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Demonstration of A Non-Aqueous Sewage Disposal System

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December 1973

DEMONSTRATION
OF A
NON-AQUEOUS SEWAGE DISPOSAL SYSTEM

by

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Project 15010 PBK
Program Element 1BB038

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ABSTRACT

A prototype non-aqueous wastewater treatment system utilizing recirculated mineral oil as a collection and transport media was installed and operated at the Mount Rushmore National Memorial, Rapid City, South Dakota. The project was conducted to demonstrate the feasibility and effectiveness of the non-aqueous system for application at recreational and similarly remote areas.

The non-aqueous system was evaluated for six months during the 1972 visitation season. During this period, data was collected to determine system usage rate and user waste loading and to evaluate the physical, biological, and chemical content of the flush oil as a function of system usage. System operation and reliability were also demonstrated during the test period.

The demonstration showed that the non-aqueous treatment system is effective in the collection, transport, and disposal of human waste. Odors in the oil flush media and from the treatment system presented an aesthetic problem which makes the use of this system undesirable for recreational areas such as Rushmore. System redesign to prevent organic accumulations and the routine use of an oxidizer-bactericide to eliminate odor-producing bacterial activity is required before this concept can be suitable for high-use visible recreational areas.

Water conservation is achieved when recirculated mineral oil is used to collect and transport human wastes. The waste volume is reduced by 98 percent in comparison with conventional water carriage systems.

This report was submitted in fulfillment of Project Number 15010 PBK under the partial sponsorship of the Environmental Protection Agency.

CONTENTS

CONTENTS (CONT.)

APPENDICES

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (CONT.)

SECTION I

CONCLUSIONS

1. The prototype wastewater treatment system (Aqua-Sans system) utilizing recirculated mineral oil can effectively collect, transport, and concentrate urine and fecal wastes associated with recreational and remote areas.

2. Bacterial populations in the mineral oil flush media can be controlled with commercial biocides. Bacterial analysis of oil samples showed that total coliform counts were effectively reduced to zero in most of the samples examined.

3. Odor problems resulted from inadequate oxidation of the organic particulate matter which collected in the system storage reservoir and the primary filter/coalescer. This organic matter harbored bacteria which were not controlled by commercial biocides. Odors resulted from the accumulation of organic solids and the associated bacterial growth. These odor problems must be eliminated before a mineral oil transport system will be feasible.

4. The waste sump for separating oil from wastes was improperly designed, and excessive turbulence caused finely divided organic particulates to carry over into oil storage units.

5. The mineral oil reservoir contained braces and cross members where the solids accumulate. Braces and cross members must be eliminated and bottom slopes designed to improve gravity separation of solids to a central collection point.

6. A user survey showed that 18 percent of the users objected to odors around the water closets, and 33 percent objected to the color of the oil in the water closet bowls.

7. Attapulgus clay filters and carbon filters used in series can maintain an interfacial tension above 30 dynes/cm in the mineral oil, which is required for adequate waste separation.

8. Water conservation is achieved by using recirculated mineral oil to collect and transport human wastes. The conservation of 240,000 gal. of water at Mount Rushmore during the demonstration resulted in a reduction in water pumping costs.

9. The waste volume was reduced by 98 percent in comparison with conventional water carriage systems, which resulted in significant reductions in hydraulic loads on the Mount Rushmore wastewater treatment system.

10. Approximately 15 instances of oil overflows from water closets and urinals resulted in a hazardous condition to users of the restroom facilities.

11. The incinerator furnished for the demonstration did not dispose of the concentrated wastes separated by the Aqua-Sans system.

12. The useful life of the mineral oil as a flush fluid could not be accurately predicted by the results of this demonstration. The data does, however, indicate that the mineral oil can be used as flush media longer than the five-month operating period conducted at Mount Rushmore. A proper filtering system is essential to maintain the oil in a serviceable condition.

13. Average user waste loading ranged from 0.059 to 0.085 gallons per user. The ratio of flushes per facility user was 0.95.

14. The oil loss with the waste is a function of facility usage rate and operating level of waste in the waste sump. During low use periods the oil loss was 3.8 gallons per 1000 gallons waste. The loss during high use periods was 47 gallons per 1000 gallons waste.

SECTION II

RECOMMENDATIONS

1. Solution of the odor problem will make the Aqua-Sans system feasible for use in recreational areas where conventional waste disposal methods are impractical or not feasible or where water conservation must be practiced; however, the following system design changes are recommended for all future Aqua-Sans systems.

   a. Enlarge the waste sump to provide a theoretical detention time of 3.5 times the maximum hourly flow.

   b. Design the inlet to the waste sump to eliminate turbulence.

   c. Time inflows to the waste sump from sensor flushing or reservoir pumping to occur during a no-use period.

   d. Design the flush media reservoir to eliminate surfaces and obstacles that retain solid and liquid wastes.

   e. Install a dual waste sensing system which requires a double failure before oil can be pumped from the waste sump.

   f. Eliminate the vacuum lift system.

   g. Use an accumulator with a bladder type air chamber.

   h. Use a metering pump to pump the oil out of the reservoir, through the bypass filter system, and back into the reservoir.

   i. Use a secondary waste holding tank of sufficient size to provide waste storage for several hours and install equipment to skim the oil from the top of the waste to reduce losses.

   j. Provide a blower in the reservoir vent to provide a forced draft on the reservoir.

   k. Use 4 in. diameter or larger piping for all waste piping. Long radius fittings should be used in all piping.

2. The four bypass filter elements should be changed after 16,000 connected restroom facility uses.

3. Biocide addition is dependent on the system usage rate. Biobor JF must be added in doses equivalent to 185 ppm every three days for usage rates in excess of 1,000 users per day.

4. The following studies are also recommended:

a. Develop water closet and urinal designs which will eliminate splashing and spillage problems.

b. Investigate methods for ultimate disposal of concentrated human wastes, which can include the following:

1. Incineration;
2. Aerobic digestion;
3. Anaerobic digestion;
4. Soil filters for effluent from 2 and 3 above;
5. Irrigation for effluent from 2 and 3 above; and
6. Air drying--natural and mechanical.

SECTION III

INTRODUCTION

Waste treatment systems which can collect, transport, and dispose of human wastes are needed at remote and recreational areas where conventional waste disposal methods are impractical, not feasible, or undesirable, or where water conservation must be practiced.

The Black Hills Conservancy Sub-District demonstrated the use of a non-aqueous, recirculating waste treatment system at the Mount Rushmore National Memorial Visitor Center under the Environmental Protection Agency grant program. The Mount Rushmore National Memorial Visitor Center was selected for the demonstration because (1) the National Park Service was agreeable to providing space for the system installation; (2) the summer visitation to the monument is sufficient to demonstrate the effectiveness of the system over a wide range of restroom usage rates; and (3) the system could be installed at an existing facility without making extensive permanent modifications.

OBJECTIVES

The project was conducted with the following objectives:

1. Demonstrate the feasibility and effectiveness of using a non-aqueous system for collecting, transporting, and disposing of human wastes.

2. Demonstrate that water conservation is achieved by using a non-aqueous transport fluid.

3. Determine if the recycled mineral oil can, under variable load conditions, maintain acceptable physical, biological, pathological, chemical, and aesthetic characteristics.

4. Determine the useful life of the mineral oil flush media.

5. Determine the system operating characteristics as a function of the per capita waste loading to aid in developing future design criteria.

6. Develop operational and maintenance techniques and reliability for the non-aqueous system.

7. Determine the effectiveness of incineration as a means of ultimate disposal of concentrated urine and fecal material.

SCOPE

In 1971 the Black Hills Conservancy Sub-District received an Environmental Protection Agency grant of $75,213 to demonstrate an Aqua-Sans system at Mount Rushmore National Memorial, South Dakota. The grant, awarded under the provisions of 33 U.S.C. 466 et seq., covered approximately 84 percent of the cost of the demonstration. The balance ($14,543) was provided by the Sub-District. Eligible costs for the grant included the purchase of the Aqua-Sans system and the incinerator, modification design and construction at the Visitor Center, system installation and operation, testing, system removal, and reporting.

The project was conducted in three phases: (1) Aqua-Sans system and incinerator design and fabrication; (2) modification, construction, and installation at Mount Rushmore; and (3) test and evaluation.

Chrysler Corporation Space Division designed and fabricated the Aqua-Sans system, designed the incinerator and contracted with a vendor for its fabrication, and provided technical support throughout the project.

The Visitor Center plumbing, electrical, and mechanical systems were modified during the fall of 1971. The Aqua-Sans system and the incinerator were installed in January and February of 1972. All system components were placed in the mechanical equipment room at the Visitor Center. The system was connected either to three women's water closets and three men's water closets and three urinals or to only the six men's facilities. The piping necessary for connecting the system to the toilet facilities was routed through an existing access tunnel.

The Aqua-Sans system was operated during the period between February 6, 1972, and July 31, 1972. Data was collected during this period to determine the number of facility users, the amount of mineral oil circulated, the amount of waste collected, the mineral oil characteristics, restroom user acceptance, operating and maintenance techniques, and system reliability. All work performed under phases two and three was either under the direction of or by Dakota Engineering Company, Rapid City, South Dakota.

An incinerator was installed to thermally reduce the concentrated human wastes collected in the Aqua-Sans system. A macerator pump to divert waste to the existing Mount Rushmore septic tank and sand filter treatment system was installed as a backup to the incinerator.

SECTION IV

AQUA-SANS SYSTEM

The Aqua-Sans system, pictured in Figure 1, is a non-aqueous sewage disposal system developed by the Space Division of the Chrysler Corporation (CCSD). This system, which utilizes recirculated mineral oil as the transport fluid, is shown schematically in Figure 2, while Table 1 presents a descriptive listing of the system's major components. A detailed description of the system and its operation is contained in Appendix A, Chrysler Corporation Space Division Technical Evaluation of Aqua-Sans System. Appendix B lists the technical specifications for the mineral oil, Sontex 60T.

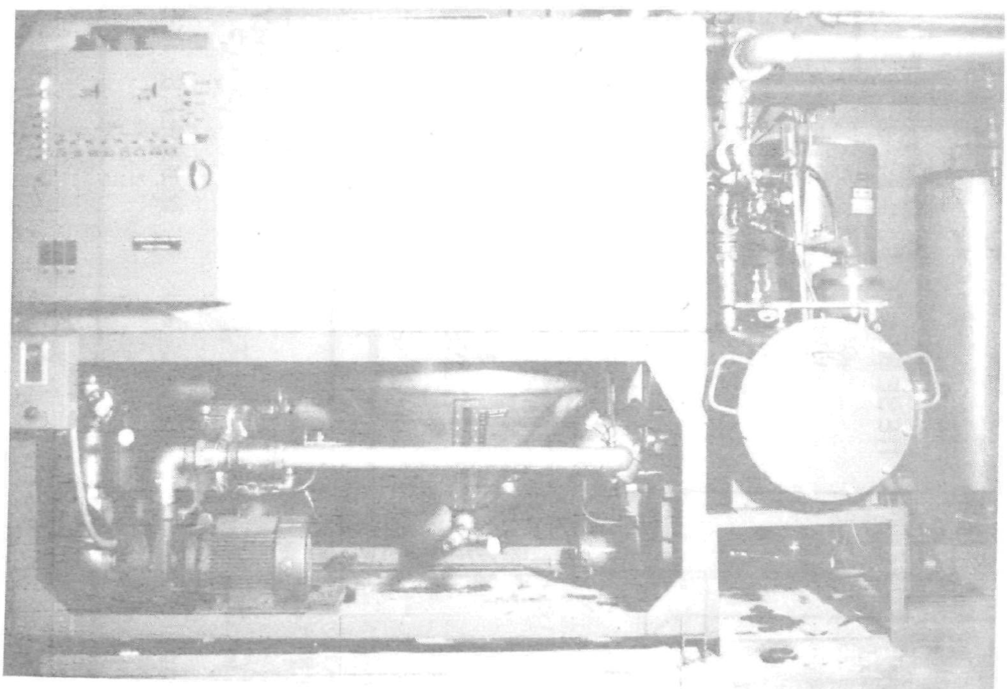


Figure 1. Aqua-Sans System

The Aqua Sans system consists of two sub-systems: flush fluid loop and waste disposal system.

FLUSH FLUID LOOP

Mineral oil flow is dependent on the toilet facility usage and the flow rate through the bypass filter system.

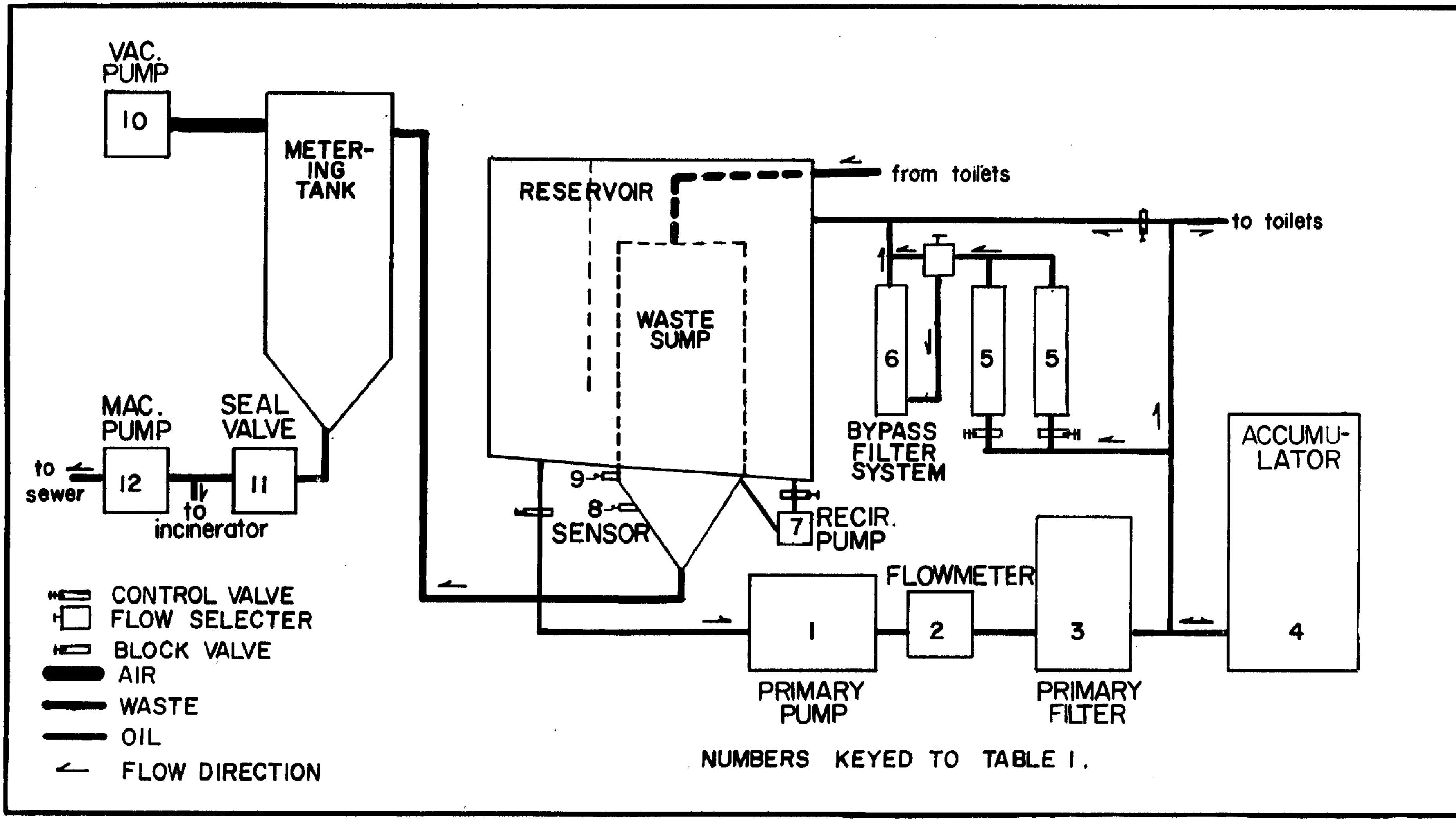


Figure 2. Aqua-Sans System--Block Diagram

Table 1. Aqua-Sans Component List

Fig. 2 Number	Component	Description	Manufacturer
1	Primary Pump	2½" x 2" Mod # C2116130	Flint & Walling, Inc.
2	Primary Flowmeter	1½" Mod # 1725C	Badger Meter, Inc.
3	Primary Filter/ Coalescer	4" x 4" Mod # V1633-B2	Velcon Filters, Inc.
	Primary Filter Elements	# I-6330 # SO-436-V	Velcon Filters, Inc. Velcon Filters, Inc.
4	Accumulator	82 gal. with separator	Flint & Walling, Inc.
5	Clay Filter Housing	1¼" x 1¼" Mod # VC-818	Velcon Filters, Inc.
	Clay Filter Elements	# CO-718CC	Velcon Filters, Inc.
6	Carbon Filter Housing		Puritan Industries, Inc.
	Carbon Filter Elements	# 6436227	Puritan Industries, Inc.
7	Sediment Pump	1200 gph Mod # 390 2690	Sears
8	Waste Sensor	Electr-O-Probe Mod # B-07-SS	CE In-Val-Co Combustion Engineering, Inc.
9	Waste Overfill Sensor	Same as 8	Same as 8
10	Vacuum Pump	3/8" Mod # 1022-V-2-G272X	Gast Manufacturing Corp.
11	Waste Transfer Seal Valve	3" flexible valve	Flexible Valve Company
12	Macerator Pump	1--1½" x 1" Mod # 406-M-1 2--4" x 1¼" Mod # SPG-150	Oberdorfer Pump Division Hydr-O-Matic Pump Co.

Primary Flow

Upon demand, resulting from the flushing of a connected toilet, mineral oil from the accumulator was delivered to flush the wastes from the toilet and transport these wastes to the Aqua-Sans system through a 4 in. diameter sewer pipe.

The oil-waste mixture entered the top of the waste sump through a vertical inlet and passed through an 8 in. air gap before meeting the oil surface in the waste sump. Here the waste, with a specific gravity close to 1.0, settled, while the oil (specific gravity 0.83) overflowed into the storage reservoir for treatment and reuse in subsequent flushes. Settled wastes collected in the bottom of the sump for transport to the incinerator for ultimate disposal.

The oil storage reservoir had a maximum oil storage of 250 gal., and the waste sump 100 gal. above the oil-waste interface. The total oil volume in the system, including storage in the accumulator, pipes, and filters, was 360 gal. The reservoir and waste sump were sized to provide a 10-minute theoretical detention time at a flow rate of 30 gpm.

Initially the oil, prior to overflowing into the storage reservoir, was passed through a cone screen for preventing large solids carryover. The oil was then passed through a horsehair-fiberglass gross coalescer (which was placed horizontally in the reservoir) for removing water from the oil. During the demonstration period (see Section VIII, Reservoir and Waste Sump), the cone screen was replaced with a cone-shaped horsehair-fiberglass coalescer. A bag filter was also installed at the top of the sump, and the horsehair-fiberglass gross coalescer removed. Figure 3 shows a sectional view of the reservoir and the modifications which were performed.

The primary pump delivered oil from the storage reservoir through the accumulative flow meter and primary filter to the accumulator and maintained the pressure in the accumulator between 30 and 50 psig.

The primary filter contained three cloth-covered filter elements for coalescing water and removing waste particles larger than 20 microns from the oil.

A small recirculating pump was provided to pump oil and water from the low end of the reservoir to the waste sump.

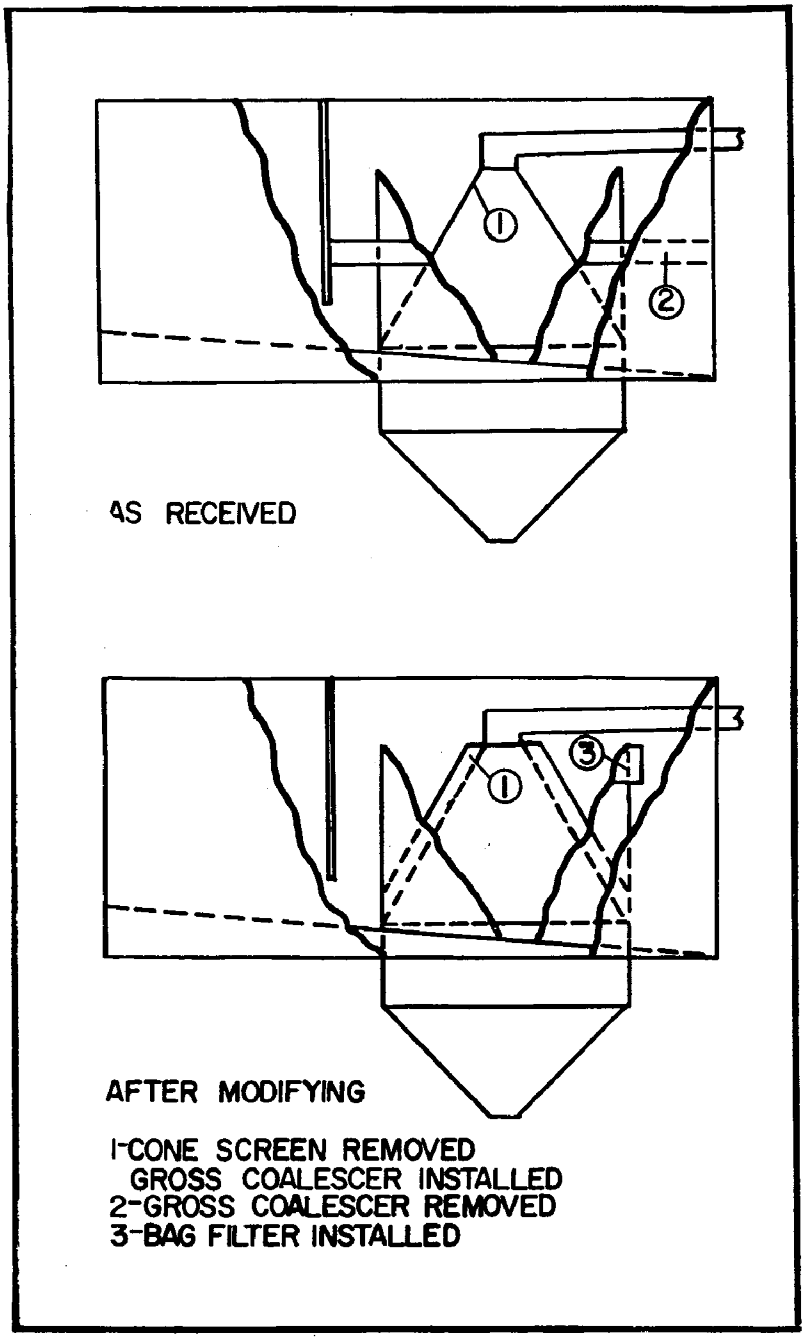


Figure 3. Aqua-Sans Reservoir
Sectional View Showing Modifications (Not to Scale)

Bypass Flow

A bypass filter system containing one attapulgus clay filter was supplied with the system for removing color, dissolved contaminants, and finely divided suspended solids from the oil. After several modifications, the bypass filter system consisted of two attapulgus clay filters, one dual element carbon filter, and a rotometer-type flow rate indicator. The filters were arranged with the clay filters in parallel with the dual-element carbon filter in series and downstream of the clay filters. Each clay filter was rated at 1 gpm and the carbon filter was rated for 2 gpm. Manual control valves were used to control the oil flow through the bypass filters (see Figure 2).

WASTE DISPOSAL SYSTEM

The waste separates from the mineral oil and settles to the bottom of and is stored in the sump for later disposal. Two capacitance-type sensors detect the oil-waste interface as it rises in the waste sump; one is located at the 12 gal. level and the other at the 35 gal. level.

When approximately 12 gal. of waste is collected in the sump, the lower waste sensor is actuated, causing the waste transfer valve to close and the vacuum pump to operate. The vacuum pump produces a vacuum in the metering tank, which causes the waste in the waste sump to flow to the metering tank. A float switch in the metering tank shuts the vacuum pump off when approximately 10 gal. of waste has entered the metering tank.

The waste flow from the metering tank depends on the method of disposal being used in conjunction with the Aqua-Sans system.

Incinerator

The Aqua-Sans system was designed for automatic operation with the primary method of waste disposal being incineration. In the "incinerator mode," the waste was delivered by gravity to the incinerator through a 3 in. diameter sewer line. Approximately one hour was required to burn the waste. Following the dump to the incinerator:

(1) the recirculating (sediment) pump came on for approximately 5 seconds to pump any liquid waste in the low end of the reservoir to the waste sump;

(2) the sensor flush selenoid valve opened and allowed oil from the high pressure system to spray past the two waste sensor probes to remove any waste which may have collected on the probes; and

(3) the water flush valve opened, allowing water to spray into the metering tank and over the cone screen in the sump. The water flush was removed at the same time the cone screen was removed.

The waste overfill sensor (upper sensor) actuates when approximately 35 gal. of waste has accumulated in the sump. This actuation causes the operating mode to automatically switch to the "sewer mode." The waste in this mode was transferred from the metering tank through a macerator pump to the Mount Rushmore sewer system.

Backup Disposal

Because of incinerator failure (see Section V), the primary mode of operation used during the demonstration period was "sewer mode."

The system was supplied with an Oberdorfer macerator pump with a 1½ in. inlet and a 1 in. outlet. This pump was designed to pump wastes from the waste sump to the Mount Rushmore system when the incinerator was not operating or waste was collecting at a faster rate than the incinerator burn rate. Tests performed with water in the sump indicated that the 1½ in. pump could pass sanitary napkins. Similar tests with plastic covered disposable diapers plugged the 2 in. waste pipe connected to the 1½ in. pump inlet. Inlet modifications did not eliminate the problem. The Oberdorfer macerator pump was replaced with a larger pump in June, 1972.

A new macerator pump, manufactured by Hydr-O-Matic Pump Company, was installed downstream from the waste transfer valve. The metering tank with a blind flange installed on the downstream side of the waste transfer valve is shown in Figure 4. The new macerator was connected where the blind flange is shown in Figure 4. The waste transfer valve was left in place to isolate the macerator pump if maintenance was required or plugging occurred.

Several alarms were installed in the control system. The waste overfill sensor actuated a waste overfill alarm. If the automatic cycle operated properly, the alarm cleared approximately 2 minutes after the waste level dropped below the sensor. A tank overfill and a long dump alarm were also provided on the metering tank.

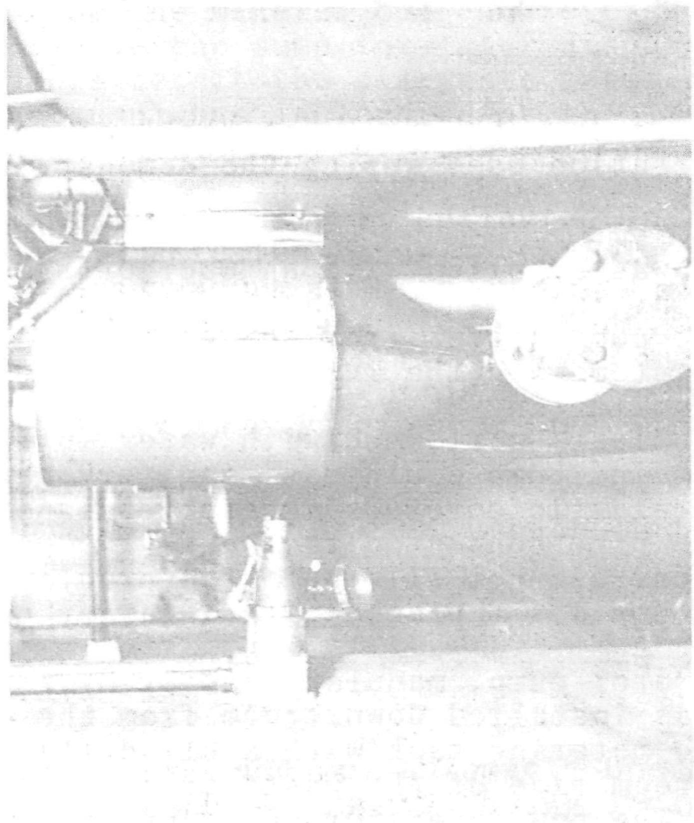


Figure 4.
Metering Tank and Waste Transfer Valve

SECTION V

INCINERATOR

A two-stage incinerator, designed to burn 10 gal. of concentrated human waste per hour, was furnished with the Aqua-Sans system as the primary method of disposing of the waste collected in the Aqua-Sans system.

Incinerator draft problems were encountered during the checkout of the incinerator in February, 1972, so no burns were made in the automatic mode. During the months of February, March, and April, approximately 25 trial burns were conducted, with water added to the burn pot, while trying to obtain a draft on the incinerator. A draft inducer was installed in March, which resulted in a marginal draft condition during portions of an operating period.

In April it was observed that the insulation in the primary chamber was starting to flake off. At about this same time, the insulation in a similar incinerator being tested for the Navy failed because of flaking. Apparently the unoxidized gases caused a thin layer of the exposed insulation to "flux" (become hard), flake off, and expose a new layer of insulation. During disassembly of the incinerator, it was found that the insulation in the secondary chamber was exhibiting the same deterioration as that in the primary chamber.

Approximately six complete waste burns were conducted in addition to the trial burns. No data was collected on the residue (ash) remaining after a burn.

The incinerator operation was discontinued because of the design problems and the time factor involved for modifying the incinerator; and all collected wastes were pumped to the Mount Rushmore sewer system.

SECTION VI

FACILITIES

The Visitor Center plumbing, electrical, and mechanical systems were modified to accept the Aqua-Sans system and the incinerator. Details regarding the modifications are presented below.

PLUMBING MODIFICATIONS

Connected Facilities

As shown in Figure 5, the six water closets, numbers W1-W3 and M1-M3, and the three urinals, numbers U1-U3, were connected to the Aqua-Sans unit. A valve header was installed to enable valve control of either the backup water supply or the Aqua-Sans system to either the three connected women's water closets, the three connected men's water closets and urinals, or all nine connected facilities.

Three-port, ballcentric valves were placed between W3 and W4 and also between M3 and M4. Ball valves were placed in the urinal drain pipes. These valves could be positioned in the drain to the Aqua-Sans system when oil was to be used as a flush fluid and to the Mount Rushmore system when water was to be used.

The waste and supply pipes for the water closets were located in a 2-foot wide divider room between the men's and women's restrooms. The piping to the urinals was located in a 5-foot high crawl space under the men's restroom. Access to the divider room was through an access tunnel from the furnace room.

Material Compatibility

The use of mineral oil as a flush fluid requires that special attention be given to materials used for pipes and valves. The "Royal" flushometer valves built by Sloan Valve Company were replaced by Sloan's "Naval" valves, which were modified to eliminate materials not compatible with mineral oil.

Flush Counts

Flow switches were installed in the individual supply pipe to each of the six connected water closets. Each flow switch was

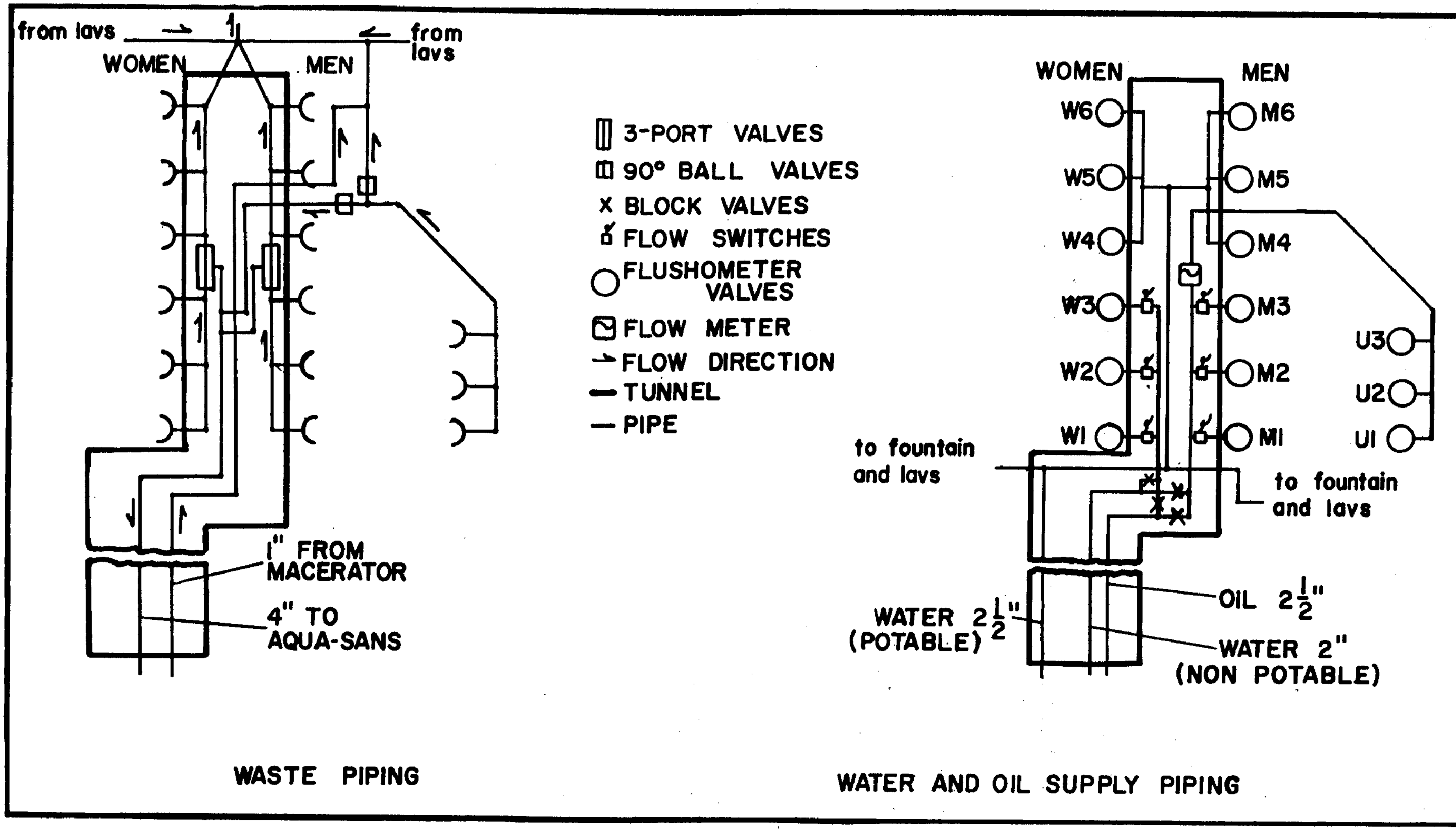


Figure 5. Visitor Center Restroom Plumbing--Line Diagram.

connected to an electromechanical counter. Flush fluid through the supply pipe to a water closet caused electrical contacts in the flow switch to close, which in turn caused the connected counter to register one count.

The total oil flow to the urinals was recorded by a cumulative flow meter placed in the urinal supply pipe.

ELECTRICAL MODIFICATIONS

Electrical power requirements for the Aqua-Sans were two 50-ampere, 115 VAC circuits. The incinerator required a 30-ampere, 115 VAC circuit. Three separate power receptacles were installed to provide power to the Aqua-Sans system and the incinerator.

EXHAUST SYSTEM MODIFICATIONS

The incinerator exhaust pipe was an 8 in. pipe capable of withstanding temperatures up to 700°F.

The chimney at the Visitor Center is constructed of stone with a 16 x 21 in. clay tile liner rated for 2000°F. An adapter was constructed and installed to connect both the incinerator exhaust pipe and the furnace exhaust pipe into the chimney.

SECTION VII

EVALUATION PROCEDURES

The following procedures were employed during the demonstration period.

MINERAL OIL TESTS

Bacteria Counts

The laboratory procedure for determining coliform bacteria counts is listed in Appendix C. The listed procedure is a modification to the Eosin Methylene Blue (EMB) presumptive test for coliform bacteria outlined in "Standard Methods for the Examination of Water and Wastewater."(1) The results of the tests were used to determine dose requirements and to evaluate the effectiveness of biocides.

Exact colony counts were not obtained since the goal was to maintain a zero bacteria count in the oil.

Interfacial Tension

The interfacial tension (IFT) of the Sontex 60T mineral oil was used as an indication of the effectiveness of the filter systems in removing oil contaminants.

Initially, IFT was determined using the oil rise on filter paper strips, as outlined in Appendix C-2-1. The oil rise method was found to be both inaccurate and impractical, however; so an Interfacial Tensiometer was obtained for IFT determination. The standard method listed in ASTM:D971-50, "Interfacial Tension of Oil Against Water by the Ring Method,"(2) was used for all IFT measurements made after June 1, 1972. Appendix C-2-2 discusses ASTM:D971-50.

Color

The color of the mineral oil was determined using an Alpha-Platinum-Cobalt scale color comparitor. The color scale used on the "Hach" color comparitor ranged from 0 to 100 color units. Tap water was used as the comparison fluid, with unused Sontex 60T having a color of 0 units.

MINERAL OIL USAGE

Usage Rates

The totalizing flow meter located downstream from the primary pump in the oil supply pipe was read at various intervals to establish average and peak oil usage rates.

Oil Loss

Oil loss was attributed to (1) leaks in the piping; (2) oil retained in filters after filter replacement; (3) oil spillage including spillage while handling and resulting from occasional overflow of urinals or water closets; (4) oil lost from testing; and (5) oil carryover with the waste. The oil lost with the waste was of greatest concern since the waste was being pumped to the Mount Rushmore septic tank-sand filter treatment plant. It was not possible to measure the total oil lost with the waste. The average oil lost per waste dump was determined for several different time intervals by calculating oil balances for the periods when it was possible to account for all oil added to or lost from the system.

PER CAPITA WASTE LOADING

The determination of the per capita waste loading required data on the number of connected facility users and the amount of waste collected from these users.

Restroom Users

A method of counting the number of connected facility users which was not subject to vandalism by the users was needed. The number of flushes for the six connected water closets was counted separately and the total oil flow to the three urinals was recorded. User counts were made during several time intervals and the ratio of the number of flushes per user was determined to provide a conversion factor for determining the number of users from the flush counts.

Waste Collected

Electromechanical counters were used to record the number of waste dumps to the incinerator and to the sewer.

The amount of waste per dump was determined to be 10.5 gal. ± .2 gal. prior to the start of the demonstration period.

The per capita waste loading (gallons per day per person) was determined by dividing the waste collected (gal.) over a time interval by the number of connected facility users during that time period to give gal. waste per person. It should be noted that there are several restrooms at Mount Rushmore, so no correlation is made for waste per monument visitor.

PUBLIC ACCEPTANCE OF THE MINERAL OIL AS A FLUSH FLUID

A survey was conducted in which the restroom users were asked to fill out the questionnaire shown in Figure 6. The questionnaires were distributed in the men's restroom after the women's facilities were disconnected from the Aqua-Sans system. Boxes with the questionnaires were hung near the three urinals and the three water closets for specified periods of time, which were usually two hours. The number of flushes were recorded for that time period and the questionnaire return rate per user was determined.

NON-AQUEOUS SEWAGE DISPOSAL SYSTEM DEMONSTRATION PROJECT

The toilet facility you just used is connected to a closed-loop sewage disposal system which uses oil instead of water for a flush fluid. You can assist in the evaluation of the system by completing this card and dropping it in the box at the restroom exit.

	Satisfactory	Not Satisfactory
Flush fluid color	☐	☐
Odor	☐	☐
General appearance and operation	☐	☐

Comments: ______________________________

____

This project is sponsored in part by the Environmental Protection Agency, the National Park Service, and the Black Hills Conservancy Sub-District.

Figure 6. Public Acceptance Questionnaire

The questionnaire shown in Figure 6 was used to determine the public acceptance of the use of a non-aqueous flush fluid which differed in appearance from water and occasionally produced odors not usually present in restrooms. Specific items included in the questionnaire were (1) flush fluid color, (2) odor, and (3) general appearance and operation. A section was also provided for comments.

MAINTENANCE AND RELIABILITY

Complete records in the form of a log book were kept during the demonstration on system reliability, maintenance requirements, down time, and repairs.

WASTE COMPOSITION

Concentrated waste samples were collected from the 1 in. waste pipe to the sewer. Each sample was analyzed for total suspended solids and volatile solids in accordance with Standard Methods.[1]

SECTION VIII

EVALUATION RESULTS

The Aqua-Sans system was operated between February 8, 1972, and July 31, 1972, with two shutdown periods, May 15 through June 8 (to obtain restroom attendants) and June 10 through June 27 (to replace macerator pump). During this period, the system was evaluated using the evaluation procedures explained in Section VII. The system evaluation results are presented under the following subheadings: (1) Mechanical System Performance, Maintenance, and Reliability; (2) Oil Maintenance and Quality; (3) Restroom Facilities; (4) Design Criteria; and (5) Water Conservation. Appendix A provides the CCSD review and analysis of test data from the system evaluation.

MECHANICAL SYSTEM PERFORMANCE, MAINTENANCE, AND RELIABILITY

Pumps

(a) Primary Pump. A total of 548,850 gal. of oil were circulated during the operating period. Soon after start of the operating period, the shaft seal began to leak a few drops of oil a day. The leak remained constant during the demonstration period, and no maintenance was required. No other problems were encountered with the primary pump.

(b) Vacuum Pump. The Gast vacuum pump was required to vacuum lift the waste from the sump into the metering tank. The average operating time was 10.5 seconds. The pump was supplied with a wick type oiler which was designed for longer operating periods. As a result of improper lubrication, vane sticking problems caused vacuum pump failure on three different occasions during the last two weeks of operation. Field repairs, which consisted of pump dismantling, cleaning, and reassembling, were performed after each failure.

(c) Macerator Pump. The system was supplied with an Oberdorfer macerator pump with a 1½ in. inlet and a 1 in. outlet. The small inlet resulted in plugging problems; and during the June shutdown, the Oberdorfer macerator pump was replaced with a 1½ hp. Hydr-O-Matic macerator pump which had a 4 in. inlet and a 1¼ in. outlet. During the June 28-July 31, 1972, operating period, the Hydr-O-Matic macerator pump transported approximately 3,300 gal. of waste with no pump malfunctions.

Reservoir and Waste Sump

A brown, flocculent residue of finely divided particulate matter began to accumulate in the oil reservoir after two weeks of operation. The residue also collected on the cone screen in the waste sump and on the horizontal gross coalescer. Turbulence at the entrance to the waste sump was the primary cause of this waste carryover. In addition, operation of the recirculation pump and the sensor flush contributed to this problem. The cone screen and the gross coalescer were removed May 14, 1972, and a smaller coalescer was installed in place of the cone screen. Removal of the gross coalescer eliminated a large collection area for the waste; however, the internal cross braces and the inadequately sloped reservoir bottom continued to provide collection surfaces and traps for the particulate matter.

Cumulative flush oil flow, facility flushes, and waste collection are shown in Figure 7. Interval oil flow, flush count, and waste collection data are presented in Tables 2 through 5. Data were collected at one- to four-day intervals for February 6 through May 15, 1972, and at daily intervals for the remainder of the operation. Hourly data were collected for oil flow and flush counts between July 6 and July 31, 1972, when the Aqua-Sans unit was connected to only the men's restroom. Hourly flush oil flow data are presented in Table 6.

The maximum facility usage occurred between 2130 hours on July 2 and 2130 hours on July 3, 1972, with 9300 gal. of flush oil being recirculated. During this period, a total oil flow of 11,120 gal. was recorded. During the 19-hour period when the restrooms were open for use, the six water closets and three urinals were flushed a total of 1766 and 1178 times, respectively, with an average flush flow of 485 gph. This flow demand and similar high demands for the June 28 through July 5, 1972, period (Table 4) resulted in insufficient oil detention time; and as a result, the water content of the oil was above saturation during portions of this period (see page 43).

The three women's water closets were switched to water flush the morning of July 6, 1972, leaving only the six men's facilities connected to the Aqua-Sans system. The peak daily usage occurred July 26, 1972, with 3260 gal. of oil being used for 546 water closet and 1227 urinal flushes, with an average flush flow of 172 gph. The peak hourly flush flow on July 26 was 378 gal. As shown in Table 6, peak hourly flows exceeded 300 gal. 18 times between July 6 and July 31, 1972, with the peak hourly demand of 385 gph occurring July 30, 1972.

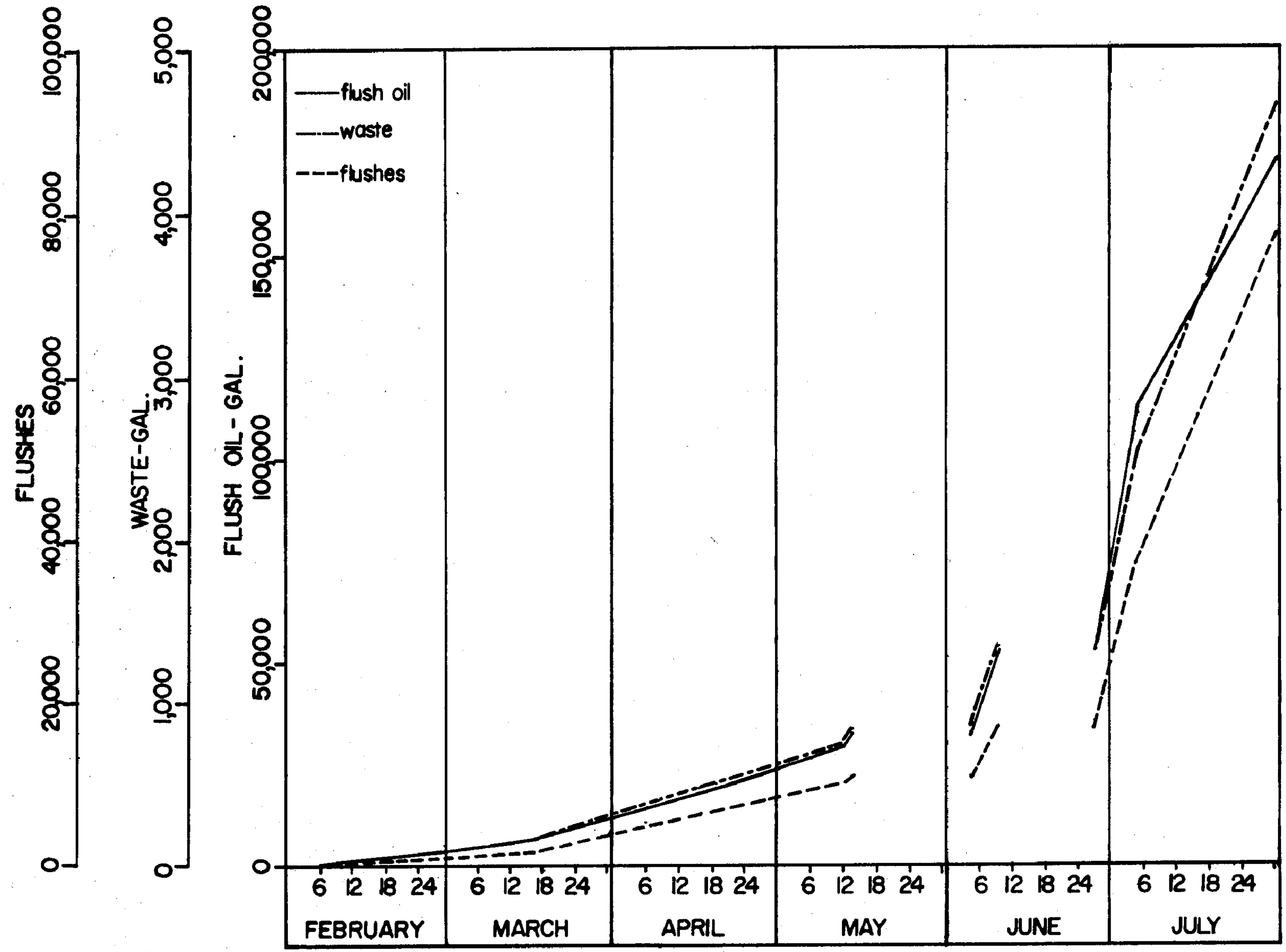


Figure 7. Cumulative Flush Oil Flow, Water Closet and Urinal Flushes, and Waste Collection. February 6 Through July 31, 1972

Table 2. Oil Flow, Flush Count, and Waste Collection Data. February 6, 1972, Through May 15, 1972, Operating Period.

Date	Time	Interval Oil Flow (Gal.) Total	Interval Oil Flow (Gal.) Flushing	Interval Water Closet Flushes	Interval Urinal Flushes	Interval Waste (Gal.)
2/6	1430	0	0	0	0	.0
2/10	0630	7,300	200	29	59	8.5
2/13	1500	7,540	495	77	143	10.5
2/15	0600	4,255	155	25	32	10.5
2/19	1445	5,460	610	102	116	10.5
2/21	0830	6,390	950	160	175	16.5
2/25	1000	8,210	495	91	43	12.5
2/28	1000	4,500	645	108	117	18.0
3/1	0745	3,130	200	31	26	4.0
3/3	0700	2,685	115	17	33	2.0
3/6	0715	4,000	570	94	108	20.0
3/10	0645	6,075	520	96	42	3.5
3/13	0700	5,940	890	144	185	27.5
3/15	0700	3,355	220	35	48	7.0
3/17	0630	3,930	275	44	37	7.5
3/20	0630	6,700	1405	231	234	44.0
3/24	0630	6,470	775	131	178	15.0
3/27	0700	6,235	1190	201	206	31.5
3/28	1730	3,920	640	105	129	17.0
3/31	1400	6,730	990	165	183	25.0
4/3	0715	7,960	1885	318	325	47.0 (est)
4/7	0730	9,350	1360	231	226	33.0 (est)
4/10	0645	6,790	1460	244	268	37.0
4/14	0930	8,820	980	158	210	37.5
4/17	0700	6,585	1575	263	302	38.0
4/21	0700	5,415	805	130	171	24.0 (est)

Table 2. (Cont.)

Date	Time	Interval Oil Flow (Gal.) Total	Interval Oil Flow (Gal.) Flushing	Interval Water Closet Flushes	Interval Urinal Flushes	Interval Waste (Gal.)
4/24	0630	5,635	1745	299	276	49.5
4/28	0700	5,955	1095	177	218	29.0
5/1	0730	8,125	2165	379	297	59.0
5/5	0700	9,270	1105	180	116	39.0
5/8	0630	6,010	1900	326	298	42.0
5/12	0745	8,310	1855	315	286	49.0
5/14	2230	10,980	3175	549	460	73.0

Note: Three women's and six men's restroom facilities connected to Aqua-Sans.

Example of Interval data: Interval oil flow--7300 gal. total oil flow between 1430 hrs on 2/6 and 0630 hrs on 2/10.

Table 3. Oil Flow and Flush Count Data. June 5, 1972, Through June 9, 1972, Operating Period.

Date	Time	Interval Oil Flow (Gal.) Total	Interval Oil Flow (Gal.) Flushing	Interval Water Closet Flushes	Interval Urinal Flushes
6/5	0915	0	0	0	0
	1400	2,153	1430	248	191
6/6	0600	4,865	2880	502	369
	1530	4,514	3445	593	480
6/7	1420	6,501	3495	600	495
6/8	0500	3,954	1910	322	300
	1400	4,356	1665	273	299
6/9	0530	4,753	1780	302	267
	1400	4,691	2325	402	315
	2000	1,994	1155	197	169

Note: Three women's and six men's restroom facilities connected to the Aqua-Sans.

Example of Interval data: Interval oil flow--2153 gal. total oil flow between 0915 and 1400 hrs on 6/5.

Table 4. Oil Flow, Flush Count, and Waste Collection Data. June 28, 1972, Through July 5, 1972, Operating Period.

Date	Time	Interval Oil Flow (Gal.) Total	Flushing	Interval Water Closet Flushes	Interval Urinal Flushes	Interval Waste (Gal.)
6/28	0530	0	0	0	0	0
	1650	6645	5855	1113	727	84
6/29	0800	3436	1710	315	333	-
	2030	7778	6090	1153	810	174
6/30	0530	1830	195	53	78	-
	1745	5539	4575	862	657	99
7/1	1400	5978	3905	730	639	77
7/2	0615	5626	3410	639	540	-
	2130	9225	8335	1586	1008	192
7/3	1645	9131	7740	1475	916	-
	2130	1989	1560	291	262	209
7/4	0600	1346	120	22	23	-
	2130	10859	7930	1485	1260	189
7/5	1400	5926	4885	932	561	-
	2130	4586	3815	717	575	178
7/6	0530	1063	205	35	76	0

Note: Three women's and six men's restroom facilities connected to Aqua-Sans.

Example of Interval data: Interval oil flow--6645 gal. total oil flow between 0530 and 1650 hrs on 6/28.

Table 5. Oil Flow, Flush Count, and Waste Collection Data. July 6, 1972, Through July 31, 1972, Operating Period.

Date	Time	Interval Oil Flow (Gal.)		Interval Water Closet Flushes	Interval Urinal Flushes	Interval Waste (Gal.)
		Total	Flushing			
7/6	0530	0	0	0	0	0
	2130	4430	2575	431	1032	84
7/7	0645	1006	60	10	17	-
	2130	4150	2545	419	1130	116
7/8	1400	2307	1065	175	477	-
	2130	1757	975	157	470	77
7/9	1400	2874	1075	180	439	-
	2130	1643	1015	163	497	77
7/10	1400	2572	1220	199	562	-
	2130	1939	1055	166	557	95
7/11	0600	1021	50	8	18	-
	1400	2543	1415	234	614	-
	2130	2372	1150	187	532	105
7/12	0600	1376	205	37	46	-
	1400	2046	1355	221	631	-
	2130	1475	970	151	536	84
7/13	1400	1691	955	147	553	-
	2130	1029	725	106	486	95
7/14	0600	474	90	14	48	-
	1400	2346	960	151	486	-
	2130	1021	1135	210	212	66
7/15	1400	2714	1220	203	514	-
	2130	1553	1010	159	533	73
7/16	1400	2232	1245	205	548	-
	2130	1734	1350	218	654	84
7/17	1400	2424	1700	289	635	-
	2130	1922	1240	198	627	95
7/18	0600	1059	165	29	52	-
	1400	2073	1725	294	634	-
	2130	1382	1070	160	672	84

Table 5. (Cont.)

Date	Time	Interval Oil Flow (Gal.) Total	Flushing	Interval Water Closet Flushes	Interval Urinal Flushes	Interval Waste (Gal.)
7/19	1400	2211	1655	282	612	-
	2130	1166	1105	177	548	105
7/20	1330	1664	1290	212	578	31
	Out of service					
7/21	0600					
	1400	1842	1065	165	593	-
	2130	1285	945	149	502	84
7/22	1400	2061	1535	253	663	-
	2130	2194	1190	194	554	95
7/23	1400	2782	1070	171	541	-
	2130	2522	1695	288	639	84
7/24	1400	3096	1605	270	642	-
	2130	1425	975	153	496	84
7/25	1400	2628	1440	235	668	-
	2130	1505	1165	182	639	84
7/26	1400	3205	1095	371	599	-
	2130	1643	1165	175	728	95
7/27	1400	3578	1550	261	610	-
	2130	1728	1165	190	531	84
7/28	1400	2288	1150	184	569	-
	2130	1100	850	133	458	73
7/29	1400	1693	1075	170	562	-
	2130	1417	675	98	464	84
7/30	1400	2291	1040	167	506	-
	2130	1539	750	113	467	73
7/31	0600	787	95	15	55	-
	1700	2944	1675	295	502	-

Note: Six men's restroom facilities connected to Aqua-Sans.
Example of Interval data: Interval oil flow--5530 gal. total oil flow between 0530 and 2130 hrs on 7/6.

Table 6. Hourly Oil Flush Flow Rates. July 6, 1972, Through July 31, 1972, Operating Period.

Time	Date												
	6	7	8	9	10	11	12	13	14	15	16	17	18
0600	-	-	-	-	-	-	-	-	-	-	-	-	-
0700	-	-	-	-	-	-	-	-	-	21	33	13	2
0800	0	-	-	49	57	41	-	-	-	45	40	34	142
0900	100	-	-	45	46	103	-	-	-	38	81	107	116
1000	270	-	-	172	160	233	-	-	-	165	150	358	172
1100	240	-	-	106	165	278	-	-	-	208	121	231	363
1200	253	-	-	236	285	183	-	-	-	264	285	323	332
1300	279	-	-	161	181	258	-	-	-	263	189	232	360
1400	184	-	-	228	258	255	-	-	-	173	239	288	226
1500	236	-	160	193	248	169	191	163	-	220	284	298	244
1600	261	227	169	171	320	178	260	142	-	145	192	208	269
1700	154	174	148	164	129	208	78	109	-	195	183	193	170
1800	166	123	134	153	81	117	147	85	251	102	326	212	120
1900	39	36	84	106	97	192	100	86	91	151	164	69	105
2000	110	109	99	150	61	145	101	75	24	78	94	103	99
2100	104	63	68	74	78	181	65	82	90	88	103	116	47
2200	56	154	118	76	80	98	94	87	79	104	69	131	93

Table 6. (Cont.)

Time	Date												
	19	20	21	22	23	24	25	26	27	28	29	30	31
0600	-	-	-	-	-	-	-	-	-	-	-	-	-
0700	15	3	12	15	-	42	9	22	26	20	67	38	17
0800	46	19	14	28	-	58	49	90	46	28	60	-	17
0900	97	56	96	77	35	137	60	40	91	18	67	-	129
1000	180	150	213	242	95	176	245	191	223	180	86	111	205
1100	365	385	138	265	116	198	251	322	325	130	80	93	248
1200	-	151	279	241	224	338	204	378	276	238	260	253	137
1300	-	360	173	257	200	221	284	353	140	230	173	202	29
1400	-	-	49	291	319	294	123	-	293	268	179	197	110
1500	269	-	216	202	314	237	204	-	216	-	88	149	-
1600	270	-	271	257	317	166	133	224	273	-	156	190	-
1700	219	-	139	210	291	166	208	176	217	59	138	148	-
1800	236	-	121	137	211	131	257	102	136	56	52	97	-
1900	58	-	79	168	254	56	128	135	82	59	105	66	-
2000	76	-	83	111	208	70	88	211	76	19	26	92	-
2100	-	-	61	85	81	122	147	184	144	78	83	92	-
2200	-	-	114	84	132	141	84	150	139	70	252	194	-

Results in gallons

- indicates flow not recorded

Note: Six men's restroom facilities connected to Aqua-Sans.

Example of Interval data: Hourly oil flow--100 gal. between 0800 and 0900 on 7/6.

The peak hourly flush flow of 385 gph represents a 6.4 gpm average flush flow. Based on a Peak to Average ratio of 3.44 as determined from the 5-minute data listed in Table 7, the peak flow for the July 6 through July 31, 1972 period was 22 gpm. Based on this peak flush flow, a 220 gal. waste sump would provide a 10-minute theoretical detention time. Further discussion is presented on page 57.

Waste Sensors

The waste overfill sensor failed several times before the capacitance was adjusted properly. The waste sensor (lower sensor) operated properly during the operating period. However, failure of this waste sensor could have resulted in the waste sump being emptied into the sewer while operating automatically in the sewer mode.

Oil Reservoir Cleaning

Residue in the oil reservoir was originally removed by washing the surfaces with water and then pumping the accumulated water into the waste sump via the recirculating pump. This produced high concentrations of suspended solids in the oil because of turbulence near the waste/oil interface. The pressure differential across the primary filter increased rapidly when the reservoir was cleaned in this manner. A hose was then connected to the suction side of the recirculating pump and the residue was "vacuumed" from the reservoir into the sump. This method was time-consuming and could only be done during no-use periods. Only a small portion of the reservoir could be cleaned before the oil overflowing the waste sump became cloudy. This cleaning method was continued to the end of the demonstration period. Proper design of the sump and reservoir for solids carryover and eliminating areas for solids and urine accumulation will eliminate the need for reservoir cleaning.

System Vent

Positive venting was required to control odors in the reservoir. The vacuum pump was originally vented with the reservoir, but separate, powered vents had to be installed to eliminate odor problems around the Aqua-Sans unit.

Miscellaneous

The metering tank flow switch failed to shut the vacuum pump off once. The cause of failure was not determined. The

Table 7. Determination of Peak to Average Flush Flow Ratio

Date	7/1/72	7/2/72	7/11/72	7/12/72	7/13/72
Facilities	3 Women's	3 Women's	6 Men's	6 Men's	6 Men's
	45	40	21	17	18
Flush	30	15	13	23	11
Flow	115	15	7	23	1
for	65	50	29	17	1
Five	65	20	28	6	6
Minute	85	10	3	9	17
Intervals	55	5	4	13	3
	55	50	19	18	2
(gal./5 min.)	180	--	25	21	6
	--	--	6	2	15
	--	--	19	2	12
	--	--	3	30	5
Average Flow (gpm)	15.4	5.1	3.0	2.8	1.6
Peak Flow (gpm)	40.0	10.0	5.9	6.1	5.5
Ratio (Peak/Average)	2.60	1.96	1.96	2.18	3.44

The peak flow is determined by the average number of flushes in a 5-minute period with a fractional average of 1½ meaning that at least 2 flushes occurred in one of the one-minute intervals or the peak flow was 10 gpm.

switch operated approximately 500 times with 80 percent of the operation occurring after the one malfunction.

During the shutdown period after June 9, 1972, the accumulator pressure switch failed to "pick up" and turn the primary pump on when the pressure dropped to 30 psig. The switch started working after it was jarred several times. An identical malfunction occurred one week later, with the switch resuming proper operation after it was "jarred." A new pressure switch was installed prior to the June 28, 1972, restart.

OIL MAINTENANCE AND QUALITY

Oil maintenance consists of: (1) removing the suspended solids and water from the oil; (2) removing dissolved and very fine suspended contaminants from the oil; (3) disinfecting the oil; (4) eliminating odors from the oil; and (5) replacing oil lost from the system. The coalescer and the primary filter/coalescer were installed to remove the suspended solids and water from the oil. The bypass filter system was installed to remove the dissolved contaminants which caused color, odor, and reduced the oil interfacial tension. Biocides were added to the oil as disinfectants. Each of the individual oil maintenance categories are discussed in the following subsections.

Suspended Solids and Water Removal

While most of the solid and liquid wastes were effectively separated from the oil in the waste sump, colloidal and finely divided suspended particles and water were carried from the sump to the reservoir. A large portion of these solids and liquid eventually settled out in the oil reservoir. The solids collected on the flat or slightly sloped surfaces in the reservoir, and the liquid eventually drained to the low end of the reservoir to be pumped back to the sump.

The initial operating plan was to replace the three filter/coalescer elements when the differential pressure reached 10 psid. As shown in Table 8, the maximum primary filter/coalescer element differential pressure was 4 psid. The filter was changed in July after more than four times as much waste had been collected as in April. The differential pressure was 4 psid prior to both changeouts. During filter replacements it was observed that both the inlet and the outlet sides of the elements contained waste particles. Strong odors were apparent during each replacement. These observations indicate that the primary filter elements are more effective as an absorbing surface than as a filter and suggest that the primary filter/coalescer entraps waste which becomes the cause of odor.

Table 8. Primary Filter/Coalescer Element Replacement Record

Date Filter Change	Filter Differential Pressure (psid)	Total Waste Collected (Gal.)	Comments
4/18/72	4	400 + (1)	Strong waste odor and waste coating inlet and outlet sides of elements.
5/13/72	2½	340	Chlorox periodically added to system between 5/1/72 and 5/10/72. Elements cleaner and less odor.
7/12/72	4	1850 + (2)	Strong waste odor and waste coating

(1) No waste collection data for the 4/1-4/6 period. Estimate 80 gal. collected.

(2) No waste collection data for the 6/5-6/9 period. Estimate 500 gal. collected.

The primary filter/coalescer was effective in removing water from the oil except during very high usage periods. As will be discussed in the following subsection, only three oil samples collected during the demonstration had a water content above saturation.

Bypass Filter System

The initial bypass filter system consisted of an attapulgus clay filter which was installed to remove color, dissolved contaminants, and finely divided suspended solids. The average bypass flow rate was maintained close to 1 gpm. Operation with the one clay filter continued until the May 15, 1972, shutdown. Table 9 shows the oil test results and clay filter changes for February 6 through May 15, 1972. The first two clay filter elements were changed before they had been depleted.

The Givaudan G-4 was dissolved in acetone and the acetone saturated the clay filter. The large drop in IFT and color rise between March 27 and April 3, 1972, is a result of the March 29 addition of G-4. Because of the inaccuracies involved in the oil rise on filter paper method for determining IFT (explained in Section VII), the low IFT was not detected and the clay filter was not changed until April 18, 1972.

The clay filter element was replaced April 18 and the IFT rose to 28 dynes/cm and the color dropped from 50 to 10 units. The IFT slowly dropped and the color increased in the following operating period. The single clay filter was capable of removing oil contaminants from approximately 5500 gal. of recirculated flush oil required for 1450 flushes.

During the shutdown period following May 15, 1972, additional bypass filters, as explained in Section IV, were installed. The method of IFT determination was also changed at that time. An additional sample valve was installed making it possible to obtain oil samples from the primary filter (bulk oil) and the outlets of the clay and carbon filters.

Operation was resumed June 5 and was halted on June 9. Table 10 shows the IFT and color results for the samples taken during the five-day period. The IFT of the bulk oil was always lower than that from the bypass filter outlets, indicating that the bypass filters were effective. The oil color increased from 10 to 20 units during the operating period. During this period, approximately 20,000 gal. of oil were required to transport the waste of 9,200 flushes. The bulk oil IFT was slightly lower than 30 dynes/cm when the system was shut down June 9.

Operation was resumed June 28 after the macerator pump was replaced and continued through July 31 (see Tables 11 and 12). Table 11 shows that on June 29 the system received 2600 flushes. This overload resulted in the IFT of the oil from the clay filters dropping below the bulk oil IFT. The carbon filters, however, remained effective.

The clay filters were replaced July 2 and the bulk oil IFT dropped to 30 dynes/cm on July 5. Three oil samples had

Table 9. Oil Interfacial Tension and Color and Clay Filter Changes. February 6, 1972, Through May 14, 1972, Operating Period.

Date	Interval Flushes	Interval Waste (Gal.)	Interfacial Tension (dynes/cm)	Color (units)
2/6	Start of demonstration period			0
2/15	345	29.5	-	0
2/21	573	27.0	33.0	0
	Changed clay filter element			
2/28	353	30.5	34.0	0
3/24	1710	130.5	31.3	0
	Changed clay filter element			
3/27	407	31.5	28.0	10
3/29	Added G-4 Biocide			
3/31	582	42.0 (est)	-	40
4/3	643	47.0 (est)	17.8	40
4/7	457	33.0 (est	20.5	40
4/12	-	-	20.0	40
4/14	880	74.5	-	40
4/17	565	38.0	-	50
4/18	Changed clay filter element and primary filter elements and cleaned reservoir			
4/19	-	-	28.0	10
4/21	301	24.0 (est)	26.6	15
4/24	575	49.5	-	25
4/28	495	29.0	-	40
5/1	676	59.0	-	45
5/5	296	39.0	-	50
5/7	624	42.0	15.8	50
5/12	601	49.0	-	55
	Changed clay filter element			
5/13	-	-	25.5	50
5/14	1009	73.0	-	50
5/15	System operation temporarily halted			

Note: Three women's and six men's restroom facilities connected to the Aqua-Sans.

- Indicates no data available.

Oil samples taken from outlet of clay filter (SV-2).

Interfacial tension results supplied by CCSD - oil sample and urea in equilibrium.

Example of Interval data: Interval flushes--345 flushes between 2/6 and 2/15.

water contents above saturation during this period. The three women's water closets were switched to water prior to the July 6 morning usage.

Table 12 lists the oil test results for the remainder of the operating period with the six men's facilities in use July 1 through 31, 1972. The bypass filters maintained the bulk oil IFT above 30 dynes/cm during this operating period. The 15,190 flushes (16,000 users) between the July 7 and July 17 bypass filter changes represented the maximum total usage for the modified bypass filter system. During this period the oil had a yellowish color (30-45 units) and occasionally produced disagreeable odors in the restroom.

Table 10. Oil Interfacial Tension and Color. June 5, 1972, Through June 9, 1972, Operating Period.

Date	Time	Interval Flushes	Interfacial Tension (dynes/cm) SV-1	SV-2	SV-3	Color (units) SV-1	SV-2	SV-3
6/1	All filters replaced prior to start-up.							
6/5	0915	0	System restart					
	1400	493	38.9	46.2	46.7	10	-	-
6/6	0600	871	37.5	41.1	41.9	-	-	-
	1530	1073	34.3	37.0	38.4	10	-	-
6/7	1420	1095	29.8	39.2	-	15	-	-
6/8	0500	622	36.5	37.6	-	10	10	-
	1400	572	34.0	39.6	-	10	10	-
6/9	2000	1591	29.5	34.6	-	20	15	-

Note: Three women's and six men's restroom facilities connected to the Aqua-Sans.

- No data available.

Interfacial tension determined for oil - water not at equilibrium.

SV-1, SV-2, and SV-3 are sample values for bulk oil, clay filter outlet, and carbon filter outlet, respectively.

Example of Interval data: Interval flushes--493 flushes between 0915 and 1400 on 6/5.

Table 11. Oil Interfacial Tension and Color and Bypass Filter Replacement. June 28, 1972, Through July 5, 1972, Operating Period.

Date	Time	Interval Flushes	Interfacial Tension (dynes/cm) SV-1	SV-2	SV-3	Color (units) SV-1	SV-2	SV-3
		Changed clay filter elements						
6/28	0530	0	Operation restarted					
	1650	1840	38.0	39.2	44.7	35	30	30
6/29	0800	648	36.9	41.9	41.9	45	30	25
	2030	1963	37.5	33.3	-	35	30	-
6/30	0530	131	35.6	33.7	38.9	30	25	25
	1745	1519	44.0	-	-	40	-	-
7/1	1400	1369	37.9	36.4	40.3	50	45	45
7/2	0615	1179	40.0	-	-	35	-	-
	0800	Changed clay filter elements						
	2130	2594	41.5	-	-	35	-	-
7/3	1645	2391	34.0	35.7	-	40*	40*	-
	2130	553	42.0	-	-	45	-	-
7/4	0600	45	42.7	43.1	-	40	40	-
	2130	2745	33.6	-	-	45	-	-
7/5	1400	1493	30.6	32.2	-	35	40*	-
	2130	1292	30.0	-	-	45	-	-

Note: Three women's and six men's restroom facilities connected to the Aqua-Sans.

- No data available.

* Samples were cloudy.

Interfacial tension determined for oil-water not at equilibrium.

SV-1, SV-2, and SV-3 are sample values for bulk oil, clay filter outlet, and carbon filter outlet, respectively.

Example of Interval data: Interval flushes--1840 flushes between 0530 and 1650 on 6/28.

Table 12. Oil Interfacial Tension and Color and Bypass Filter Changes. July 6, 1972, Through July 31, 1972, Operating Period.

Date	Time	Interval Flushes	Interfacial Tension (dynes/cm) SV-1	SV-2	SV-3	Color (units) SV-1	SV-2	SV-3
7/6	0530		31.9	32.1	32.8	40	40	40
	2130	1574	34.2	35.3	-	45	40	-
7/7	0645	27	32.9	-	-	40	-	-
	0830	Changed both clay filters						
	1400		35.5	40.6	-	35	35	-
	2130	1549	36.9	-	-	40	-	-
7/8	1400		37.5	-	-	40	-	-
	2130	1279	36.2	-	-	35	-	-
7/9	1400		36.5	-	-	35	-	-
	2130	1279	38.4	-	-	35	-	-
7/10	1400		38.2	41.6	40.8	35	30	30
	2130	1484	36.5	-	-	40	-	-
7/11	0600		37.5	40.1	40.0	35	30	35
	1400		37.8	39.6	37.5	40	35	35
	2130	1593	38.0	-	-	40	-	-
7/12	0600		37.8	39.4	-	40	35	-
	1400		36.9	41.5	33.3	35	35	35
	2130	1622	34.9	-	-	40	-	-
7/13	1400		39.2	36.5	36.4	30	30	30
	2130	1292	32.6	-	-	30	-	-
7/14	0600		35.4	39.4	42.3	30	30	30
	1400		31.0	35.9	34.8	40	35	35
	2130	1131	36.8	-	-	35	-	-
7/15	1400		35.3	29.5	-	35	40	-
	2130	1409	36.2	-	-	35	-	-
7/16	1400		32.2	-	-	40	-	-
	2130	1625	34.1	-	-	40	-	-
7/17	1200	924	39.2	39.8	-	45	40	-
	1300	Removed clay filters - Replaced carbon filters						
	1400		33.2	-	35.7	40	-	40
	2130	825	41.2	-	44.0	35	-	30
7/18	0600		43.1	-	42.5	30	-	25
	1400		31.9	-	31.3	35	-	35
	2130	1841	33.6	-	-	40	-	-
7/19	1400		33.5	-	35.0	35	-	35
	2130	1619	33.0	-	33.5	40	-	40
7/20	1000	Replaced one clay filter and both carbon filters						
	1330	790	33.1	-	33.8	40	-	35
	2200		35.6	-	33.2	40	-	40
7/21	1400		35.3	39.5	41.0	35	30	30
	2130	1409	35.9	39.4	41.4	35	30	35

Table 12. (Cont.)

Date	Time	Interval Flushes	Interfacial Tension (dynes/cm) SV-1	SV-2	SV-3	Color (units) SV-1	SV-2	SV-3
7/22	1400		36.2	39.8	-	35	30	-
	2130	1664	35.3	-	-	40	-	-
7/23	1400		33.6	-	-	40	-	-
	2130	1639	34.8	-	-	40	-	-
7/24	1400		35.5	34.2	35.8	40	40	35
	2130	1563	35.4	-	-	35	-	-
7/25	1400		37.2	35.8	37.2	40	35	35
	2130	1724	39.8	-	-	35	-	-
7/26	1500	Replaced both clay and both carbon filters						
	1500	970	33.0	35.8	35.4	40	35	40
	2130	903	36.8	-	-	35	-	-
7/27	1400		37.9	39.8	40.9	40	40	35
	2130	1592	36.1	-	-	30	-	-
7/28	1400		37.4	40.2	-	35	35	-
	2130	1344	40.6	-	-	30	-	-
7/29	1400		36.5	36.4	38.8	40	35	35
	2130	1294	38.6	-	-	35	-	-
7/30	1500		40.0	-	-	40	-	-
	2130	1253	41.0	-	-	35	-	-
7/31	0600		40.6	43.2	41.5	35	35	30
	1700	867	38.1	41.0	40.6	35	30	30

- No data available.

Interfacial tension determined for oil - water not at equilibrium.

SV-1, SV-2, and SV-3 are sample values for bulk oil, clay filter outlet, and carbon filter outlet, respectively.

Note: Six men's restroom facilities connected to Aqua-Sans.

Example of Interval data: Interval flushes--1574 flushes between 0530 and 2130 on 7/6.

Bacteria Control

Maintaining a zero bacteria population in the oil is desirable for hygienic reasons and odor control. Biobor JF was the primary method of bacterial control used during the demonstration period. Two attempts were made to get Givaudan G-4, a longer lasting biocide, in solution with the oil. The technical data for both biocides are presented in Appendix D.

Initially, 135 ppm (chemical) of Biobor JF was added to the oil weekly. The amount was increased to 185 ppm on March 22, 1972, after two samples had low coliform bacteria counts. Table 13 lists the results of all coliform bacteria tests and the date biocide was added to the oil.

The first attempt on March 29 to get G-4 in solution with the oil was apparently not successful, since a large amount of the chemical was found in the reservoir. In the month following the March 29 G-4 addition, there were three samples which showed coliform bacteria; two of these had massive populations. There was no Biobor JF added during the period from March 29 to April 27.

During the June 5 to June 9 operating period, massive coliform bacteria counts occurred on two successive days, with 250 ml of Biobor JF being added on the day prior to each test.

One hundred ppm of G-4 (chemical dosage) was added to the oil on June 22. During the June 28 to July 5 operating period, Biobor JF was added either daily or every other day. Only one sample showed coliform bacteria during this period. The system usage was higher than the usage between June 5 and June 9, when bacteria were present in the oil, so apparently the G-4 assisted the Biobor JF in killing bacteria in the mineral oil.

Biobor JF was added to the oil in two- and three-day increments during the July 6 to July 31 operating period. During this period, three samples showed coliform bacteria.

Odor Control

The main problem, and the one not resolved, was odor. The odor problem affected both the operating area and the restrooms.

As discussed in the previous section, there was usually no bacteria population in the oil; however, the organic waste material which collected in the oil reservoir and absorbed

Table 13. Biocide Addition Record and Coliform Bacteria Test Results.

Date	Interval Flush Oil (Gal.)	Coliform Bacteria (Colonies)*	Biobor JF Addition (ml)(2)
1/31	-	-	180
2/8	-	0	180
2/15	660	-	180
2/17	150	0	-
2/21	1410	-	-
2/22	-	-	180
2/28	1140	0	180
3/3	315	4	-
3/10	1090	1	-
3/17	1385	0	180
3/22	-	-	250
3/24	2180	0	-
3/27	1190	0	250
3/29	Added G-4 Biocide		
3/31	1630	0	(1)
4/3	1885	0	(1)
4/7	1360	8	(1)
4/14	2440	0	(1)
4/17	1575	-	(1)
4/19	-	300	(1)
4/21	805	0	(1)
4/28	2840	100	250
5/5	3270	2	-
5/12	3755	0	250
5/15	System off line		
6/1	-	-	250
6/5	System restart	0	-
6/6	4310	0	250

Date	Interval Flush Oil (Gal.)	Coliform Bacteria (Colonies)*	Biobor JF Addition (ml)
6/7	6935	100	250
6/8	1910	100	(1)
6/9	3445	6	(1)
System off line (June 9 Flood)			
6/19	-	-	250
6/22	Added G-4 Biocide to system (100 ppm)		
6/27	-	0	250
6/28	System restart	-	-
6/28	5855	0	-
6/29	1710	6	250
6/29	6090	0	-
7/1	8675	-	250
7/3	19495	-	250
7/4	120	-	250
7/4	7930	0	-
7/5	4885	0	250
7/6	4020	0	250
	Switched women's side to water		
7/6		0	250
7/7	2635	0	-
7/7	2545	3	-
7/8	1065	-	250
7/10	4285	-	250
7/10	1055	100	-
7/11	50	0	-
7/11	2565	0	-
7/12	205	0	250

Table 13. (Cont.)

Date	Interval Flush Oil (Gal.)	Coliform Bacteria (Colonies)*	Biobor JF Addition (ml)(2)	Date	Interval Flush Oil (Gal.)	Coliform Bacteria (Colonies)*	Biobor JF Addition (ml)
7/13	3280	0	-	7/21	2010	0	-
7/14	815	0	250	7/22	1535	0	-
7/16	6920	0	-	7/23	-	-	250
7/17	1700	0	250	7/25	9040	0	-
7/17	1240	0	-	7/26	2095	0	250
7/18	165	0	-	7/29	6955	-	250
7/19	5555	0	-	7/30	2465	0	-
7/20	1290	10	250	7/31	95	0	-

- Indicates no data available.

* 1 ml trypticase-soy-broth added to 10 ml oil and centrifuges for 10 min. 0.1 ml of extract streaked on agarplate.

(1) Ran out of Biobor JF.

(2) 180 ml (135 ppm)
250 ml (185 ppm)

Example of Interval data: Interval flush oil--660 gal. between 2/8 and 2/15.

on the primary filter/coalescer elements was not oxidized by the biocide added to the oil. The G-4 was soluble only in oil and the Biobor JF soluble in oil and water. The Sontex 60T mineral oil contained an oxidation inhibitor, Parabar 441, to prevent color changes due to oxidation of the oil. The oxidation inhibitor tended to prevent oxidation of the organic waste material and neither of the two biocides had sufficient contact with the organic material to permit oxidation.

Chrysler Corporation Space Division has worked extensively on odor control since June, 1972. A summary of the Chrysler Corporation Space Division findings concerning odor control is presented in Appendix A.

Table 14 shows the results of the public acceptance questionnaires explained in Section VII. There were 72 questionnaires returned representing 643 urinal users and 30 questionnaires returned representing 230 water closet users. Thirty percent of the urinal users and 18 percent of the water closet users stated that the odor was objectionable.

The public acceptance of the oil color is also given in Table 14. Nine percent of the urinal users and 33 percent of the water closet users indicated that the oil color was objectionable.

Oil Loss

There were many forms of oil loss, but loss of oil with the waste caused the greatest concern. Oil losses were caused primarily by turbulence in the waste sump during high use periods combined with the short detention time (average of less than one hour) between dumps. Table 15 lists the oil lost with the waste during the periods of time when it was possible to determine all volumes of oil in the system and waste in the sump.

During low-use periods, the rate of oil loss with the waste was 3.8 gal./1000 gal. of waste. During the high-use period starting June 28, the loss was 47 gal./1000 gal. of waste.

Table 14. Results of Public Acceptance Questionnaires

Date & Time Interval	Number Users	Number Quest. Returned	Percent Return	Facility	Satisfactory			Not Satisfactory		
					Color	Odor	Gen. App.	Color	Odor	Gen. App.
7/27 1500-1800	252	31	12.3	Urinals	28	18	26	3	11	4
7/28 1700-2100	190	25	13.1	Urinals	23	20	23	2	5	2
7/30 1700-2100	201	16	8.0	Urinals	10	11	11	1	5	1
Total	643	72	11.2	Urinals	61	49	60	6	21	7
7/27 0700-1000	66	11	16.7	Water Closets	9	10	10	2	1	1
7/29 1400-2100	99	13	13.1	Water Closets	5	9	8	8	4	5
7/30 0700-1200	65	6	9.2	Water Closets	5	5	6	1	1	0
7/31	Not Recorded	31	----	Water Closets	22	26	24	9	5	7
Total (excluding 7/31)	230	30	13.0	Water Closets	41	50	48	20	11	13

		Percent Satisfactory	Percent Not Satisfactory
Urinals	Color	91	9
	Odor	70	30
Water Closets	Color	67	33
	Odor	82	18

Note: Men's restroom only.

Table 15. Oil Lost with Waste

Date	Oil Loss with Waste Dumps (Gal.)	No. of Waste Dumps	Oil Loss (Gal./Dump)	(Gal./ 1000 Gal. Waste)
4/21/72 to 5/5/72	0.8	18	0.04	3.8
6/28/72 to 6/30/72	13.0	23	0.56	47.0
7/12/72	9.0	46	0.20	19.0

Several checks were made to determine the amount of oil being lost with the waste by allowing the waste to sit in the metering tank before macerating and pumping it to the sewer. After a few minutes in the metering tank, oil would rise to the surface of the waste.

The mode of operation was switched to "incinerator" so that the overfill waste sensor would initiate a waste dump. This resulted in the waste level in the waste sump fluctuating between 25 and 35 gal. at all times. The amount of oil loss per waste dump was reduced.

The rate of oil loss during the operating period with only the men's restroom facilities connected to the Aqua-Sans system was 19 gal./1000 gal. of waste. The reduction in oil loss was a result of the increased detention time and the increased volume of waste retained in the waste sump.

Useful Life of Mineral Oil Flush Fluid

No accurate prediction of oil life can be made based on data collected during the demonstration period. The useful life of the mineral oil as a flush fluid appears, however, longer than the five-month operation period conducted at Mount Rushmore. No reduction in serviceability was detected during this period. Proper filtering is essential, however, to maintain the oil in a serviceable condition.

Miscellaneous

Appendices B and D contain Chrysler Corporation Space Division information on "Flush Fluid Specifications" and "Effects of Flush Fluid on Humans," respectively.

RESTROOM FACILITIES

Several problems were encountered in the restroom facilities which must be considered whenever an Aqua-Sans system is to be used.

Flushing

The six water closets were rim flush-siphon jet water closets. Fecal matter tended to settle rapidly out of the oil in the water closet bowls. Fecal matter would stick to portions of the porcelain bowl. Toilet paper would then stick to the fecal material. Paper continued to build up in the bowl until a plug-up and runover occurred. Increasing the flush volume from four to five gal. per flush partially relieved the problem. The inside surfaces of the water closets were also sprayed with "FluoroGlide," a fluorocarbon (Teflon) based solution. The Teflon coating did help prevent the fecal matter from sticking. Experience indicated that a Teflon coating would have to be applied monthly to the closet bowls to prevent fecal matter and toilet paper accumulations.

Oil Spillage

A few instances of oil spillage occurred because of water closet overflows. Oil spillage occurred as a result of urinal overflows on three successive evenings in May. Operation of the Aqua-Sans system was temporarily discontinued. The system was restarted June 5, 1972, with full-time restroom attendants available in both the women's and men's restrooms in case of an oil runover.

During the remainder of the operating period, a few instances of water closet overflows occurred and many cases of urinal overflows occurred. The urinal flush volume was adjusted to 0.4 gal. per flush prior to the June 5 restart. The drainage from two of the urinals got progressively slower, and urinal overflowing problems occurred. The urine being transported with the oil was undiluted when it came in contact with the pipes, and buildups in the urinal drain pipes occurred at a much faster rate with the mineral oil flush media than with water.

Several attempts were made to clean the drain pipes with a 3N solution of acetic acid. While drainage improvements were noted, they were short-term.

Oil Splashing

Small oil droplets usually splashed onto the seat during a water closet flush cycle. The oil did not evaporate, and the droplets accumulated and became unsightly.

Several attempts were made to adjust the flush cycle to eliminate the splashing, but each flush cycle adequate to remove waste from the water closet resulted in oil splashing. A different water closet was installed in place of one of those in use. The new water closet reduced the splashing but did not eliminate it.

Spring-loaded seats were ordered, but these did not arrive prior to the end of the project. These would definitely help with the oil splash problem and may eliminate any oil splashing onto the seat.

Cleaning

Conventional cleaning agents normally used for water closet and urinal cleaning are not to be used with the mineral oil flush media. Two different cleaning agents were provided by Chrysler Corporation Space Division during the demonstration period.

The first cleaning agent was difficult to completely remove from the surfaces inside the water closet bowl and tended to compound the waste sticking problem discussed under "Flushing." The second supply of cleaning agent differed only slightly from the first but did not have the removal problem. The difficulty in removal may have been due mainly to insufficient dilution with water prior to use.

The urinals were very difficult to keep clean, and some of the not satisfactory urinal odors were undoubtedly a result of this.

The supply of cleaning agent was used up in July and the water closets and urinals were cleaned with brushes and water. This method appeared to be adequate for the water closets (which had a teflon coating) but not for the urinals.

Chrysler Corporation Space Division's recommended restroom cleaning procedures are listed in Appendix E.

DESIGN CRITERIA

Waste Loading

One objective of the demonstration project was to gather useful data for establishing design criteria. In addition to the Visitor Center restrooms, there are three other restrooms at Mount Rushmore. The waste loadings were determined for restroom users and not for visitors to the Monument.

The number of individual water closet flushes was automatically counted and the number of urinal flushes determined by the total oil flow to the urinals. The relationship between facility users and flushes was determined from the number of users continuously recorded by an observer while another person recorded the number of flushes at five-minute intervals. Five observations were conducted for either 40 or 60 minute periods.

Table 16 lists the results of the five observation periods. Based on 365 restroom facility users, the average ratio of flushes per user is 0.95. The maximum deviations recorded were 1 user per 3 flushes and 3 users per 0 flushes. The general trend is for the flush per user ratio to decrease as the number of users increases.

The waste collection data are presented in Table 17. Except for three short periods, the amount of waste collected was determined. Excluding these periods, 4,056 gal. of waste were collected. Based on 67,438 flushes, the average ratio of gal. waste per flush is 0.060. Using the 0.95 flush per visitor ratio, the average waste collection per user is 0.063 gal. This number is biased by the minimum ratio of 0.059 gal. per user determined for the July 6 through July 31 operating period with only the men's restroom facilities connected to the Aqua-Sans system. Excluding this period, the average ratio is 0.070 gal. waste per user and is the recommended value for design purposes. The maximum ratio determined was 0.085 during a nine-day collection period.

Waste samples were collected and analyzed for suspended (volatile and fixed) solids. Table 18 shows that the suspended solids in the separated (concentrated) human waste are 92 percent volatile. The total suspended solids concentration for the three collected samples ranged from approximately 0.9 to 3.6 percent.

Based on the maximum suspended solids measured, the 4660 gal. of human waste collected during the operation period contained 1400 and 131 lb of total and fixed suspended solids, respectively.

Table 16. Restroom Facility Flushes per User Determination.

Date	Study Period (Min)	Restroom Facilities	Facility Users	Facility Flushes	Ratio (Flushes/User)
7/1/72	40	women's 3 water closets	38	41	1.08
7/2/72	40	women's 3 water closets	84	85	1.01
7/11/72	60	men's 3 water closets	21	28	1.33
7/12/72	60	men's 3 urinals & 3 water closets	130	109	0.84
7/13/72	60	men's 3 urinals & 3 water closets	90	83	0.92
Total			363	346	0.95

Maximum Deviations

1 user, 0 flushes
3 users, 0 flushes
1 user, 3 flushes

Table 17. Waste Collection and Water Closet and Urinal Flushes.

Operating Period	Flushes: Water Closet	Flushes: Urinal	Flushes: Total	Waste Collected (Gal.)	Ratio[1] Gal./Flush	Ratio[1] Gal./User
2/6/72 - 2/29/72	623	711	1,334	91	0.068	0.072
3/1/72 - 3/31/72	1,263	1,383	2,646	200	0.075	0.079
4/1/72 - 4/6/72	549	551	1,100	80 (2)	(2)	(2)
4/7/72 - 4/16/72	665	780	1,445	112	0.077	0.081
4/17/72 4/20/72	130	171	301	24 (2)	(2)	(2)
4/21/72 - 5/14/72	2,225	1,951	4,176	340	0.081	0.085
6/5/72 - 6/9/72	3,439	2,885	6,324	503 (2)	(2)	(2)
6/28/72 - 7/5/72	11,408	8,465	19,873	1,202	0.061	0.064
7/6/72 - 7/31/72	10,026	27,938	37,964	2,111	0.056	0.059
Totals (excluding periods of estimated waste collection (2))			67,438	4,056	0.060	0.063
(excluding (2) and the 7/6/72-7/31/72 operating period)			29,474	1,945	0.066	0.070
(all values included)	30,328	44,835	75,163	4,663	-----	-----

(1) Based on 0.95 flush per user.

(2) Waste volume estimated.

Table 18. Suspended Solids Concentration of Concentrated Human Waste.

Suspended Solids (mg/1)			Percent
Total	Fixed	Volatile	Volatile
8,790	720	8,070	91.8
26,280	1,600	24,680	93.9
36,100	2,800	33,300	92.4

System Sizing

The primary factor involved in system sizing is having the waste sump large enough to provide sufficient detention time for the waste to separate from the mineral oil transport media. The size determined below is for a sump properly designed to have a minimum turbulence caused by the waste-oil inflow and to have no other inflow during use periods. The 3.44 ratio of peak flow to average flow, determined from peak hourly flush oil flows, is applied to the average ratio of peak hourly flush oil flow (Table 6) to average hourly flush oil flow. Table 19 lists these ratios for nine days which had peak hourly flush oil flows exceeding 300 gph. The average ratio is 2.40.

Multiplying the two ratios gives a ratio of peak flow (determined for 5-minute intervals) to average flow (determined for daily operating periods) equal to 8.3.

Table 19. Determination of Peak Hourly Flow to Average Flow Ratio.

	Flush Oil Flow (gph)		
Date	Peak Hourly	Average Hourly	Ratio (Peak/Average)
7/10	320	120	2.67
7/16	326	136	2.40
7/17	358	154	2.37
7/18	363	156	2.39
7/19	665	145	2.52
7/23	319	145	2.20
7/24	338	136	2.48
7/26	378	173	2.18
7/27	325	143	2.27
	Average ratio		2.40

The sizing of the waste sump for a certain number of daily users is dependent upon the number of hours a facility is open, the ratio of women to men users, the volume of oil required per flush, and the ratio of water closets to urinals in the men's restroom. The data were collected when the visitor center restrooms were open 19 hours a day. The average ratio of urinal flushes to men's water closet flushes is difficult to determine, since there were six water closets in the men's restroom and only three of these were connected to the Aqua-Sans system. Using an equal ratio of water closets to urinals, a 2.86 ratio of urinal users to water closet users was determined for Mount Rushmore. This ratio would probably be higher if there had been more urinals available for use.

Table 20 indicates that the waste sump size is highly dependent on the ratio of water closet flushes to urinal flushes and the volume of oil required per flush.

The waste collection, bypass filter element replacement, and biocide addition requirements per 1,000 users are 70 gal. waste, 16-day intervals, and 185 ppm of Biobor JF every three days, respectively.

WATER CONSERVATION

The use of the Aqua-Sans system for transporting human wastes at Mount Rushmore resulted in a total local water saving of 240,000 gal., with 175,000 gal. being conserved between June 28 and July 30. These figures were determined by multiplying the number of water closet flushes by 5 gal. per flush and the number of urinal flushes by 2 gal. per flush. Both flush volumes are conservative figures for restroom facilities utilizing flushometer valves.

In addition to the water conservation achieved, the hydraulic load to the Mount Rushmore septic tank-sand filter sewage treatment facility resulting from the 79,000 Aqua-Sans users was reduced 98 percent.

SUMMARY OF EVALUATION RESULTS

There was 4660 gal. of concentrated waste collected from 79,000 Aqua-Sans users during the five-month demonstration period. The cumulative processed and recirculated flush oil was 173,000 gal. This oil was required for 30,328 water closet and 44,825 urinal flushes.

Table 20. Sump Size, Waste Collection, and Maintenance as a Function of Users

Daily Usage		0	500 Men[4] 500 Women	1,000 Men[4]	1,000 Women
Daily Oil Flow (Gal.)[1]	Bypass	2,880	2,880	2,880	2,880
	Flush	0	2,140	1,530	4,750
Waste Sump Size (Gal.)[2]	19 hr. day	-	230	113	350
	12 hr. day[3]	-	364	178	554
Daily Waste (Gal.)		-	70	70	70

Biobor JF added every 3 days--250 ml (185 ppm)

Bypass filter elements (2 clay, 2 carbon) replaced every 16 days.

[1]0.95 flush per user, 5 gal. water closet flush, and 0.4 gal. urinal flush.

[2]Providing 10 minutes theoretical detention time.

[3]Assuming 8.3 ratio still applies.

[4]2.86 urinal flush per water closet flush.

Turbulence in the waste sump resulted in excessive waste carryover from the waste sump into the oil reservoir. Inlet conditions were the primary cause of the turbulence during "low use" periods. During "high use" periods, the turbulence was increased because of the high flush oil flow rate and corresponding short detention time in the waste sump.

Bacteria control in the oil is possible through the proper addition of biocides. However, neither of the two biocides used controlled bacterial growth in the organic material which accumulated in the oil reservoir and on the filter elements.

Odor in the oil and around the Aqua-Sans system resulted from the bacterial growth in the organic accumulations. A forced draft on the reservoir vent will reduce the odors around the system. An oxidizer capable of oxidizing any organic material that collects outside the waste sump is necessary.

The bypass filter system with 2 clay filters and 2 carbon filters maintained the oil IFT above 30 dynes/cm for 16,000 users. The bypass filters also maintained the oil color below an acceptable 55 units throughout the demonstration.

Most public objections to the oil flush were due to color and odor. Thirty percent of the urinal users objected to the odor and 33 percent of the water closet users objected to the oil color.

Most of the separated waste was pumped to the Mount Rushmore sewage treatment facility. A commercial macerator with a 4 in. inlet adequately ground and pumped the waste.

The amount of oil loss with the waste was a function of the facility usage rate and the operating level of waste in the waste sump.

There were 0.95 flushes per facility user. The average user waste loading ranged from 0.059 to 0.085 gal. per user with 0.07 gal. per user recommended for design purposes.

The ratio of peak flow (gpm averaged over 5 minutes) to average flow (gpm averaged over 19 hrs) is 8.3.

Water conservation is achieved by using a recoverable, non-aqueous flush media. A total of 240,000 gal. of water was conserved during the demonstration.

Problems were encountered in the restrooms as a result of using the mineral flush media. These problems were 1) waste sticking, 2) oil overflows, and 3) oil splashing onto toilet seats.

SECTION IX

ACKNOWLEDGEMENTS

The support and cooperation of the National Park Service, Mount Rushmore National Memorial, under Park Superintendent Wallace O. McCaw, are gratefully acknowledged.

The support of the project by the Water Quality Office, Environmental Protection Agency, and the assistance provided by Mr. William Librizzi and Mr. Leo T. McCarthy, Jr., the project officers, have been very much appreciated.

SECTION X

REFERENCES

1. "Standard Methods for the Examination of Water and Wastewater," 13th Edition, American Public Health Association, New York (1971).

2. "1972 Annual Book of ASTM Standards," Part 29, American Society for Testing and Materials, Philadelphia, Pa. (1972).

SECTION XI

GLOSSARY

The following abbreviations and terms are used in this report.

cm = centimeter(s)

^{o}F = degrees Fahrenheit

gph = gallons per hour

gpm = gallons per minute

gal. = gallon(s)

hp = horsepower

IFT = interfacial tension

in. = inch(es)

ppm = parts per million

psig = pounds per square inches gage-pressure reading referenced to atmospheric pressure

psid = pounds per square inches differential-pressure difference between two locations

<u>Accumulator</u> - The system pressure tank.

<u>Biocide</u> - An agent which kills bacteria.

<u>Coalescer</u> - A device used for removing water from the mineral oil.

<u>Interfacial Tension</u> - A measurement of the force per unit length existing at the interface of two dissimilar fluids.

<u>Macerator</u> - A grinder-pump unit used for grinding and pumping the concentrated waste.

<u>Waste Sump</u> - The waste separation and waste storage tank located inside the oil storage reservoir.

APPENDIX A

CHRYSLER CORPORATION SPACE DIVISION TECHNICAL EVALUATION OF AQUA-SANS TREATMENT SYSTEM

TECHNICAL REPORT TR-RE-73-262

SEWAGE TREATMENT SYSTEM

DEMONSTRATION PROJECT FINAL REPORT

FOR

BLACK HILLS CONSERVANCY SUB-DISTRICT

CONTRACT BH 61771

JANUARY 1973

Prepared by: R. W. Loomis, Project Manager

Approved by: V. J. Vehko, Director of Engineering

Chrysler Corporation Space Division, P. O. Box 29200, New Orleans, Louisiana 70189

1.0 INTRODUCTION

This final report documents the design, fabrication, installation and operational test of a Chrysler Aqua-Sans sewage treatment system, which was installed at the Mount Rushmore National Memorial Visitors' Center (figures 1 and 2). The report includes test objectives and results, and conclusions and recommendations based on Chrysler's review and analysis of test data.

The Chrysler Aqua-Sans system uses a non-aqueous, recirculated flush medium to transport human waste from the toilet facility to a separation tank. After separation, the waste can be incinerated, or disposed of with a septic tank or aerobic system.

Chrysler's contract with the Black Hills Conservancy Sub-District was partially funded by a Class II demonstration grant from the EPA. The project objectives of that grant proposed to demonstrate the feasibility of using a non-aqueous system for the collection, transport and disposal of human waste, to demonstrate that water conservation could be achieved by use of such a system and that the recycled flush fluid was acceptable for the intended purpose. In addition, operational maintenance techniques were to be developed and demonstrated so that the concept could be subsequently applied in remote areas where more conventional sewage treatment methods were not applicable.

The major project objectives were achieved within the 18-month program schedule. The Mount Rushmore unit was the first field installation of Chrysler's sewage treatment concept, and there were system deficiencies noted during the test program. These problems were either resolved during the program by system modification or have been resolved during concurrent and subsequent development under other Aqua-Sans contracts and Chrysler research and development.

Figure 1. Mount Rushmore Visitors' Center

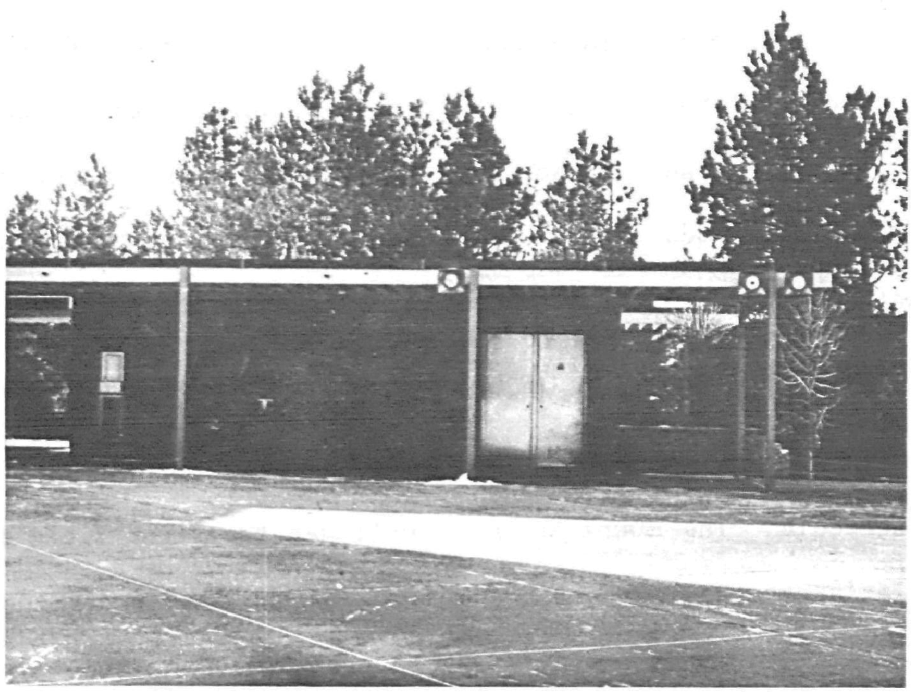


Figure 2. Restroom Building, Mount Rushmore Visitors' Center

Significant data were collected during the test program relating to high-use public restroom facilities

2.0 DESIGN AND DEVELOPMENT

2.1 CRITERIA

System design criteria were based on rough estimates of facility usage at Mount Rushmore as expressed in Chrysler's proposal MI-212A, dated May 20, 1971. These criteria, and the actual design parameters of the delivered system are shown in Table 1.

Table 1 - Design vs Delivered System Criteria

	MI-212A Criteria	Delivered System
Commode Uses/day	400	400
Urinal Uses/day	600	600
Flush Fluid Flow/day (capacity)	4000 gal	4000 gal
Primary Pump (capacity)	20 gpm at 50 psi	50 gpm at 50 psi
Accumulator (capacity)	100 gal	60 gal
Waste (capacity)	120 gal	120 gal
Main Tank (capacity)	300 gal	360 gal

A major constraint in the design of the unit was the requirement that the system be installed in the Mount Rushmore Visitor's Center basement through a 33-inch-wide door. In order to meet this constraint, the tank, tank stand, major functional components, and the incinerator were all designed so that the system could be assembled on site.

2.2 SEPARATION SYSTEM

A schematic drawing of the separation system is shown in figure 3. Photographs of major elements are shown in figures 8, 9 and 10. The design of the major subsystems is discussed in the following paragraphs.

2.2.1 Flush Fluid Supply

A 360-gallon separation tank (figure 4) was designed to store flush fluid and provide a sump for temporary storage of separated waste. This stainless steel tank contains a barrel with a 100-gallon capacity which serves as a first-stage separation container. Flush fluid and waste from the soil drain are introduced at the top of this barrel and separated flush oil passes through a screen, over the circular weir and through a gross coalescer. Water which settles out from the coalescer is periodically pumped back into the first stage barrel by a recirculating pump (figure 5). The tank is fitted with a 3-section lid; the center section contains a transparent window and a light for observation. The tank is vented and contains a flush fluid sight glass and overfill float switch, (figure 1).

A centrifugal pump is used to pressurize an accumulator and supply the facilities with flush fluid. The pump is rated at 50 gpm at 50 psig outlet pressure. The accumulator contains a usable volume of 16 to 23 gallons, depending on line pressure and accumulator precharge. The air side of the accumulator is charged by the vacuum pump used to transfer waste. The flush fluid pump is controlled by a pressure switch on the air side of the accumulator. A 4-element filter/coalescer is installed downstream of the pump; a bypass valve and relief valve are also included.

Figure 3. Separation System Mechanical Schematic - legend

Number	Component Name
1.	Vacuum Pump Inlet Valve
2.	Metering Tank Vacuum Valve
3.	Vacuum Pump Vent Valve
4.	Macerator Pump Drain Valve
5.	Sediment Drain Valve and Flush Fluid Fill Valve
6.	Sediment Pump Inlet Valve
7.	Sump Drain Valve
8.	Waste Sensor Valve
9.	Waste Overfill Sensor Valve
10.	System Drain Valve
11.	Inlet Screen Water Isolation Valve
12.	Metering Tank Water Isolation Valve
13.	Filter Drain Valve
14.	Clay Filter Isolation Valve
15.	Accumulator Charge Valve
16.	Filter Drain Charge Valve
17.	Primary Filter Isolation Valve
18.	System Bypass Valve
19.	System Shutoff Valve
20.	Primary System Suction Valve
21.	System Relief Valve
22.	Sensor Flush Valve
23.	Incinerator Transfer Valve
24.	Vacuum Breaker Check Valve
25.	Incinerator Transfer Control Valve
26.	Water Flush Solenoid Valve
27.	Vacuum Breaker Solenoid Valve
28.	Water Flush Check Valve
29.	Sediment Pump Check Valve
30.	Primary System Check Valve
31.	Metering Tank Check Valve
32.	System Pressure Gage
33.	Primary System Pressure Switch
34.	Accumulator
35.	Clay Filter Differential Pressure Gage
36	Clay Filter
37.	Primary Filter Differential Pressure Gage
38.	Primary Filter/Coalescer
39.	Primary System Flowmeter
40.	Primary Pump
41.	Sensor Flush Check Valve
42.	Recirculating and Sediment Pump

Number	Component Name
43.	Macerator Pump
44.	Vacuum Pump
45.	Metering Tank Vent Float Valve
46	Metering Tank Fill Float
47.	Reservoir Overfill Float Switch
48.	Waste Overfill Sensor (Approximately 32 gallons)
49.	Waste Sensor (Approximately 12 gallons)
50.	Filter Bleed Valve
51.	Sample Valve
52.	Pump Inlet Screen
53.	Gross Coalescer
54.	Strainer
55.	Clay Filter Calibration and Sample Valve
56.	Bypass Flowmeter

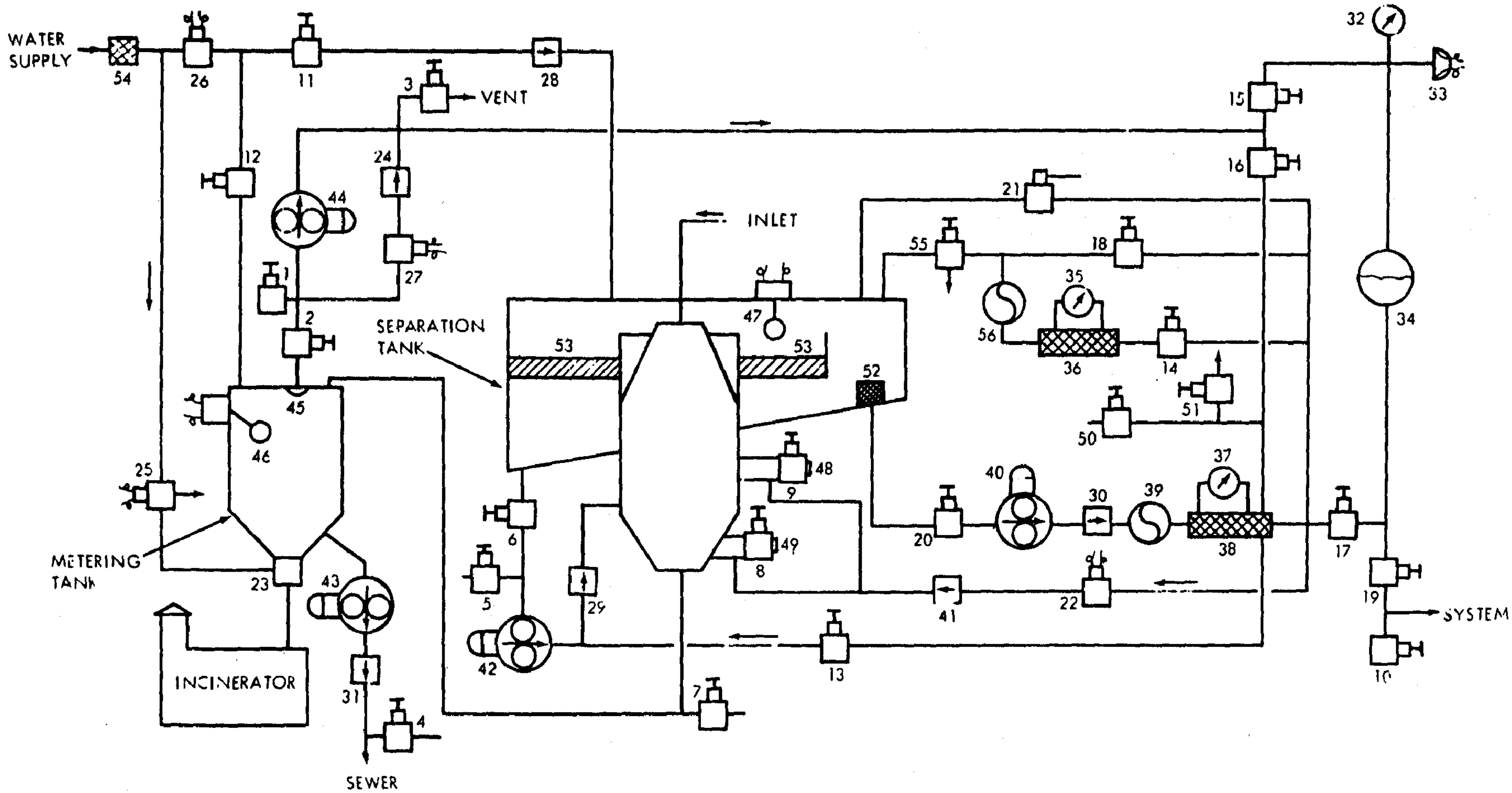
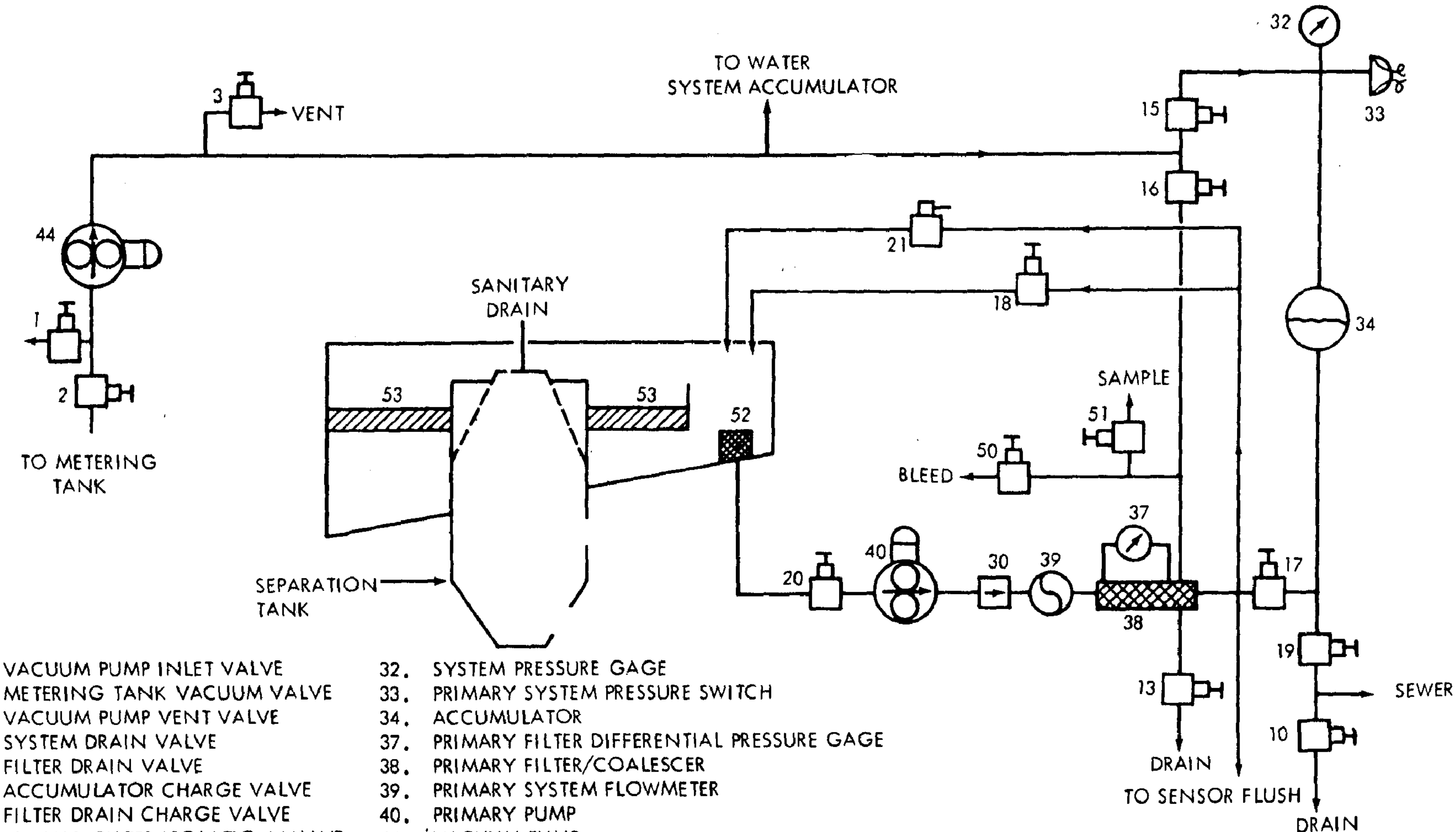
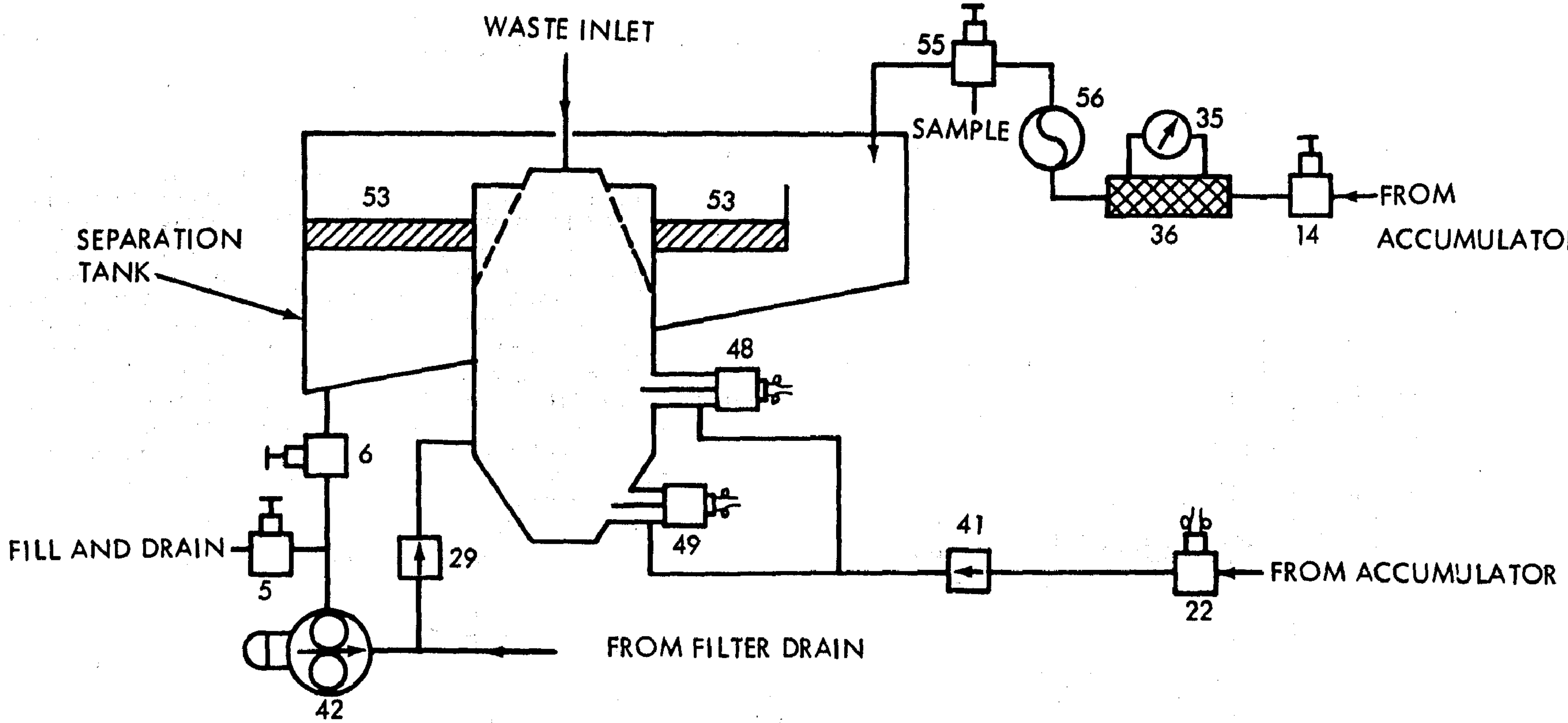


Figure 3. Separation System Mechanical Schematic



1. VACUUM PUMP INLET VALVE
2. METERING TANK VACUUM VALVE
3. VACUUM PUMP VENT VALVE
10. SYSTEM DRAIN VALVE
13. FILTER DRAIN VALVE
15. ACCUMULATOR CHARGE VALVE
16. FILTER DRAIN CHARGE VALVE
17. PRIMARY FILTER ISOLATION VALVE
18. SYSTEM BYPASS VALVE
19. SYSTEM SHUTOFF VALVE
20. PRIMARY SYSTEM SUCTION VALVE
21. SYSTEM RELIEF VALVE
30. PRIMARY SYSTEM CHECK VALVE
32. SYSTEM PRESSURE GAGE
33. PRIMARY SYSTEM PRESSURE SWITCH
34. ACCUMULATOR
37. PRIMARY FILTER DIFFERENTIAL PRESSURE GAGE
38. PRIMARY FILTER/COALESCER
39. PRIMARY SYSTEM FLOWMETER
40. PRIMARY PUMP
44. VACUUM PUMP
50. FILTER BLEED VALVE
51. SAMPLE VALVE
52. PUMP INLET SCREEN
53. GROSS COALESCER

Figure 4. Flush Fluid Supply Schematic



5. SEDIMENT DRAIN VALVE AND FLUSH FLUID FILL VALVE
6. SEDIMENT PUMP INLET VALVE
14. CLAY FILTER ISOLATION VALVE
22. SENSOR FLUSH VALVE
29. SEDIMENT PUMP CHECK VALVE
35. CLAY FILTER DIFFERENTIAL PRESSURE GAGE
36. CLAY FILTER
41. SENSOR FLUSH CHECK VALVE
42. RECIRCULATING AND SEDIMENT DRAIN PUMP
48. WASTE OVERFILL SENSOR
49. WASTE SENSOR
53. GROSS COALESCER
55. CLAY FILTER CALIBRATION AND SAMPLE VALVE
56. BYPASS FLOWMETER

Figure 5. Fluid Maintenance Schematic

2.2.2 Fluid Maintenance

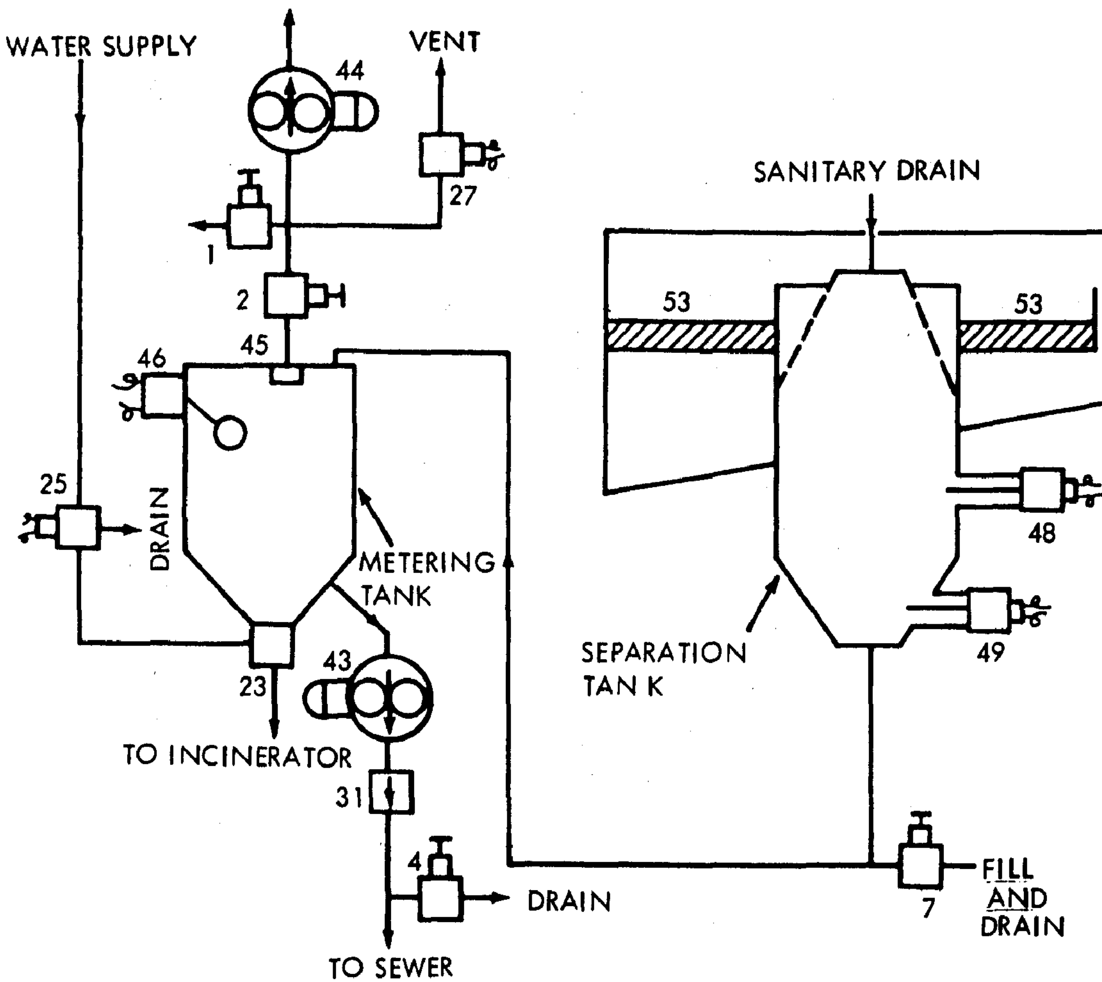
In addition to the in-line filter mentioned in the previous paragraph, an Atapulgus clay filter is used in a 1 to 2-gpm bypass system to remove color and dissolved contaminants, (figure 5). During the test period, an additional clay filter and a 2-element activated carbon column were added to this bypass loop for more effective odor control. A screen in the barrel and the gross coalescer are designed to remove large particles and coalese water carryover from the barrel. This water is periodically pumped back into the sump with a small pump. Midway in the demonstration program the coalescer was removed from the tank to reduce solids carryover into the main tank, and the screen in the barrel replaced with a coalescer. Bacteria control is achieved by periodic applications of biocide, which is partially soluable in both oil and water.

2.2.3 Waste Transfer

Waste is transferred (figure 6) from the sump to a metering tank by evacuating the metering tank with a vacuum pump. This transfer cycle is initiated by a capacitance probe which signals a transfer cycle when approximately 12 gallons of waste have accumulated in the sump. Waste is transferred until actuation of a float switch in the metering tank stops the pump and vents the tank. From the metering tank, waste flows by gravity to the incinerator to be burned or to the macerator for transfer to the sewer system.

2.2.4 Water System

The water system (figure 7) provides water pressure to actuate the incinerator transfer valve and is routed to two sprays which rinse the



1. VACUUM PUMP INLET VALVE
2. METERING TANK VACUUM VALVE
4. MACERATOR PUMP DRAIN VALVE
7. SUMP DRAIN VALVE
23. INCINERATOR TRANSFER VALVE
25. INCINERATOR TRANSFER CONTROL VALVE
27. VACUUM BREAKER SOLENOID VALVE
31. CHECK VALVE
43. MACERATOR PUMP
44. VACUUM PUMP
45. METERING TANK STOP VALVE
46. METERING TANK FLOAT SWITCH
48. WASTE OVERFILL SENSOR (APPROX. 32 GAL.)
49. WASTE SENSOR (APPROX. 12 GAL.)

Figure 6. Waste Transfer Schematic

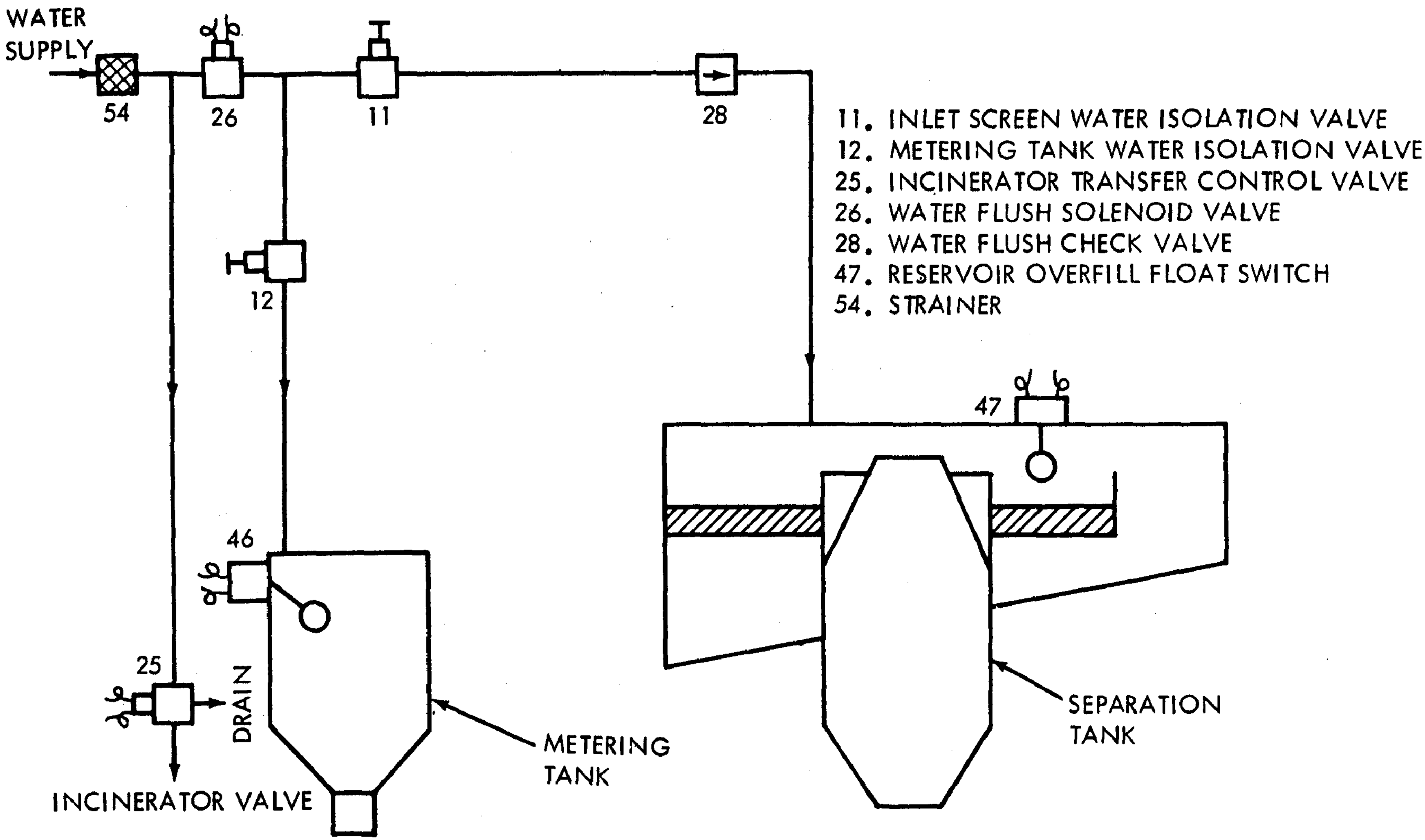


Figure 7. Water System Schematic

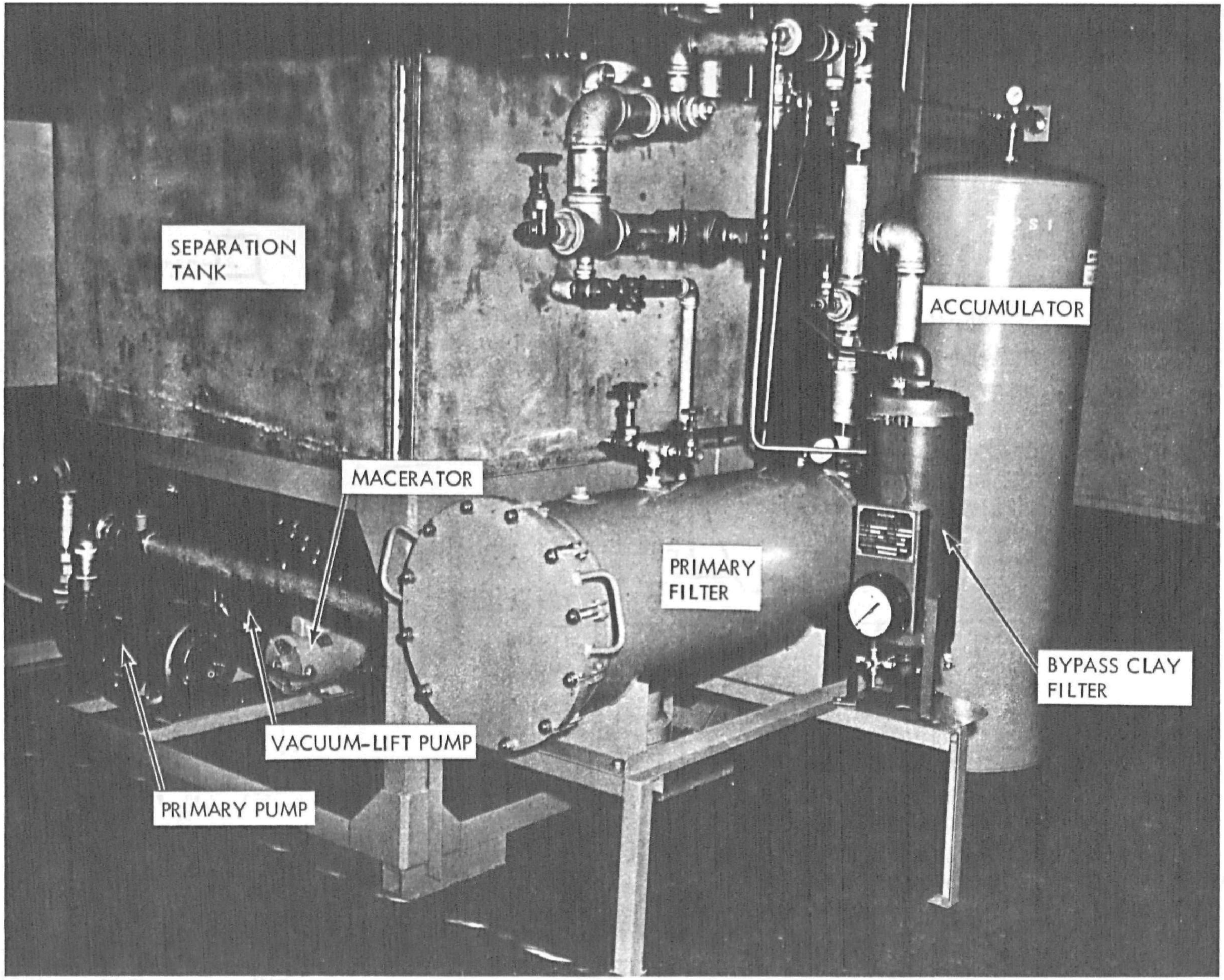


Figure 8. Separation System

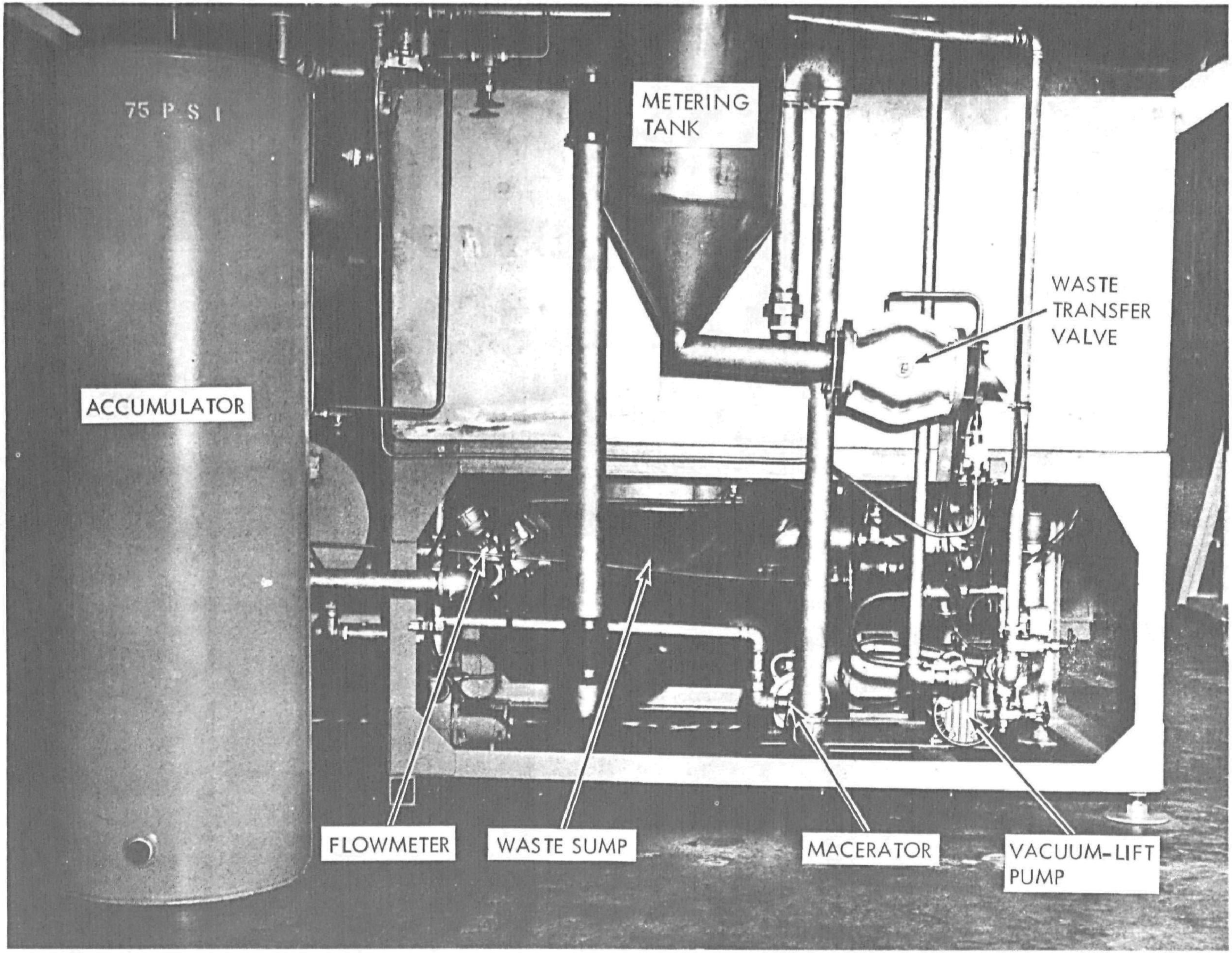
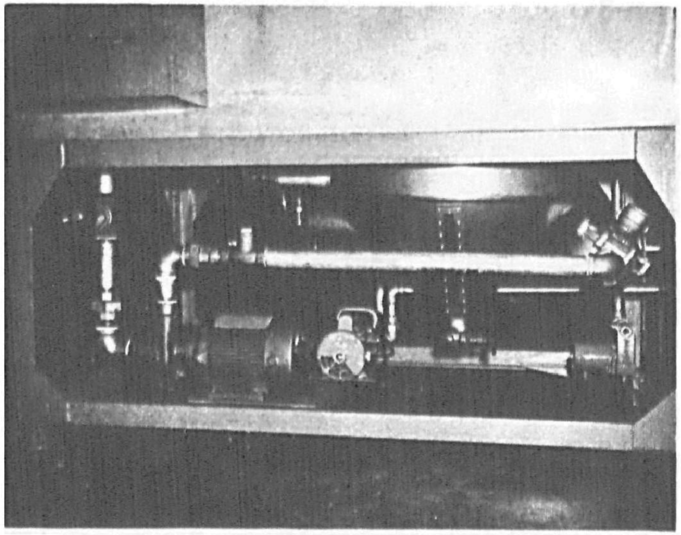
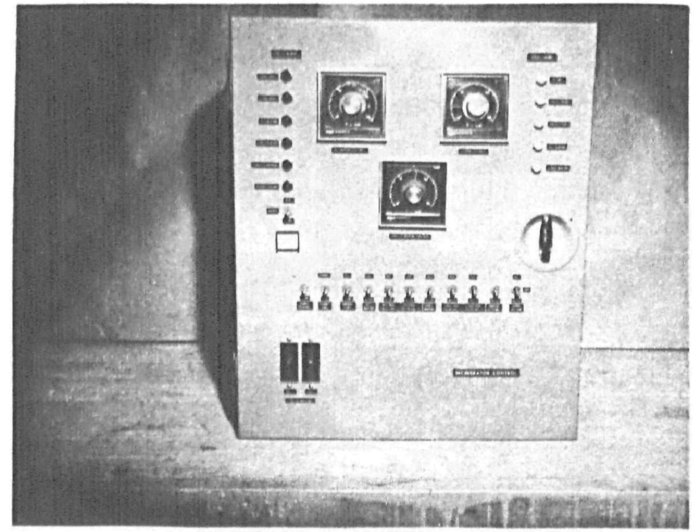


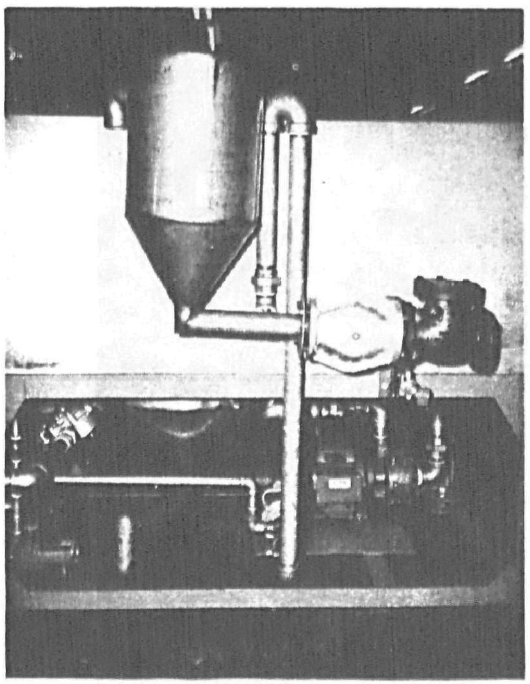
Figure 9. Separation System



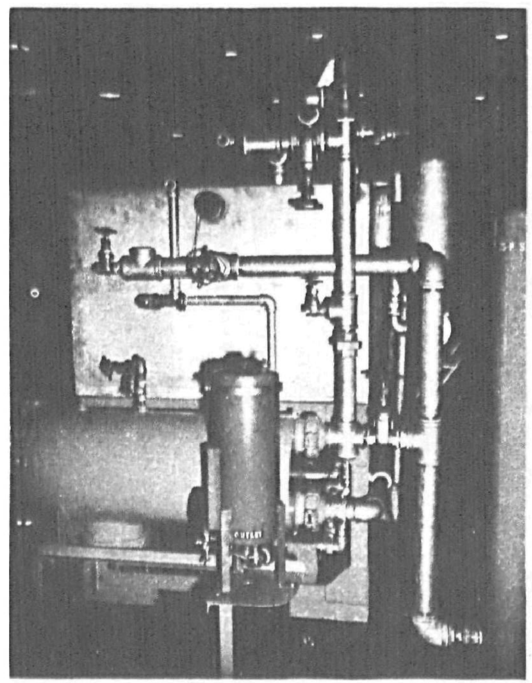
INSTALLATION OF MAIN PUMP AND WASTE SUMP



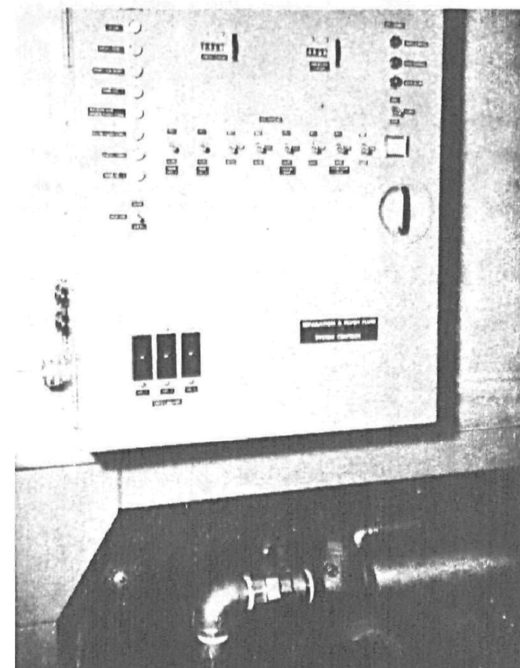
INCINERATOR CONTROL PANEL



METERING TANK, WASTE VALVE, AND ASSOCIATED PLUMBING



CLAY FILTER, FILTER SYSTEM, ACCUMULATOR, AND ASSOCIATED PLUMBING



SEPARATION AND FLUSH FLUID CONTROL PANEL

Figure 10. Mount Rushmore Unit

metering tank following a waste transfer cycle and periodically rinse down the waste inlet screen.

2.3 INCINERATOR

A 2-stage, oil burning incinerator (figure 11) fabricated of type 309 stainless steel, was designed for the system The first stage contains a crucible into which approximately 10 gallons of waste can be transferred. Exhaust gases are passed into a second stage where they are maintained at 1100 to 1300°F for sufficient time to ensure complete oxidation of exhaust products. Both stages are insulated with ceramic fibre insulation and are air cooled.

2.4 CONTROLS

Control panels (figures 10, 12 and 13) are installed on both the separation system and incinerator. Test and automatic operation modes are provided for all functional components with switches. Status lights indicate system condition, and audible and visual alarms are provided for critical operations.

2.5 INSTRUMENTATION

Flowmeters are provided to indicate total primary pump output (figure 4), and to measure bypass flow rate (figure 5). Counters are included to monitor incinerator and macerator cycles, and three temperature indications are displayed on the incinerator control panel (figures 12, 13). The Black Hills Conservancy Sub-District provided flush counters for each commode (figure 14) and a flowmeter to monitor urinal flush volumes (figure 15).

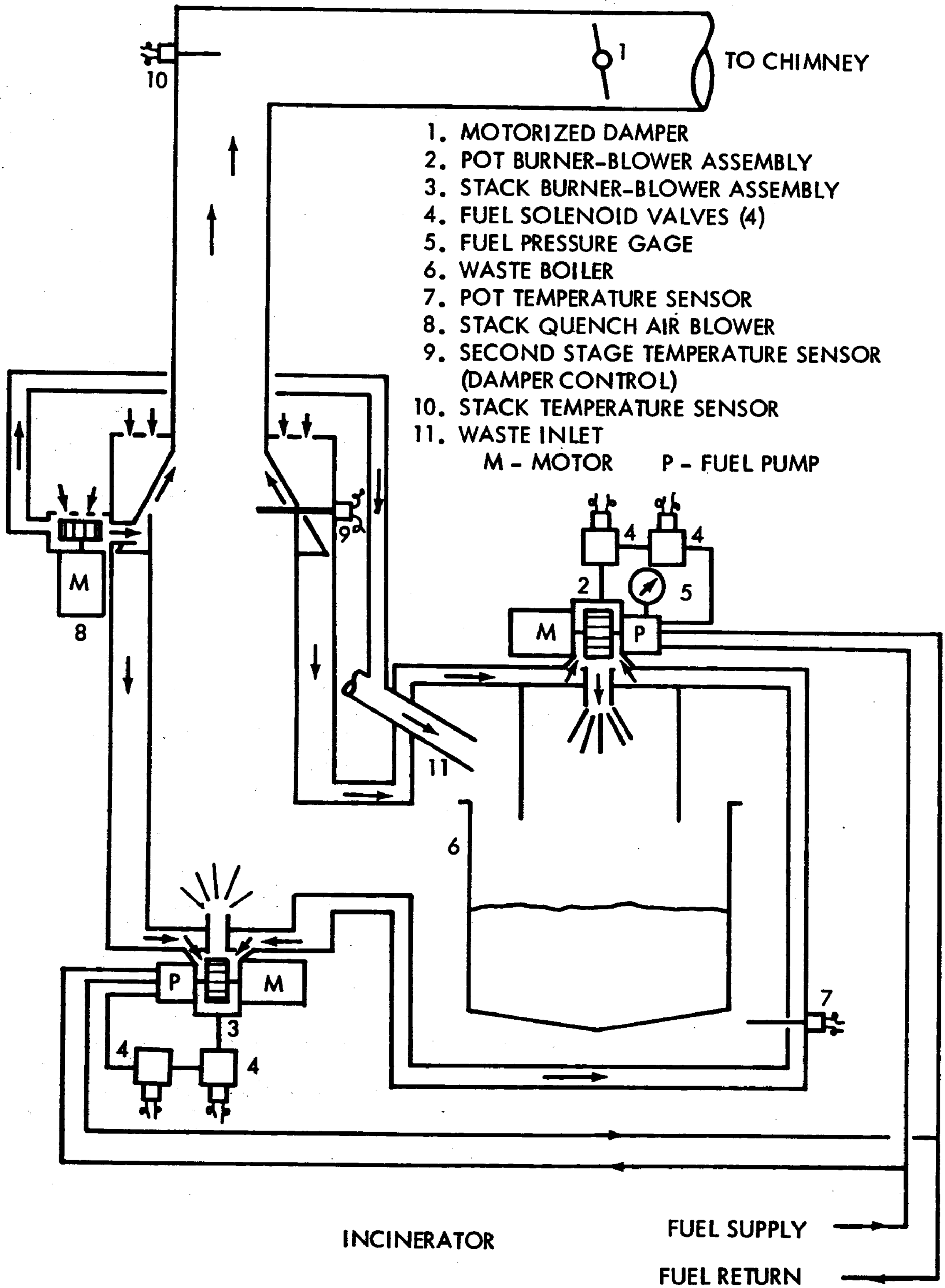


Figure 11. Incinerator System Mechanical Schematic

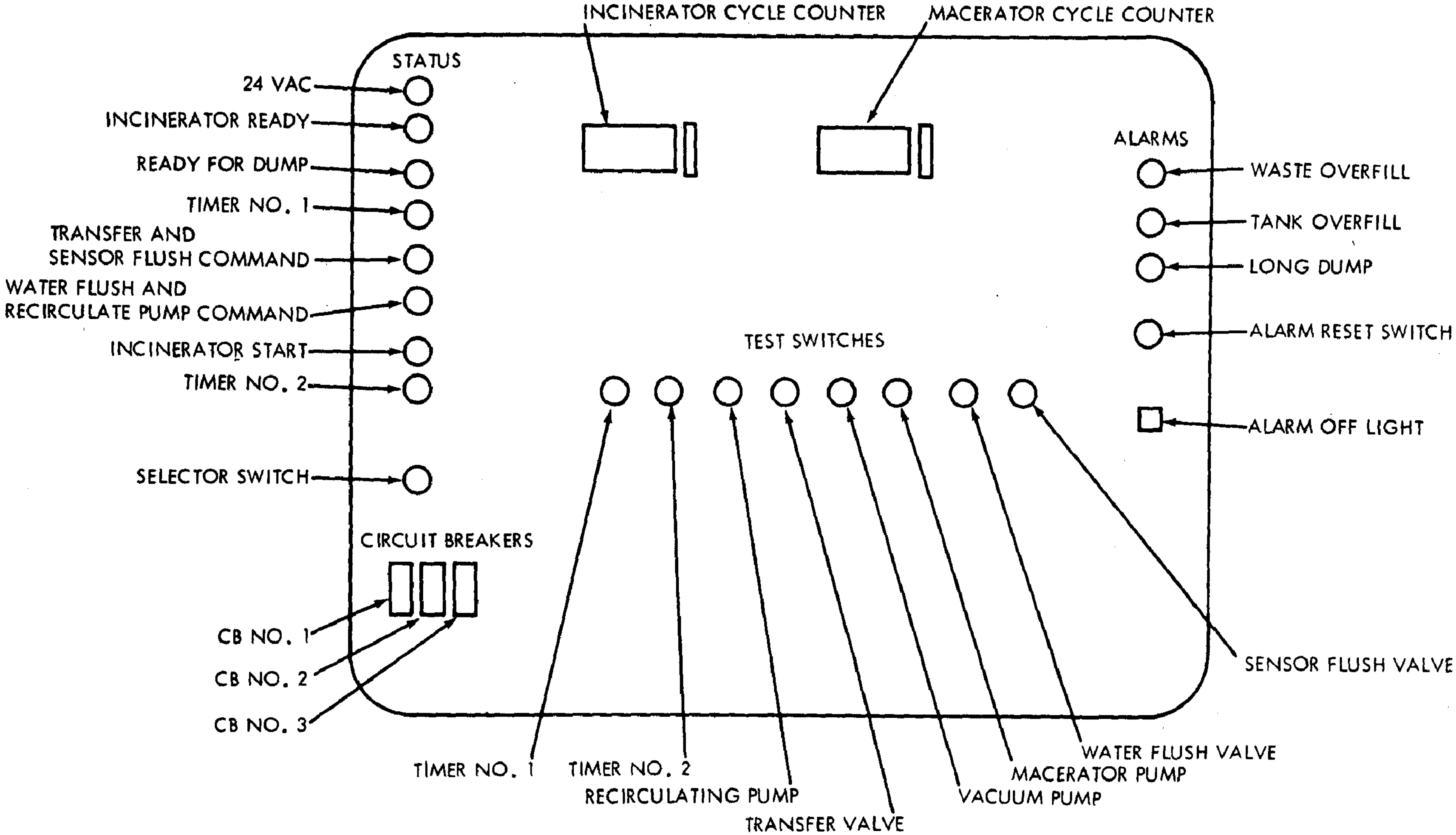


Figure 12. Separation System Control Panel

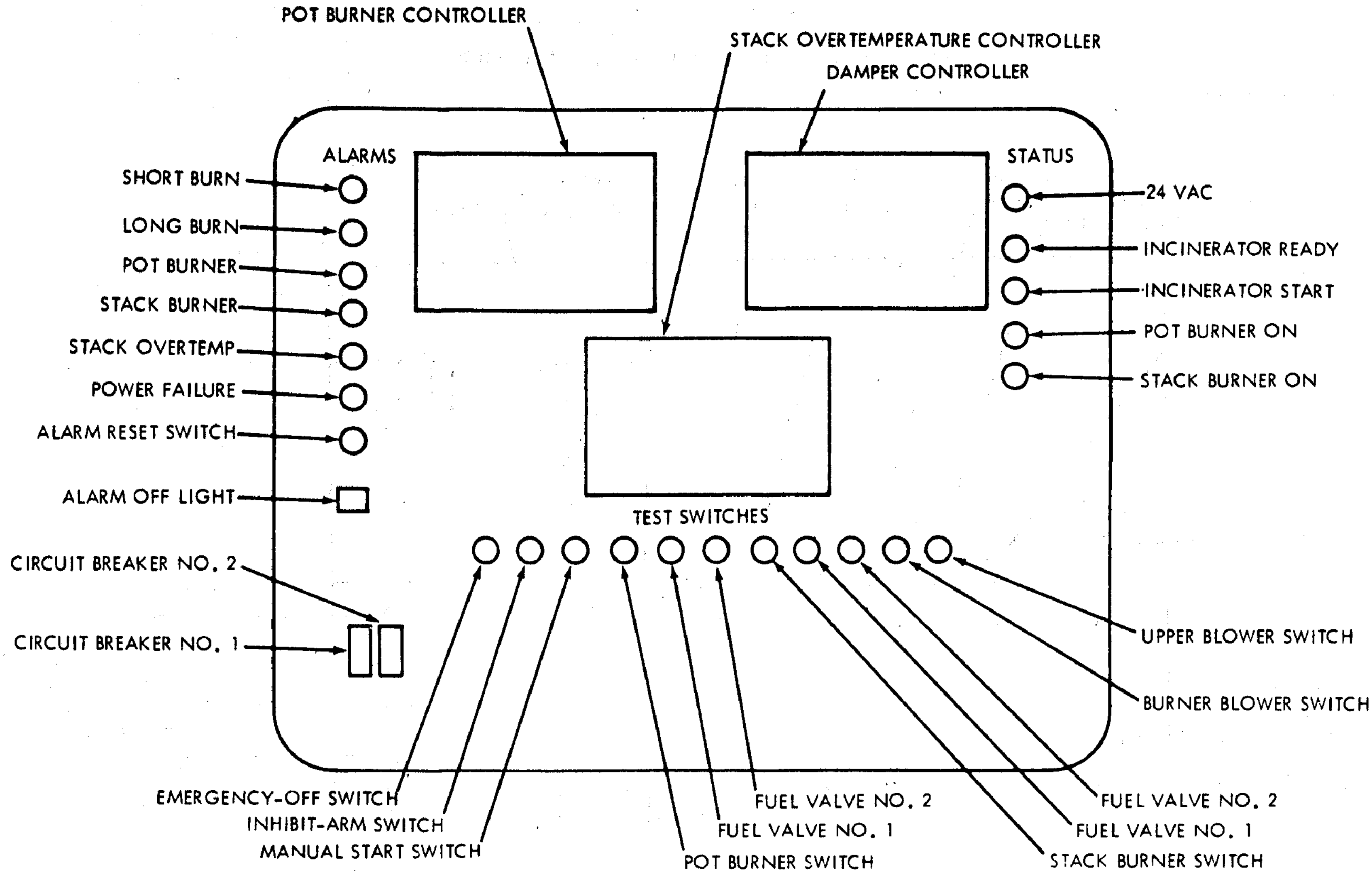


Figure 13. Incineration System Control Panel

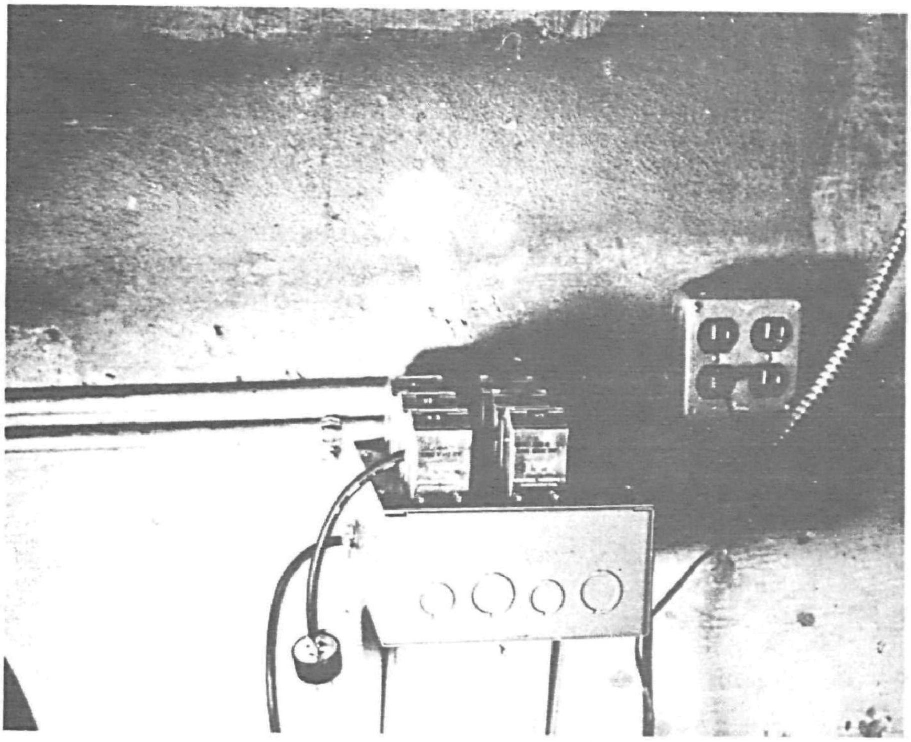


Figure 14. Commode Flush Counters

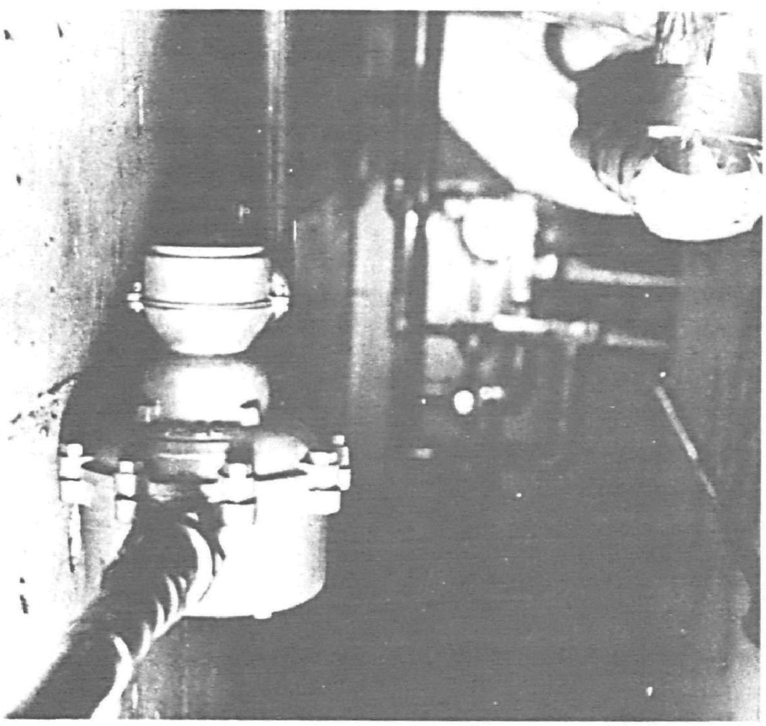


Figure 15. Urinal Flowmeter

3.0 FABRICATION AND CHECKOUT

3.1 SEPARATION SYSTEM

The separation system tank was fabricated by Chrysler and the system assembled at New Orleans. Due to unanticipated delays in procurement of some key components, the separation system was completed approximately 4 weeks behind the original schedule. Checkout was accomplished early in December 1971, with the performance of leakage, functional and integrated subsystem tests. During these tests, six pipe fitting leaks were repaired, transfer volumes and level sensors were calibrated and control system function was verified. After ten successful transfer cycles, checkout was considered complete. Following checkout, the system was dissassembled, packaged, and shipped. The unit arrived at Mt. Rushmore January 7, 1972.

3.2 INCINERATOR

Early in the program, a decision was made to subcontract the incinerator fabrication to an outside vendor. The unit was not delivered to Chrysler until December, and some rework and a considerable amount of tuning/adjustment of air flow control and burner nozzles was required before successful waste burns were accomplished. The incinerator was shipped assembled, and arrived at Mount Rushmore February 2, 1972

4.0 INSTALLATION AND SYSTEM START-UP

4.1 SEPARATION SYSTEM

Installation and checkout of the separation system (figure 16) was successfully accomplished in 1 week. Start-up procedures in the Operation and Maintenance manual were verified and some changes recommended. Facility switchover from water flush to oil flush and return was verified, and sanitary napkins were successfully processed through the macerator The

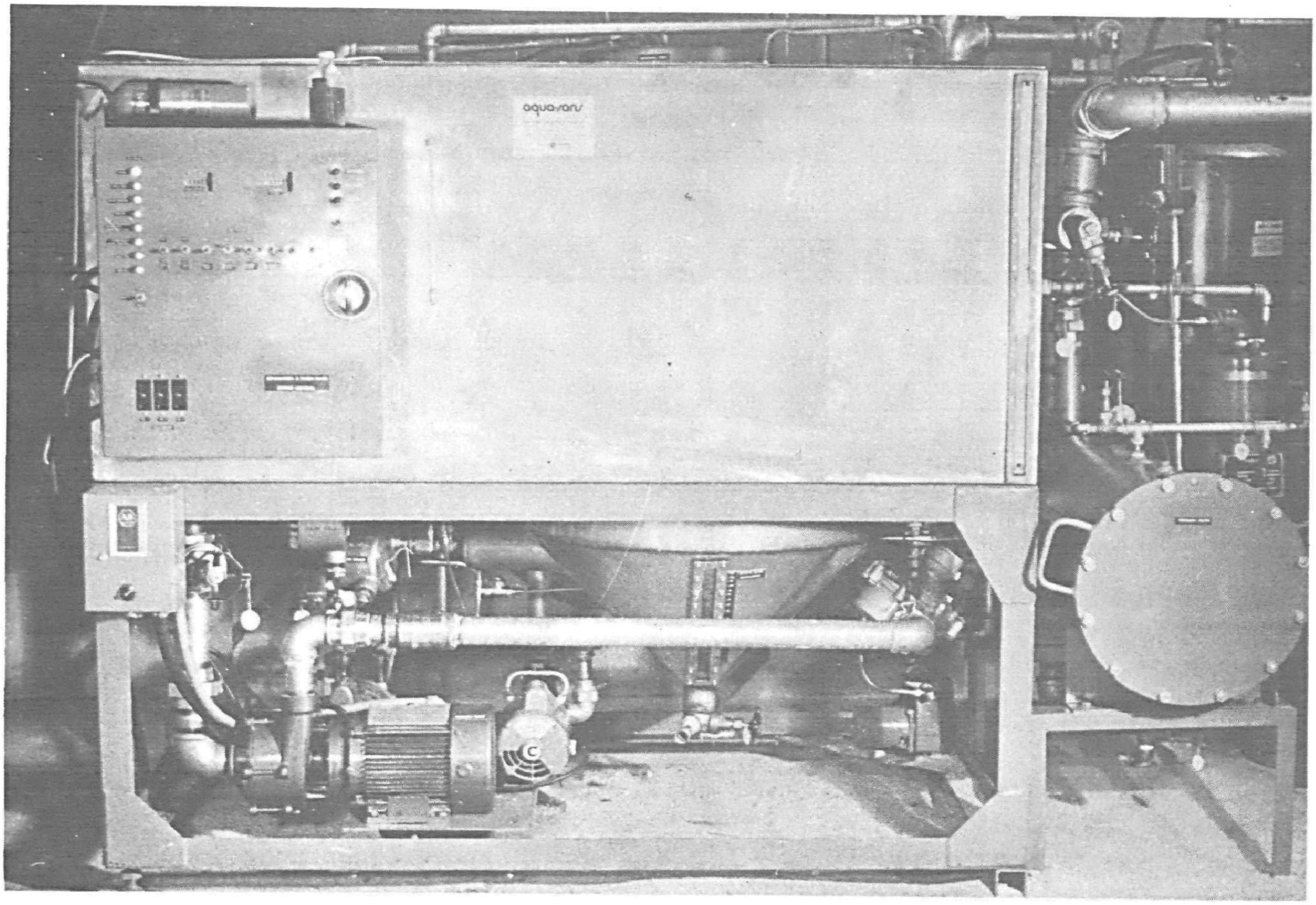


Figure 16. Separation System after Installation

system was connected to the restroom facilities for a shakedown during the week of January 15, prior to receipt of the incinerator While awaiting arrival and installation of the incinerator, collected waste was macerated and pumped into the Mount Rushmore septic tank.

4.2 INCINERATOR

The incinerator (figure 17) arrived at Mount Rushmore February 2, was then uncrated, dissassembled, moved to the basement of the Visitors' Center and reassembled. Initial tests were begun February 4. Problems with incinerator draft were immediately evident, due to altitude (1 mile) and problems of sharing the Visitors' Center chimney. These problems are discussed in more detail in section 5.2. During February, March and April, the draft problem was investigated and a number of incinerator modifications performed to induce an adequate draft condition. A proper draft condition is a requirement for this incinerator design since it is a double-wall, air cooled unit. Without proper draft conditions, the required air/fuel ratio could not be maintained, and cooling of the double-wall chamber was marginal. The draft problem was never completely resolved, and when results with another similarly designed unit indicated that the insulation and the 309 CRES material used in the design had a limited life, the decision was made to macerate and pump all waste to the Mount Rushmore septic system.

5.0 DEMONSTRATION TEST PROGRAM

5.1 TEST OBJECTIVES

The following test objectives were delineated in the Operational Evaluation Test Plan, TP-RE-71-233 (reference 3) covering the actual operational evaluation of the Aqua-Sans system at Mount Rushmore:

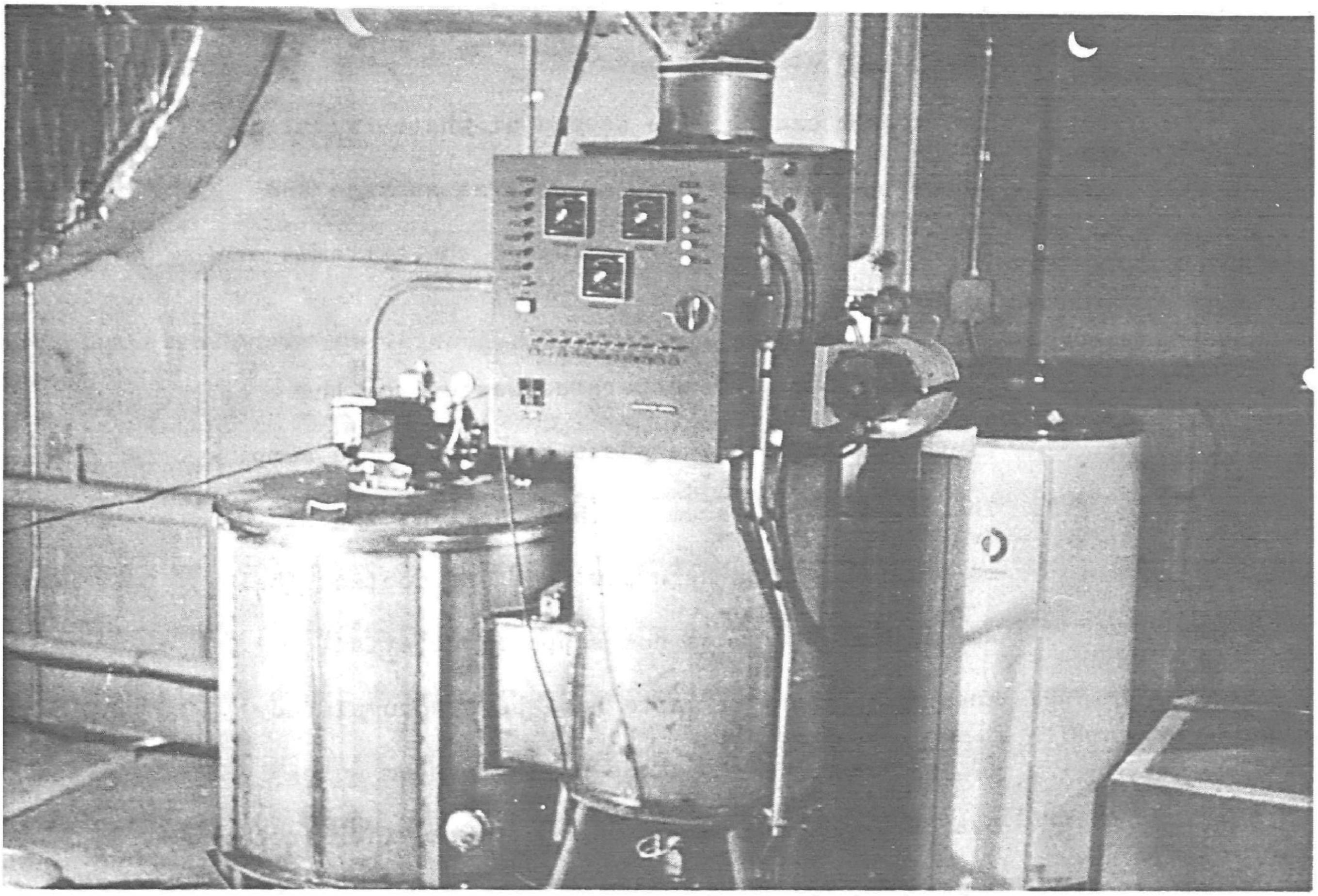


Figure 17. Incineration System after Installation

a. The system can be started up at the site with all components operating satisfactorily.

b. The system can be used in conjunction with a conventional sewer system, with the capability of changing back and forth from one system to another.

c. The system can perform its functional task of disposing of human waste at the site.

1. The system can receive sewage at whatever rate delivered to it at peak as well as average and below average periods, and under the extremes of temperature anticipated.

2. The separation tank separates waste from the flush fluid, with the waste going into the sump.

3. The separation system further purifies the fluid so that it maintains a low moisture content (below saturation) and does not support bacteria.

4. When 10 gallons of waste have been accumulated in the separation tank sump, the system automatically transfers that waste to the incinerator via a metering tank.

5. The system will automatically turn on the incinerator and, within the prescribed time limits, reduce the waste to sanitary ashes and non-polluting stack gases which are odor free and below 800°F as they enter the chimney.

6. When overloaded beyond its incinerating capacity, the system will automatically dump the excess waste to the sanitary sewer system.

d. The system can sustain certain operator errors without being permanently disabled.

e. The system indicates via lights on the control panel if any component is malfunctioning and allows rapid checkout to locate possible problem areas.

f. The actual functional capacity of the system will be established so that plans can be made for installation of units at other sites

5.2 RESULTS

5.2.1 Summary

The majority of general and specific objectives of the project were met. The areas where deficiencies became apparent will be discussed later in this section.

During a 6-month test period, over 4,500 gallons of undiluted human waste was collected and processed through the Aqua-Sans system. Original plans were to incinerate the majority of this waste, but due primarly to the chimney draft problems, the secondary disposal mode was used and the waste was pumped to the Mount Rushmore septic tank. The waste was collected during 45,000 urinal flushes and 31,000 commode flushes. If water had been the transport medium during this period, approximately 275,000 gallons of water-borne sewage would have gone through the Mount Rushmore septic system. Comparing 4,500 gallons with 275,000 gallons represents a fresh water saving of 270,000 gallons over a 6-month period, and a reduction in the hydraulic loading of the septic tank of over 98 percent, based on the facilities connected to the Aqua-Sans system during this period.

During the test period, over 500,000 gallons of oil was circulated by the primary pump system; only about half of this amount was used to flush the facilities, the remainder was bypassed through the filtering system to maintain the flush fluid in an acceptable condition.

The primary flush fluid performance parameters - bacteria, color, water content, and interfacial tension were all effectively controlled during the test period to within acceptable limits. Unacceptable odors were intermittently evident, both from the separation tank and in the restrooms. Odor causes and control are discussed in more detail in section 5.2.3.2.

The system operated in an automatic mode for a major portion of the test period, and was unattended for much of the first 3 months. The only component failure that caused an extended shutdown was failure of the original macerator pump. A high capacity pump installed in June operated successfully throughout the remainder of the test period.

The Mount Rushmore incinerator was never operational in an automatic mode because of the inability to achieve acceptable draft condtions using the Visitors' Center chimney, which also handled the exhaust from a large, oil-fired furnace. Six to ten incinerators cycles, consuming approximately 100 gallons of waste, were performed during efforts to install a draft inducer in the stack, but it was concluded that only a separate stack for the incinerator would resolve the problem. Additional funds for this installation and replacement of insulation were not available, and because a similar Chrysler-built incinerator was under evaluation by the U.S. Navy at Annapolis, Md., the decision was made to pump all waste collected to the Mount Rushmore septic system.

A summary of results relative to specific test objectives listed in section 5.1 follows:

a. The system was installed and started on site successfully.

b. Changeover from oil flush to water was demonstrated.

c.1. The unit accepted sewage at all flow rates imposed during the test period.

c.2. Separation of waste from flush oil was achieved, although some waste material was carried over into the reservoir (See paragraph 5.2.3.1).

c.3. Moisture content and bacteria were controlled, with proper periodic addition of biocides.

c.4. Automatic waste transfer was reliably achieved.

c.5. The incinerator was never operational in an automatic mode; therefore, this objective was not achieved.

c.6. All waste collected was transferred to the sewer system.

d. The control system was functional at all times.

e. The control panel indicators were adequate to display system condition and to allow rapid isolation of problem areas.

5.2.2 Test Data

Figures 18 through 22 are plots of the data recorded during the test period. Data on these plots are based on information received from the Black Hills Conservancy Sub-District. Figure 18 depicts the cumulative oil circulated by the primary pump. Maximum oil circulation peaked above 10,000 gpd on 7 days in May, late June and over the July 4th holiday.

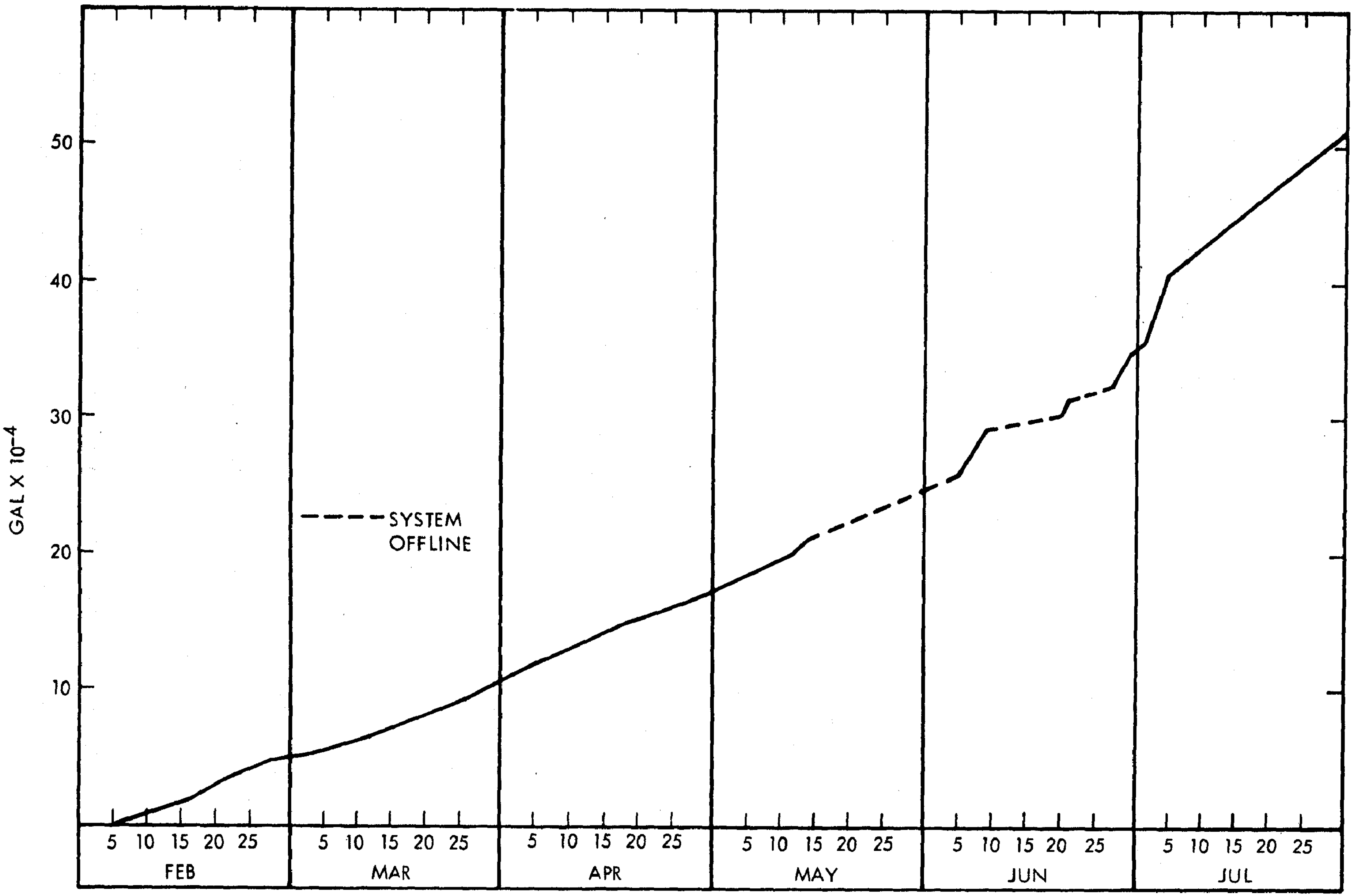


Figure 18. Total Flush Fluid Circulation

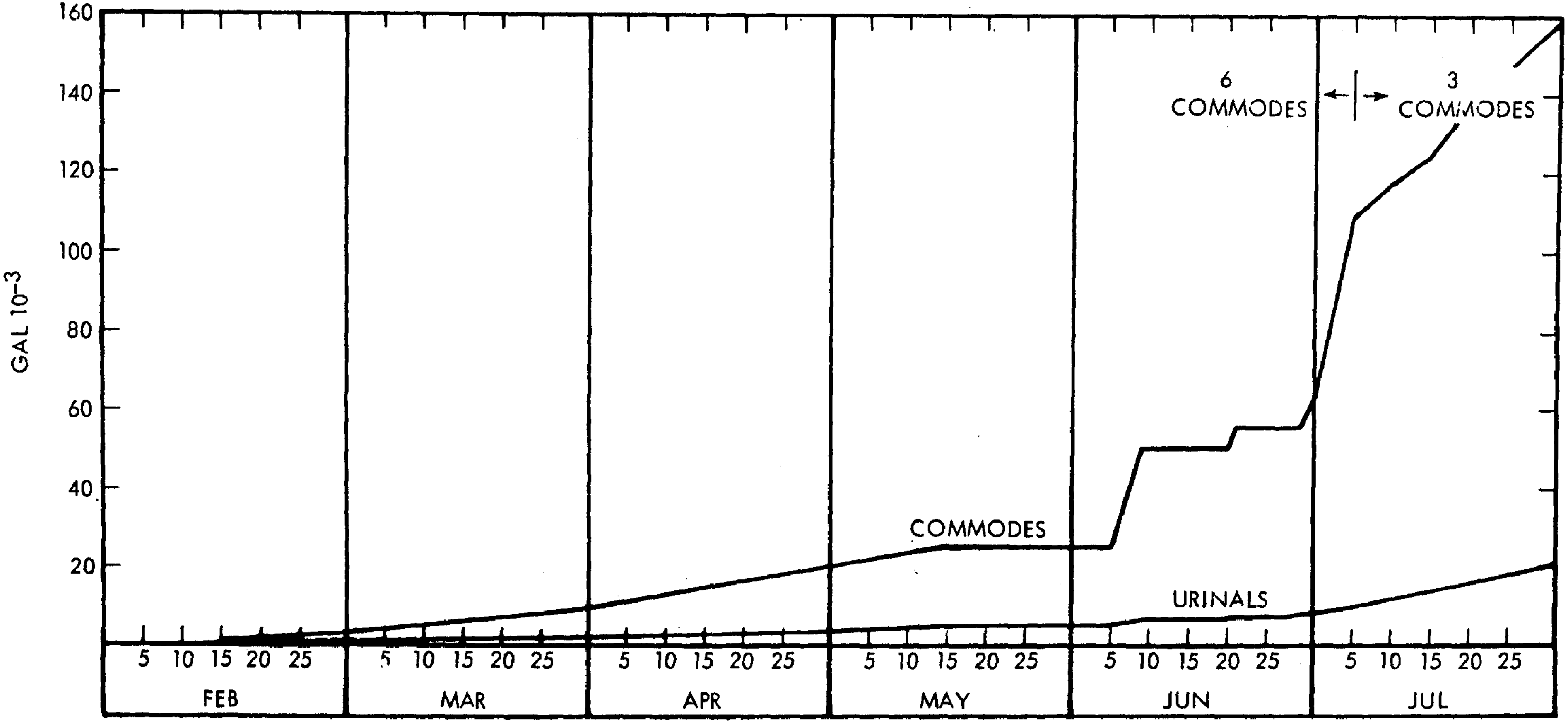


Figure 19. Commode and Urinal Flush Flow

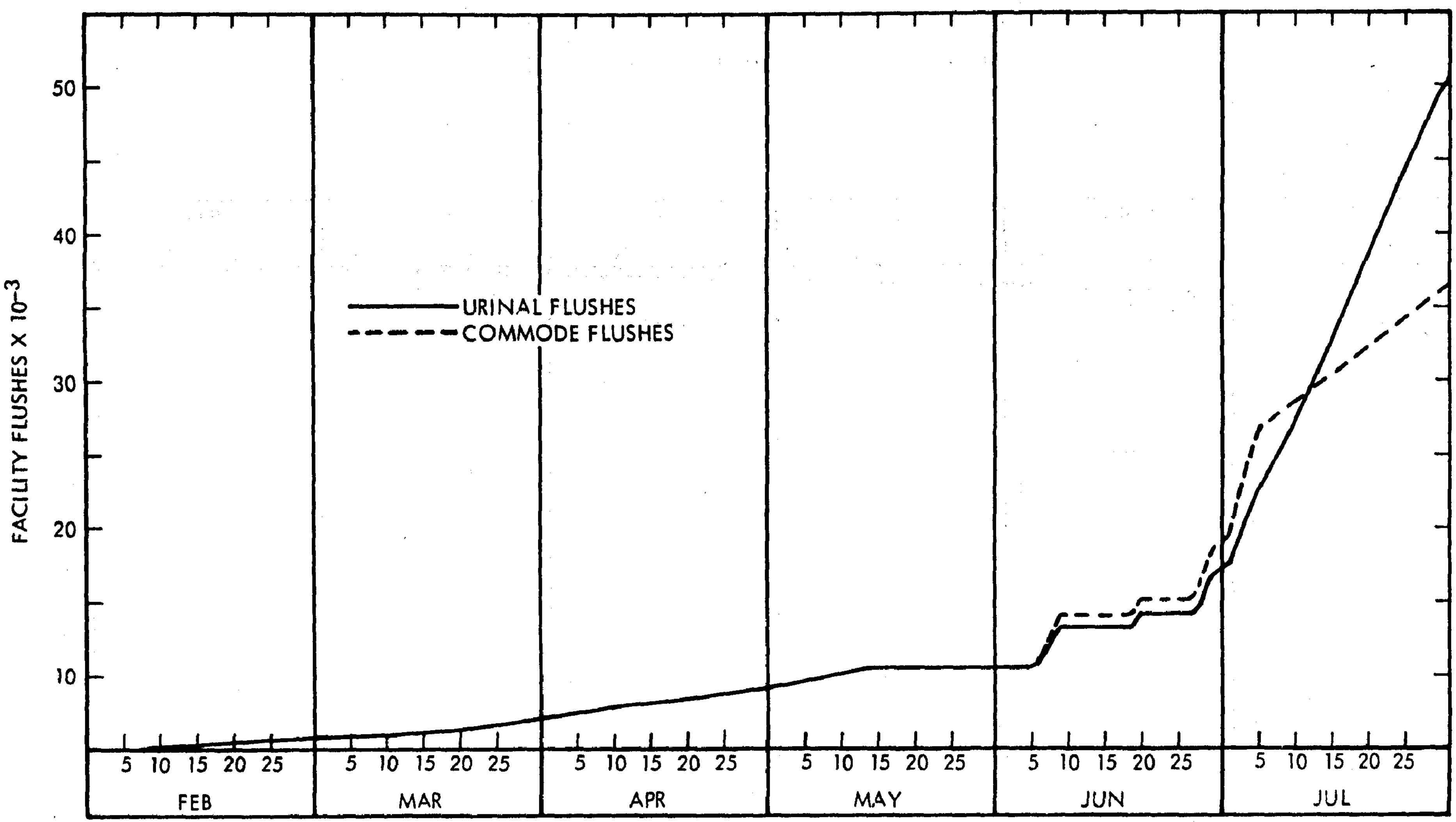


Figure 20. Cumulative Commode and Urinal Flushes

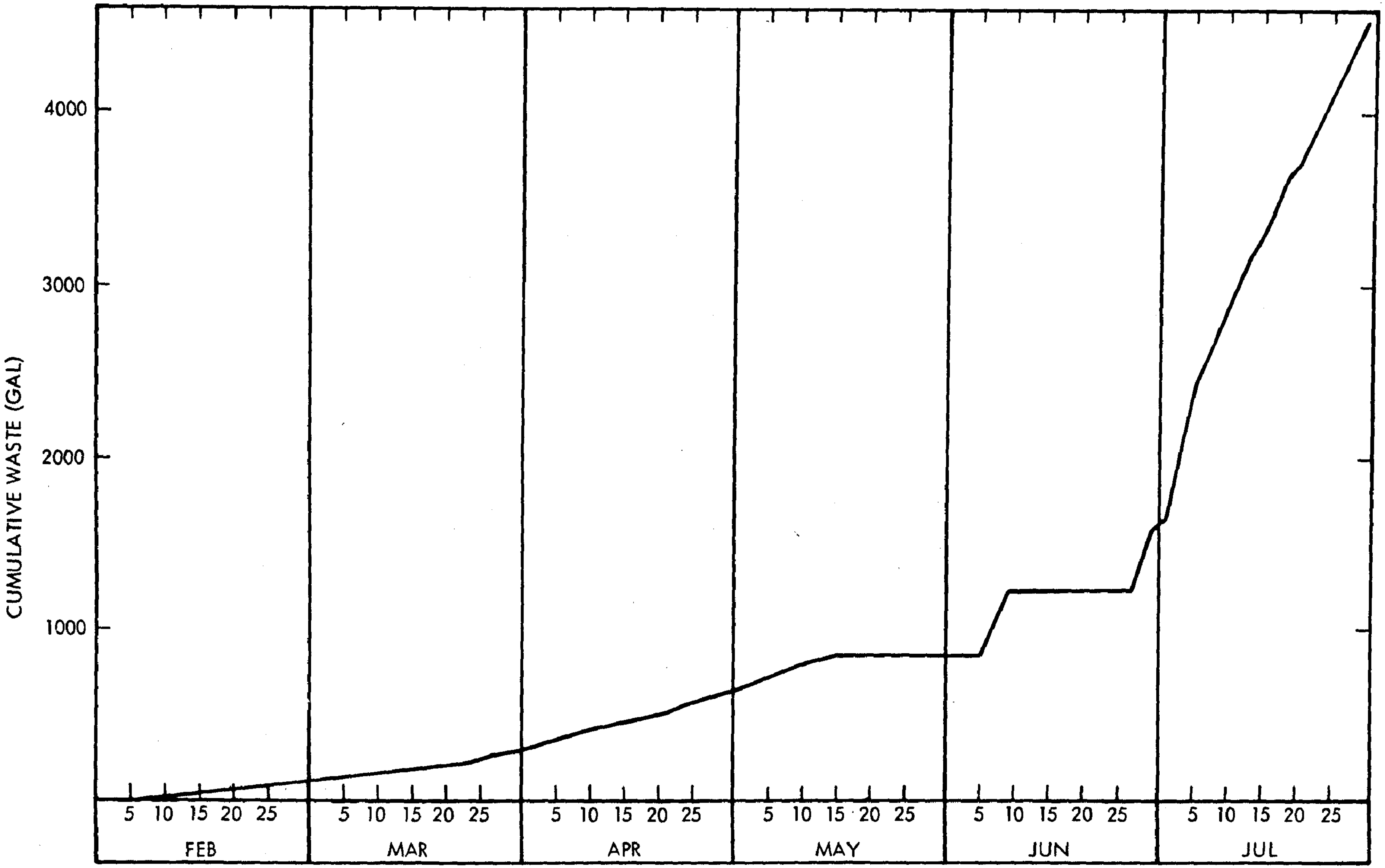


Figure 21. Cumulative Waste Transferred

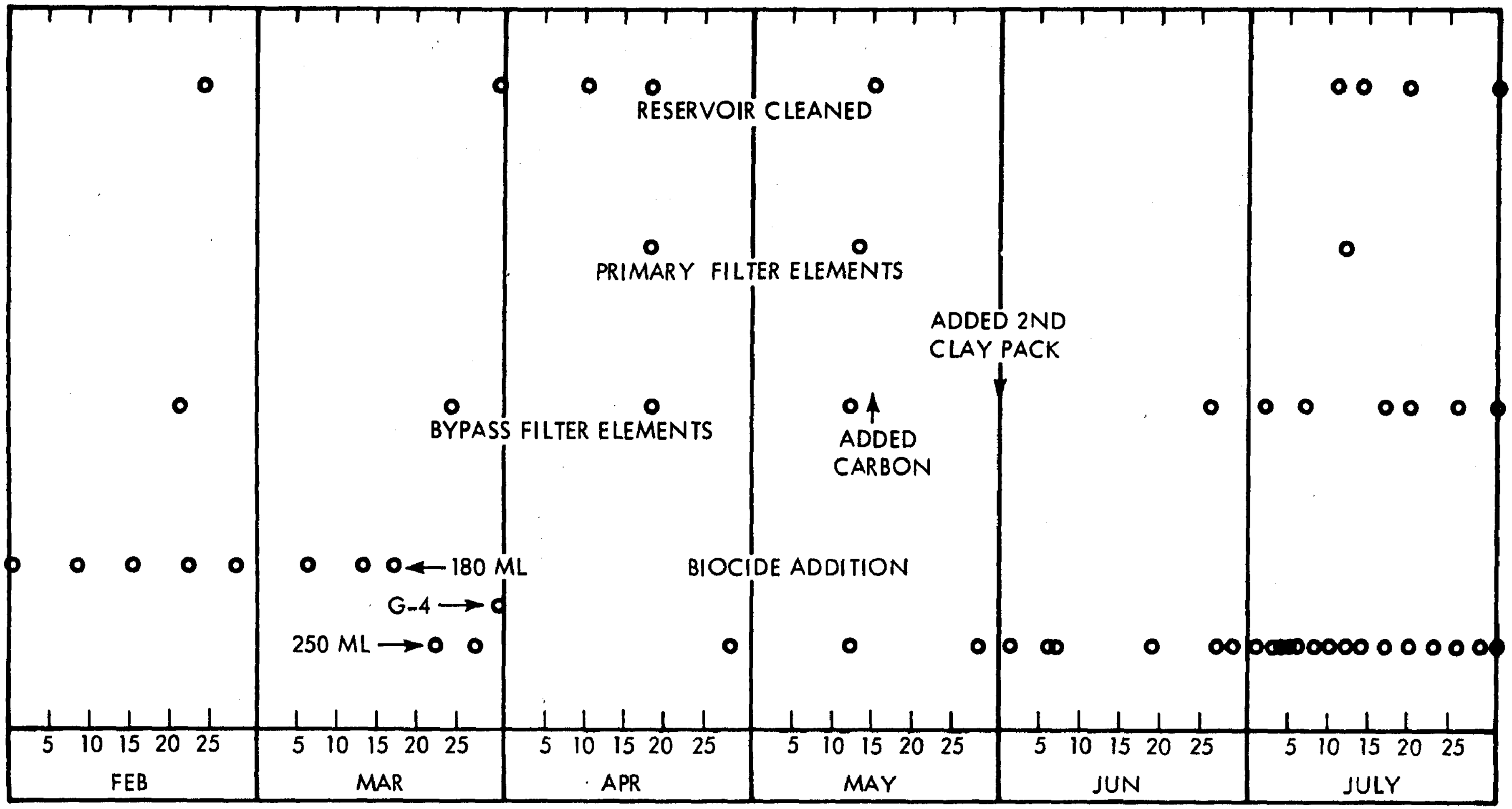


Figure 22. Maintenance

Figure 19 reflects cumulative flow to commodes and urinals. Urinal flow was measured directly; commode flow was estimated from commode flushes, using an average flow per flush. Figure 20 plots the commode and urinal flushes, and figure 21 plots the estimated volume of waste collected and transferred through the system. Figure 22 indicates maintenance functions performed with respect to time, during the 6-month test period.

5.2.3 Separation System

5.2.3.1 Flush Fluid Supply

The primary pump operated without malfunction throughout the test program. The accumulator proved adequate, though it had to be precharged on approximately a weekly basis. The accumulator used contained a loose fitting piston which served to separate the air from the oil. A bladder type accumulator has been used in subsequent systems, and these units have not required re-charging in over 6 months of operation. The pressure switch operated erratically during April and was replaced. Analysis of the original switch revealed no deficiencies.

A number of design deficiencies in the separation tank became evident shortly after the system was put into operation. The 110-gallon barrel was, in effect, a first stage separator but had insufficient volume. The screen in this barrel stopped large particles, but a large amount of solid material, of a colloidal nature was carried into the reservoir. This material collected on the gross coalescer and on the bottom of the tank. The tank structural members used to support the coalescer prevented this contamination from migrating to the low point in the tank and being recirculated to the sump. In April, the coalescer in the reservoir was removed and a coalescer installed in the barrel. This improved the situation, but contamination continued to accumulate in the reservoir. Accumulated material was one of the main odor sources in the tank. Present systems contain a much larger first-stage volume and a system of easily disposable bag filters between the first stage and the reservoir to reduce carryover. The primary pump inlet is located at the lowest point in the reservoir to prevent accumulation of small amount of waste that may migrate through the bag filters.

The primary filter/coalescer functioned satisfactorily as a coalescer but did not effectively filter solids. Tests have indicated that conventional filter elements only tend to break up waste particles into smaller particles Waste tends to adsorb onto the filter elements where biocides in solution have no effect, and the elements become odor traps. Though the differential pressure across the primary filter never exceeded 4 psid, the elements were changed three times. Each time, an ammonia odor was noticeable, indicating biological activity in the elements. Based on this knowledge, current systems contain no in-line filters other than the bag filters previously mentioned. Bag filters, which operate under a very low differential (18 inch head) are significantly more effective in retaining waste particles, can be easily disinfected, and are disposed of readily.

5.2.3.2 Fluid Maintenance

Interfacial Tension (IFT)

Early in the test program IFT was measured by Gulf South Research Institute (GSRI) using an optical technique developed for this program. With this method, Chrysler determined an IFT rating as follows:

	IFT, dynes/cm
- Unused, new, flush oil	30 - 33
- Satisfactory range for flushing	20 - 30
- Lower acceptable value for adequate separation	15

Test results obtained by the Black Hills Conservancy Sub-District using a ring tension-meter per ASTM Method D971-50 gave results 10 to 15 points higher than those recorded by GSRI. From June 5 until July 31, 179 samples were analyzed. Samples ranged between 29 and 46 dynes/cm, with an average value of 35 dynes/cm. Even when making allowance for the differences in the methods of measurement, the bypass clay pack adequately maintained IFT throughout the test program.

Color

Originally it was anticipated that the flush oil would turn yellow as a result of dye in the waste material. A small amount (0.1 percent) of Tarabar 441 was added to the oil as an oxidation inhibitor. During the test the oil remained relatively clear, as indicated by color comparison tests with a Hach CO-1 color comparator, with an α - Platinum-Cobalt standard. During the June-July period, the color ranged from 10 to 50 units, with an average of 34. It has been found that a value below 50 units is aesthetically acceptable by practically all users.

Water Content

Early in the program, a few fluid samples were checked for water content and the results indicated total water content to be below 100 ppm. Excessive water clouds the oil, and this condition was observed on 2 days only (July 3 and July 5) in a total of three samples. Since these 2 days were peak (over 200 percent of design criteria) usage days, the system design for removing water appears to be adequate.

Bacteria

During the test period, 69 samples were analyzed for bacteria. The results were as follows:

Number of Samples	Bacteria Colonies
48	None
7	1 - 6
4	7 - 10
6	11 - 100
4	> 100
69	

These tests demonstrated that the water and oil soluable biocide used with the system (Biobar JF) adequately controlled bacteria when added to the system at proper intervals.

Odor

Odor was the main problem encountered during the test program. Odor from waste material in the reservoir and also from material adsorbed onto the filter elements became apparent during the flushing action of the facility flush valves.

Chrysler has been involved in the development of more effective odor control techniques since this problem was first noted at Mount Rushmore. Some of the findings of this program are as follows:

As discussed in section 5.2.3.1, the separation tank and flush fluid reservoir must be designed so that no odor causing material can be trapped in the system. In-line filters should not be used.

- Activated carbon columns added to the clay filter in the bypass system assist in the control of objectionable odors. The carbon columns should be upstream of the clay filter and the bypass system should be sized to recirculate all the flush fluid in the system every 2 to 3 hours. A small carbon filter was added to the Mount Rushmore system in June, but it contained insufficient carbon to be effective.
- Oxidation is the most effective method for removing odors Chrysler has experimented with materials such as calcium hyprochlorite and di-and trichloro-S-triazine trione. Treating such areas as the filter housings, tank bottoms, and the coalescer elements with these materials has been effective, and has been demonstrated at three other Aqua-Sans Installations.
- Conventional restroom deodorizers should be used to mask any slight residual odors not removed by other methods.

5.2.3.3 Waste Transfer

<u>Level Sensing</u>

Two capacitance probes were installed in the sump of the Mt. Rushmore Aqua-Sans unit to sense waste level. The lower sensor is set at 12 gallons, and initiates the waste transfer cycle. The upper (overflow) sensor is set at 35 gallons and serves as a backup to initiate transfer, and to sound an alarm. This overfill sensor operated erratically during April, but was finally adjusted and both units operated satisfactorily for the remainder of the test program. The current system design contains a transparent tubular sight glass with level sensors installed. This configuration allows immediate visual inspection of the operation and the sight glass can be isolated for cleaning or maintenance.

Vacuum Lift System

The vacuum lift concept was used because no reliable waste pump was known to Chrysler at the time the Mt. Rushmore unit was designed. The system operated satisfactorily until late in July, when the vacuum pump failed due to insufficient lubrication. A source is now available for a reliable waste transfer pump; the vacuum lift system will no longer be used for waste transfer.

Macerator

The macerator pump was added to the Mt. Rushmore system design when it became apparent that more waste would be collected than could be incinerated in a 24-hour period. This pump, originally intended as a backup operation mode, became the primary means of moving waste. The original pump installed was not adequate, because it had a 1½ inch inlet and toilet paper would jam the inlet; this problem continued to exist even after the inlet line was enlarged. The pump was changed out in June for a higher capacity unit with a 4-inch inlet. This unit operated successfully during July and subsequently the same pump was installed in the Navy system at Annapolis, Md., where it functioned successfully for the remainder of the Navy test program.

5.2.4 Incinerator

Although the incinerator at Mount Rushmore was never operational, a similar unit at Annapolis was modified and has successfully incinerated human waste from a 140-man barracks over a 2-month period without malfunction. The modifications performed on the Annapolis incinerator were as follows:

- The crucible was constructed of Haynes No. 25 alloy, a high temperature nickel cobalt material with good corrosion resistant properties.
- The Koalin fibre insulation was shielded by Haynes No. 25 alloy to prevent degradation due to the exhaust gases.
- The first stage burner was modified to accept ambient air, and the cooling air from this stage was rerouted to the stack blower. This significantly reduced external surface temperatures.
- Primary stage burner temperature was limited to approximately 1150°F by cycling the burner.
- Waste was macerated and introduced into the incinerator in 2-gallon increments, every 20 minutes with burners on.

Operation with these mods incorporated resulted in successful incineration of all waste with a minimum of residual ash. During two months of tests at Annopolis, the incinerator consumed approximately 25 gallons of waste per day, operating successfully in an automatic mode.

During this same period, a supplier of commercial incinerators was located. These units are heavy incinerators using a cast, refractory lined burn chamber, but appear to be a cost effective method for waste incineration in installations where weight is not a constraint.

5.2.5 Restroom Facilities

During the test program, complaints were received from restroom maintenance personnel concerning odors, oil spills, and oil splashing on commode seats. The odor problem has been discussed previously Oil spills, due to plugged commodes and overflowed urinals are a hazard if the spills flow into walk areas. Restroom floors should be pitched away from traffic areas to prevent any accumulation of flush fluid, whether oil or water. Floor drains should be installed at the wall to drain any potential overflow flush flow back into sanitary drain lines. Small amounts of flush fluid, oil or water, is splashed on commode seats during flush action of flush valve type units. Since oil does not evaporate, these drops tend to accumulate. The answer to this problem is to utilize spring loaded seats, that will be raised when the commodes are vacated. This modification would provide a more sanitary installation even in a water flush system.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Under a purchase order from the Black Hills Conservancy Sub-District, Chrysler designed, fabricated and installed a sewage treatment system using a non-aqueous flush medium During a 6-month test program from February through July 1, 1972, the feasibility of employing this concept was demonstrated. A number of technical problems arose and were resolved by system modification and additional research and development. Future Aqua-Sans systems will be designed and installed with the following changes:

- Separation System
  - Larger first-stage volumes should be used, to allow 10 minute residence time, based on peak flow conditions.
  - Traps for solids should be avoided.
  - Primary flow filtration should take place upstream of the flush fluid reservoir.
  - Both activated carbon and clay should be used in the bypass fluid maintenance system.

- Effective biocides and oxidation agents should be applied to all filters to eliminate odors in the flush fluid.
- The separation tank and reservoir should be force vented.

. <u>Incinerator</u>

- For installations such as Mount Rushmore, where incineration is the desired mode for disposal, a commercial waste incinerator and a waste holding tank should be used.
- The incinerator should be located in a building separated from office or restroom areas.

. <u>Restroom Facilities</u>

- Tank type toilets function better with the Aqua-Sans system than flush valve units.
- Spring-loaded commode seats should be used to prevent oil accumulation on seats.
- Restroom floors should be pitched toward the walls where commodes and urinals are located to prevent accumulation of flush oil from overflowed facilities. Floor drains to the sanitary drain line should be installed at the low point.
- Disintegrating toilet paper should be investigated to prevent clogged toilets and pumps.
- Wall mounted commodes and urinals simplify rest room cleaning and should be used wherever practical.

REFERENCES

1. MI-212A, Proposal for Mount Rushmore National Memorial Park Prototype Sewage Disposal System, Chrysler Corporation Space Division, May 20, 1971

2. Purchase Agreement, BH 61771, between Black Hills Conservancy Sub-District and Chrysler Corporation Space Division, June 17, 1971.

3. TP-RE-71-233, Sewage Treatment System Operational Evaluation Test Plan for Black Hills Conservancy Sub-District, December 22, 1971.

4. TM-RE-71-1, Sewage Treatment System Operational and Maintenance Manual for Black Hills Conservancy Sub-District, February 18, 1972.

APPENDIX B

FLUSH FLUID SPECIFICATIONS

Excerpts From

SPECIFICATION FOR FLUID FOR WASTE FLUSH SYSTEMS

By

CHRYSLER CORPORATION SPACE DIVISION

March 1, 1972--Revised September 12, 1972

1. SCOPE

This specification presents requirements for two grades of waste carrying flush fluid.

2. APPLICABLE DOCUMENTS

- Federal Test Method Standard No. 791--Lubricants, Liquid Fuels, and related products; methods of testing.
- MIL STD 290--Packaging, Packing and Marking of Petroleum and Related Products.
- ASTM Manual (Parts 17, 18, and 23 on measurement and sampling of petroleum and petroleum products).

3. REQUIREMENTS

3.1 Qualification - The fluids furnished under this specification shall be a product which has been tested and has passed the qualification tests specified herein, and has been approved by Chrysler Corporation for listing on the applicable qualified products list.

3.2 Materials

3.2.1 Base Fluid - The composition of the fluid base is not limited so long as the final flush fluid meets the requirements of this specification.

3.2.2 Additives - No additives shall be added which increase the polarity of the fluid. Other additives must be declared (chemical composition and approximate amount) on the test report, and their toxilogical effects explained before they can be approved for use. Silicons shall not be used as additives for any purpose.

3.3 Laboratory Tests - The flush fluid shall meet the following physical and chemical properties:

	Grade I	Grade II
3.3.1 Viscosity, Csts. @ (210°F) 98.9°C, Min.	2.75	
3.3.2 Viscosity, Csts. @ (100°F) 37.8°C, Max.	12.0	7.0
3.3.3 Viscosity, Csts. @ (32°F) 0°C, Max.	61.0	31.0
3.3.4 Flash Point, (COC), Min.	168.3°C(335°F)	168.3°C(335°F)
3.3.5 Pour Point, below	-17.8°C(0°F)	-40.0°C(-40°F)
3.3.6 Density @ 60°F, Max.	0.85	0.85
3.3.7 Interfacial Tension with H_2O, Min.	30 Dynes/Cm	30 Dynes/Cm
3.3.8 Color-Alpha platinum cobalt units, Max.	15	15
3.3.9 Analine Point, Min.	215°F	190°F
3.3.10 Unsulfonatable residue (Min.)	99%	99%
3.3.11 Total Acid Number, Max.	0.0	0.0

3.3.12 Evaporation - Evaporation loss of Fluid Grades I and II shall not exceed 5% by weight when tested at 48.9°C (120°F) for 48 hours.

3.3.13 Foaming - The foaming tendency and foam stability of Fluid Grades I and II shall not exceed the following limits:

Temperature	Foam Volume at End of Five Minute Aeration	Foam Volume After One Minute Settling Period
24°C (75°F)	65 ml	None

3.3.14 Rubber Swell - Swelling of standard rubber L by the Fluid Grades I and II shall be less than 5%.

3.3.15 Paragraph deleted.

APPENDIX C

TEST PROCEDURES

C-1. COLIFORM BACTERIA COUNTS OF MINERAL OIL

1. To a centrifuge tube add 10 ml of oil and 1 ml of trypticase-soy-broth.
2. Shake thoroughly.
3. Centrifuge for 10 minutes at 2000 rpm.
4. Take 1/10 ml from the bottom layer containing the bacteria.
5. Streak the aliquot on an Eosin-Methyleneblue-agarplate.
6. Incubate for 24 hours at 37^{o}C.
7. Count bacteria colonies.

C-2. INTERFACIAL TENSION OF MINERAL OIL

1. Filter Paper Method

   The height that the oil will climb on a strip of Whatman #54 filter paper was tested as a method of IFT determination. A calibration was established between the height of rise and the IFT (as measured by Gulf South Research Institute). The time for testing is two hours with the temperature at 30^{o}C and the oil sample and filter paper placed in a dessicator.

2. ASTM: D971-50, Standard Method of Test for Interfacial Tension of Oil Against Water by the Ring Method

   SCOPE

   This method of test describes a procedure for measuring, under non-equilibrium conditions, the interfacial tension of mineral oils against water, which has been shown by practice to give a reliable indication of the presence of hydrophilic compounds.

OUTLINE OF METHOD

Interfacial tension is determined by measuring the force necessary to detach a planar ring of platinum wire from the surface of the liquid of higher surface tension, that is, upward from the water-oil interface. To calculate the interfacial tension, the force so measured is corrected by an empirically determined factor which depends upon the force applied, the densities of both oil and water, and the dimensions of the ring. Measurements are made under rigidly standardized nonequilibrium conditions in which the measurement is completed within 1 minute after formation of the interface.

APPENDIX D

EFFECT OF FLUSH FLUID ON HUMANS

Reproduction of

EVALUATION OF THE EFFECT OF CHRYSLER AQUA-SANS FLUSH FLUID ON HUMANS

By

CHRYSLER CORPORATION SPACE DIVISION

Technical Note

TN-RE-72-103

March 10, 1972

TABLE OF CONTENTS

EVALUATION OF THE EFFECT OF CHRYSLER AQUA-SANS FLUSH FLUID ON HUMANS

1.0 OBJECT

The object of this investigation was to establish through laboratory testing and review of published documents relating to test results of similar products, the suitability of the Chrysler Aqua-Sans flush fluid for use in a closed-loop sewage treatment system where toxicant and allergenic producing agents are of concern.

2.0 CONCLUSIONS

Evaluation of the Chrysler and fluid manufacturer's test data has led to the conclusion that the flush fluid used in a properly operating Aqua-Sans System has no deleterious effects on either equipment users or operating maintenance personnel. The base fluid and its additives have all been used for many years in applications where there has been frequent human contact. As a result, extensive testing has been done to confirm the absence of toxicant or allergenic producing agents.

3.0 EFFECT OF AQUA-SANS FLUID ON HUMANS

The Aqua-Sans fluid is an N.F. white oil of the general type and grade sold to cosmetic firms to make baby oil and hand creams. As such, it has been tested repeatedly for toxicity by the cosmetic people and HEW and found to be non-toxic. In addition, it has, for years, been advertised as beneficial to the skin.

When splashed into the eyes, the fluid forms a temporary film that distorts vision but the substance is rapidly carried away by the eye's normal drainage system. It is non-irritating to normal conjunctiva. When splashed on clothes it causes an oily spot which can pick up dirt. It usually travels out over the fabric, spreading itself thinner and thinner until it seems to disappear on dense fabrics like wool. The film does not evaporate, harden or polymerize with time and can be removed with dry cleaning solvent or detergent-water.

Small amounts of the fluid can be ingested with no ill effect. It is non-digestable and in large quantities (quarter ounce or more) can disrupt normal digestion by coating the interior of the intestinal walls with an inert film. In time, the symptoms, if any, are naturally eliminated. (See exhibit 1, a toxicity report on tests conducted by the Gulf South Research Institute.) The effect of additives that are now or might in the future be used in the fluid have been investigated and found to be non-toxic in concentrations used.

4.0 DISCUSSION

4.1 Oxidation Inhibition

The oxidation inhibitor which is added by the manufacturer is Parabar 441 (Enjay Chemical Co.) or an identical chemical made by one or two other major chemical manufacturers. This additive, a butyleted hydroxy toluene, has been used for many years in hydraulic fluids, lubricants, waxes (often sold for candles and jelly-glass sealing), etc. The fluid manufacturer adds approximately 0.05 percent of this inhibitor. (See exhibit 2, Enjay Environmental Health Bulletin.) Exhibit 2 indicates that there are no health hazards from the usual concentrations of the additive in fluid (0.1 to 0.5 percent).

4.2 Biocide-G4 (Givaudan Corporation)

Biocide-G4 has been proved to be quite effective in rendering the fluid biocidal at concentrations of 200 ppm. Chemically, it is 2,2-Dihydroxy-5,5-Dichloro-diphenyl-methane developed originally under Government incentives as a material for treating army cloth (tents, cordage and clothes) to prevent decomposition. G-4 is an effective bactericide and fungicide, and because of its use on military clothing, has been tested extensively and found non-toxic in concentrations far higher than that used in our flush fluid. (See exhibit 3, Givaudan Technical Bulletin D-1.) This product is a powder which is only slightly soluble in our fluid and insoluble in water. It is, therefore, in a very difficult form to combine with the flush fluid as it is received from the manufacturer. These same properties, however, make it extremely interesting as a base for automatic or permanent addition. Once added, it does not decompose and is very slowly removed by the clay filters. Chrysler is presently doing research on methods of addition and we are quite sure that within a few months G4 will be the biocide used.

4.3 Biocide-Biobor JF (U. S. Borax)

Chrysler is presently using this product at a concentration of 135 ppm to keep the fluid biocidal. We use it instead of other available products; for example, G4 because its easily miscible liquid form makes it extremely convenient to add. Chemically, it is a mixture of two related dioxaborinanes. Because of its hydrolytic instability and physical polarity, it is dissipated by decomposition with moisture and absorbtion on the clay filter. Therefore, we add a new minimum dose each week. Experience has shown that adding more only increases filter load, while adding less allows growth of bacteria. Biobor JF is considered mildly toxic in the concentrated form but relatively harmless in the low concentrations used in the Aqua-Sans system. (See exhibit 4, U. S. Borax Product Bulletin.)

4.4 Fluid Dye

This material is considered non-toxic and is, in addition, added in such small proportions (2 to 3 ppm) that harmful effects need not be considered.

Exhibit 1

TOXICITY REPORT ON TESTS CONDUCTED BY THE GULF SOUTH RESEARCH INSTITUTE

Work Carried Out for the Chrysler Corporation, Space Division, New Orleans, La., from October 14, 1970, to December 1, 1970

Study of animal skin sensitivity to the recycle oil from the Chrysler Sanitation Device.

This study comprised two separate tests with live animals (two) rabbits):

1. A "swab test." The Chrysler oil was swabbed on shaved rabbit skin for four consecutive days;

2. The oils were injected intracutaneously under the rabbit skin.

Procedure

The rabbit backs were shaved and no visible skin reaction was observed the following day.

A rectangle was then marked on the back of each rabbit and divided into four equal parts. The control oil (Pure Sontex 75) was used on two squares and "used Sontex 75" (sample taken from the unit on November 17, 1970) was used for the two other squares.

On the first day each rabbit was treated as follows:

Pure Sontex 75 was swabbed on one square and two 0.1 mls injections of pure Sontex 75 were administered intracutaneously in the adjacent square. The same procedure was carried out on the other two squares with "used Sontex 75." The injections were made only once. The swab tests were repeated for four consecutive days.

Results

After 24 hours all of the injected materials had been absorbed and no detectable skin reactions occurred during the following six days.

No detectable skin reactions were observed from the swab tests after six days of observation.

GULF SOUTH RESEARCH INSTITUTE

C O P Y

Exhibit 2 - Enjay Environmental Health Bulletin

ENVIRONMENTAL HEALTH BULLETIN ENJAY

PARABAR 441

USE:

Parabar 441 is an oxidation inhibitor used to fortify industrial lubricants and waxes. The typical use concentration is about 0.5% by weight in oils and less than 0.1% in waxes. Parabar 441 is chemically butylated hydroxy toluene (BHT).

PHYSIOLOGICAL CHARACTER:

The vapor pressure of Parabar 441 is low and no hazard from inhalation exists at room temperature. No adverse effect was seen in test animals exposed to air saturated with sublimed vapor (concentration of 6.46 ppm) for 130 seven-hour exposure periods over a 190-day interval.

Large-scale tests by skin contact on humans using the patch technique showed that Parabar 441 is relatively innocuous to the skin. Repeated guinea pig tests indicated that it is not a sensitizer.

Crystals of Parabar 441 produced superficial, transient ulceration in the eye of one of several rabbits on test. A solution of 0.4% concentration in U.S.P. mineral oil was non-irrating to the eyes of test animals.

Extensive series of toxicity tests with Parabar 441 have shown it to have a relatively low order of toxicity by the usual routes of administration in six species of test animals. The oral LD_{50} by skin exposure to rabbits is greater than 5 g/kg.

PRECAUTIONS:

Care should be taken to avoid eye and skin contact with the neat crystals. In case of contact with Parabar 441, it should be removed by flushing with water. Oils and other substances containing Parabar 441 require only the usual precautionary handling procedure for the other substances.

September 15, 1963

Enjay Chemical Company · 60 West 49th Street · New York 20, N.Y.

GIVAUDAN™
sindar division

TECHNICAL BULLETIN D-1

Exhibit 3 - Givaudan Technical Bulletin D-1

G-4® Technical

(Brand of Dichlorophene Technical)

As a Fungicide and Bactericide

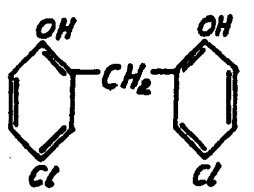
I. Introduction

G-4® is a potent fungicide and bactericide which is used to preserve cotton and woolen textiles and other materials. Mold, mildew, rot, mustiness and some types of rancidity are common expressions for the various types of deterioration caused by fungi and bacteria. G-4 is particularly effective against such deterioration.

II. Chemical and Physical Properties

Name: 2,2'-dihydroxy-5,5'-dichloro-diphenylmethane or 2,2'-methylenebis-(4-chlorophenol) or bis (5-chloro-2-hydroxy phenyl) methane.

Structure:



Melting point: 164° C. minimum

Appearance: Light tan, free-flowing powder

Odor: Weak phenolic

Vapor pressure: 10^{-4} mm. of mercury at 100° C.; about 10^{-10} mm. at 25° C. (extrapolated value)

Solubility: (grams in 100 ml. of solvent at 25° C.)

Solvent	
Water	0.003
Ethyl alcohol	53
Isopropyl alcohol	54
n-Butyl alcohol	43
t-Butyl alcohol	60
Propylene glycol	45
Acetone	80
Methyl ethyl ketone	75
Benzene	1.6
Toluene	1.7
Xylene	1.5
Stoddard solvent	0.2
Mineral Spirits	0.1

Soluble, with heat, in fatty acids and vegetable oils.

To obtain completely clear solutions of the technical grade of G-4, it may be necessary to filter the solutions.

III. Toxicity

G-4 is generally regarded to be non-irritating to the skin at the usual concentrations of use. In patch tests on humans with a cotton fabric containing 1.0% of G-4, no primary irritation or sensitization of the skin resulted. Its non-irritating characteristics have often been a major factor in deciding on the use of this product.

Using the rabbit skin irritation technique, a petroleum jelly containing 5% of G-4 was applied twice daily for 10 days. This high concentration was selected to increase the severity of the test and the margin of safety for the interpretation of the results. It was concluded from this work that G-4 was not a primary irritant even under the severe conditions used in this test.

Patch tests were also conducted on 194 humans using G-4 at a concentration of 4% in a petrolatum base ointment. The patches were applied to the inside of the forearm and were removed after 48 hours.

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Out of the 194 persons tested, 191 gave negative reactions and 3 were positive.

The acute oral toxicity in animals has been determined to be as follows:

LD_{50} — Guinea Pigs 1.25 gms/Kg
LD_{50} — Dogs 2.0 gms/Kg

In chronic toxicity studies on rats, 0.2% of G-4 was added to the food for a period of ninety days; this dosage corresponds to a daily intake of approximately 400 mg/Kg of body weight. The animals were autopsied and histopathological studies were made on various tissues. There was no evidence of toxicity after 90 days. At a concentration of 0.5% daily in the diet there was evidence of kidney changes at the end of ninety days.

IV. Biological Activity

G-4 exhibits both fungicidal and bactericidal properties which is an important advantage since both fungi and bacteria may be contributing factors to deterioration. The effectiveness of G-4 has been well-established by the Armed Forces who consume large quantities for the protection of their equipment.

Fungicidal Properties:

The literature on the fungicidal properties of G-4 is so voluminous that only a few examples can be cited here to illustrate its activity.

Various laboratories have tested G-4 against fungi in nutrient agar medium. In these tests, the center of the agar plate was inoculated with a drop of a spore suspension of the test organism and periodic measurements of the size of this colony were made for several days. The ratio of these measurements to those of a control plate which did not contain G-4 was recorded as percentage inhibition. (See Table 1—page 3).

Using Trichophyton interdigitale in a standard agar plate method, a zone of 6 mm. was obtained with filter paper impregnated with a 2% solution of G-4 in alcohol; at a solution strength of 0.2% only a trace of a zone was noted.

The results of laboratory tests on cotton duck treated with G-4 are given in Table II (Page 3). Since certain of these tests are not standardized procedures, fabric samples treated with copper naphthenate were used for control purposes. These samples were tested without the beneficial effects of a water repellent treatment.

A concentration of 0.25% of G-4 in a fabric has been found to be the minimum concentration which will pass the Aspergillus niger and Chaetomium globosum tests.

Bactericidal Properties:

Table III (page 3) shows the dilution of G-4 which will kill the various micro-organisms in 10 minutes, but not in 5.

The F.D.A. method of test was used with modifications necessary for growing the different bacteria. Since G-4 is not soluble in water, the following test solution, containing 0.1% G-4, was employed: 0.1g. of G-4 was dissolved in 1 ml. of 95% alcohol and 0.75 ml. of 0.5 N-alcoholic potassium hydroxide and, to this solution, water was added to make a total volume of 100 ml.

The data in Table III may also be expressed as phenol co-efficients as follows:

	20° C/10 min.	37° C/10 min.
Salmonella typhosa	75	100
Micrococcus pyogenes var. aureus	42	100

V. Methods of Application to Textiles

Recommended Concentrations:

For outdoor use, it is recommended that G-4 be applied with a water-repellent finish to obtain maximum effectiveness.

The following concentrations of G-4 are suggested:

0.25-0.5% for textiles not used out-of-doors.
0.8-1.0% for textiles subject to weathering.

Most Government specifications on mildewproofing with G-4 require that the treated fabric contain about 1% G-4 based on the dry weight of the goods.

From Alkaline Solution:

While G-4 is quite insoluble in water, an aqueous solution of its sodium salt can be readily prepared. Such a solution, at a concentration of 40% of the mono-sodium salt is called G-4-40 and can be prepared as follows:

G-4	100 lbs.
Caustic soda flakes Tech.	18 lbs.
Water	18 gals.

The G-4 and caustic soda are mixed together and put into the water under stirring until solution is complete. The heat of solution of the caustic soda is usually sufficient to get the G-4 into solution; additional heating may be desirable to speed the process. This stock solution is then diluted with water to the desired strength. To eliminate the cloudy appearance of this solution, filter with an aid such as Super-Cel® (Johns-Manville Corp.)

Knowing the percentage pickup of the pad liquor by the fabric and the percentage of G-4 that should be deposited in the fabric, one can determine, from Table IV (page 3), the dilution of the stock solution (G-4-40) that is required.

The diluted solution should be padded on at a temperature of 140-180°F. The material must then be passed through a cold 3-5% acetic acid bath which converts the soluble sodium salt of G-4 to the insoluble free phenol. Intermediate drying is not required; the acetic acid should be fed at a rate which will insure that the goods leave the squeeze in an acid condition; indicator paper can be used to check this factor. The goods are then dried in the usual manner.

When a water repellent treatment is desired also, the above procedure is modified in either of two ways depending upon the type of water repellent.

A. Emulsion-type repellent.
After applying the alkaline G-4 solution in the first bath, the material is dried; about 2% of acetic acid is added to the second bath which in this case would contain the water repellent emulsion. After padding, the material is dried in the usual manner.

C O P Y

Exhibit 4 - U. S. Borax Product Bulletin

BIOBOR* JF

Use

BIOBOR JF is a biocide for the control of microorganisms in jet aircraft, diesel and other hydrocarbon fuels. BIOBOR JF is manufactured and sold for the above uses, except gasoline, under a license agreement with the Standard Oil Company (OHIO). This product is licensed for use only in the specific applications for which it is sold. USE AS DIRECTED.

Chemical Composition (typical)

Active Ingredients	
2,2'-oxybis(4,4,6-trimethyl-1,3,2-dioxaborinane	)
2,2'-(1-methyltrimethylenedioxy)bis-(4-methyl-1,3,2-dioxaborinane	)95%
Inert Ingredients	
Petroleum Naphtha	5%
	100%

Boron Content	7.4%
Water (free hydroxyl)	0.4%

Physical Properties (typical)

Flash Point	144 ± 2°F.
Viscosity	29.0 cps @ 70°F.
Density	1.05 g/cc @ 70°F.
Pour Point	-27.5°F.
Color (ASTM)	0.5

Instructions for Storage, Handling and Blending of BIOBOR JF

BIOBOR JF is an effective microbiocide because of its equilibrium solubility in both fuel and water under conditions of fuel storage, handling and use. All BIOBOR JF containers must be kept closed from the atmosphere. Protect BIOBOR JF from any water contamination. The normal working concentrations of BIOBOR JF in fuels are 135 to 270 ppm (10 to 20 ppm boron). The preferred method of blending is by metered injection directly into a flowing stream of fuel. If necessary, the additive can be satisfactorily batch-blended in water-free mix tanks. If batch-blending is used, e.g., tank truck or aircraft wing tanks, BIOBOR JF should be introduced into the tank while it is being filled. To insure uniform dispersion throughout the hydrocarbon phase, BIOBOR JF should be added when the tank is approximately one-half filled.

Packaging - All Non-returnable

55 gallon drums - net weight 450 lbs.
5 gallon drums - net weight 40 lbs.
Case: six X one quart containers - net weight 2.2 lbs. each
1 quart container - sample

Toxicity

BIOBOR JF is mildly toxic. Caution should be taken to prevent contact with the eyes and prolonged exposure to the skin. Do not take internally.

Antidote: In case of contact with skin - wash with soap and water. In case of contact with eyes - wash with water. If irritation persists, consult your doctor.

*Trade name United States Borax and Chemical Corporation

NOTICE: Use of this product for any purpose not already established by usage should be determined in each instance by investigation and experiment with due regard for the properties thereof. Uses suggested by us, if any, are based upon technical data or literature which we believe to be entirely trustworthy but for which we assume no responsibility. All risk of injury or damage resulting from the use or handling of this product is assumed by the user. We assume no responsibility therefore and make no warranty, express or implied, of the fitness of this product for any particular purpose.

If possible uses of this product have been mentioned by us, it is not our intent to suggest that it be used to practice the invention of any applicable patent, whether mentioned by us or not, without a license from the owner thereof. The patent situation should, therefore, be investigated by the user in each instance and a license procured when required.

Toxicity Studies with BIOBOR

SUMMARY

The acute oral LD_{50} of BIOBOR for male albino rats is 3.16 ml/kg of body weight.

The acute dermal LD_{50} of BIOBOR for albino rabbits is 4.64 ml/kg of body weight, with confidence limits from 2.98 to 7.23 ml/kg. A single application of the undiluted material produced mild to moderate dermal irritation characterized by erythema and edema and followed by desquamation.

A single application of BIOBOR to the eyes of albino rabbits produced moderate eye irritation characterized by conjunctivitis and iritis in all rabbits and mild corneal opacity in two of three rabbits.

APPENDIX E

RESTROOM CLEANING PROCEDURE

By

CHRYSLER CORPORATION SPACE DIVISION

January 11, 1972

Absolute cleanliness is a mandatory health and aesthetic requirement for all lavatory-washroom facilities. Cleanliness is even more aesthetically important in facilities which deviate in some way from the usual water-flush system.

Because the Aqua-Sans System cannot tolerate surface active agents (soap, detergents, or detergent containing compounds), two precautions must be rigidly adhered to in cleaning procedures --

Never pour mop water or other waste water down a flush fluid toilet or urinal.

Never use conventional toilet bowl cleaners in a flush fluid toilet or urinal.

Procedure for Cleaning Toilets and Urinals

Pour an appropriate amount of the special Aqua-Sans toilet bowl cleaner into a small container (a one-pound coffee can is adequate). Raise both the cover and seat of a toilet bowl. Dip a toilet bowl brush into the cleaner and scrub the interior toilet surfaces. Additional amounts of cleaner may be necessary to remove old rust spots or mineral deposits. Replace the brush into the can, being careful not to drip flush fluid onto the exterior surfaces of the toilet bowl or the floor. Flush the toilet to inspect effectiveness of the job. Keep the brush in the container to prevent dripping while going to the next fixture. Any remaining bowl cleaner contaminated with fluid may be dumped into a toilet. Store the container with the brush in it. Please note that flush fluid dripped on toilet seats or the front exterior of the toilet will not evaporate and can cause oil spots on the clothes of subsequent users of the toilet. Drips on the floor form an oily spot which spreads out to pick up dirt and, if large, can cause a slippery hazard.

In a small bucket, make up a strong solution of hot water and commercial detergent. Powdered laundry detergents are very appropriate. They can be fortified with a little laundry bleach to add cleaning and disinfecting action and produce a cleaner appearing surface. Most pine oil liquids are not very effective in spite of their strong smell. Spread the mixture on the oil and dirty areas of the floor with a broom and scrub the soap out until all of the floor has been scrubbed. Areas behind fixtures and under appliances must not be missed. Rinse and dry with a mop, using clear water which must be changed when it becomes soapy. Clean the external surfaces of restroom fixtures and walls using a small brush or rag soaked with detergent and a clean rag with clear water to rinse.

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SELECTED WATER RESOURCES ABSTRACTS

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Floyd L. Matthew, Ervin E. Nesheim

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15010 PBK

9. Organization

Black Hills Conservancy Sub-District
P. O. Box 1692
Rapid City, SD 57701

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12. Sponsoring Organization

15. Supplementary Notes

Environmental Protection Agency report number, EPA-670/2-73-088, December 1973.

16. Abstract

A prototype non-aqueous wastewater treatment system utilizing recirculated mineral oil as a collection and transport media was installed and operated at the Mount Rushmore National Memorial, Rapid City, South Dakota. The project was conducted to demonstrate the feasibility and effectiveness of the non-aqueous system for application at recreational and similarly remote areas.

The non-aqueous system was evaluated for six months during the 1972 visitation season. During this period, data was collected to determine system usage rate and user waste loading and for the evaluation of the physical, biological, and chemical content of the flush oil as a function of system usage. System operation and reliability were also demonstrated during the test period.

The demonstration showed that the non-aqueous treatment system is effective in the collection, transport, and disposal of human waste. Odors in the oil flush media and from the treatment system presented an aesthetic problem which makes the use of this system undesirable for recreational areas such as Rushmore. System redesign to prevent organic accumulations and the routine use of an oxidizer-bactericide to eliminate odor-producing bacterial activity is required before this concept can be suitable for high-use visible recreational areas.

Water conservation is achieved when recirculated mineral oil is used to collect and transport human wastes. The waste volume is reduced by 98 percent in comparison with conventional water carriage systems.

This report was submitted in fulfillment of Project Number 15010 PBK under the partial sponsorship of the Environmental Protection Agency.

17a. Descriptors

*Ship sanitation, *Wastewater treatment, *Water reuse, Water pollution control, Operating costs, Elsan Yarrow, Chemical treatment

17b. Identifiers

Elsan Yarrow. Chemical treatment. Recirculating system. Watercraft waste.

17c. COWRR Field & Group

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Abstractor Ervin E. Nesheim | *Institution* Dakota Engineering Company