine within the cell rather than the condition of the water within the storage tank.

To assess the capability of the Iodine Addition System to maintain selected iodine levels during refill, the water tank containing 32 l was drained and refilled at a rate of 70 mL/min (equivalent to 132% of nominal flow rate from the fuel cell), at a set point of 5 ppm I_2 . Thus, inlet and outlet flow rates were balanced.

From a beginning concentration of 5.3 ppm I_2 , a decrease to 5.0 ppm was observed in 30 minutes. At this point, an injection command was given.

Three additions were made at ten-minute intervals over the next 30 minutes bringing the concentration back to 5.3 ppm. Thus at flow rates significantly exceeding nominal rates, the addition system was capable of maintaining iodine concentrations within desired limits.

As a worst-case test, water at a rate of 200 ml/min (26 lb/h) representing twice maximum flow rate was treated. The level switch remained at 5 ppm. From a starting point of 5.4 ppm, the iodine level had dropped to 5.0 ppm within 15 minutes. Iodine was added every ten minutes thereafter but these additions could not quite keep up with the rate of incoming water. By the time the tank was full the iodine level had equilibrated at about 4 ppm. By the end of another hour, however, the iodine concentration was once again under control at 5.0-5.3 ppm.

2.2.6 Effect of Trace Interferences

The effect of trace interferences was assessed by noting changes in apparent iodine concentration induced by trace levels of various substances. An iodine level of 3 ppm was selected as the baseline level. One hundred μ l of iodine concentrate in 1 l of water provides this level. The results of this study are presented in the following table:

<u>Interferring Chemical</u>	<u>Concentration (ppm)</u>	<u>AIMS Reading (ppm)</u>	<u>DK-2 Reading (ppm)</u>	<u>Deviation (ppm)</u>
--	0	3.0	3.0	0.0
Cr ⁺³	1	3.1	2.8	0.1
Cr ⁺³	10	3.3	3.3	0.3
Ni ⁺²	1	3.0	2.8	0.0
Ni ⁺²	10	2.9	2.8	-0.1
Fe ⁺³	0.1	3.2	2.8	0.2
Fe ⁺³	0.5	4.0	3.5	1.0
Fe ⁺³	1.0	4.7	4.1	+1.7

Thus, results observed in this test closely parallel those observed previously. Chromogens absorbing in the same region as I₂ can and do interfere with the AIMS reading but the anticipated levels of such chromogens are so low that in a practical sense, no degradation of the analysis is expected.

2.2.6.1 Shuttle Worst-Case Water

A sample of synthetic "Shuttle Worst-Case Water" was obtained from Life Systems, Inc. This water had the following composition:

<u>Property</u>	<u>Synthetic</u>
pH	6.0 to 8.0 (adjusted with NaOH)
Total Solids	100 ppm (from silica)
Odor	None
Turbidity	-
True Color	None Expected
Total Organics	10 ppm
Particulate Matter	
0 to 10 µm	-
10 to 25 µm	-
25 to 50 µm	-
50 to 100 µm	100 ppm #250 Silica
100 to 250 µm	-
Cd ⁺²	0.01 ppm
Cl ⁻¹	3.5 ppm
Cr ⁺⁶	0.05 ppm
Cu ⁺²	1.0 ppm
Fe ⁺³	0.3 ppm
Pb ⁺²	0.05 ppm
Mn ⁺²	0.05 ppm
Hg ⁺²	0.005 ppm
Ni ⁺²	0.05 ppm
K ⁺	0.05 ppm
Se ⁺⁴	0.05 ppm
Silica	100 ppm
Ag ⁺	0.05 ppm
NH ₄ ⁺	0.5 ppm
Na	0.43 ppm
NO ₃ ⁻	0.17 ppm

The test of this water was conducted as follows. The water lines from the tank were disconnected and placed in a 3 l flask of deionized water. The AIMS read +0.024 ppm. When this water was replaced with "worst case" Shuttle water,

the readout was 1.3 ppm. Thus, there was an immediate baseline offset. Iodine concentrate at the 5 ppm level was then added to each sample. The deionized water gave an AIMS reading of 5.1 ppm (DK: 5.0 ppm). The "worst case" water read 6.6 ppm or approximately equivalent to the baseline offset and then fell rapidly to 5.5 ppm (DK: 5.0 ppm) I₂ indicating iodine utilization, probably by the organic material in the water. A DK scan of the "worst case" water is shown in Figure 2-5. Although the absorption band is centered at 418 nm, there is enough absorption in the 466-nm area to cause the observed offset.

2.2.7 Effect of Orientation

Operation in different orientations simulates, in some respects, operation in zero-gravity. That is, if no discrepancies are observed in any orientation, it is probable that none will be observed in zero-g either. On the other hand, if discrepancies are observed, and if these may be explained on the basis of gravity effects, there is reasonable expectation that operation in zero-g will be satisfactory. To assess the effects, changes from a 0.0 reading in a "normal position" were observed when the AIMS was reoriented. The following results were noted:

<u>Position</u>	<u>Meter Reading</u>	<u>Changes from Normal</u>
Normal	0.0	--
On Face	0.2	0.2
On Side	1.6	1.6
Upside Down	1.4	1.4

We believe that these changes are due to a sagging of the hot filament in the light source which changes the geometry of the source/detector relationship. While this effect will probably not be observed in zero-g, it would be worthwhile to consider alternate sources with shorter filaments to minimize the effects of this phenomenon.

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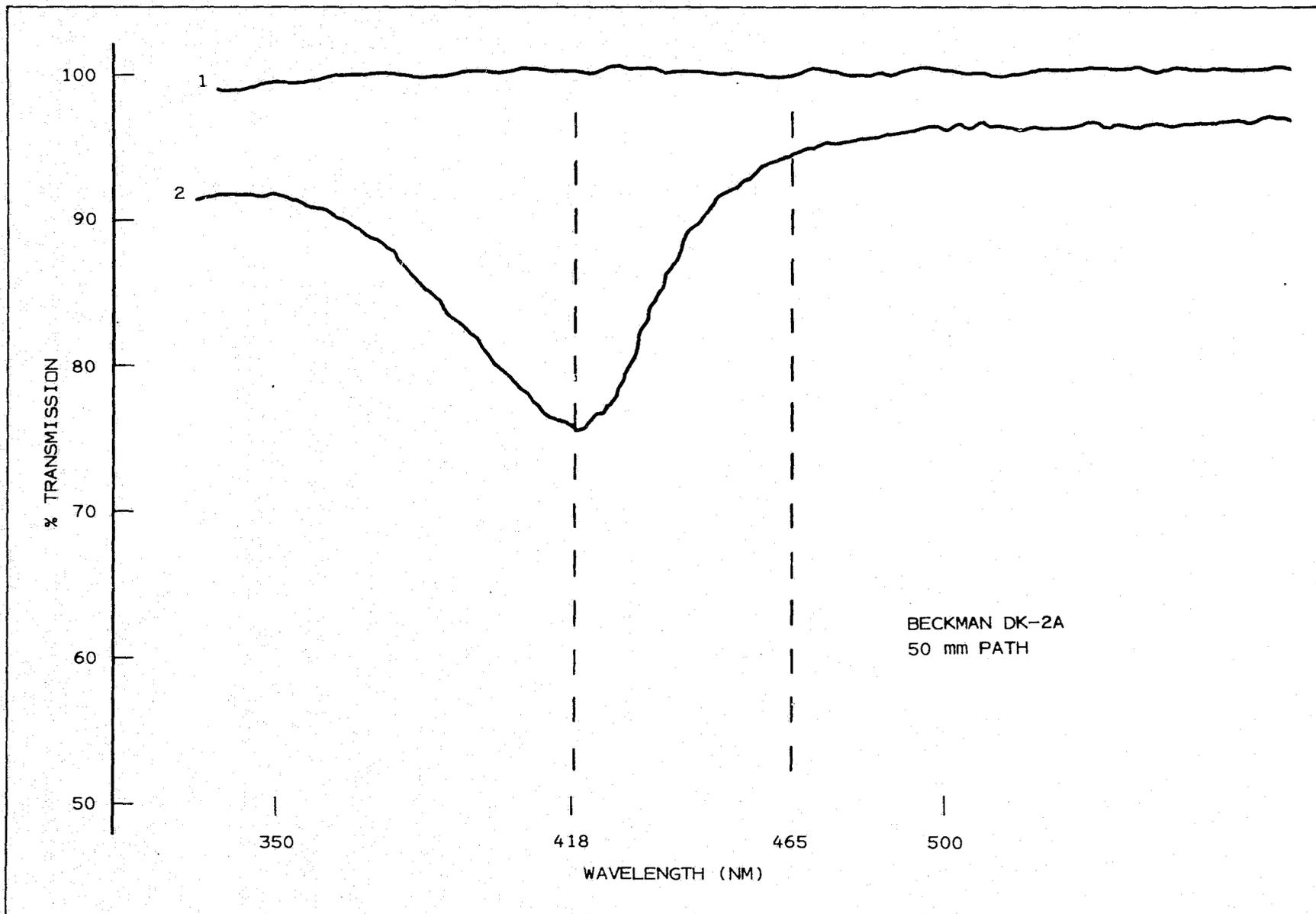


Figure 2-5. Scan of "Worst Case" Shuttle Water

2.2.8 Requirement for Bubble Elimination

Under conditions of our tests, a bubble eliminator was found to be required. Using air pressure to maintain system pressure and with head space in the tank, dissolved gases were unavoidable and over a period of days, small bubbles would accumulate in the optical cell. This condition may not obtain in the Shuttle potable water supply system where low dissolved gas levels are expected.

3.0 TEST CONCLUSIONS AND RECOMMENDATIONS

The tests conducted under this program conclusively demonstrate that the AIMS approach to iodine monitoring and controlling is suitable for spacecraft use. A change of the light source may be indicated, however, to minimize orientation effects.

APPENDIX B

SHUTTLE PROTOTYPE AUTOMATED MONITORING/CONTROLLER SYSTEM

PRELIMINARY PRIME ITEM DEVELOPMENT SPECIFICATION

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1.0 SCOPE

1.1 General

This specification establishes the performance, design, development, and test requirements for the Automated Iodine Monitoring/Controller (AIMS) System hereinafter referred to as the System).

2.0 APPLICABLE DOCUMENTS

2.1 Government Documents

The following documents of the issue in effect on the date of invitation for bid or request for proposal, form a part of this specification to the extent specified herein:

Specifications:

Federal
Military
Others

Standards

Drawings

Other Publications

} To be determined

2.2 Non-Government Documents

The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

Specifications

Standards

Drawings

Other Publications

} To be determined

3.0 REQUIREMENTS

3.1 System Definition

This specification describes one type of water bactericidal system (Iodine Monitoring/Controller System) for use in the Space Shuttle in conjunction with the Shuttle water system (Figure 1). The system includes three individual items:

- Iodine Addition System
- Monitor Assembly
- Iodine Concentrate Tank

Functionally, the system is composed of two subsystems:

- Iodine Monitoring Subsystem, and
- Iodine Controller Subsystem

3.1.1 Missions

The System shall be capable of 720 successful continuous operating hours (minimum).

3.1.2 System Diagrams

Figure 2 is the System Electronic Block Diagram, and Figure 3 is the System Mechanical Block Diagram.

3.1.3 Interface Definition

The System shall meet the following interface requirements.

3.1.3.1 Water Source

The System shall accommodate a supply of water at the rates of 8.8×10^{-4} kg/s (7 pounds/hr, nominal), and 1.5×10^{-3} kg/s (12 pounds/hr, maximum).

3.1.3.2 Water Quality

The System shall be compatible with essentially distilled water with a minimum I_2 demand (0.1 ppm of iodine).

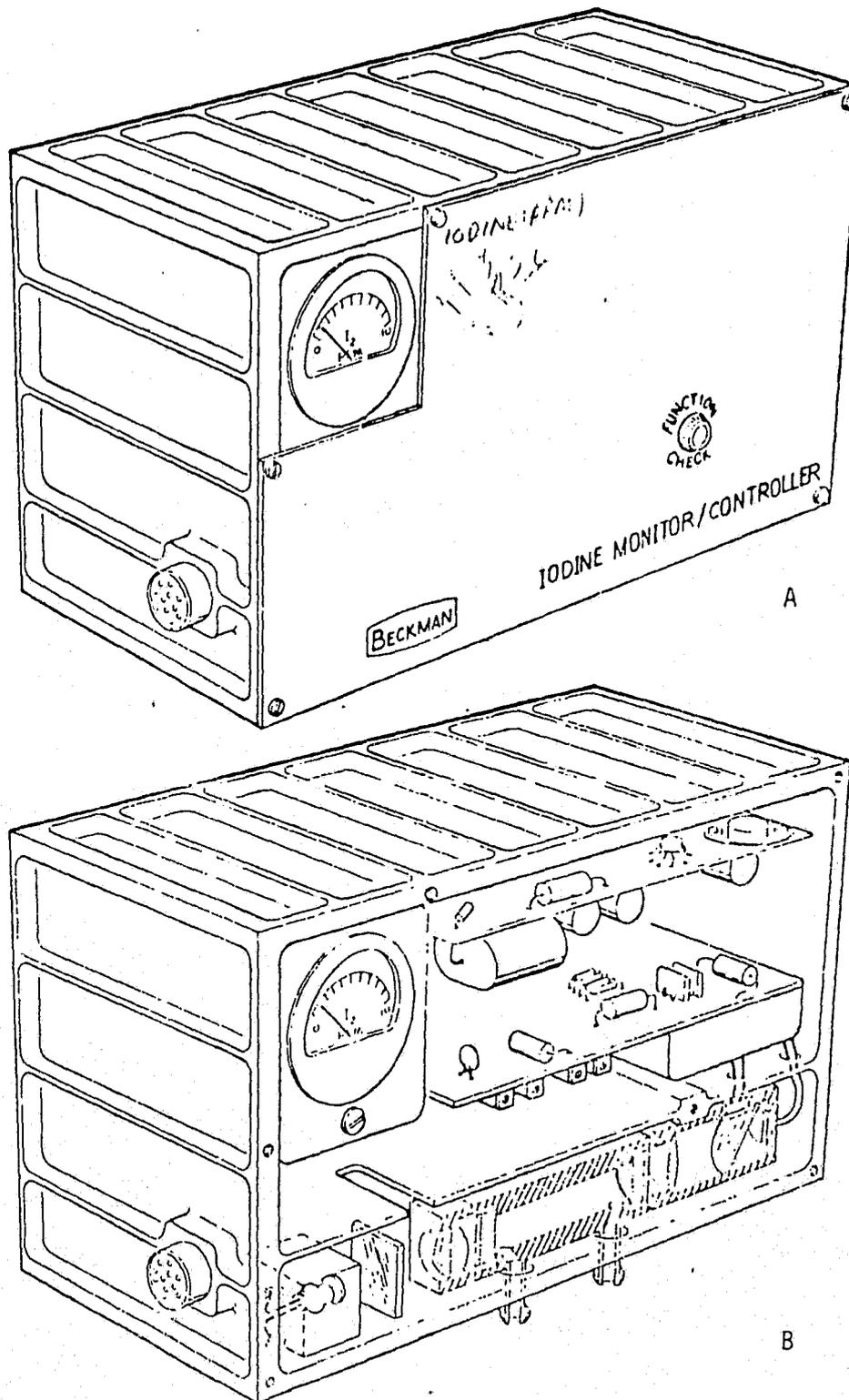


Figure 1. Iodine Monitor/Controller (Preliminary Flight Prototype Status)
A: With Cover; B: Cover Removed

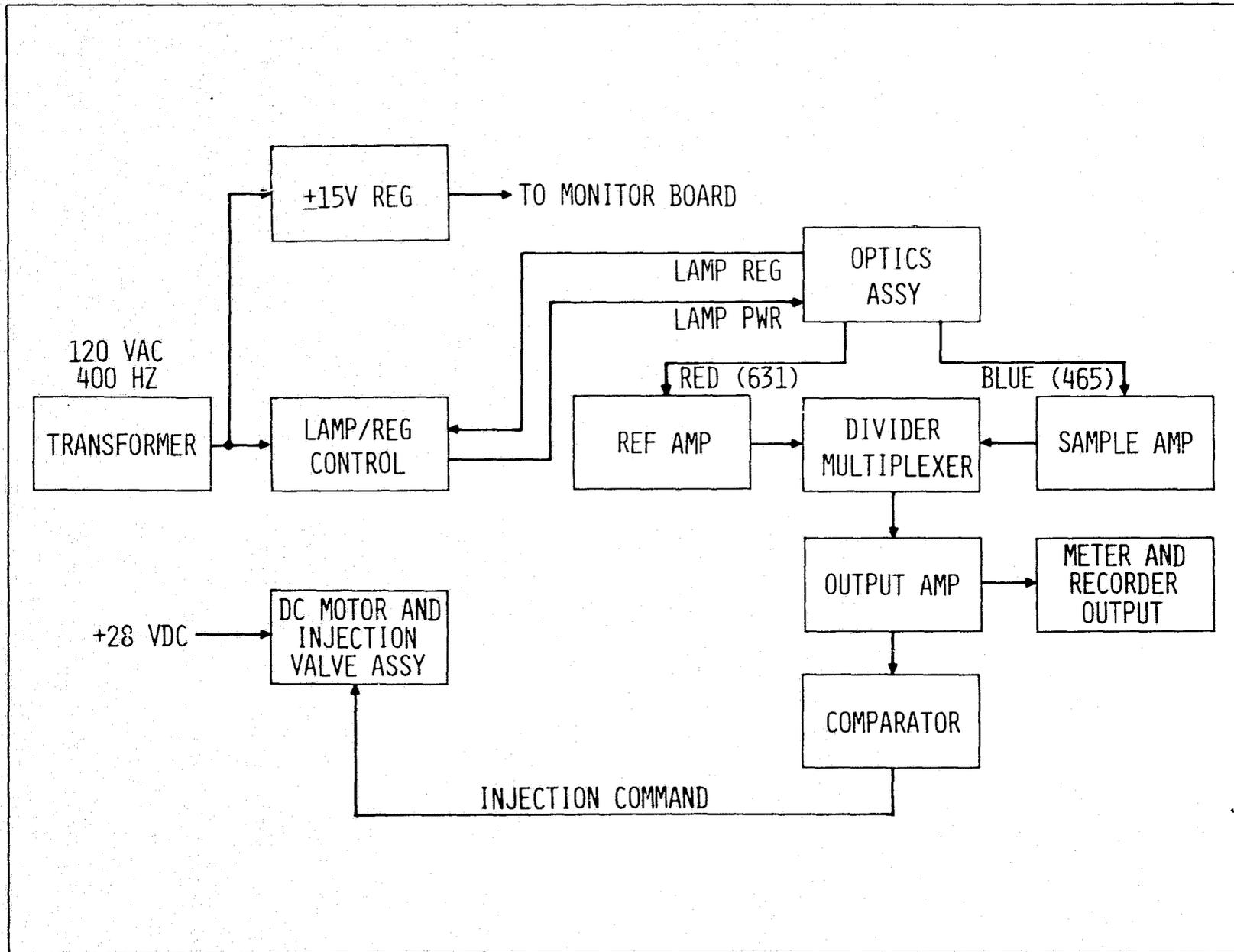


Figure 2. Electronic Block Diagram

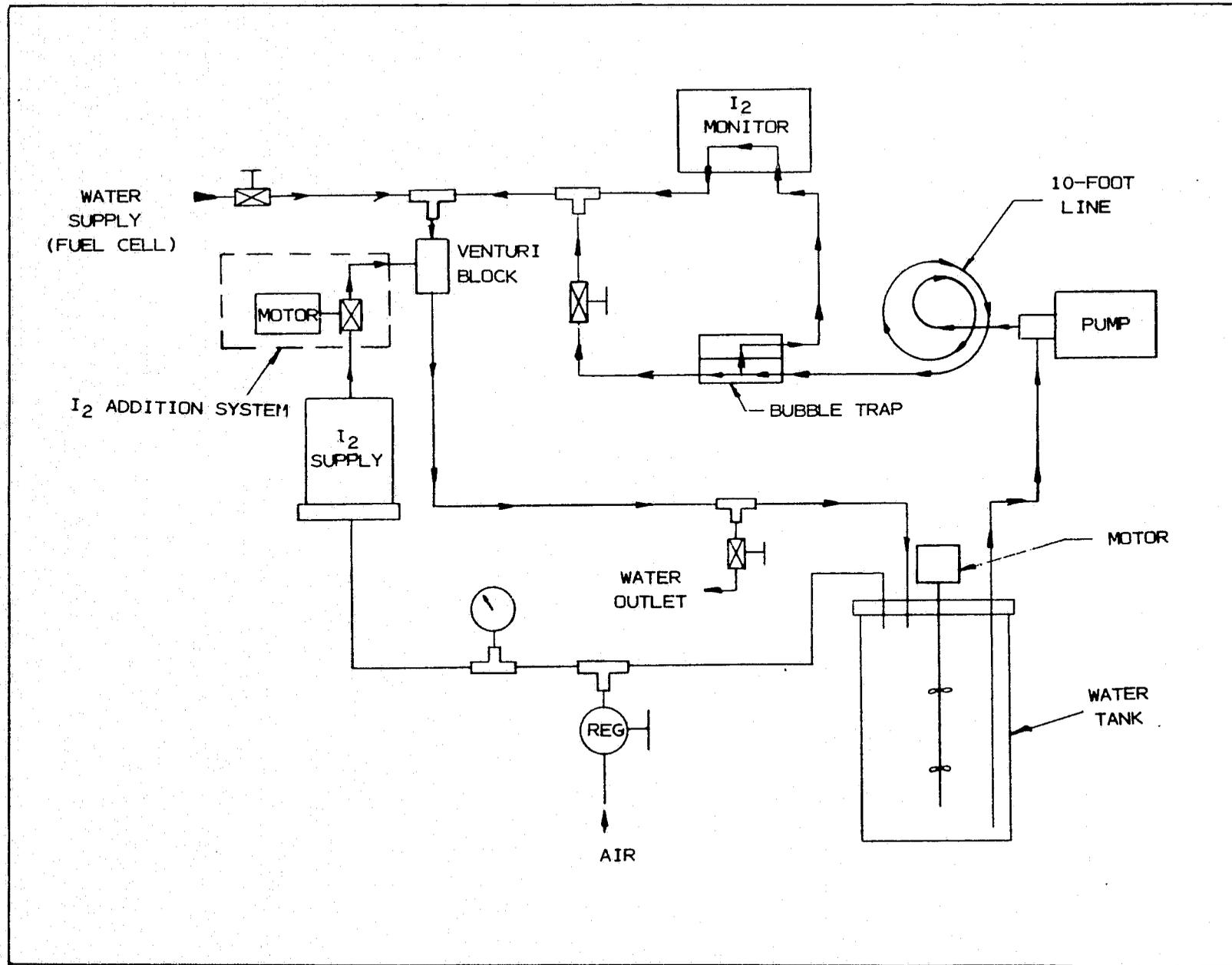


Figure 15. Test System

3.1.3.3 Water Input and Output

The water input and output interfaces shall mate with 6.35 mm (1/4-inch) stainless-steel swagelock fittings.

3.1.3.4 Electrical Power

The System electrical interface shall accommodate 120 Vac, 400 Hz, and 28 Vdc power.

3.1.4 Government-Furnished Equipment

The following equipment to be incorporated into the System design shall be furnished by the Government:

	<u>Name</u>	<u>Part No.</u>
•	Iodine Storage Container, Skylab	To be determined

3.1.5 Operational and Organizational Concepts

To be determined.

3.2 System Specifications

The Iodine Monitoring/Controller Systems shall meet the following specifications:

- a. Iodine Level - The System shall control iodine level between 2 and 6 ppm. The System shall hold the iodine level to within ± 1 ppm of desired level.
- b. Iodine Level Display - The System shall display the iodine level on a 38-mm (1-1/2 inch) analog meter. The analog meter shall have a range of zero to 10 ppm.
- c. Iodine Controller Signal - The Iodine Monitor shall provide a zero-to five-Vdc signal to the Iodine Controller.
- d. System Output - The System shall provide an output signal of 100 mV full scale for a recorder.

- e. Power Source - The System shall operate from 120 Vac, 400 Hz, and 28 Vdc power.
- f. Self Check - System design shall include a functional check device which shall indicate normal system operation.
- g. Weight and Volume - Emphasis shall be placed on minimizing System volume and mass. A design goal shall be to achieve a volume of 1443 cm³ (88 in.³) and a weight of 2 kg (4.5 lb).
- h. Optical System Alignment - The Optical System subsystems (optical bench and electronics) shall be positively located, aligned, and locked in place to ensure reliable functioning under varying g forces and in any orientation.
- i. Transport and Storage - System design shall enable transport, storage, and handling by a common carrier complying with best-commercial practice.
- j. Health and Safety Criteria - Iodine in high concentrations is unpalatable and corrosive. All containers of concentrated iodine, either a part of the System or located in the contractor's facility, launch facility, or on board the Shuttle or Skylab, shall be legibly marked with appropriate caution or warning notices.

3.3 Operational Modes

- a. Monitor - Optics and electronics shall continually monitor iodine level for meter readout or recording.
- b. Iodine Addition Enable - The System shall compare the iodine level to a predetermined desired iodine level. Iodine level in excess of desired level shall maintain the System in the monitor mode. An iodine level below the desired level shall induce injection of iodine.
- c. Iodine Injection - The System shall add iodine to the water supply in response to a low iodine level indication by the Iodine Addition Enable operation mode.

3.4 Minimum Life Expectancy

Minimum System life expectancy shall be equal to the total shelf life, from the time of Government receipt of the item to launch, and the mission duration of 720 continuous operating hours (Paragraph 3.1.1).

3.5 Reliability

The System shall have no single failure points that result in a constant dump sequence.

3.6 Maintainability

To be determined.

3.7 Availability

The System shall be fully available at the start of the mission. All interface connections shall be complete, fluids added, and functional checks performed.

3.8 Environmental Conditions

The system shall meet the following environmental conditions:

- To be determined.

3.9 Design and Construction

Using flight hardware design concepts and choosing appropriate materials, the design shall minimize the volume and weight of the System without reducing the operational characteristics, reliability, or ruggedness of the System. The design shall specify flight-rated components. However, commercial standard parts may be employed where form, fit, and function are not affected.

3.9.1 Iodine Monitoring Subsystem

The Iodine Monitoring Subsystem shall be based on the prototype system developed under NAS9-14298. The design of this portion of the system shall incorporate the following:

- a. The optical components, provided with locating pins, shall be positively positioned and locked on an "optical bench" mounted on the base plate of the enclosure.
- b. The electronics shall be mounted on printed circuit boards which also will be locked in place as a discrete system. The instrument power shall be in accordance with Paragraph 3.1.3.4.
- c. A "Function Check" device shall be included. A selected filter-type design, which can be brought into the light path by turning a knob on the front panel, shall be used. Its effect shall be to cause the meter reading to increase by a known amount (e.g., 4 ppm) and thus will indicate that the Monitor is operating properly.

3.9.2 Iodine Controller Subsystem

The design of this subsystem shall be based on the concept employed in the iodine-addition portion of the prototype system. This subsystem shall incorporate the following:

- a. The selectable control range for iodine shall be in accordance with Paragraph 3.2a. Iodine shall be held within the limits specified in Paragraph 3.2a.
- b. Technology developed during the Skylab Program and associated with the Skylab Iodine Addition System shall be considered in the design of the Iodine Controller Subsystem. In particular, a reservoir for containing the stock iodine solution along with proven materials shall be considered for incorporation in the design.

3.9.3 Materials and Processes

To be determined.

3.9.4 Electromagnetic Radiation

To be determined.

3.9.5 Nameplates and Product Marking

To be determined.

3.9.6 Workmanship

To be determined.

3.9.7 Interchangeability

Items identified with the same part number shall be interchangeable without having to change, alter, or select the parts to fit.

3.9.8 Safety

The System shall be capable of indicating an excess or deficit of iodine.

3.9.9 Human Performance/Human Engineering

To be determined.

3.10 Documentation

The System shall be identified by detail fabrication drawings, photographic coverage of subassemblies and assemblies, and a System Test Plan and Test Report.

3.11 Logistics

To be determined.

3.11.1 Maintenance

3.11.1.1 Zero Check

The following ground-based checkout shall be performed between missions:

NOTE

Do not turn Monitor off.

- a. Close valves at inlet and outlet to Monitor.

- b. Disconnect inlet and outlet lines from Monitor flow-through cell.
- c. Allow iodine-free water to flow in and out of sample cell to flush cell thoroughly.
- d. Note meter reading. It should be zero. If meter reading is off zero, remove four screws holding the sample cell in place. Carefully remove cell and look through all windows to see if air bubbles are present. Remove air bubbles by tilting and jarring the cell.
- e. Carefully replace sample cell, making sure its O-ring gasket seats properly. Replace four screws.
- f. Recheck zero.
- g. If meter reads above zero, remove cell, remove screws holding one window in place, and remove the window.
- h. Clean window using detergent, then thoroughly rinse. (The other window can be cleaned without removal.)
- i. Replace window, then replace cell (make sure gasket seats properly). Refill cell with iodine-free water (eliminate bubbles as in step d., if necessary).
- j. Recheck zero.
- k. If zero deviation persists, it will be necessary to reset zero. This is done by removing the front cover of the Monitor, laying it down flat. The zero trimpot is the middle one of the three in the middle of the top circuit board. Carefully turn the zero trimpot adjustment screw slightly (CW or CCW, as required) to obtain a zero indication. The cover can be raised enough to see the meter during this adjustment. Temporarily replace the cover, using one or two screws, and observe the zero for about three minutes. Another small adjustment may be necessary.

NOTE

Do not attempt to check zero over a long time interval with a static sample--circulating water through the cell is required for long-term thermal stability.

- l. Complete replacement of front cover.
- m. Push "Function Check." Meter should read approximately 5 ppm I₂.
- n. Reconnect Monitor to input line only.
- o. Connect a temporary drain line to the output of the sample cell.
- p. Open input line and allow enough water to flow through the cell to remove all bubbles. Turn input off.
- q. Remove temporary output line and reconnect normal output line.

3.11.1.2 Replacement of Lamp

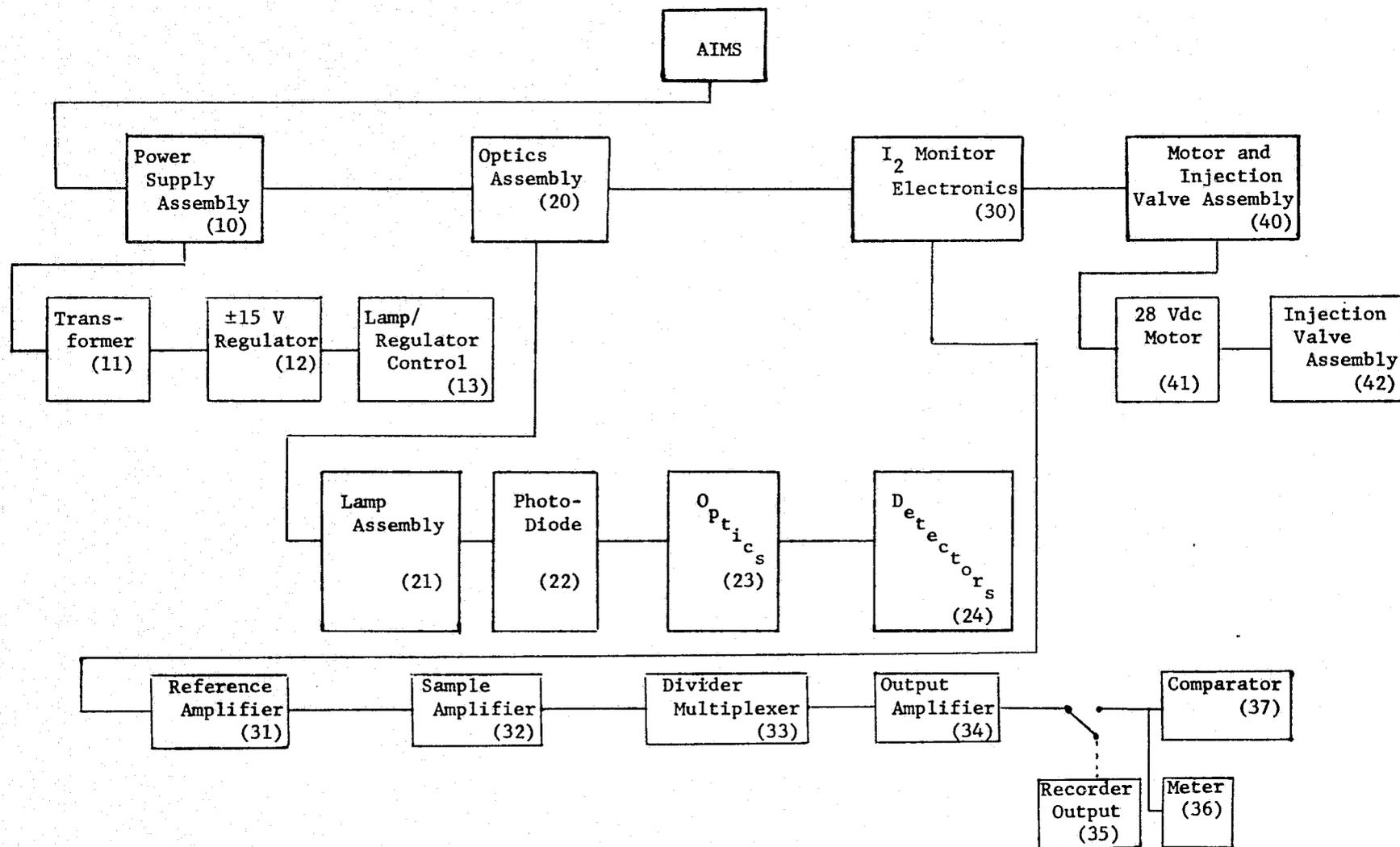
- a. Turn Monitor OFF.
- b. Remove front cover.
- c. The lamp housing is located on the right of the sample cell. Remove two screws holding it in place. Do not disconnect the two wires soldered to the brass plug.
- d. Remove four screws holding brass plug assembly. The lamp assembly may now be removed.
- e. Unscrew brass shield surrounding lamp and remove lamp.
- f. Insert new, preselected GE #1855 lamp.
- g. Screw lamp assembly onto brass base.
- h. Replace four screws.
- i. Replace lamp housing (2 screws).
- j. Turn Monitor ON. Allow three hours minimum warmup.
- k. Check zero (Paragraph 3.11.1.1, above).

APPENDIX C

SHUTTLE PROTOTYPE AUTOMATED MONITORING/CONTROLLER SYSTEM

PRELIMINARY FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

This document contains the FMEA for the developmental Automated Iodine Monitoring/Controller System (AIMS). Figure 1 is a reliability logic diagram which shows the system is basically a single line without redundancy provisions.



- Notes: 1. Assembly 35 is not operational during flight.
 2. Assembly 36 is for indication only during flight.

Figure 1. Reliability Logic Diagram (AIMS)

COMPONENT	FAILURE MODE	FAILURE EFFECT	REMARKS
<u>Power Supply</u> Transformer	No output to $\pm 15V$ regulator.	I_2 content of water system falls below acceptable level.	Meter reads zero.
	No output to lamp/regulator control.	Indeterminate.	Blue and red output equal zero but electronics does not recognize 0:0.
----- $\pm 15V$ Regulator	Loss of both +15V and -15V power.	I_2 content of water system falls below acceptable level.	Meter reads zero.
	Loss of -15V power.	Meter reads maximum. System will not inject I_2 .	
	Loss of +15V power	Meter reads zero. System will not inject I_2 .	
	$\pm 15V$ output out of tolerance.	Incorrect meter reading. System may or may not inject I_2 .	
	----- Lamp/Regulator Control	Loss of output to lamp.	Indeterminate.
Low lamp voltage.		No effect.	
High lamp voltage.		Decreased lamp life. Possible temperature-related errors.	
<u>Optical Assembly</u> Lamp Assembly		Loss of output.	Indeterminate.

COMPONENT	FAILURE MODE	FAILURE EFFECT	REMARKS
Photodiode	Loss of output	Decreased lamp life (Lamp/Regulator drives to maximum output). Possible temperature related errors.	

Optics and Detectors	Loss of red (631nm) output.	I ₂ content of water system rises above acceptable level.	
	Loss of blue (465nm) output.	I ₂ content of water system falls below acceptable level.	
	Red output increases with respect to blue.	I ₂ content of water system falls below acceptable level.	
	Blue output increases with respect to red.	I ₂ content of water system rises above acceptable level.	
Iodine Monitor Electronics	Fails to provide I ₂ inject command.	I ₂ content of water system falls below acceptable level.	
	Constant I ₂ inject command.	I ₂ content of water system rises above acceptable level.	
	Loss of recorder output or incorrect recorder output.	No effect. Output is used for ground checkout only.	
	Loss of meter output.	Meter indicates zero.	
	Incorrect meter output.	Meter may read high or low.	
Motor and Injector Valve Assembly	Premature operation (system constantly injects I ₂).	I ₂ content of water system rises above acceptable level.	Possible mechanisms include I ₂ leak through valve.
	Fails to operate (system will not inject I ₂).	I ₂ content of water system falls below acceptable level.	Mechanisms include motor failure, valve blockage and loss of I ₂ supply.

CONCLUSIONS

This FMEA has been conducted on a rather high level due to the preliminary nature of the design. Certain conclusions can be drawn at this stage:

- The mission effect of very-high or very-low meter readings must be defined before design effort is expended to control failures affecting the reading. Consideration should be given to designing a more comprehensive self-check feature.
- Many of the failure modes defined in this report are the result of problems unique to the prototype and test setup. To control these failure modes, it is recommended that subsequent procurements establish criteria for elimination of single failure points and that the FMEA of the system be expanded down to the part level in cases where the effect is catastrophic. This will enable more realistic risk assessment.

APPENDIX D

SHUTTLE PROTOTYPE AUTOMATED MONITORING/CONTROLLER SYSTEM

PRELIMINARY OPERATING AND MAINTENANCE INSTRUCTIONS

1.0 IODINE MONITOR DESCRIPTION

The Monitor houses the optical and electronic systems (Figures 1-1 and 1-2). The optical system comprises, in effect, an "optical bench" with the following elements in series:

- Lamp Housing. The lamp housing contains a 6-volt tungsten lamp as a source and a filtered (465 nm) photodiode to monitor the light output. A lens on the front of the housing collimates the light into the sample cell entrance window. A Microdot connector on the housing makes internal connections to the light monitoring photodiode, and a double brass ring at one end of the housing connects internally to the lamp. External leads from these connections go to the PC board below.
- Sample Cell. This is a 50-mm-long, flow-through, stainless-steel cell with two windows and two 1/4-inch (6.4 mm) water connections. The water inlet is in the end facing the lamp housing. An O-ring on the sample cell establishes a seal between the cell and the monitor housing.
- Detector Housing. A lens (facing the sample cell exit window) focuses the collimated beam into the housing, where a beamsplitter reflects light onto one detector (through a 631-nm filter), and transmits light to a second detector (through a 465-nm filter).

A movable filter (yellow) actuated by a pushbutton on the front of the monitor (Function Check) can be inserted between the sample cell and the lamp housing to simulate an iodine upscale change of approximately 5 ppm. It serves simply as an indicator of proper functioning.

The electronic system (Figure 1-3) occupies the optical bench. It receives and processes the detector signals and performs several functions:

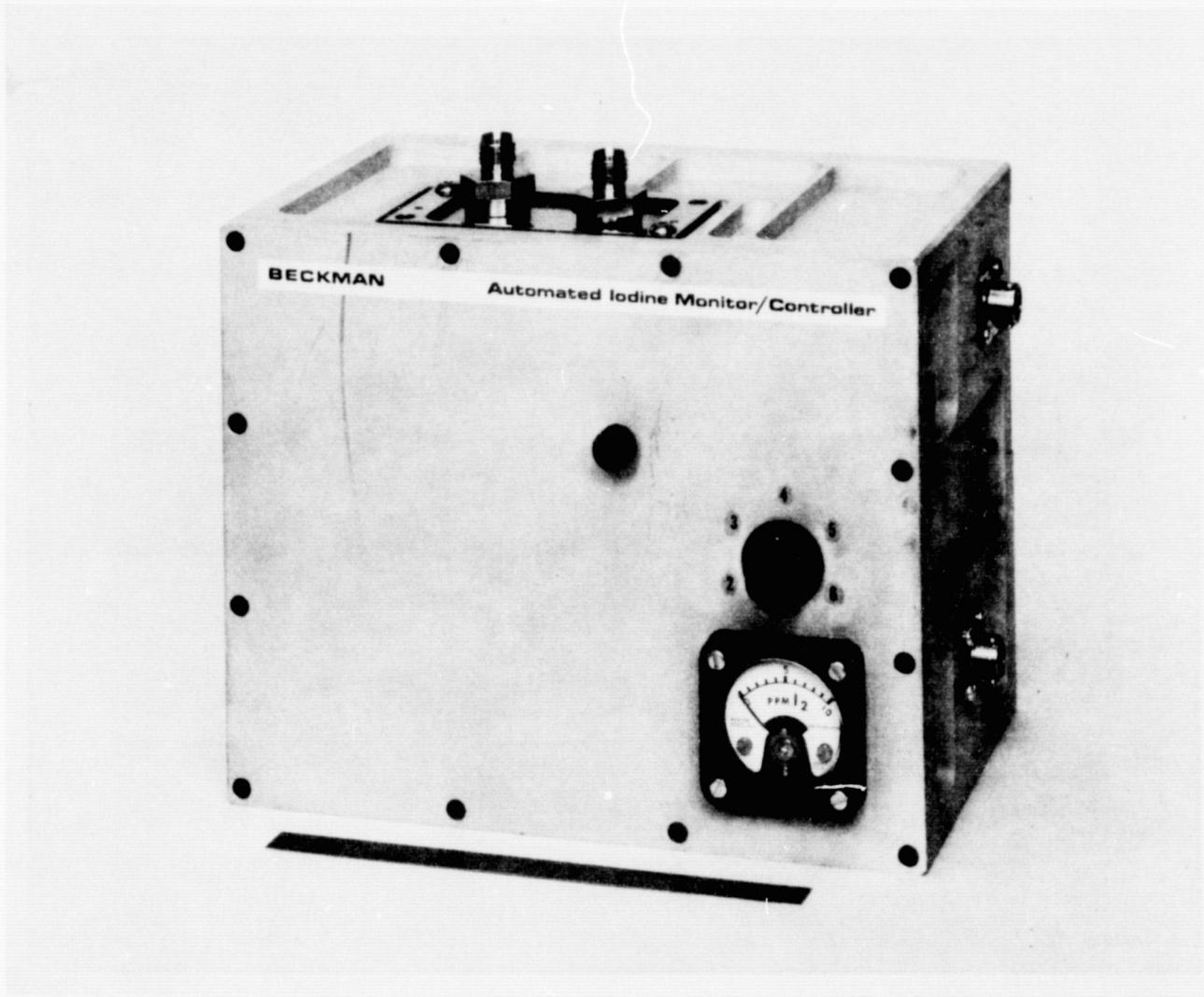


Figure 1-1. AIMS Monitor

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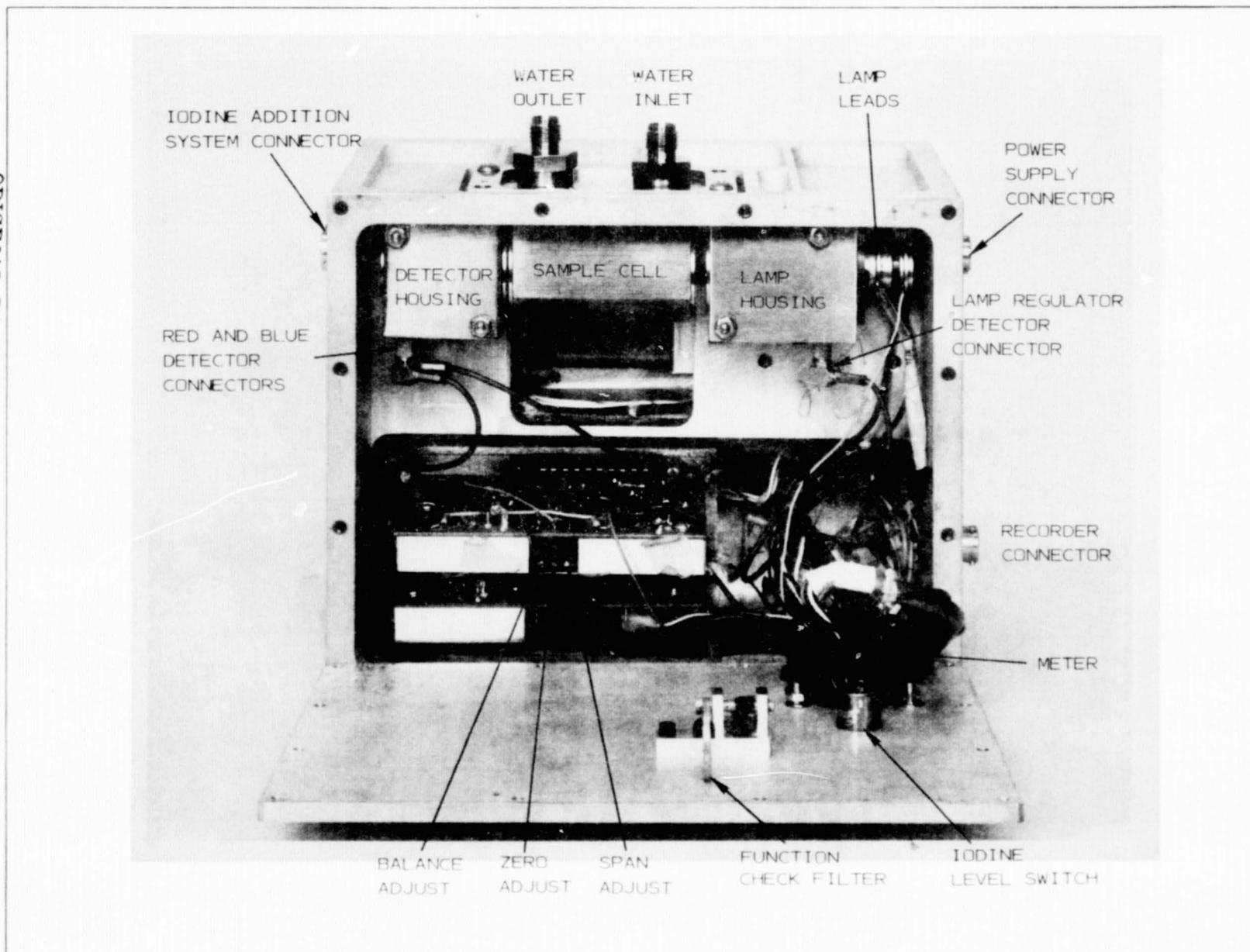


Figure 1-2. AIMS Monitor, Interior View

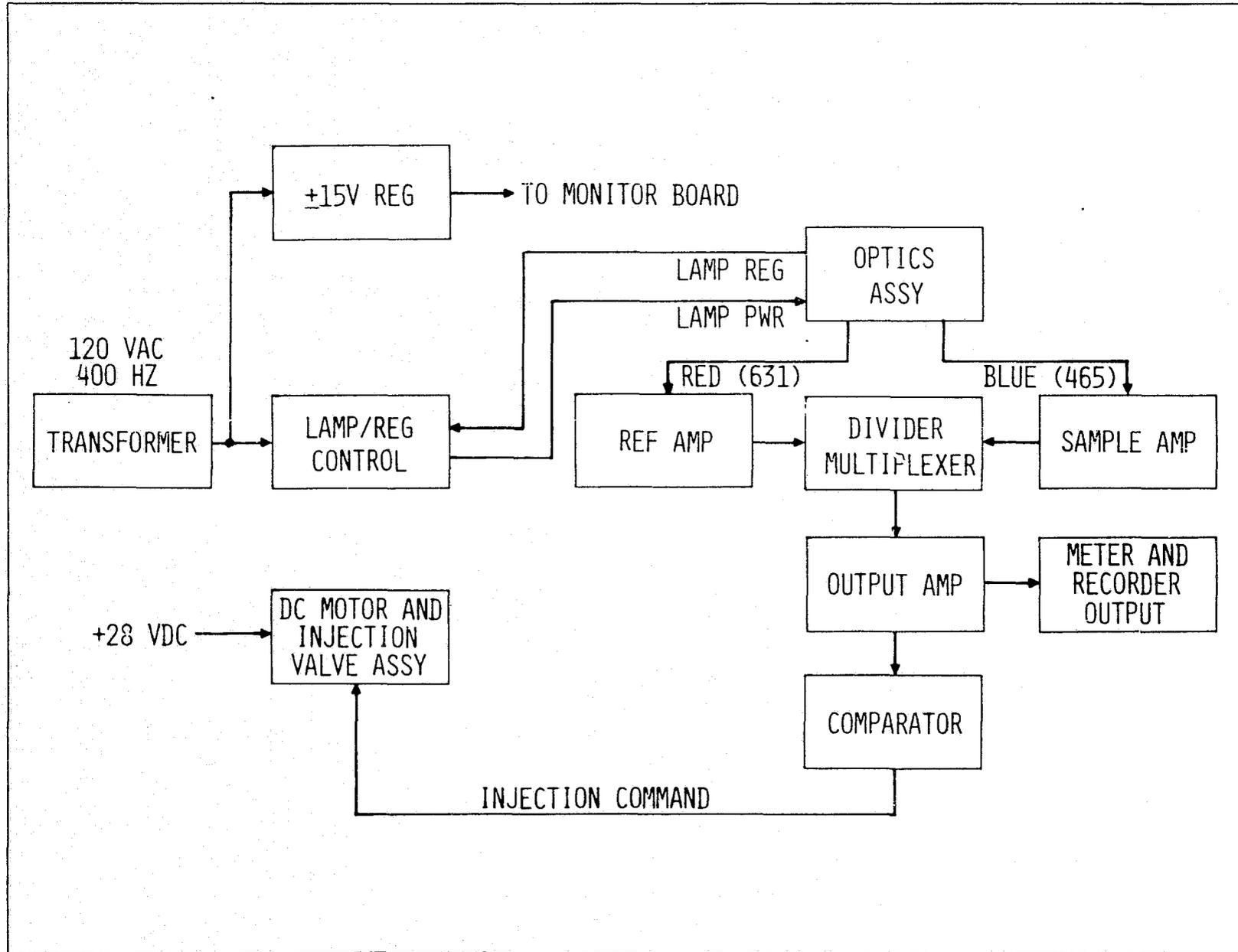


Figure 1-3. Electronic Block Diagram

- Controls the brightness of the source;
- Ratios the 631- and 465-nm signals;
- Presents the ratio on the readout;
- Provides a signal to the Iodine Addition System

The blue signal (465 nm) decreases with increasing aqueous iodine; the red signal (631 nm) remains constant. With no iodine in the water the ratio of the two signals is 1, represented on the readout by "zero ppm I₂." The ratio of these two signals varies, then, with changing concentrations of iodine.

1.1 Electrical Connections

The female connector on the power supply cables connects to the top connector on the double connector side of the Monitor. Attach the free ends, as marked, to a 110 Vac, 400 Hz power supply, and to a 16 Vdc supply as indicated by cable labels.

Connect one end of the black, blue, red, and orange cable to the single connector side of the Monitor (as indicated). (Later, the other end will be connected to the Iodine Addition System.)

1.2 Water Lines

See Figures 1-4, 1-5, and 1-6 for plumbing layout. Tubing may be 1/4-inch (6.4 mm) Teflon or stainless steel. A 3.05 M (10 ft) section of stainless steel is indicated in Figure 1-4 and shown in Figure 1-5. The pump is indicated in Figure 1-4, but is not visible in Figure 1-5 as it is behind the Monitor.

1.3 Bubble Trap

A simple bubble trap is used in this system because it is difficult to avoid all bubbles in a ground test system and they disturb the output signal. The trap is connected as shown in Figures 1-4 and 1-5. The trap is a plastic chamber divided into two parts by a fine mesh screen supported by a heavier screen. Water passes across the top part carrying any bubbles with it into

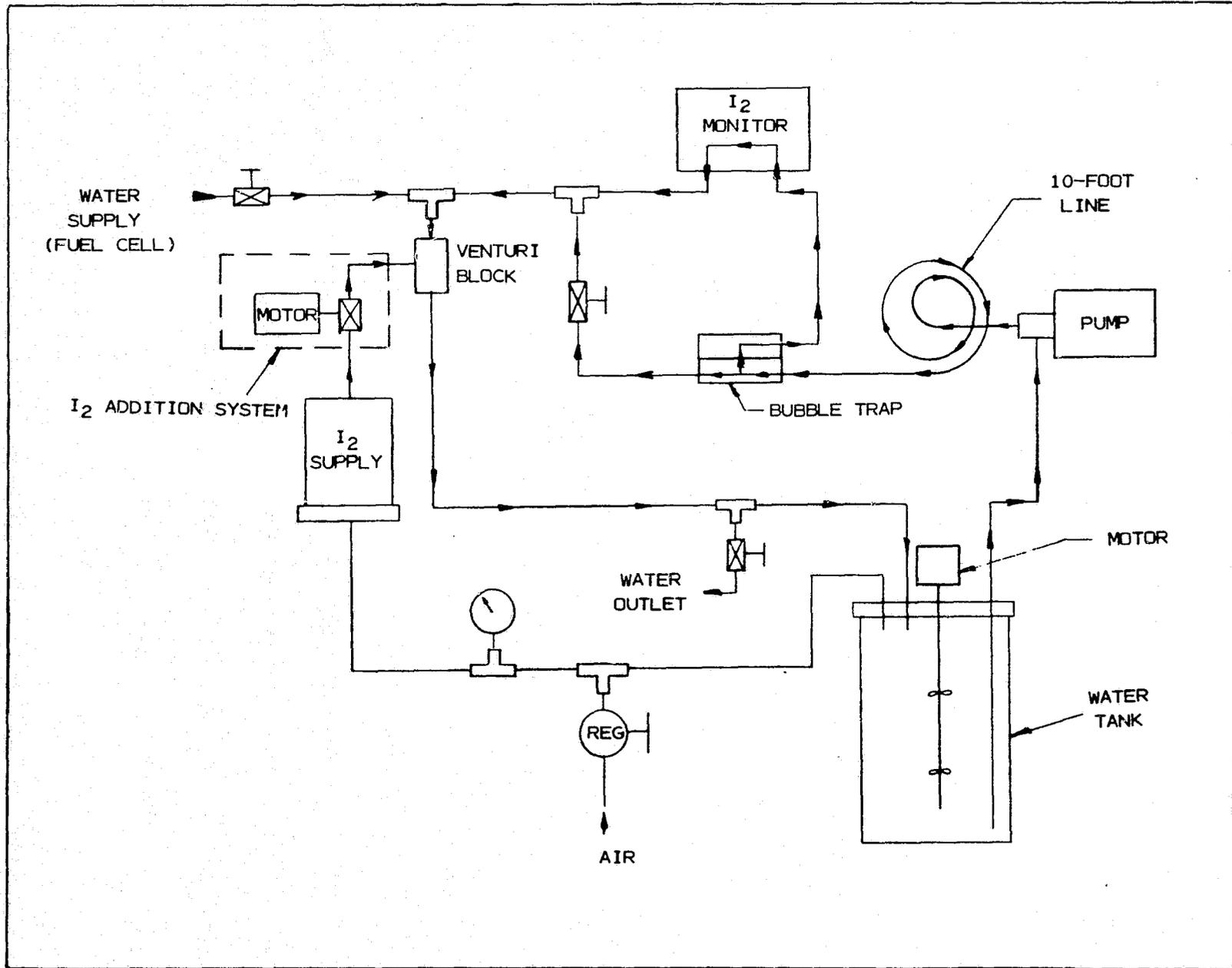


Figure 1-4. Test System

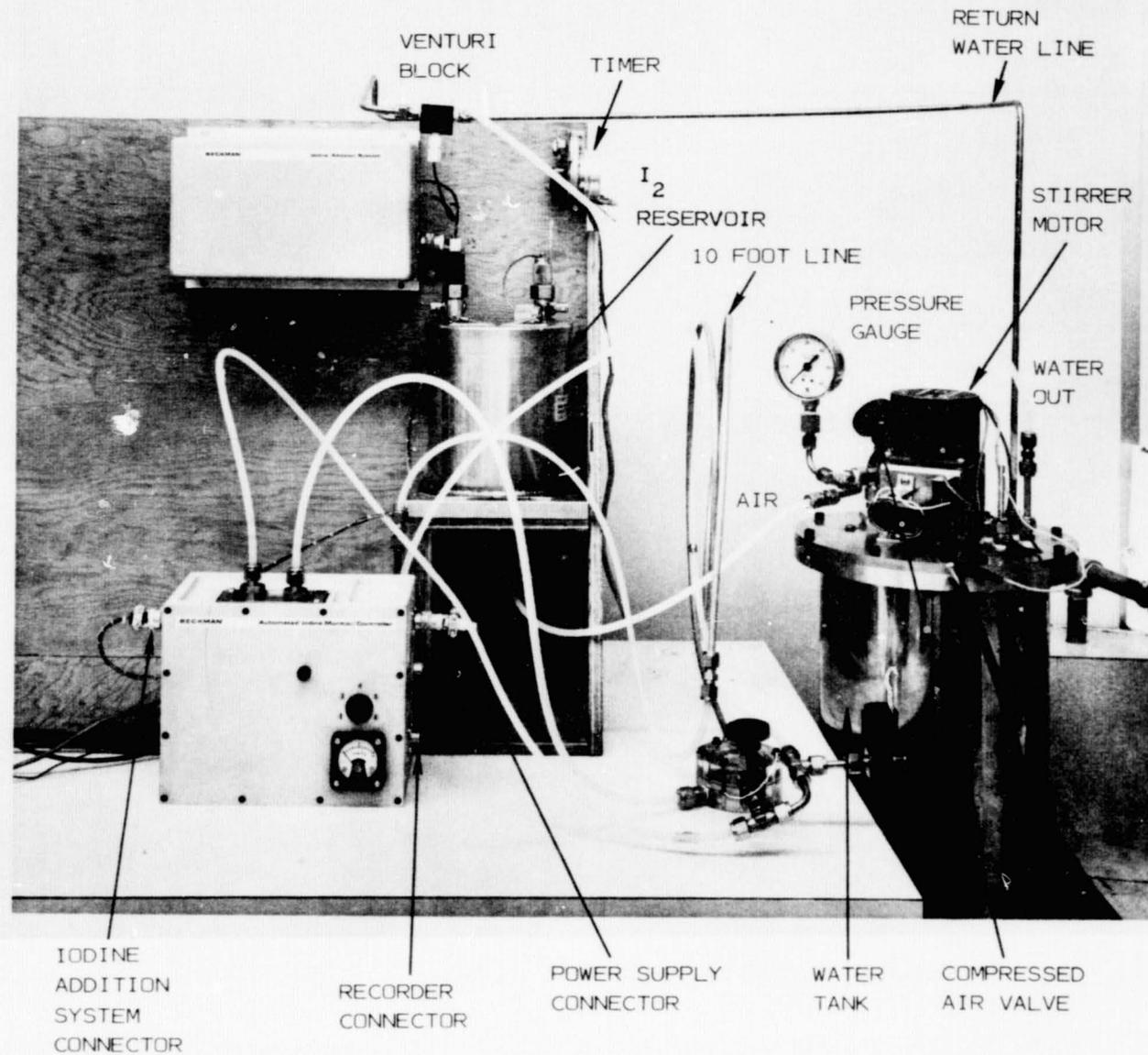


Figure 1-5. System Plumbing

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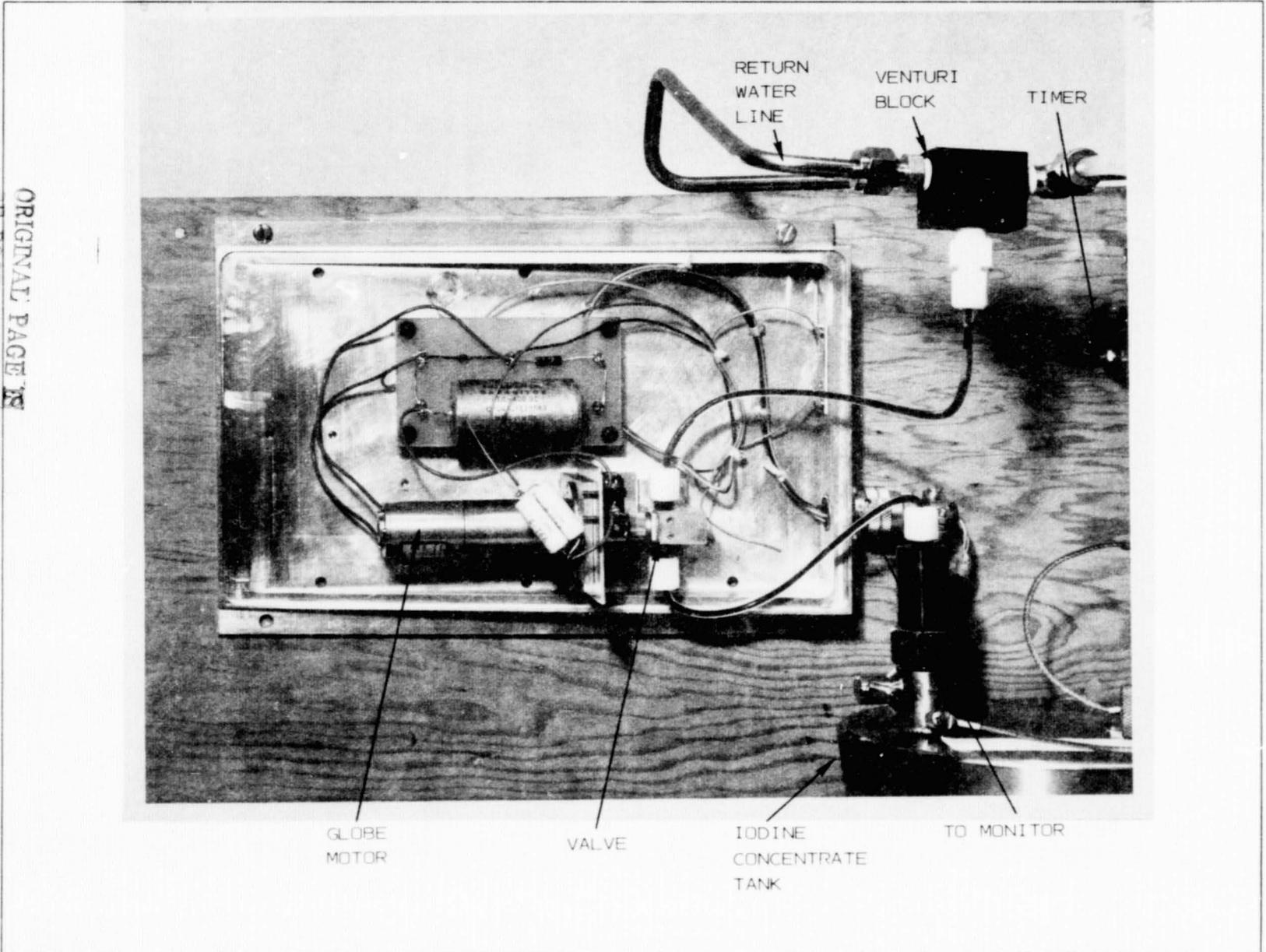


Figure 1-6. Iodine Addition System

the return water line. Part of the incoming stream passes through the screens and enters the flow-through sample cell in the Monitor. This water is bubble-free. A valve in the output side of the water/bubbler line controls the flow rate through the screens.

1.4 System Pressure Lines

Compressed air is used to vary the pressure for the pressure tests on the Monitor. Air at regulated pressures from 0 to 20 psig (0 to 138 kPa) is applied to the top of the water tank and also to the underside of the Iodine Supply Tank. It is applied at these points to maintain a pressure differential across the spring-loaded Iodine Supply Tank. Teflon tubing (1/4 inch, or 6.4 mm) is used to connect the air supply to the plate in the bottom of the Iodine Tank.

1.5 Recorder Connection

The recorder cable (male) connects between the Monitor bottom connector (on the two-connector side) and a recorder. Signal output is 0 to 100 mVdc, full scale.

1.6 Startup

The inlet and outlet tubes of the sample cell have been connected to the water tank. In order to check the Monitor's zero, it will be necessary to disconnect these water lines from the water tank and place the ends in a large beaker or flask (3 l, e.g.) of distilled or deionized water.

Turn the Monitor on. This will be done by turning on the 110 Vac, 400 Hz power supply as the Monitor does not have an on/off switch.

1.6.1 Filling Sample Cell and Bubble Trap

Start pump (for water circulation). Make certain that both the bubble trap and the sample cell are bubble-free. The bubble trap should be checked first. It is important that there be no bubbles in the lower section--the section that provides bubble-free water to the sample cell. Bubbles here can be

eliminated by tilting and tapping the bubble trap. Bubbles in the upper section will pass on out, if the valve is opened slightly. Varying the pump speed will facilitate bubble removal. Once the start-up bubbles are removed from the lower section of the trap, no more should appear during normal operation.

Having eliminated bubbles from the trap, it is next essential to make sure they are not present in the sample cell where they can degrade the signal-to-noise ratio and also cause offsets in the readout.

Remove four screws and carefully remove the sample cell for visual inspection. Keep the pump on and remove any bubbles by tilting, shaking, and tapping the cell. Replace the cell, making certain the O-ring gasket seats properly.

1.6.2 Checking Zero Stability (Plain Water Only)

When the monitor is first turned on there will be an appreciable zero offset in the upscale direction. This offset will slowly decrease over a period of several hours as the system warms up. It is desirable to monitor this drift on a recorder. When a stable reading prevails, note the zero level. It may be necessary to reset the zero. If so, follow the instructions under "Zero Check," Paragraph 4.3, starting with step d.

1.6.3 Function Check

After a stable, accurate zero is obtained, check span by depressing the FUNCTION CHECK button on the front of the Monitor. This action inserts a yellow filter into the colorimeter light path, thus simulating a color change equivalent to 5 ppm I_2 , approximately. When FUNCTION CHECK is operated, the meter should read 5 ppm I_2 when the sample cell contains plain water, and it should "add" 5 ppm to the reading of an aqueous iodine solution.

NOTE

In general, the function check will not affect the automatic Iodine Addition System, except under one unique condition. If the function check is performed immediately before the Monitor output signal would

have initiated an iodine addition event, then the apparent addition of 5 ppm I_2 (equivalent) will, of course, prevent the addition of iodine to the water supply. Since the Monitor interrogates the iodine status of the water supply once every ten minutes, there would only be a ten-minute delay in making the iodine addition.

1.6.4 Iodine Level Control

The Iodine Level Control is identified by the five position switch knob located above the meter on the front of the Monitor. When the Monitor is interfaced with the Iodine Addition System this switch can be set to control the iodine level in the water supply at 2, 3, 4, 5, or 6 ppm I_2 .

2.0 IODINE ADDITION SYSTEM DESCRIPTION

The Iodine Addition System uses a modified Hamilton Microvalve to permit iodine to flow from the Iodine Concentrate Tank (at 5 psig, or 34 kPa) to the venturi section of the water supply return line. This two-way valve is rotated by a small Globe motor. When the iodine level falls below a preset value, the Monitor sends an ON signal to a microswitch in series with the Monitor and the valve motor. The microswitch is closed for a short period once every ten minutes by a cam on a timer (part of the test setup). The valve motor has a cam that overrides the timer cam, thus ensuring that the motor will stay on for a complete revolution and that the valve will stop in the closed position. The notch in the cam has been adjusted in the present system so that the valve will undergo two complete revolutions. This provides enough iodine (200 μl at 30,000 ppm) to make a small change in the iodine level in the 39-l tank used in the test setup. If the iodine level in the water system requires no additional iodine, then the addition system remains inactive.

2.1 Iodine Reservoir Interface

Mount the Iodine Reservoir (also known as the Iodine Concentrate Tank) as shown in Figure 1-4. A Teflon tube connects one of the two valves on the tank to one end of the Hamilton valve. Since the iodine is under about

5 psig pressure (34 kPa) in the tank, the tank valve is not opened until the complete AIMS has been assembled and checked. A second length of Teflon tubing connects the other side of the Hamilton valve to the venturi block as shown in Figures 1-4 and 1-5.

If the AIMS is to be operated in a pressurized mode (air pressure), tubing is connected from the compressed air "Tee" (Figure 1-4) to the connection on the plate below the Iodine Reservoir. This will allow the Δp of the reservoir to be preserved under varying system pressures.

2.2 Water Supply Interface

The Iodine Addition System interfaces with the water supply at the venturi block site. The input water from the supply flows through the venturi and picks up concentrated iodine whenever the Addition System valve opens. This stream, carrying the iodine concentrate, is conveyed by 1/4-inch (6.4 mm) stainless-steel tubing to the water tank, where a motor driven stirrer mixes the iodine with the tank water.

2.3 Electrical Interface

The Iodine Addition System motor is powered by a 16-Vdc supply. When iodine is required by the system, a relay in the Monitor closes. This brings power from the dc supply to a microswitch. Closure of the microswitch by a cam on a ten-minute timer transmits the power to the motor in the Iodine Addition System.

One end of a black, blue, red, and orange cable has already been connected to the Monitor (Paragraph 1.1). The other end is now connected to the connector on the Iodine Addition System.

The timer cord is plugged into a 110-Vac/60 Hz outlet when it is desired to activate the Addition System. (The 16-Vdc power supply leads for the Addition System motor have already been connected per instructions in Paragraph 1.1.)

The pump is connected to a Variac (110 Vac/60 Hz) so that the voltage may be varied from 50 to 110 Vac to control the pump speed.

2.4 Pressure Interface

Compressed air is applied to the system through a regulator at 0 to 16 psig (0 to 110 kPa). The air is applied simultaneously to the space above the water in the water tank and to the bottom of the Iodine Concentrate Tank.

3.0 OPERATION

3.1 Start-up

At this point, the water lines are still connected to the flask of plain water. They should now be connected to the water tank. When operating in the normal configuration, make certain that the bottom section of the bubble trap is bubble-free. Occasionally when going from the plain water flask to the Water Tank, the bubble trap may drain to the point that air gets into the bottom section. The bubble trap may be cleared of air bubbles by tilting and tapping it. It will then be necessary to recheck the sample cell to make sure it is bubble-free.

3.2 Check List

Before adding and controlling iodine to the system, check the following:

- All plumbing connections are tight;
- The circulation pump is ON;
- The power supply for the Monitor and the Addition System are ON;
- The timer is ON;
- The recorder, if used, is ON;
- The valve on the bubble trap is open one turn;
- The function check makes a 5-ppm meter response when it is activated.

3.3 Adding and Controlling Iodine

Set the iodine level switch to the desired I₂ level. Open the iodine reservoir valve.

About seven double injections will be required to raise the iodine level by 1 ppm in a 39-l tank of water. Since injections are made at ten-minute intervals, this change will require one hour and ten minutes.

4.0 MAINTENANCE INSTRUCTIONS

4.1 Tools, Support, and Facilities Equipment

No special tools are required to service or set up the AIMS. The screws holding the sample cell and the front cover in place require a 3/32-inch Allen wrench for removal. A very small screwdriver (jeweler's) is required to adjust the zero trimpot. Ordinary wrenches are used to make plumbing connections.

A high input impedance digital multimeter should be used to make electrical measurements.

4.2 Maintenance Schedule

4.2.1 Lamp Replacement

For preventive maintenance, it is recommended that the lamp be replaced every six months.

4.2.2 Bubble Trap

The fine mesh screen in the bubble trap will gradually clog with continued use and finally, if not cleared, will cut off water circulation in the cell. Before this happens the screen will develop a darkened, less transparent color. Also, sudden 100% closure followed by 100% opening of the bypass valve will produce a signal offset when the screen is offering increased impedance to the passage of water.

The bubble trap can be easily removed and disassembled. The screen can be cleared by scrubbing with a brush and vigorous washing. An excellent cleaning is obtained by using an ultrasonic cleaner.

4.3 Zero Check

Since AIMS-IV is fully automated, no maintenance procedure is specified for a one month's mission. Between missions the following check-out is recommended:

NOTE

Do not turn Monitor off.

- a. Close valves at inlet and outlet to Monitor.
- b. Disconnect inlet and outlet lines from Monitor flow-through cell.
- c. Allow iodine-free water to flow in and out of sample cell to flush cell thoroughly.
- d. Note meter reading. It should be zero. If meter reading is off zero, remove four screws holding the sample cell in place. Carefully remove cell and look through all cell windows to see if air bubbles are present. Remove air bubbles by tilting and jarring the cell.
- e. Carefully replace sample cell, making sure its O-ring gasket seats properly. Replace four screws.
- f. Recheck zero.
- g. If meter reads above zero, remove cell, remove screws holding one window in place, and remove the window.
- h. Clean window using detergent, then thoroughly rinse. (The other window can be cleaned without removal.)
- i. Replace window, then replace cell (make sure gasket seats properly). Refill cell with iodine-free water (eliminate bubbles as in step d., if necessary).
- j. Recheck zero.
- k. If zero deviation persists, it will be necessary to reset zero. This is done by removing the front cover of the Monitor, laying it down flat. The zero trimpot is the middle one of the three in the middle of the top circuit board (Figure 2). Carefully turn the zero trimpot adjustment screw a little (CW or CCW, as required) to obtain a zero indication. The cover can be raised enough to see the meter during this adjustment. Temporarily replace the cover, using one or two screws, and observe the

zero for about three minutes. Another small adjustment may be necessary.

NOTE

Do not attempt to check zero over a long time interval with a static sample--circulating water through the cell is required for long-term thermal stability.

- l. Complete replacement of front cover.
- m. Push "Function Check." Meter should read approximately 5 ppm I_2 .
- n. Reconnect Monitor to input line only.
- o. Connect a temporary drain line to the output of the sample cell.
- p. Open input line and allow enough water to flow through the cell to remove all bubbles. Turn input flow off.
- q. Remove temporary output line and reconnect normal output line.

4.4 Changing Lamp

The following steps describe the procedure for changing the source in the Monitor:

- a. Turn Monitor off.
- b. Remove front cover.
- c. The lamp housing is located on the right of the sample cell. Remove two screws holding it in place. Do not disconnect the two wires soldered to the brass plug.
- d. Remove four screws holding brass plug assembly. The lamp assembly may now be removed.
- e. Unscrew brass shield surrounding lamp and remove lamp.
- f. Insert new, preselected GE #1855 lamp.
- g. Screw lamp assembly onto brass base.
- h. Replace four screws.
- i. Replace lamp housing (2 screws).
- j. Turn monitor on. Allow three hours minimum warmup.
- k. Check zero (Paragraph 2.3, above).

4.5 Electronic Test Points

Inside the Monitor are five colored, nonterminated leads taped together at their free ends. Four different electronic parameters may be measured by attaching a high impedance voltmeter (0-10 Vdc) to each of four colored wires (black wire is common):

- Red: The "red signal" only.
- Blue: The "blue signal" only.
- Green: The ratio signal (output signal to meter).
- White: The lamp voltage.

When the water contains no iodine, the red and blue signals should be approximately equal and measure 8 ± 1 Vdc. The output signal (green wire) should read approximately zero. The lamp voltage may read between 5.9 and 6.4 Vdc, depending on its age and the ambient temperature at the time of measurement.

The lamp voltage is nominally 6.3 Vdc. Its actual value depends, however, on the ambient temperature and may range from 5.9 to 6.4 Vdc. As the lamp ages, the voltage will slowly rise but will still fluctuate with temperature. The lamp regulator circuit can control the lamp brightness over the range of 5.9 to 7.5 Vdc.