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REPORT NO. 1701

DEVELOPMENT EFFORT TO DESIGN AND DESCRIBE PINK WATER ABATEMENT PROCESSES

FINAL TECHNICAL REPORT 1 May - 31 Jul 77

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ABSTRACT

This report summarizes engineering effort to obtain firm design, operating and cost data for a 5,000 GPD pink water abatement, pilot plant using ULTROX (UV-ozone) technology. This 5,000 GPD pilot plant can be directly scaled-up to a 100,000 GPD pilot plant using the ULTROX modular system concept.

In this program, a short pilot plant test program was carried out to obtain design, operating, and cost information needed for developing the 5,000 GPD pilot plant. This test program used an available 1,000 GPD ULTROX pilot plant at Westgate Research Corporation's facilities in Los Angeles. Initially, TNT in tap water equivalent in content to ARRADCOM pink water was used to establish minimum power/ residence time operating conditions. The final tests were made using pink water shipped from ARRADCOM.

The engineering analysis of the pilot plant data showed that the 5,000 GPD pilot plant reactor should have a wet volume of 625 gallons and will require up to 37.5 pounds of ozone per day and 144, 65 watt UV lamps. The pilot plant should contain a maximum of six reaction stages. Preliminary design drawings have been prepared for the 5,000 GPD pilot plant. Overall assembly, reactor assembly, and UV wiring schematic prints are included in this report as well as specifications on standard ozone generators.

A program for developing the 5,000 GPD pilot plant including the costs involved is presented along with the costs for operating the pilot plant. Based upon the data developed in this program, projected operating and capital costs are given for a 100,000 GPD pink water abatement plant.

FOREWORD

This is the final technical report describing work performed under Contract DAAK 10-77-C-0041 for the period May 1, 1977 to July 31, 1977.

The contract was under the direction of Mr. Milton Roth of the U.S. Army Armament R&D Command, Dover, New Jersey.

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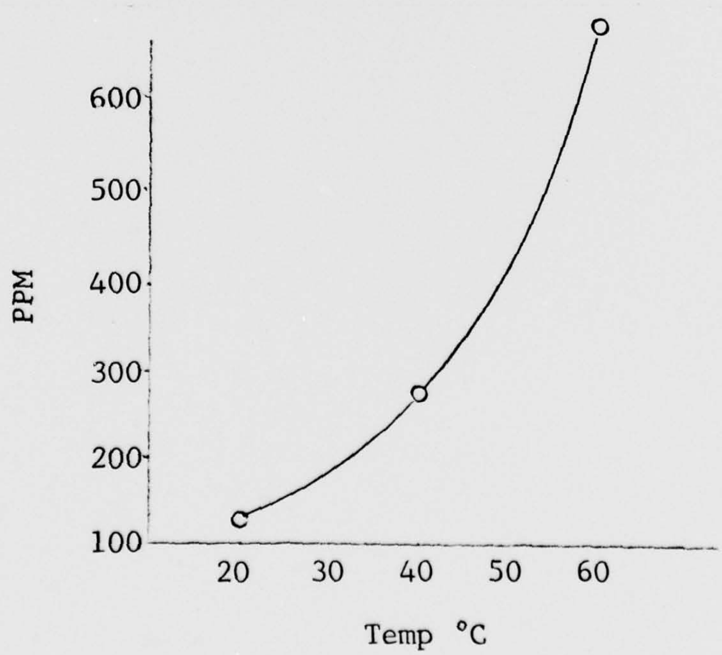
SECTION 1 INTRODUCTION

Pink water which is a solution of TNT in water appears everywhere TNT is made, processed or loaded. There is as yet no completely satisfactory way of purifying such waste streams to an acceptable level for release to receiving waters; however, UV-ozone shows promise of solving this problem.

1.1 PROPERTIES OF PINK WATER

Pink water is a solution of TNT in water and may contain other dissolved explosives. α-TNT is soluble in water to the extent of approximately 100 ppm at ambient conditions, the exact value depending strongly upon temperature and the presence or absence of other solutes.



1.2 SOLUBILITY OF PURE α-TNT IN WATER

Freshly-made solutions of TNT in water are virtually colorless; but exposure to ultraviolet light, including sunlight, causes the formation of highly-colored, complex, incompletely identified substances similar to dyes. They impart a characteristic pink color which persists even after dilution down to a few ppm with clean water. The release of pink water to receiving streams is thus objectionable even at concentrations below any known visible level because TNT is toxic below levels of visibility.

There is also a pink color which develops in TNT solutions when the solutions are made alkaline, but the color bodies are different from those generated by UV exposure. The alkaline color is reversible upon acidification, but acidification does not discharge the color of sun-exposed solutions. Under field conditions, where TNT solutions may be in contact with (alkaline) concrete or earth <u>and</u> exposed to sunlight, the chemistry of the color bodies becomes hopelessly complex.

1.3 DERIVATION OF PINK WATER

Pink water comes from both manufacturing plants and from LAP's. That from manufacturing plants arises from the stack fog filters of SAR units, from nitration fume scrubbers, from red water concentration distillates, from finishing building hood scrubbers and washdowns, and from some spent acid recovery operations. Pink water from the manufacturing and acid recovery operations may contain TNT isomers and dinitrotoluenes as well as α-TNT; that from LAP operations contains essentially pure α-TNT, often contaminated with RDX, HMX and wax. Pink Water also arises from unloading or demilitarization of munitions, and its composition there resembles that from LAP operations. The volumes and concentrations of particular pink water streams vary widely, but 80,000 gpd at 100 ppm is a not unrealistic case.

1.4 PRESENT PINK WATER CLEAN-UP METHODS

In some operations, particularly small-volume and remote ones, pink water is given essentially no treatment except dilution; but this is not considered acceptable practice, and a variety of treatment processes have been and are being tried. In the dry West and Southwest parts of the country, pink water is simply run into holding lagoons where it either evaporates to dryness (as at NAD Hawthorne) or evaporates enough so that the lagoon never overflows to receiving waters (as at NAD McAlester). Dried-up Hawthorne-type lagoons are occasionally flashed to burn any deposited explosives, a procedure which is acceptable in their remote locations. The McAlester lagoon cannot be flashed because it never evaporates to dryness.

Fresh carbon is very effective at removing TNT from water solutions, but no fully satisfactory way of regenerating the carbon has yet been found. Thermal regeneration leads to high attrition losses as granules burst from internal pressure and abrade in the bed, and the regenerated carbon also exhibits greatly reduced capacity upon attempted re-use. Currently, carbon is used once and then burned; the result is a high cost operation and a black smoke air pollution problem.

Still other approaches that have been tried, at least in the laboratory, include direct solvent extraction, reverse osmosis, fly ash adsorption, biodegradation and ozonolysis. None has been successful, but the last still holds promise.

It has been shown by several Army laboratories and contractors that ozonolysis under normal laboratory conditions degrades TNT, but not fully. The TNT itself disappears; but refractory, aromatic, degradation products persist even after prolonged, vigorous ozone treatment. Attempts to identify and characterize these products have met with little success; and that has led to unease, because many of TNT's refractory, incomplete degradation products are known to be more toxic to aquatic life than TNT itself.

SECTION 2 BACKGROUND INFORMATION ON UV-OZONE OXIDATION OF MUNITION WASTE WATERS

Prior to award of contract, Westgate conducted a number of tests on the bench and in pilot plants on TNT in water and pink water. A brief review of the pilot plant tests are given in this section.

One 25 gallon reactor was used in these tests. As shown in Figure 2-1, the reactor contains 5 stages with an accommodation of 3 - 40 watt UV lamps per stage. Ozone was introduced into each stage in equal proportion via 2 spargers per stage. The overall dimensions of the pilot unit was 15 x 15 x 30 inches high.

2.1 TNT OXIDATION

Table 2-1 summarizes the results of oxidizing 54 mg/l TNT in Los Angeles tap water.

Four, 40 watt lamps were used in these tests. Three lamps were used in the first stage and one lamp in the second stage. No lamps were used in the subsequent stages.

As shown in the table, less than 1 mg/l TOC can be achieved at a ratio of 16:1 O_3/TOC with this UV input arrangement and a residence time of 95 minutes.

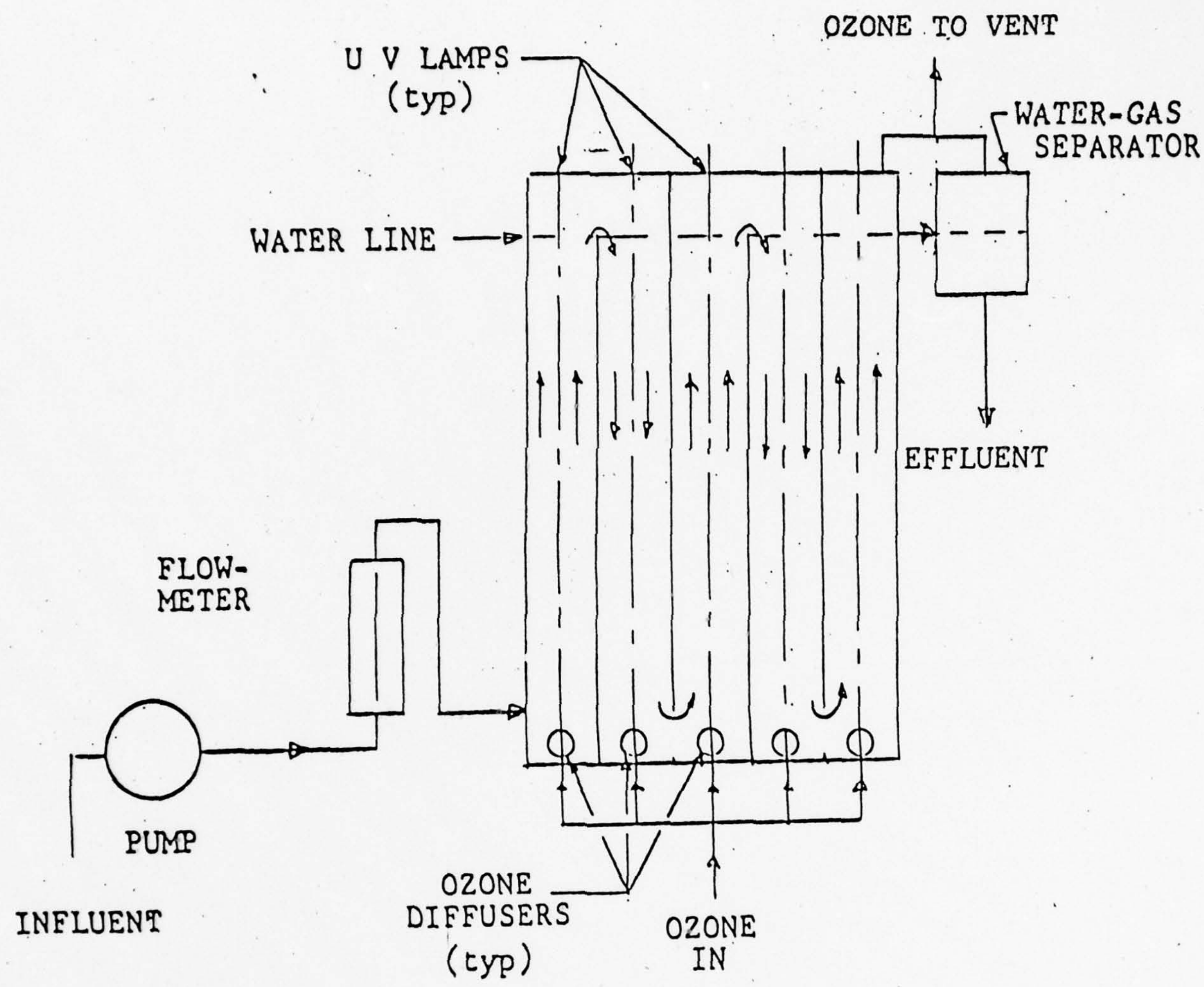


Figure 2-1 SCHEMATIC OF PILOT SYSTEM

Table 2-1

PILOT PLANT TEST

TNT IN TAP WATER

TNT CONC:	54 mg/l
TOC CONC:	20 mg/l
pH:	7.6
TEMPERATURE:	31°C

ONE REACTOR USED - 25 GAL

4- 40 w UV LAMPS

O_3 MASS FLOW IN:	320 mg/min
O_3 CONC:	1.4%
RESIDENCE TIME:	95 min
FINAL EFFLUENT:	<1 mg/l TOC
RATIO O_3/TOC	16:1

2.2 PINK WATER OXIDATION

A 55 gallon drum of pink water was obtained from the Burlington, Iowa AAP. The oxidation of this water is summarized in Table 2-2. The UV lamp placement was the same as the TNT test. Less than 1 mg/l TOC was achieved with a residence time of 86 minutes and an O_3/TOC ratio of 18.8:1.

Table 2-2

PILOT PLANT TEST

PINK WATER FROM BURLINGTON IOWA AAP

TOC CONC:	10 mg/1
pH:	9
TEMP:	25°C

ONE REACTOR USED 25 GAL

4- 40 watt UV LAMPS

O_3 MASS FLOW IN:	188 mg O_3/min
O_3 conc:	1.3%
RESIDENCE TIME:	86 MIN
FINAL EFFLUENT:	$<$1 mg/1 TOC
RATIO O_3/TOC:	18.8:1

SECTION 3 PILOT PLANT TEST PROGRAM

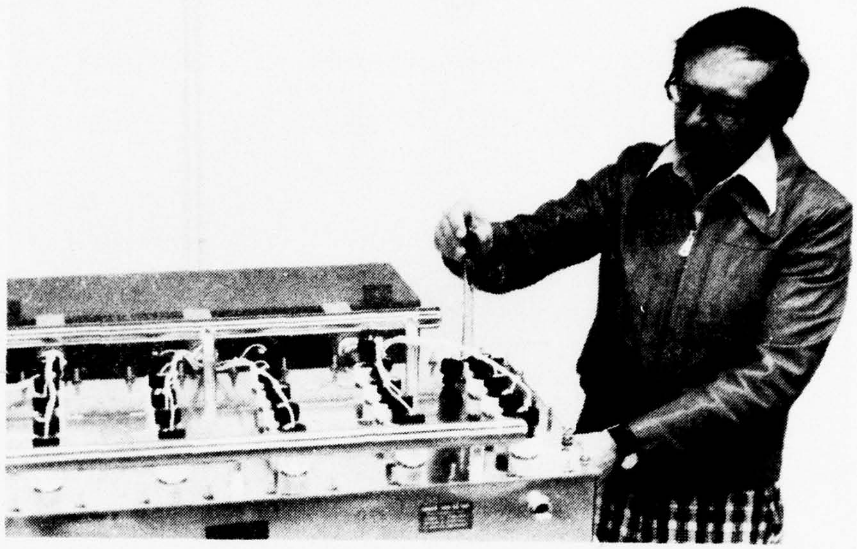
Prior to establishing the design criteria and the preliminary design of the 5,000 GPD pilot plant, a series of engineering tests were conducted in Westgate Research Corporation's P602 pilot plant, nominally rated at 1,000 GPD.

3.1 DESCRIPTION OF P602 ULTROX PILOT PLANT

This recently developed pilot plant is designed to demonstrate on a scale larger than bench size, the practicality and cost effectiveness of UV-ozone oxidation for cleaning up organics in waste water. The pilot plant is designed to be transported to a waste water treatment site and to operate on a slip-stream of the polluted water.

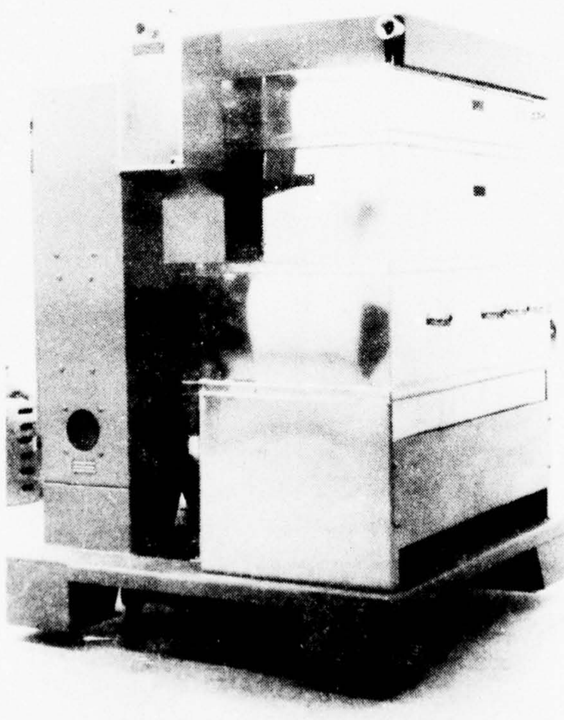
The pilot plant can vary (1) UV light, input and intensity, (2) ozone introduction, (3) mixing, and (4) water flow characteristics. Photographs of the pilot plant are shown in Figure 3-1. The UV-ozone reactor assembly drawing is presented in Figure 3-2. The pilot plant reactor is 28" wide x 45" long and 45" high, and is fabricated from 304 stainless steel, which is passivated and electropolished to reduce chemical attack and increase UV reflectivity.

There are six operating stages within the reactor.



View of Reactor
with
UV Lamps Exposed

Figure 3-1

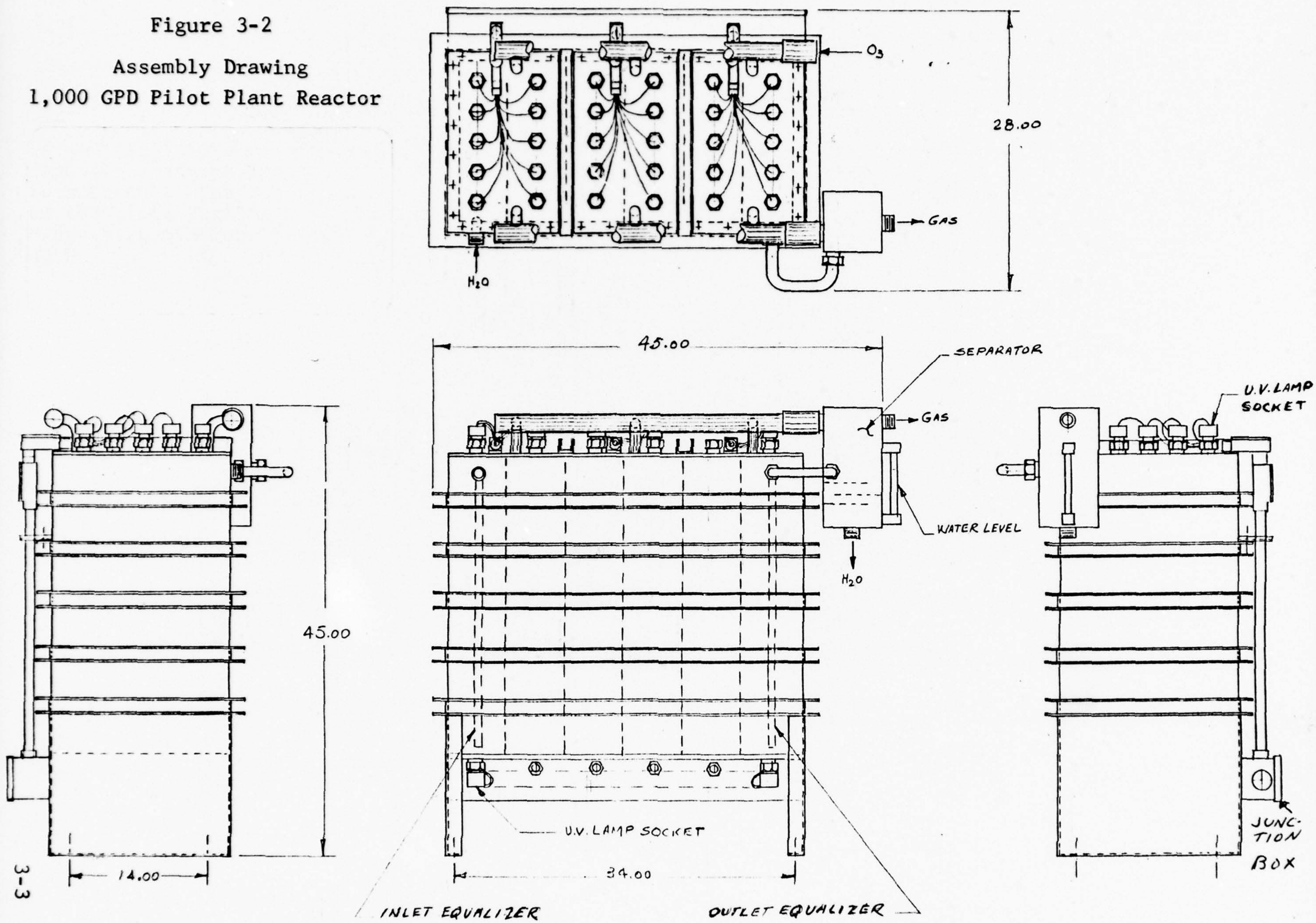


View Showing Skid-
Mounted Reactor &
NEMA Enclosure for
UV Lamp Ballasts

P602 ULTROX PILOT PLANT

Figure 3-2

Assembly Drawing
1,000 GPD Pilot Plant Reactor



The reactor can accommodate up to 30, SL36G, low pressure, UV lamps. From 0 to 30 lamps can be turned on in a test run. Ozone is uniformly diffused from the base of the reactor through spherical, porous spargers, which generate gas bubbles of <2.5mm diameter to obtain maximum mass transfer. The number of spargers can be varied from stage to stage; also, the overall pattern of ozone introduction and diffusion can be changed if required.

The reactor is designed for low-pressure operation (2 psig maximum) to reduce the cost for pumping water and compressing air for O_3 generation. Low pressure operation also provides greater safety and reduces the thickness, weight, and cost of materials of construction; both for the pilot plant and for large-scale plants.

As shown in Figure 3-1, a separate NEMA cabinet enclosure mounted on the skid with the reactor houses the ballasts for the UV lamps.

3.2 PILOT PLANT OPERATION

Figure 3-3 shows the pattern of water flow through the 1,000 GPD pilot plant reactor. The water passes through each of the stages in a tortuous path to achieve a greater degree plug-flow. In each stage, the water is contacted by the ozone gas -- and in certain stages, UV light.

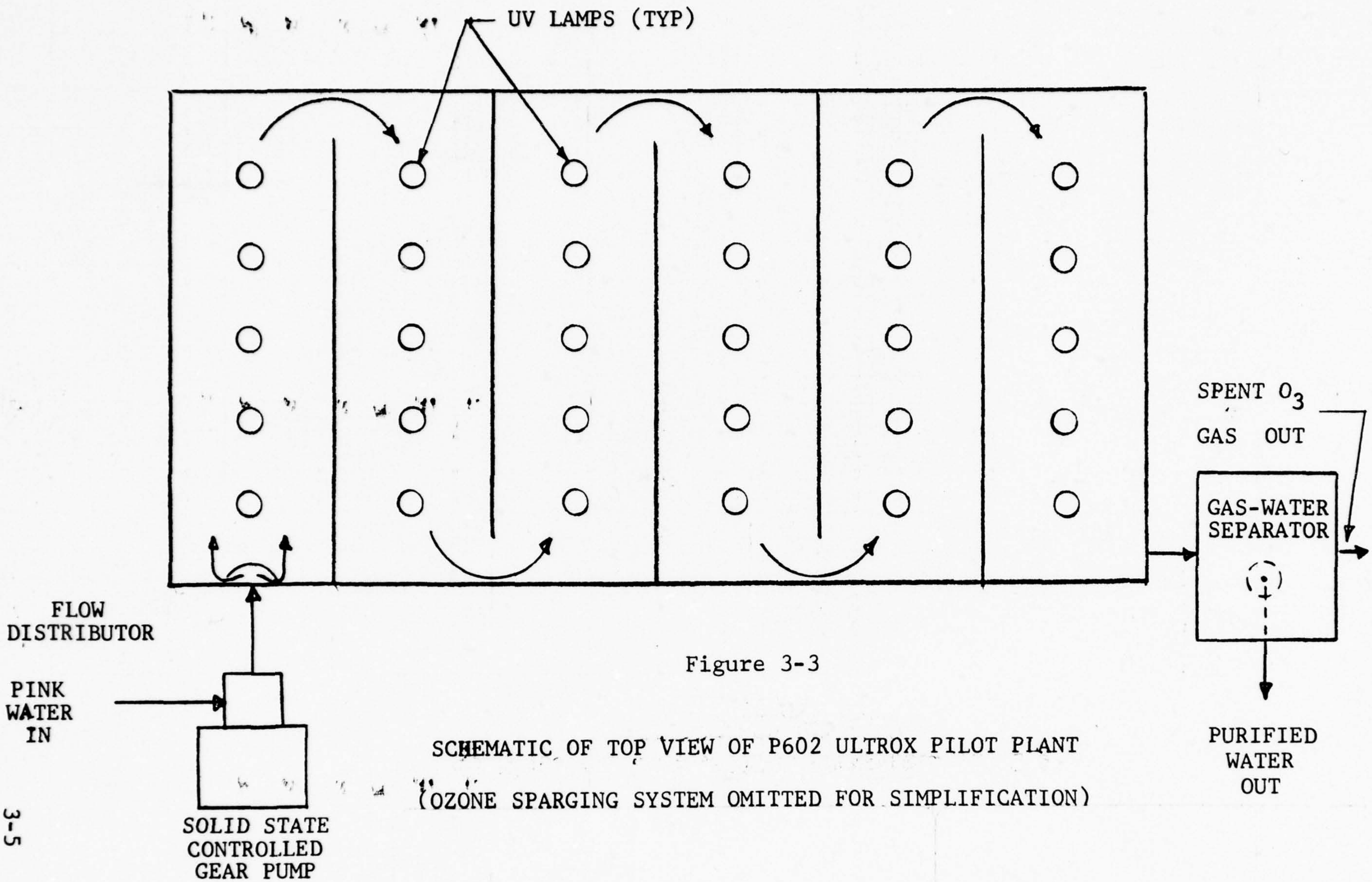


Figure 3-3

SCHEMATIC OF TOP VIEW OF P602 ULTROX PILOT PLANT

(OZONE SPARGING SYSTEM OMITTED FOR SIMPLIFICATION)

The pink water is fed to the reactor by the use of a single, gear type, seal-less, magnetic drive pump with integral solid-stage speed control. The flow of pink water through the reactor can be varied by this pump from 0.2 to 2 GPM, and the retention time will vary from 37 to 375 minutes.

The incoming pink water flow rate is measured by a rotameter in-line between the pump and the reactor inlet. The purified water, as it leaves the reactor, overflows into a gas-water separator to eliminate any entrainment of water in the exhaust gas. The water then drains from the reactor by gravity to a receiving sump. No internal level controls are required within the reactor.

3.3 ENGINEERING TEST PROGRAM

3.3.1 OBJECTIVE

The objective of the P602 ULTROX Pilot Plant testing was to define the level and combination of operating and design variables of the ULTROX Pilot System which attains the minimum power demand and retention time for a given concentration of pink water shipped from ARRADCOM.

3.3.2 APPROACH

The approach of Westgate Research Corporation to establish the best combination of operating parameters for the ULTROX Model P602 Pilot Plant was the following:

(1) Conduct a series of tests using α-TNT in tap water. The TNT content of this water was to be equivalent to the pink water received from ARRADCOM. These test results would then be useful for setting operating levels when treating the pink water.

(2) From the test results, previously derived mathematical models are to be refined to aid in defining the relationship between power demand or reactor design and the operating variables.

From the derived data, capital and operating costs for the pink water would then be predicted for a 5,000 GPD pilot plant, and the 100,000 GPD full-scale plant.

The cost of the program to construct the 5,000 GPD pilot plant would then be derived from the test results and the data analysis.

3.3.3 TEST PLAN

From previous test experience on pink water, TNT in water, and other waters of similar composition, it has been determined that the following variables have the greatest influence on total power demand and reactor size:

1) O_3 Concentration in Sparging Gas
2) UV Light Intensity
3) Placement of UV Lamps within Reactor
4) Temperature of Incoming Water
5) Composition and Concentration of Waste Water Influent

It was assumed that the pink water shipped from ARRADCOM would have a dissolved solids content of 70-80 ppm, consisting mainly of TNT and RDX. The TOC content was assumed to be about 30 mg/l.

The actual TNT content of the pink water received from ARRADCOM was 140 mg/l and the TOC content was 68 mg/l; approximately double the assumed content. The analysis of the pink water as furnished by ARRADCOM was as follows:

TNT - 140 mg/l; RDX - 72 mg/l; wax - 10 mg/l

For more detail on this pink water and the effect of these high concentrations, please refer to the next subsection.

3.3.4 SHAKEDOWN TESTING

The shakedown tests were designed to find the best approximate levels of ozone mass flow, ozone concentration, UV lamp density, and residence time for TNT concentrations of 80 mg/l (30 mg/l TOC). It was thought that this would be the concentration of the pink water sample being shipped from ARRADCOM.

After receipt of the 5 drums of the sample, it was found that the TOC was 68 mg/l. Analysis provided by ARRADCOM showed 140 mg/l TNT, 72 mg/l RDX, and 10 mg/l wax. The TNT/H_2O solution was then made up to this high a concentration of TNT. The water contained large amounts of undissolved TNT which went into solution and reacted as the oxidation progressed. It was difficult to control operating conditions and effluent quality. This problem was corrected by dissolving smaller quantities of TNT in boiling water prior to dilution and by the use of an in-line filter upstream to the inlet of the pilot plant.

With this high concentration of TNT, additional ozone generator capacity was needed. Both an OREC 03B2-0 and a Welsbach W-20 were used to provide up to 2 gm/min O_3 (in oxygen). A TOC of 4 mg/l was obtained with a 140 minute residence time using 29 UV lamps and 2 wt% O_3 in O_2 at 1 gm/min.

3.3.5 TNT-IN-WATER TESTS

Table 3-1 summarizes the seven pilot plant tests using 140 mg/l TNT in tap water. As shown, the TOC can be reduced to 5 - 10 mg/l TOC in the first 3 stages with a 118 minute residence time, using 13 lamps (Test No. 1024), or 9 lamps (Test No. 1025). To reduce the TOC further to 1 - 3 mg/l, 9 to 14 lamps are required in the last 3 stages, and an additional residence time of 118 minutes is required. Table 3-2 provides data on pH, temperature, O_3/TOC and UV/TOC ratios.

3.3.6 PINK WATER TESTS

Tables 3-3 and 3-4 summarize the results of pilot plant tests using ARRADCOM pink water. The first test (No. 1027) was run at the same approximate conditions as Test No. 1026 for TNT in water. There was greater resistance to oxidation when using pink water than TNT/H_2O, and the TOC was only reduced to 17 mg/l in a 240 minute residence time. The residence time and number of UV lamps had to be increased in subsequent tests (1028 and 1029) to obtain a greater degree of oxidation.

Table 3-5 shows a quantitative comparison of conditions and results for TNT/H_2O and pink water in Test No. 1024 and 1029. The ozone to organic carbon ratios are about the same

Table 3-1 - TNT in Water Pilot Plant Tests

Test No.	Residence Time - min. Stages 1 - 3	Residence Time - min. Stages 4 - 6	O_3 Conc wt%	O_3 Mass Flow mg/min Stages 1 - 3	O_3 Mass Flow mg/min Stages 4 - 6	TOC - mg/l at Steady State Influent	TOC - mg/l at Steady State After 3 Reaction Stages	TOC - mg/l at Steady State After 6 Reaction Stages	UV Lamp Arrangement Stage 1 2 3 4 5 6
1020	142	142	2.5	773	773	54	4	2	5 5 5 4 5 5
1021	89	89	2.6	832	832	47	12	9	5 5 5 4 5 5
1022	118	118	2.8	1180	1180	60	13	3	5 5 5 4 5 5
1023	118	118	2.4	1044	1044	55	7	2.5	5 5 5 4 3 3
1024	118	118	2.4	1186	1186	66	5	1.2	5 5 3 3 3 3
1025	118	118	2.6	1359	1359	66	5	2	3 3 3 3 3 3
1026	118	118	3.1	1192	1192	54	10	6.5	3 3 3 3 2 0

Table 3-2 - Additional Data - TNT in Water Pilot Plant Tests

	Average pH		Ave	O_3/TOC Mass Ratio mg/mg		UV/TOC Input Watts/mg	
Test No.	Influent	Effluent	Effluent Temp °F	First 3 Stages	Second 3 Stages	1st 3 Stages	2nd 3 Stages
1020	6.5	5.3	95	14	193	11	140
1021	6.5	5.3	93	11	43	31	29
1022	6.5	4.7	96	16	76	8	36
1023	6.5	5.3	90	16	124	91	48
1024	6.5	5.3	78	15	198	7	60
1025	6.5	5.3	91	17	226	4.5	60
1026	6.5	5.3	91	18	99	5.5	17

Table 3-3 - - - Pink Water Pilot Plant Tests

Test No.	Residence Time - min. Stages 1 - 3	Residence Time - min. Stages 4 - 6	O_3 Conc wt%	O_3 - Mass Flow mg/min Stages 1 - 3	O_3 - Mass Flow mg/min Stages 4 - 6	TOC mg/l at Steady-State Influent	TOC mg/l at Steady-State After 3 Reaction Stages	TOC mg/l at Steady-State After 6 Reaction Stages	UV Lamp Arrangement Stage 1 2 3 4 5 6
1027	118	118	2.2	850	850	68	22	17	5 5 3 3 3 3
1028	177	177	2.1	942	942	67	6.5	5	5 5 5 4 4 3
1029	177	177	1.8	721	721	70	5	3	5 5 5 4 5 5

Table 3-4 - Additional Data - Pink Water Pilot Plant Tests

Test No.	Average pH		Average Effluent Temp °F	O_3/TOC Mass Ratio mg/mg		UV/TOC Input Watts/mg	
	Influent	Effluent		First 3 Stages	Second 3 Stages	First 3 Stages	Second 3 Stages
1027	6.2	3.8	85	10	32	6	14
1028	6.2	3.8	86	18	181	11	85
1029	6.2	3.8	86	13	180	11	140

Table 3-5 Comparison of TNT/H_2O and Pink Water Tests at Approximately the Same O_3/TOC Mass Ratio

		O_3/TOC Mass Ratio mg/mg		Input Watts/mg		TOC - mg/1		
Test No.	Type of Influent	1st 3 Stages	2nd 3 Stages	1st 3 Stages	2nd 3 Stages	Influent	After 3 Reaction Stages	After 6 Reaction Stages
1024	TNT/H_2O	15	198	7	60	66	5	1.2
1029	Pink Water	13	180	11	140	70	5	3

for the first 3 stages and the last 3 stages; however, the UV input power to carbon ratio had to be increased in both the first 3 stages and second 3 stages in order to achieve 5 mg/l TOC and 3 mg/l TOC.

3.3.7 SPECIFIC ANALYSIS

In Table 3-6, the analysis indicates that less than 1 ppm TNT and 1 ppm RDX remained in all effluent samples analyzed. The wax did not appear to be affected by UV-ozone, since the original pink water contained 10 ppm wax. This analysis is suspect since wax is reported in effluent samples 1023-2, 1024-2 and 1025-2; which were oxidized TNT/H_2O samples and contained no wax. Test No. 1029 indicates that the TNT and RDX levels were below 1 ppm after the pink water had passed through the first 3 stages of the reactor. This result was most encouraging, since at these operating conditions, the residence time, the number of UV lamps and ozone mass flow input can be reduced by one-half of the total values used in Test No. 1029.

3.3.8 DISCUSSION OF TEST RESULTS

A comparison of TOC and TNT analyses indicates that when the TOC is 5 mg/l or less, the TNT is less than 1 ppm. A gas chromatography - mass spectrometry analysis will identify the remaining organic residuals in the water. Some

Table 3-6

Specific Analysis of Processed TNT/H_2O and Pink Water

Test Number	Type of Sample	TNT Conc ppm	RDX Conc ppm	Wax Conc ppm
1020	Feed TNT/H_2O	76	-	-
1020-2	Effluent from TNT/H_2O	<1	-	-
1023-2	Effluent from TNT/H_2O	<1	-	11
1024-2	Effluent from TNT/H_2O	<1	-	8
1025-2	Effluent from TNT/H_2O	<1	-	6
1028-2	Effluent from Pink Water	<1	<1	12
1029-1	Effluent after 3 stages - from Pink Water	<1	<1	9
1029-2	Effluent after 6 stages - from Pink Water	<1	<1	11

organic or inorganic acid forms after oxidation as indicated by a pH of 3.8.

Referring to Table 3-6, in Test 1029 the effluent, after passing through 3 reaction stages, attained <1 ppm TNT and RDX. As shown in Table 3-5, the input ozone and UV in the first 3 stages was 13 mg O_3/mg TOC and 11 watts/mg TOC respectively. On a volume basis, assuming 70 mg TOC/l, the ozone requirement is 910 mg/l and the UV requirements is 770 watts/l.

The mass ratio of ozone to TOC in Test 1029 for the first 3 stages was 13 which is 1.6 x the stoichometric ratio. Bench testing and pilot plant testing on a wide variety of waste waters indicate that the minimum stoichometric ratio of O_3/TOC usually runs between 1.3 and 2.0, depending upon TOC concentration and the chemical structure of the organic contaminants. However, this calculation does not account for hydrogen and nitrogen oxidation.

It is more accurate to examine the total oxidation of TNT and RDX, as follows:

<u>TNT</u>

$$C_6H_2CH_3(NO_2)_3 + 18\ O_3 \longrightarrow 7\ CO_2 + H_2O + 3\ HNO_3 + 18\ O_2$$

<u>RDX</u>

$$C_3H_6N_3\ (NO_2)_3 + 18\ O_3 \longrightarrow 3\ CO_2 + 6\ HNO_3 + 18\ O_2$$

The above equations assume that the molecular O_2 does not enter into the reactions.

The pink water by analysis contained 140 mg/l TNT and 72 mg/l RDX. According to the above equations, the theoretical amount of ozone required per liter to carry out the complete oxidations is 813 mg. Since the testing found that 910 mg/l was required to obtain an acceptable effluent, the ratio of actual to stoichiometric ozone is 1.12:1 (or an ozone efficiency of 89.3%).

It may be possible to reduce the ozone input in the last stages of the reactor and decrease the O_3/consumption further. This should be investigated in the 5,000 GPD pilot plant testing.

A greater number of UV lamps were required when the pink water was oxidized than when oxidizing TNT/H_2O. The specific number of lamps required per square foot and in each reaction stage has not been defined. From the tests, the number per square foot will be anywhere from 4 to 8. The exact number will be established in the 5,000 GPD pilot plant testing.

There is a question of whether the wax analysis is accurate and whether the wax can be removed by UV-ozone oxidation. Further study of the oxidation of wax can be carried out in the 5,000 GPD pilot plant if so desired.

From the TNT/H_2O and the pink water pilot plant tests, nominal values for ozone mass flow, ozone concentration, residence time, and UV lamp placement can be established for the 5,000 GPD pilot plant. Due to an apparent large difference in UV requirements between pink water and TNT/H_2O there was insufficient data obtained on the number of UV lamps per stage and number of UV lamps per unit area. It was therefore not possible to refine the existing mathematical models which represent the P602 pilot plant.

More detailed, design-of-experiment testing using the 5,000 GPD pilot plant and the utilization of the present mathematical models and computer programs will define the optimum operating conditions for achieving the minimum fixed and operating costs for the 100,000 GPD plant. (See Section 6.3.)

SECTION 4 ENGINEERING ANALYSIS

The engineering analysis in this section is based upon pilot plant data and other previously generated UV-ozone information. The purpose of the analysis is to derive the operating and design parameters for the 5,000 GPD (18.9 m^3/d) pilot plant.

4.1 REACTOR SIZING

The volume of the reactor is selected on the basis of flow rate and hydraulic retention time.

$$V_R = Q\theta$$

where

V_R = wet volume of reactor gals (l)

Q = flow rate of waste water GPM (l/min)

θ = hydraulic retention to achieve TNT, RDX levels of <1 ppm, min

In the pink water pilot testing, an acceptable effluent was achieved at θ = 180 minutes.

Q = 3.47 GPM (13.1 l/min) is the design flow rate for the selected pilot plant size.

Therefore, V_R = 13.1 (180) = 625 gal (2,366 l)

The height of the reactor is fixed by the length of the UV lamps. The longest UV lamp available with a practical life and low cost is the G64T6 lamp. This lamp is 64 in (162.6 cm) long x 3/4 in (19 mm) diameter, draws 65 watts, has a life of 7500 hours, and has average UV power output through life of 25.5 watts. The height of the reactor will therefore be approximately 5 ft (152.4 cm), the working or arc length of the lamp. The L/W ratio of the ULTROX type reactor is 2:1. The W x L for a 625 gal (2366 l) reactor will then be 2.9 ft x 5.8 ft (88 cm x 176 cm).

This size reactor is approximately the same as Westgate's ULTROX STAC Model No. 7606. (See Bulletin No. 101 in the Appendix.) To reduce design cost, it is suggested that this STAC model be adapted for use as the 5,000 GPD (18.9 m^3/d) pink water pilot plant.

4.2 OZONE REQUIREMENTS

The pilot plant testing determined that about 900 mg of ozone at 1.8 - 2.0 wt% was required to reduce the TOC to 5 mg/l and the RDX and TNT to $<$ 1 ppm. It is possible that less than this amount will be needed, but this has yet to be proven in 5,000 GPD (18.9 m^3/d) pilot plant tests.

The required mass flow of ozone required per day will therefore be:

$$\frac{900 \text{ mg } O_3}{\text{pink } H_2O} \times \frac{18.9 \text{ m}^3 \text{ pink } H_2O}{\text{day}} \times \frac{1000 \text{ l pink } H_2O}{1 \text{ m}^3 \text{ pink } H_2O}$$

$$\times \frac{1 \text{ kg } O_3}{1{,}000{,}000 \text{ mg } O_3} = \frac{17 \text{ kg } O_3}{\text{day}} \left(\frac{37.5 \text{ lb}}{\text{day}}\right)$$

This direct linear scale-up assumes that the diffusion of ozone throughout the reactor stages and the bubble sizes will be the same as in the P602 pilot plant. Equivalent diffusion can be accomplished by proper selection, sizing, and placement of the ozone diffusers in the 5,000 GPD pilot plant.

4.3 UV LAMP REQUIREMENT

The UV output of the G64T6 lamps per linear inch is about the same as the G36T6 lamp used in the P602 Pilot Plant. Therefore, the number of lamps per unit cross-sectional area will be the same for the STAC No. 7606 as for the P602 Pilot Plant.

In the P602, the number of lamps per unit area are 2 lamps/15.24 cm x 15.24 cm or 0.00861 lamps/cm^2 (8 lamps/ft^2). For the Model 7606 Pilot Plant, the number of G64T6 lamps required will then be: $0.00861 \frac{\text{lamps}}{\text{cm}^2} \times 91.44 \text{ cm} \times 182.88 \text{ cm} = 144$ lamps.

4.4 NUMBER OF REACTION STAGES

Testing in the P602 Pilot Plant (Test 1029) indicated that 3 stages were sufficient for achieving a satsifactory quality water. In the Model 7606 STAC any number of stages up to 6 can be installed by the use of stainless steel baffling. For maximum flexibility and versatility, up to 6 reaction stages will be incorporated by the use of movable and removable baffles.

SECTION 5 PRELIMINARY DESIGN - 5,000 GPD PILOT PLANT

This section describes the design of the 5,000 GPD pilot plant as derived from the P602 Pilot Plant tests and the engineering analyses.

5.1 DESIGN CRITERIA

From the engineering analysis, the following design criteria were established for the 5,000 GPD (918.9 m^3/d) pilot plant:

Reactor Wet Volume	675 gal (2.6 m^3)
Reactor Dimensions (W x L x H) .	3 x 6 x 5 ft (0.9 x 1.8 x 1.5m)
Water Flow Rate	3.47 GPM (13.1 lpm) or 5,000 GPD (18.9m^3/d)
No. of UV Lamps @ 65 w/lamp . .	144
O_3 Required (1% by wt) from Air .	37.5 lb/day (17 kg/day)

5.2 PRELIMINARY DESIGN

The major components of the pilot plant are:

(1) Reactor Assembly

(2) NEMA Ballast Enclosure

(3) Ozone Generator

Components (1) and (2) are assembled on one skid and Component (3) is mounted on a separate skid. The entire pilot plant assembly is illustrated in Figure 5-1 and a flow schematic is shown in Figure 5-2.

5.2.1 Reactor Assembly

The reactor assembly is presented in Figure 5-3. The assembly consists of a stainless steel tank with baffles and a cover assembly consisting of the reactor cover, ozone diffusers, UV lamps, and supporting structure.

5.2.1.1 Reactor Tank

The reactor tank, 3' x 6' x 5' deep, is fabricated from 3/16", 316 stainless steel sheet. The bottom of the tank is formed from stainless steel. Sides of the tank are supported horizontally by 1 3/8" 90°L confining rectangles. All parts are certified heliarc welded. A 4 inch wide lip is welded to the top periphery of the tank to form a gasket flange. A groove is cut into the flange to accommodate a rectangular Hypalon seal to enclose and seal the reactor. The tank is mounted by bolting onto the metal skid as shown in Figure 5-1.

Five baffles are located longitudinally to create 6 reaction stages. Water flows in a tortuous path from

5000 GPD-PILOT PLANT

PINK WATER ABATEMENT

FIGURE 5-1

UV OZONE REACTOR:

5000 GPD - 3.5 GPM
140 PPM TNT AND 70 PPM RDX
7' X 5' X 6' OVERALL DIM.
9.4 KW, 110 V., 1Ø, 60 HZ.

OZONE GENERATOR:

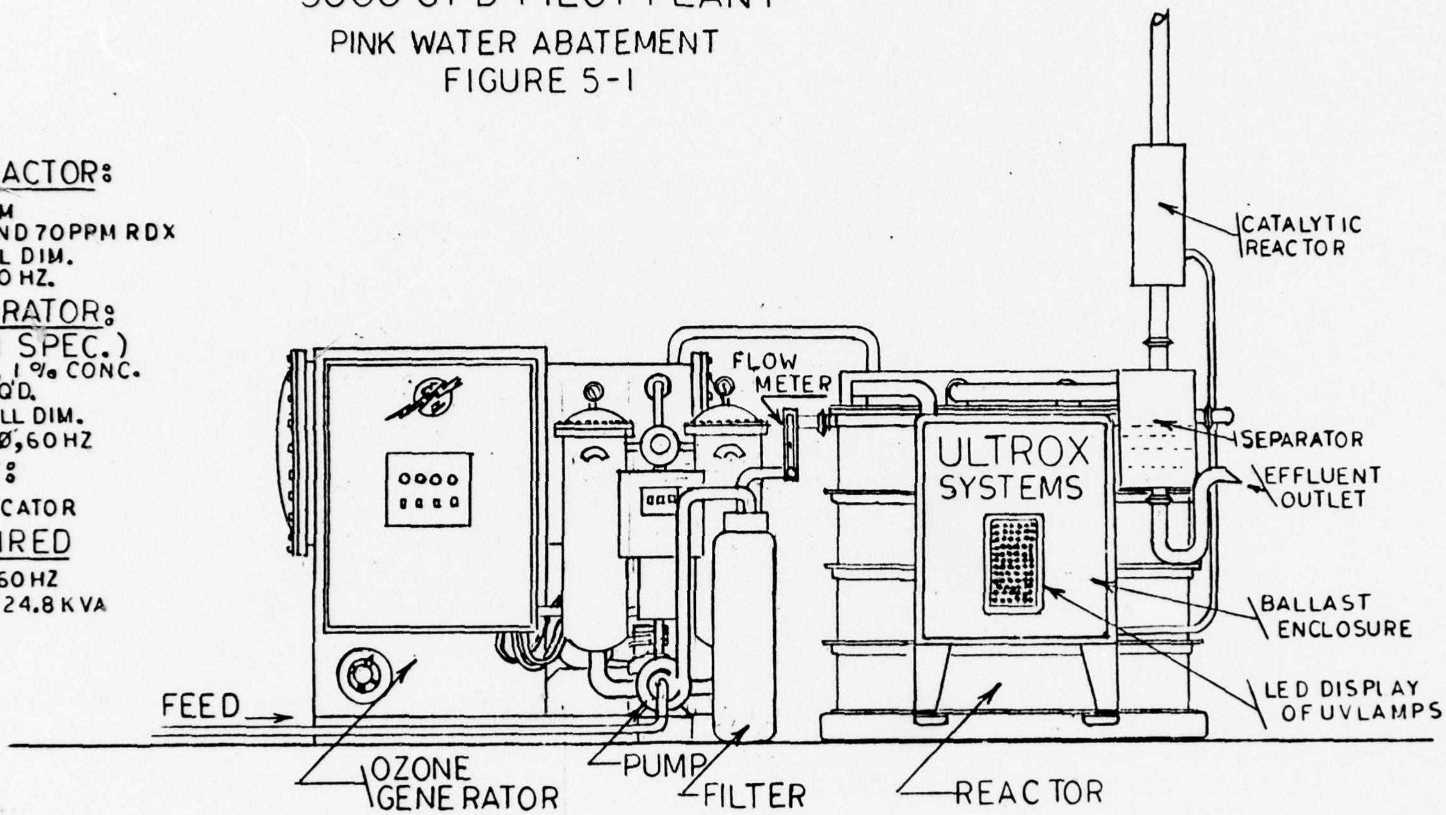
(WELSBACH SPEC.)
37.5 LBS/DAY, 1% CONC.
32 CFM AIR REQ'D.
8' X 7' X 7' OVERALL DIM.
16.7 KW, 460 V, 3Ø, 60 HZ

LED DISPLAY:

144 POINT INDICATOR

POWER REQUIRED

460-110 V, 3Ø-1Ø, 60 HZ
26.1 KW, .95 P.F., 24.8 KVA



SCALE 1" = 2'
F2 7/7/77

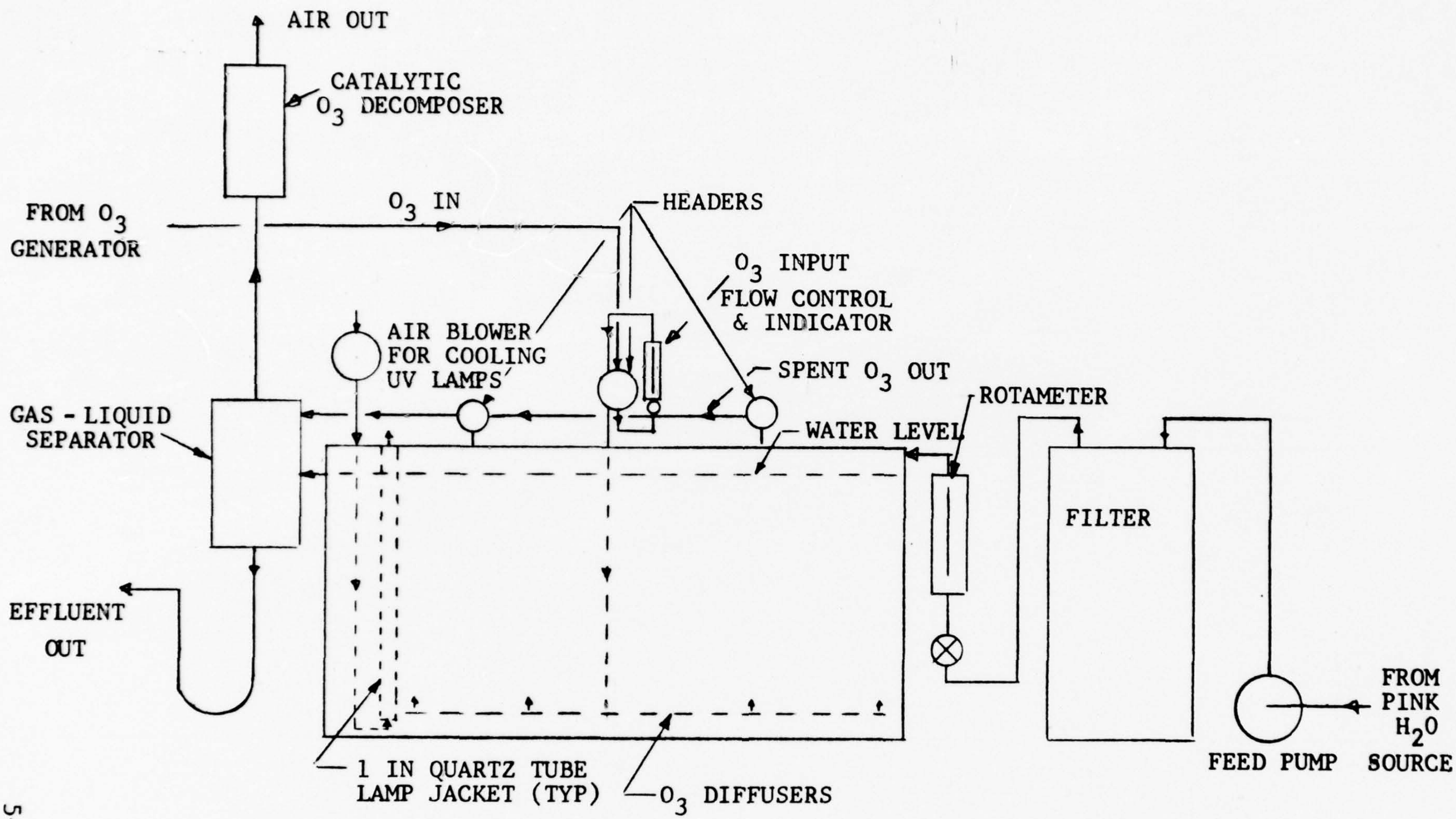
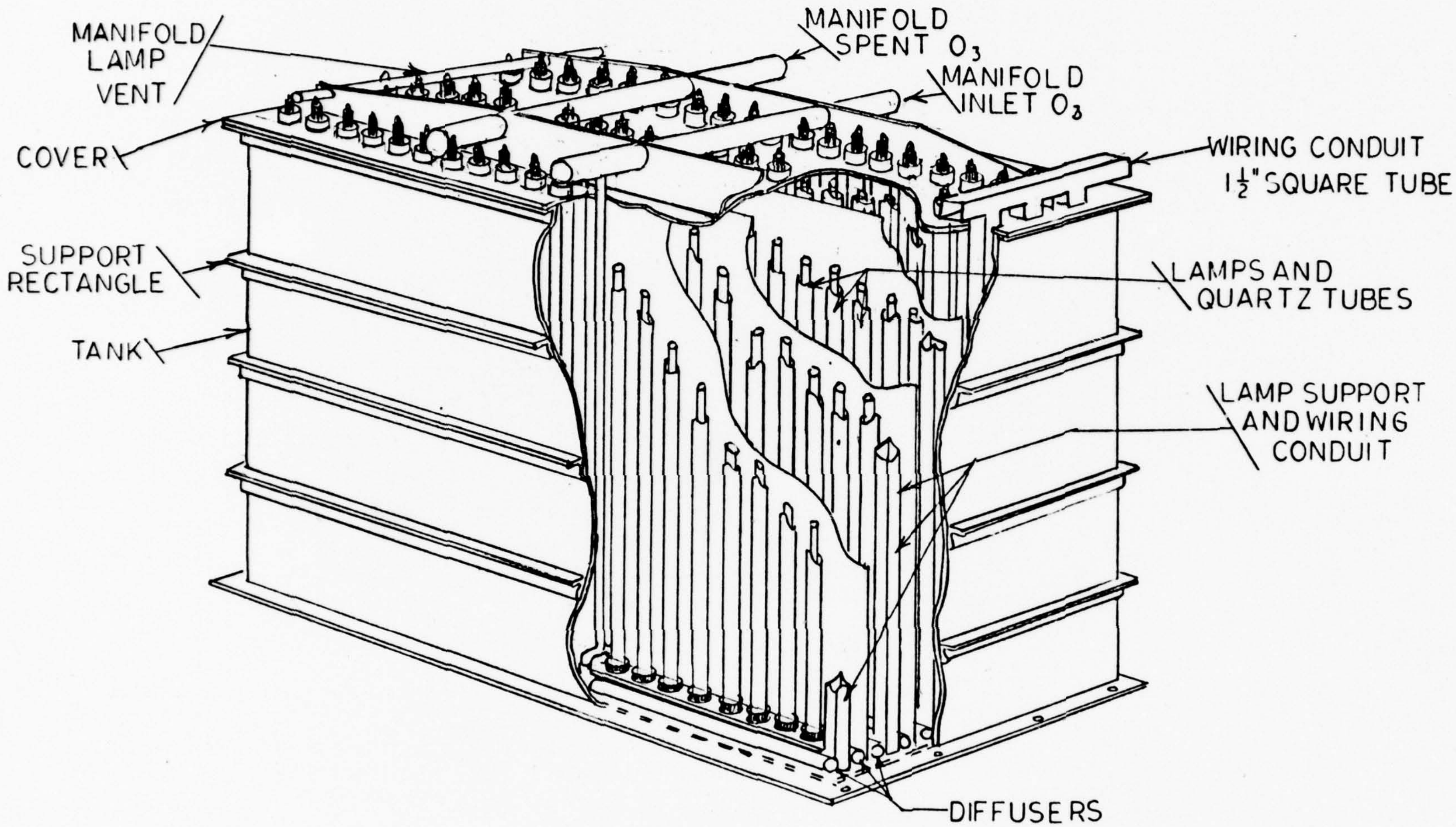


FIGURE 5-2 FLOW SCHEMATIC FOR 5,000 GPD PILOT PLANT

REACTOR ASSEMBLY
ISOMETRIC VIEW
FIGURE 5-3



stage to stage via holes of sufficient size, strategically placed at alternate ends of the baffles. The baffles are designed for easy removal to alter the number of reaction stages if so desired.

The manifolds for the ozone inlet tubes, lamp venting tubes and lower and upper lamp conduits are welded across the reactor and provide adequate crosswise stiffening. Longitudinal stiffening is achieved by 3 strips of 3/16" x 4 " SS welded intermittently to the cover plate and to the manifolds to ozone air vent and wiring conduit.

Effluent outlets are located 2 inches from the top of the tank in 2 positions to control the water level at design flow conditions.

5.2.1.2 Cover Assembly

The following openings are punched into the cover plate:

(1) 144 holes, 1 1/8 inch diameter in a geometric pattern for the quartz tubes which enclose the UV lamps. Nipples are welded at the top surface of these openings so that compression nuts with O-rings seal the quartz tubes to the cover.

(2) 6 holes, 1 inch diameter for the spent ozone gas outlets.

(3) 6, $1\frac{1}{2}$ inch square holes for mating with the lamp support structure.

(4) 6, 5/8 inch holes for the outboard lamp support/ cooling air vent lines.

(5) 2, $1\frac{1}{2}$ inch NPT nipples for water inlets.

The lower lamp support structure consists of a $1\frac{1}{2}$" square tube with .0625 inch wall thickness. Holes of 1" diameter are drilled on the upper side of the tube at appropriate positions to install the quartz tube support and sealing assemblies, which are welded to the upper side of the tube. A $\frac{1}{2}$" diameter hole is drilled through the outboard end of the conduit to attach the vent tube which also acts as a support for the end of the square tube. The center of the square tube is supported by welding the ozone line to the diffusers running parallel to the conduits.

5.2.2 NEMA Ballast Enclosure

A standard 5' x 3' x 1' deep NEMA 16 gauge cabinet is used to contain and cool 72 lamp ballasts. The ballasts are mounted on racks in 6 rows within the NEMA. A rotary air blower mounted at the base of the cabinet directs the air upward for cooling the rows of ballasts. The air exits at the top of the cabinet.

The cabinet door contains a mounted LED display within a glass window. The display provides a visual indication of the number of UV lamps "on" in the reactor. The door is sealed to the NEMA housing by means of elastomer gasketing and spring-loaded screw clamps.

5.3 OZONE GENERATORS

A number of manufacturers of ozone generators can supply generators which meet the 5,000 GPD pilot plant criteria of 37.5 pounds of ozone per day. Specification sheets, Figures 5-4, 5-5, and 5-6 for OREC, PCI, AND Welsbach ozone generators provide examples of the size, weight, and characteristics of these standard generators. It is recommended that in the case of either OREC or PCI, two 20 lb/day ozone generators be acquired since neither manufacturer has an off-the-shelf 40 pound generator. The Welsbach generator is oversized, but it can produce 40 pounds efficiently by lowering the input voltage using a variable voltage transformer.

5.4 PILOT PLANT ELECTRICAL CIRCUITRY

Figure 5-7 shows the wiring diagram for the UV lamps and lamp ballasts. As shown, each ballast (212ASTF) accommodates 2 lamps. The design of the circuitry is devised to allow the individual lighting of any number of lamps, so that there is maximum flexibility in the application of UV light.

(Figure 5-4)

SPECIFICATIONS OREC OZONATORS

(See footnote explanation of terms)

MODEL	OZONE OUTPUT[a] GR/HR	LBS/DAY	PARENT GAS[b]	GAS FLOW L/MIN	CFM	MAX PSIG[c]	WATER GPM[d]	DIMENSIONS W"xH"xD"	EST. GROSS WT./LBS.	STD.[E] NOMINAL VOLTAGE	STANDARD EQUIPMENT[F]
03V1-O	.2[g]		O_2	1		5	.15	22x14x14	40	120	2-7, 24, 27
03V5-O	4.5	.24	O_2	2.8	.1	10	.05	22x14x14	60	120	1-7, 24
03V9-O	9	.48	O_2	5.7	.2	10	.1	42x14x14	100	120	1-7, 24
03B1-O	19	1	O_2	12	.42	30	.2	44x20x16	265	120	1-12, 24
03B2-O	38	2	O_2	24	.84	30	.4	44x20x16	315	120	1-12, 24
03B3-O	57	3	O_2	36	1.26	30	.6	46x26x24	410	120	1-12, 24
03B4-O	76	4	O_2	48	1.7	30	.8	46x26x24	480	230	1-12, 24
03V9-AR	4.5	.24	AIR	6.3	.22	10	.15	42x14x14	140	120	1-7, 13-14, 24
03B1-AR	9.5	.5	AIR	13	.46	30	.2	46x26x30	390	120	1-11, 13-20, 24
03B2-AR	19	1	AIR	26	.92	30	.3	46x26x30	450	120	1-11, 13-20, 24
03B3-AR	28	1.5	AIR	39	1.38	30	.4	46x26x30	475	120	1-11, 13-20, 24
03B4-AR	38	2	AIR	52	1.85	30	.5	46x61x30	650	230	1-11, 13-24
03DV4-AR	76	4	AIR	—	3.7	30	.9	36x75x42	850	230	1-11, 13-24
03DV5-AR	95	5	AIR	—	4.6	30	1	36x75x42	900	230	1-11, 13-24
03DV6-AR	113	6	AIR	—	5.5	30	1.3	36x75x42	950	230	1-11, 13-24
03DV7-AR	132	7	AIR	—	6.5	30	1.5	36x75x42	1000	230	1-11, 13-24
03DV8-AR	151	8	AIR	—	7.4	30	1.7	36x75x46	1070	230	1-11, 13-25
03D10-AR	189	10	AIR	—	9.2	30	2	72x72x54	2540	230	1-11, 13-24
03D12-AR	227	12	AIR	—	11.1	30	2.5	72x72x54	2650	230	1-11, 13-24
03D15-AR	283	15	AIR	—	13.9	30	3.1	72x72x54	2800	230	1-11, 13-24
03D20-AR	378	20	AIR	—	18.5	30	4.1	72x72x54	3100	230	1-11, 13-24
03D25-AR	473	25	AIR	—	23.1	30	5.2	72x72x54	3300	230	1-11, 13-25
03H25-AR	473	25	AIR	—	23.1	10	5.2	78x78x78	3250	230	1-11, 13-23, 26
03H35-AR	661	35	AIR	—	32.4	10	7.3	78x78x78	3500	460	1-11, 13-23, 26
03H75-AR	1418	75	AIR	—	69.3	10	16	78x144x78	5300	460	1-11, 13-23, 26
03H100 AR	1890	100	AIR	—	92.4	10	21	78x144x78	6800	460	1-11, 13-23, 26
03H-150-AR	2835	150	AIR	—	139	10	31	84x156x84	9800	460	1-11, 13-23, 26

EXPLANATION OF TERMS

a. Rated output at 1% wt. if parent gas is air or 2% *wt.* if oxygen at 60 Hz. Output reduced 16% at 50 Hz. Maximum concentration in air is 4%; in oxygen 8%.

b. Ozonators which use atmospheric air have integral air processing equipment. Ozonators which use cylinder oxygen may operate from cylinder air or a pure air source of a dryness of −60°F dew point at 1/2 rated oxygen output. Models which are listed for air operation can be provided for oxygen operation and achieve twice the listed ozone output.

c. Maximum pressure at which ozone may be delivered.

d. Cooling water flow of 70° water.

e. Price adjustment for ordering in other than standard voltage. Standard 460 volt ozonators require 120 volts for control circuits.

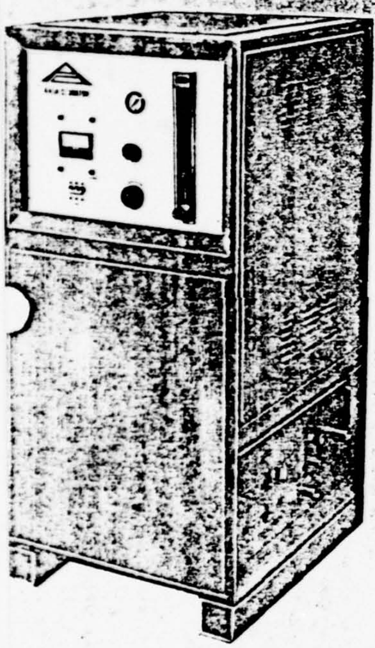
f. See equipment listing by code number. 1-7 means 1 through 7 inclusive. Ozonators can be provided with various additional non-standard equipment: timers, measurement instrumentation, interlocks, etc.

g. Rated output @ .2% concentration in oxygen. Output and concentration reduced to 1/5 of cited values if parent gas is air.

EQUIPMENT LISTING (Code numbers in Standard Equipment Column)

1. Stainless steel ozone generator with dielectrics.
2. Variable voltage control.
3. High voltage transformer.
4. Ammeter, ozone generator.
5. Gas flowmeter (air or oxygen).
6. Gas flow valve (air or oxygen.
7. Ozone generator pressure gage.
8. Voltmeter, ozone generator.
9. Gas pressure regulator (air or oxygen).
10. Gas pressure relief valve (air or oxygen).
11. Water pressure limit switch.
12. Thermal safety oxygen shut-off valve.
13. Air compressor with filters.
14. Automatically cycling air processing (drying) towers.
15. Drying towers ammeter.
16. Air pressure limit switch.
17. Air/ozone temperature gage.
18. Cooling water pressure gage.
19. Compressor pressure gage.
20. Drying tower cycling signal lights.
21. Air/ozone temperature limit switch.
22. Horn and signal light indicating cause of auto shutdown.
23. Cooling water exit temperature gage.
24. Integral, cabinet enclosed ozonator.
25. External compressor.
26. Skid mounted ozonator.
27. Ultra-violet ozone generator.

OZONE



from PCI OZONE CORP.

INDUSTRIAL OZONE GENERATORS

- HIGH OZONE CONCENTRATION 2% FROM AIR, 5% FROM OXYGEN OR FROM OXYGEN ENRICHED AIR (40% O_2).
- BROAD RANGE OF OPERATING TEMPERATURES AND PRESSURES.
- LOW OPERATING AND LOW MAINTENANCE COSTS.

DESCRIPTION: The PCI Model G ozone generators have three main advanced design features:

a) Direct liquid cooling of the two electrodes and dielectric of the electric discharge field leading to low discharge gas temperatures and avoiding thermal decomposition of the ozone produced.

b) High frequency (2000 CPS) and low voltage (~13,000 V RMS) operation using solid state proprietary frequency inverters which essentially eliminate glass failure.

c) Highly homogeneous electric discharge field achieved by precision manufacturing of electrodes and dielectric avoiding local overheating and stresses.

OZONE CAPACITY

Model Number	From Air	Oxygen or Oxygen Enriched Air (40% O_2)	Air/Oxygen Feed (SCFM)
G100-40	40 gr/hr	80 gr/hr	2.5
G100-60	60 gr/hr	120 gr/hr	3.0
G100-80	80 gr/hr	160 gr/hr	4.5
G100-120	120 gr/hr	240 gr/hr	7.0
G-10	10 lb/day	20 lb/day	10.0
G-15	15 lb/day	30 lb/day	15.0
G-20	20 lb/day	40 lb/day	20.0

CAPACITY: The ozone generating capacity is determined using dry -60°F dew point feed gas at 1% ozone concentration from air and 2% ozone concentration from oxygen.

INSTRUMENT PANEL: Power switch, ozone output control, ampere meter, pressure gauge, pressure regulator, flow meter, pilot lights.

SERVICE PANEL: Main circuit breaker (optional), power inlet, power outlet for air preparation unit (optional), purge timer (optional), air inlet, ozone outlet and cooling water inlet and outlet.

(Figure 5-5)
(1st page)

(Figure 5-5)
(2nd page)

DIMENSIONS:

Model	Height	Width	Depth	Approximate Shipping Wgt. (lbs.)
G100-40-60	52"	22"	24"	750 lbs.
G100-80-120	62"	29"	36"	1,250 lbs.
G-10-15	62"	29"	36"	1,350 lbs.
G-20	71"	29"	26"	1,500 lbs.

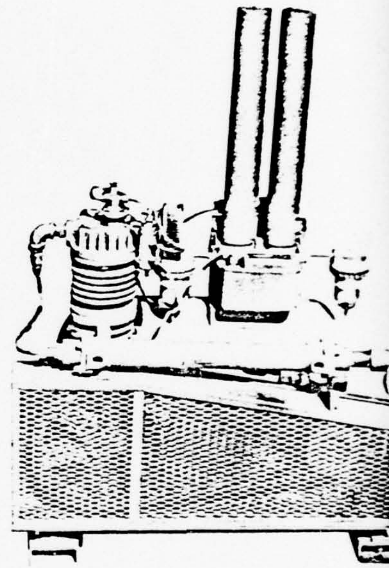
POWER SUPPLY: 208/230/460 volts, 60 Hz, 3 phase, optional 550v, 60 Hz, 3 phase or 380/500v, 50 Hz, 3 phase.

AIR SUPPLY: Clean, oil free, dry (dew point -60°F at least) 0-100 PSIG pressure air. Dry oxygen or oxygen enriched dry air (at least 40% oxygen content) increases ozone output proximately two fold.

COOLING WATER: 0.16-0.3 GPM of clean 80° F water per each lbs/day ozone capacity.

POWER REQUIREMENTS: 6.5-8.5 KWH/lb ozone from air; 2.5-3.5 KWH/lb ozone from oxygen (at 1% and 2% ozone concentration respectively).

DRY AIR PREPARATION UNIT: Auxiliary dry air preparation units for continuous operation of Airox Industrial Ozonators are designed for installations where no compressed dry air or oxygen is available. These units are the most economical air supply equipment. They produce compressed oil free dry air with a dew point of -60°F or below. All units are skid mounted, complete with non-lubricated compressor, dryer, air filters and controls for automatic operation.



Model Number	Dry Air Capacity (SCFM)	Approximate Shipping Weight	Recommended For Airox Ozonator Models
PS71	3.0	400	G100-40
PS72	4.0	400	G100-60
PD72	6.0	430	G100-80
PD73	8.0	500	G100-120
PRE11	11.0	650	G-10
PRE17	17.0	850	G-15
PRE23	23.0	1000.	G-20

TYPICAL OZONE APPLICATIONS INCLUDE:

a) Treatment of industrial waste water containing cyanide, phenol, sulphur compounds, surfactants, polymers;
b) Sterilization of process water;
c) Algaecide for cooling towers;
d) Bleaching agent for paper and textile industries;
e) Odor control in waste water treatment plants and industrial plants;
f) Treatment of domestic waste water (tertiary treatment)
g) Disinfection of biologically treated waste water.

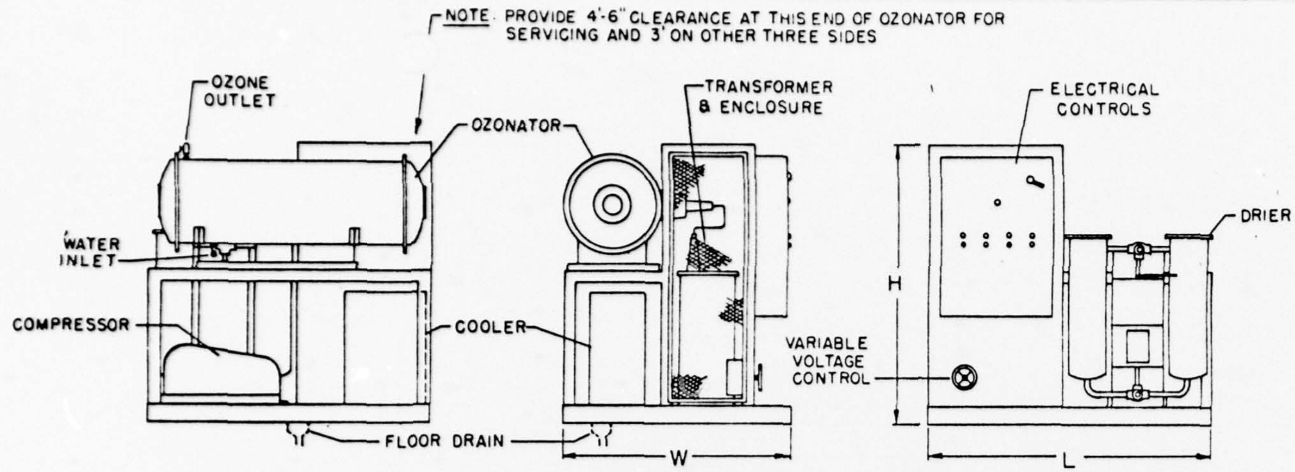
The data given here are based on testing and experience and are believed to be accurate. However, we cannot guarantee identical results under all operating conditions and no obligation or liability is assumed in connection with the use of this information.

SEND STANDARD PURCHASE ORDER OR USE COMPANY LETTERHEAD

PCI OZONE CORP.

A SUBSIDIARY OF POLLUTION CONTROL INDUSTRIES, INC.

ONE FAIRFIELD CRESCENT, WEST CALDWELL, N.J. 07006 • 201-575-7052



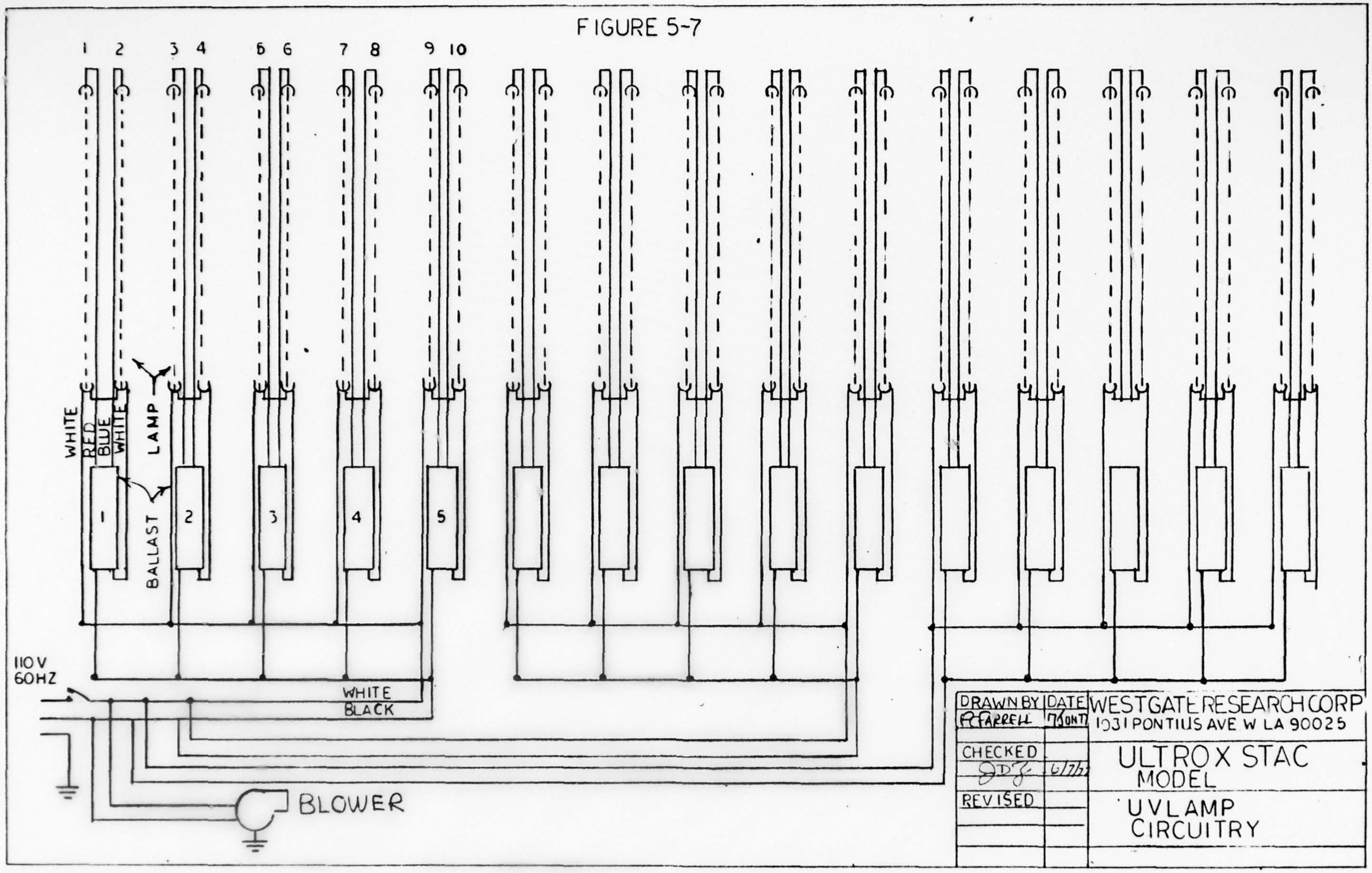
TYPICAL CLP OZONATOR ELEVATIONS

Figure 5-6

SPECIFICATIONS FOR WELSBACH CLP OZONATORS

Model No.	Ozone Production Pounds per Day	Ozone Production Grams per Hour	Air Flow CFM	Cooling Water GPH @ 70°F.	Piping Connections Water In	Piping Connections Water Out	Piping Connections Ozone Out	Dimensions (approx.) Length	Dimensions (approx.) Width	Dimensions (approx.) Height	Shipping Wt. Lbs. (approx.
CLP-4-D19L	3.7	70	3.5	47	1/2"	Floor Drain	3/4"	8'-0"	5'-0"	6'-0"	2600
CLP-9-D19L	8.35	158	7.5	102	1/2"	"	3/4"	8'-0"	6'-0"	6'-0"	3300
CLP-19-D19L	17.6	333	16.1	217	3/4"	"	1"	9'-0"	6'-1"	6'-7"	4900
CLP-34-D19L	31.5	596	28.8	388	3/4"	"	1-1/4"	9'-5"	6'-7"	7'-9"	6000
CLP-51-D19L	47.2	893	43.1	580	1"	"	1-1/2"	9'-5"	8'-8"	8'-10"	7000
CLP-68-D19L	63.0	1,192	57.5	775	1"	"	1-1/2"	9'-5"	8'-8"	8'-10"	8900
CLP-85-D19L	78.6	1,486	74.0	1,000	1"	"	2"	9'-5"	8'-8"	8'-10"	9500

NOTES:
(1) CURRENT CHARACTERISTICS for the CLP-4-D19L and CLP-9-D19L are 115 or 230 V., 60 Hz. All other CLP units are designed for 230 or 460 V., 60 Hz.
(2) OZONE PRODUCTION figures are based on use of 60 Hz. current. At 50 Hz., production is 5/6 the above figures.
(3) POWER CONSUMPTION per pound of ozone produced is 7 to 7.5 KWH for the ozonator and 2.5 to 4 KWH for the auxiliaries. Variations are caused by conditions of operation, especially as these affect the air drying equipment.
(4) POWER FACTOR for CLP models is approx. 40% leading; the ozonator is a capacitance electrical load.



Wiring Diagram for the UV Lamps and Lamp Ballasts

SECTION 6 5,000 GPD PILOT PLANT DEVELOPMENT PROGRAM AND COSTS

The design, fabrication, assembly, and installation of the 5,000 GPD pilot plant can be completed within four months after receipt of the contract amendment. After installation of the pilot plant, it is recommended that a 3-month, engineering design-of-experiment test program be conducted on a slip-stream of pink water. Optimum operating conditions can be established to obtain minimum operating costs and capital costs for the 100,000 gal per day plant.

6.1 COST OF PILOT PLANT

The installed cost of the pilot plant as described in Sections 5 and 6 is estimated to be as follows. This cost includes shipping, set-up, check-out, instructions to operating personnel, and an Instruction and Operating Manual.*

Engineering		
Supervision	1,120	
Engineering	3,000	
Technician	3,900	
		$8,020

(continued on next page)

* These costs are for a non-explosion-proof system. Costs for an explosion-proof system will be about 20% greater than non-explosion-proof.

Engineering	$ 8,020	
Materials	16,000	
Outside Services	2,500	
Packing and Shipping	2,000	
Travel and Communication	2,000	
		30,520
G&A @ 75%	22,890	
Fee @ 7.2%	3,845	
		57,255
Ozone Generator*	40,000	
		$ 97,255

6.2 PROJECTED OPERATING COSTS

The costs of operating the pilot plant involve operating labor, analytical services, and electrical power.

6.2.1 Electrical Power Cost

The maximum power consumption (without optimization) for the 5,000 GPD (18.9 m^3/d) plant will be as follows:

---

*Cost of ozone generator is negotiable. Westgate will endeavor to make the best buy with the shortest delivery time.

Ozone Generation (10 KWH/LB O_3)	15.6 KW
UV Lamps (144 lamps @ 65 W/lamp)	9.4 KW
Total	25.0 KW

For 24 hour operation, the energy consumption will be 600 KWH. If a KWH cost $0.02, the daily cost will be $12.00 (or $2.40/1000 gal).

6.2.2 Operating Personnel

One supervisor and one technician are required per shift. The technician will monitor ozone mass flow, ozone concentration, effluent flow rate, and will take the necessary water samples. The supervisor will oversee the operation and keep the operational log.

Estimated maximum time required per shift is

Supervisor	2 hours
Technician	6-8 hours

Costs involved depend upon labor rates and overhead at the wastewater treatment site.

6.2.3 Analytical Services

Analytical service requirements depend upon the type and frequency of analyses to be conducted. It is recommended that for pink water TOC, TNT, and RDX analyses be undertaken. In a test run, samples of effluent are usually taken once every hour for 4 hours after the theoretical hydraulic retention time has been reached. Samples are taken of the influent, the mid-reactor effluent and the final effluent. TOC analysis can be conducted on each sample. TNT and RDX analysis can be made either on composite samples of the two effluent streams and of the influent, or if the analytical laboratory workload allows, on each sample as it is taken.

Costs for conducting these analyses depend on current laboratory labor rates and overhead.

6.3 SUGGESTED OPTIMIZATION TEST PROGRAM

It is recommended that an optimization study be undertaken after the pilot plant is installed. A statistically-designed set of experiments will be conducted by ARRADCOM personnel at a selected pink water site with Westgate Research support. Approximately 24-30 tests will be carried out. In the test program, instructions will be telephoned to ARRADCOM to set the operating levels for the first three tests. ARRADCOM will then telephone the test results (e.g., flow rate, effluent analysis, pH and temperature). A new set of operating parameters will then be given to ARRADCOM for the next three tests. This procedure will be repeated until all of the tests are completed.

Existing mathematical models and computer programs will be used to obtain minimum power usage and maximum flow rate (minimum residence time) to produce an effluent of specified purity. The operating variables to be examined include:

1) O_3 mass flow per stage
2) UV lamp locations
3) number of UV lamps per stage
4) O_3 concentration

This information would then be used to define the ozone requirements and the number and location of UV lamp placements both for the pilot plant and the 100,000 GPD plant (see Section 7.4).

The total cost for carrying out the optimization study (including Westgate Research Corporation supervisory personnel, UCLA computer time, key punch operators, and statisticians) will be $9,700.00. An engineering report will be issued by Westgate Research Corporation summarizing the results of the optimization, and providing preliminary designs, specifications, and costs for the 100,000 GPD plant. The estimated time for carrying out the optimization test program is 7-10 weeks.

6.4 APPLICATION OF THE OPTIMIZATION STUDY RESULTS

With completion of the optimization program, the installation details of UV lamps and ozone generating and dissolution equipment can be defined. The pilot plant (Standard Cell or STAC) is the basic building block for large scale ULTROX plants. Any number of STAC's can be installed in parallel in a rectangular concrete or steel tank to make up a large ULTROX system.

If the optimum residence time is determined to be 150 minutes, the total wet volume of a 100,000 GPD (378.6 m^3/d) reactor will be 10,420 gals (89.4 m^3). The number of STAC's which make up a 100,000 GPD plant will then be 15. The approximate overall dimensions will be 12 x 24 x 5 feet (W x L x H) or 3.7 x 7.3 x 1.5 meters.

If the optimum number of UV lamps are 72, or 4 lamps/ft^2, in the pilot plant, the number of lamps required for the full scale plant will be 1,080 or 72 per STAC.

Assuming an optimum amount of ozone is 800 mg/liter, the total ozone requirement for the pilot plant or STAC will be 36 lbs (16.3 kg), and for the 100,000 GPD plant, the total ozone quantity per day will be 666 lbs (302 kg).

SECTION 7 PROJECTED COSTS FOR A 100,000 GPD AUTOMATED ULTROX SYSTEM

As indicated in Section 6.4, a 100,000 GPD ULTROX plant can be constructed by using fifteen (15) Model No. 7606 STAC's, operating with 1,080 UV lamps and 666 pounds of ozone per day. Table 7-1 provides a summary of the capital costs and the annual operating cost for a 100,000 GPD plant which will accommodate pink water with 140 ppm TNT and 70 ppm RDX.

Tables 7-2 to 7-5 provide detail on capital costs, ozone generator operating, UV operating, and maintenance costs.

Table 7 - 1

Cost Analysis Summary

100,000 GPD ULTROX SYSTEM (AUTOMATED)
TO REMOVE 140 ppm TNT AND 70 ppm RDX FROM PINK WATER,
EFFLUENT TO <1 ppm TNT and <1 ppm RDX

CAPITAL COSTS

ULTROX SYSTEM INSTALLED INCLUDING ENGINEERING		$962,500

ANNUAL OPERATING COST

OZONE GENERATION POWER COST @ $0.02/KWH	48,200	
UV LIGHT POWER COST @ $0.02/KWH	12,400	
MAINTENANCE COST	30,700	
		$ 91,300

TOTAL DIRECT COST/1000 GAL* = $2.61

*Assumes 350 day operating year

Table 7 - 2

PINK WATER 100,000 GPD ULTROX SYSTEM

CAPITAL COST

REACTOR RESIDENCE TIME		150 min
FLOW Q	69 gal/min (261 ℓ/min)	
OZONE PROD & CONTROLS	660 lb/day (299 KG/day)	$500,000
REACTOR W/15 STACS/ 1080 UV LAMPS INSTALLED		375,000
	TOTAL COST	$875,000
	+ 10% ENGINEERING	87,500
	GRAND TOTAL	$962,500

Table 7 - 3

PINK WATER - 100,000 GPD OZONE GENERATION

POWER COST

$\frac{LBS}{DAY}$ O_3, FEED GAS AIR	660 (299 KG/Day)
INSTALLED KW	277
$\frac{KWH}{DAY}$ FOR O_3 PROD (1% by wt from Air)	6600
$\frac{COST}{DAY}$ @ $0.02/KWH	$132

Table 7 - 4

PINK WATER - 100,000 GPD

UV LIGHT POWER COST

INSTALLED KW 1080 UV Lamps @ 65 w/lamp	70 KW
$\frac{\text{KWH}}{\text{DAY}}$ FOR UV	1685
$\frac{\text{COST}}{\text{DAY}}$ @ $0.02/KWH	$34

Table 7 - 5

PINK WATER - 100,000 GPD

MAINTENANCE COST

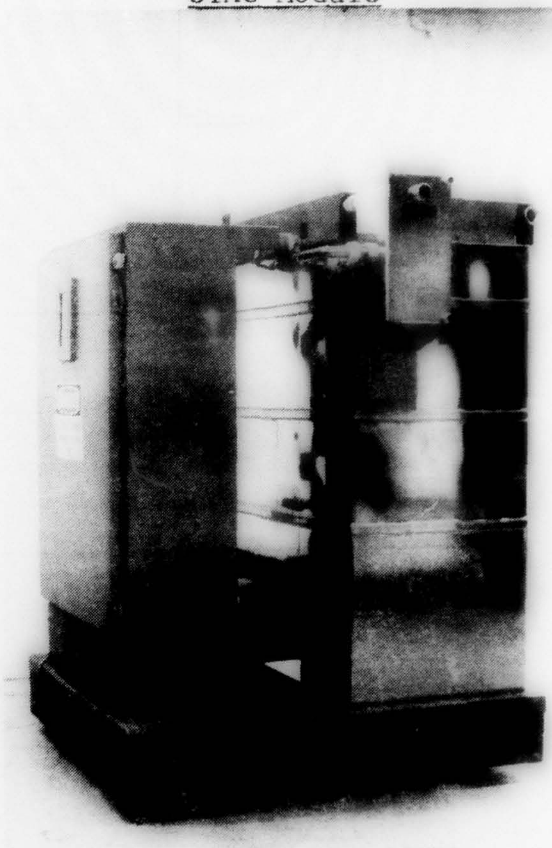
UV LAMP REPLACEMENT AVE COST/DAY	$59
LABOR AND PARTS AVE COST/DAY	$25
TOTAL COST/DAY	$84

APPENDIX

BULLETIN #101

ULTROX Systems

STAC Module



THE ULTROX™ STAC

The ULTROX STAC (STAndard Cell) is a compact modular unit that uses UV/ozone for the removal of organics and for the disinfection of water. Water treatment plants from 1,000 GPD to 10,000,000 GPD can be quickly installed by using multiple STAC units.

APPLICATIONS

The ULTROX STAC equipment when optimally adjusted can remove the TOC (total organic carbon) values to practically zero. It is an extremely powerful disinfectant capable of totally destroying viruses and micro-organisms. ULTROX has been effective in removing the following contaminants:

alcohols	kepone	
aldehydes	microorganisms	pesticides
chlorinated hydrocarbons	munition wastes	PCB's (polychlorinated
chloroform	(e.g., TNT & RDX)	biphenyls)
cyanides	organic acids	sugars
detergents	organic amines	and others

Operating Characteristics

- ULTROX oxidizes organics to a harmless carbon dioxide exhaust
- Selective contaminants or total organic values can be reduced to practically zero
- The ULTROX STAC requires little operator attention and can be installed as an automatic system away from the plant floor or below grade
- No regenerative cycle, no disposal required of sludges, no leaks or break-through surges resulting from changing carbon adsorbent beds
- ULTROX is simple, reliable, and clean, requiring only minimum maintenance

Services: Laboratory and consulting services are available to most effectively solve your specific water problems and to establish proper operating parameters of ULTROX modules.

- Portable STACs are available on a rental basis. A short test program will establish the capital and operating costs for your optimum water treatment facility.
- Support services include installation, operating manuals, maintenance, and spare parts.

STANDARD CELL (STAC) SPECIFICATIONS

STAC Model No.*	7604	7605	7606
Ext. Dimensions (ft)	4 x 4 x 5	1/2 x 6 x 5	4½ x 6½ x 6
Shipping weight(lbs)	1,000	1,000	1,800
Volume (gallons)	84	112	675
Capacity GPM	1.4	1.9	11.25
" GPD	2,016	2,688	16,200
Lamp Watts	40	65	65
# Lamps	30 max	12	72 max
Total Watts	1200 max	780	4680 max
Ozone Required***			
gm/min	0.95	1.3	7.7
lb/day	3	4.1	24.3
Power Required			
UV KW	1.2	0.8	4.7
O_3 KW**	1.2	1.7	10.1
Total KW	2.4	2.5	14.8
KWH/DAY	57.6	60.0	355

*Special order for additional sizes **Based on 10 KWH/LB O_3

***Power demand is dependent on nature and concentration of contaminants. Each STAC can be optimized to obtain minimum power usage. Ozone quantity based on 15 ppm TOC in influent.

Interface Requirements

Electrical - 115 Volts, 60 HZ, 1 phase power supply (Standard)

Piping - Water - 7604 - 3/8" NPT, female fitting, to PVC pipe
7606 - 1 1/4" NPT, male fitting, to PVC pipe

- Head - 6 foot - PVC or PP reservoir w/piping, float valve inlet

Venting - Spent ozone/air mixture - 1¼" tubing, Liquid gas separator and catalytic reactor to decompose residual ozone-outlet gas trap

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Contact our Sales Department or our local authorized representative for further information and detailed installation data

WESTGATE RESEARCH CORPORATION
1931 PONTIUS AVE
213/473-4541
WEST LOS ANGELES
CA 90025

AD-A045 126 WESTGATE RESEARCH CORP LOS ANGELES CA F/G 13/2
DEVELOPMENT EFFORT TO DESIGN AND DESCRIBE PINK WATER ABATEMENT --ETC(U)
AUG 77 F C FARRELL, J D ZEFF, T C CRASE DAAK10-77-C-0041

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WESTGATE RESEARCH CORPORATION
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October 7, 1977

Defense Documentation Center
Cameron Station - ATTN: DDC
Alexandria VA 22314

Reference: Report No. 1701, Contract DAAK 10-77-C-0041

Gentlemen:

Please find enclosed corrected pages 1-4/5, 7-2, and 7-3, which replace the original pages 1-4, 1-5, 7-2, and 7-3 respectively. These pages are to be included in the two (2) copies of Report 1701 which were sent to you last month.

Very truly yours

WESTGATE RESEARCH CORPORATION

Jack D. Zeff

Jack D. Zeff
President

enclosures

to burn any deposited explosives, a procedure which is acceptable in their remote locations. The McAlester lagoon cannot be flashed because it never evaporates to dryness.

Other approaches that have been tried, at least in the laboratory, include direct solvent extraction, reverse osmosis, fly ash adsorption, and biodegradation. None have been entirely satisfactory.

Activated carbon is very effective at removing TNT from water solutions. Currently, carbon is used once and then burned; the result is a high cost operation and a black smoke, air pollution problem. Thermal regeneration has been piloted and proven successful, significantly reducing the cost of the carbon treatment.

It has been shown by several investigators that ozonolysis, under normal laboratory conditions, degrades TNT, but not fully. The TNT itself disappears; but refractory, aromatic, degradation products have met with little success; and that has led to unease, because many of TNT's refractory, incomplete degradation products are known to be more toxic to aquatic life than TNT itself.

Table 7-1

Cost Analysis Summary

100,000 GPD ULTROX SYSTEM (AUTOMATED)
TO REMOVE 140 ppm TNT and 70 ppm RDX FROM PINK WATER,
EFFLUENT TO <1 ppm TNT and <1 ppm RDX

CAPITAL COSTS		
ULTROX SYSTEM INSTALLED INCLUDING ENGINEERING		$432,000
ANNUAL OPERATING COST		
OZONE GENERATION POWER COST @ $0.02/KWH	46,200	
UV LIGHT POWER COST @ $0.02/KWH	11,900	
MAINTENANCE COST	29,400	
		$87,500

TOTAL DIRECT COST/1000 GAL* = $2.50

*Assumes 350 day operating year

Table 7 - 2

PINK WATER 100,000 GPD ULTROX SYSTEM

CAPITAL COST

REACTOR RESIDENCE TIME		150 min
FLOW Q	69 gal/min (261 ℓ/min)	
OZONE PROD & CONTROLS	660 lb/day (299 KG/day)	$168,000
REACTOR W/15 STACS/ 1080 UV LAMPS INSTALLED		225,000
	TOTAL COST	393,000
	+ 10% ENGINEERING	39,000
	GRAND TOTAL	$432,000