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FINAL REPORT TO:

THE DEPARTMENT OF THE ENVIRONMENT

# ELECTROLYTIC GENERATION OF CHLORINE FOR DISINFECTION OF PRIVATE WATER SUPPLIES

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DESIGN UNIT

University of Newcastle upon Tyne

Department of Mechanical,
Materials & Manufacturing Engineering
Stephenson Building
Newcastle upon Tyne NE1 7RU

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Final Report

# ELECTROLYTIC GENERATION OF CHLORINE FOR DISINFECTION OF PRIVATE WATER SUPPLIES

## 1. Introduction

Most people in Britain are supplied with water by the national water authorities or water companies. The quality of such water has to meet certain standards set by the government in London or Europe.

Nearly 5% of the British population, however, rely on private water supplies for their domestic water. In these instances the water source will be a spring, bore hole, or private dam, and the quality of water in terms of bacterial content will depend largely on how well the systems are maintained.

In order to ensure that all domestic water in Europe is covered by the statutory requirements it is the intention of the EEC that legislation of member states include private water supplies. This means that either the private water supply has to be replaced by mains water, or that there have to be regular site visits to monitor the quality of water at each source. In many cases the former may not be practical because of high installation costs. In the latter case there may be need for the installation of a simple, cheap, device which would ensure the quality of water over a predictable length of time. Ideally such a device would have high reliability, be inexpensive to install and run, have long running time with minimum maintenance and attention, and require no addition of chemicals.

It is with these requirements in mind that the Department of the Environment proposed that a device be developed which generates chlorine at an appropriate concentration for the disinfection of individual or local water supplies by electrolysis of chlorides present in the naturally occurring water. The project which is the subject of this report is concerned with the development and testing of an electrolytic cell suitable for this application.

Experts in the Dept. of Chemical Engineering, Civil (Public Health) Engineering, and Chemistry were involved. The Design Unit in the Department of Mechanical, Materials and Manufacturing Engineering is responsible for co-ordinating the project, carrying out the design and manufacture of prototypes and monitoring the tests.

This is a final report summarising the work carried out, describing the experimental equipment used and the test procedures followed, and discussing the results and conclusions.

## 2. Summary of Work

This project has been running from the end of 1984 to the end of 1989. A summary of the work is given. Part way through, it was realised that generation of free chlorine was not essential for the destruction of bacteria and perhaps undesirable operationally. In consequence emphasis was shifted to the direct effect of an electrolytic current, the presence, or absence, of chloride ions being treated as one of several influential variables.

### 2.1 Experimental Determination of Constants Governing the Evolution of Chlorine.

Initial experimental work was carried out to elucidate the kinetics of the anodic chlorine production from chloride ions and competitive oxygen evolutionary reaction. This work was carried out with rutherium oxide coated titanium and graphite anodes. The kinetic constants indicated that at low chloride concentrations graphite would be far superior, and that a current density of approximately 1-3 $A/m^2$ was required to release $C\ell_2$ from aqueous solution containing chloride ions at the levels which would be met in potable water supplies, namely 10 to say 100 ppm.

### 2.2 Literature Survey

A literature survey showed that many devices for generating chlorine from aqueous chloride solutions were available for water treatment but the solutions employed were synthesised or only depended upon advantageous presence of chlorides in the case of hypochlorite generation from sea water.

### 2.3 Bench Scale Studies

A full scale undivided, bipolar, plane-parallel plate cell with a total electrode area of 225 $cm^2$ was constructed, based on the parameters determined from the above work, and was tested using an electrolyte containing chloride ions at a concentration of 20 ppm. The first few runs failed to produce the expected chlorine, however, and so further experimentation with this cell was suspended in favour of preparative bench scale studies of a diagnostic nature. A new anodic material, Ebonex, (a suboxide of titanium), which became available at this stage was included in these studies and proved to be superior to graphite as a chlorine generator. Initially these studies were carried out with both rotating and stationary anodes. In a divided cell and with a rotating anode, be it Ebonex or graphite, chlorine was readily liberated from chloride ions at low concentrations (e.g. 20–40 ppm) but not so with a stationary electrode in a stirred electrolyte. It was therefore deduced from this that a high shear rate is needed at the anode surface.

With an Ebonex rotating anode, chlorine production rates of approx. 700 $mg/m^2h$ at 15 $A/m^2$ and approx. 6000 $mg/m^2h$ at 70 $A/m^2$ were recorded with chloride concentrations of 20–40 ppm.

Further experimentation was carried out to establish whether the production rates could be extrapolated to larger electrode sizes. The results showed that the amount of chlorine produced from a 30mm dia. anode is proportionally less than that predicted from the 5mm dia. anode.

These results led to the construction of a thin gap parallel plate cell divided by a nafion (cationic) membrane and equipped with a mesh turbulence promoter to improve the shear rate. An Ebonex anode was used with an exposed area of 600 $mm^2$. The anolyte and catholyte were circulated separately through the cell by centrifugal pumps in a recirculating mode, see Section 3.1. Initial tests with the cell gave promising results with chlorine production rates of approx. 2,600 $mg/m^2hr$. being achieved at chloride concentrations as low as 10 ppm in distilled water and a current density of $50A/m^2$.

Up to this point, work concentrated on the anodic generation of chlorine from distilled water containing low levels of chloride ions. In the next stage the work was extended to natural waters but the results were inconclusive with no detectable chlorine being generated. In an attempt to understand them the work was continued with distilled water in which constituents present together in natural water were studied separately, in particular, humic and fulvic acids and ammonium salts. Both were found to be extremely reactive towards chlorine but did not prevent the destruction of *Eschevichia Coli* and, in fact, these studies eventually led to the conclusion that the presence of free chlorine is not essential to the destruction of *E.coli* which is most likely to be due to direct anodic oxidation. This further suggests that the presence of a membrane, the function of which was to stabilise chlorine, was also no longer necessary. This was subsequently confirmed by experiment.

In the light of these tests it was decided at this stage that rotating electrodes and divided cells be abandoned for the remainder of the programme, a decision which also meant that their inherent complexity was avoided.

## 2.4 Large Scale Cell Development

Calculations based on the above work predicted that an electrode size of over 200 $cm^2$ based on a contact time of 1.6 sec. was required to disinfect 45l. of water per hour. The electrode gap was to be 1mm to hold down the ohmic losses incurred by passage of current through the relatively poor conducting water.

Designing for a flow velocity of approx. 0.5 m/sec. this would require the electrodes to be 25mm wide and 800mm long or 25mm x 200mm if 4 cells were in series. This configuration, however, presents a problem from the point of view of using Ebonex for the following reason.

To maintain the 1mm gap to within say ±0.2mm requires a tolerance of ±0.1mm on flatness of each electrode. This can not be achieved with Ebonex for the required size of electrode by present production methods and nor can it be machined to tolerance because of its brittleness. For the same reason it is not easy to form a good seal between it and the cell walls.

Although it was established in previous bench scale studies that Ebonex is far superior to normal graphite for the production of $Cl_2$ from small concentrations of chlorides by the electrolysis process, a similar comparison had not been undertaken regarding the destruction of bacteria. As graphite is a much easier material to use, and so lends itself to a simpler cell design, it was thought appropriate to do this comparison before thought was given to the more sophisticated cell design which would be demanded by Ebonex.

From experiments on this comparison it was found that Ebonex required a residence time of 1.6 sec. compared with graphite which required over 3 secs. In this context, residence time is the average time an element of fluid resides in the cell. It was concluded therefore that, if possible, Ebonex should be the preferred electrode material and that a cell design be sought which could accommodate it.

An appropriate design of cell was thought to be the Bipolar Rod Cell. This type of cell was developed in the Department of Chemical Engineering at the University of Newcastle upon Tyne and patented through NRDC, and consists of a stack of rod electrodes separated by O-rings of an appropriate thickness. The electrodes can be comparatively small and are rugged. Furthermore, the sealing between the electrodes and cell walls is less critical.

A cell of this type, designed to treat 50ℓ of water per hour, was built using both round and square rods. Unfortunately, due to supply difficulties, Ebonex was not available at this development stage and therefore graphite was used. As in previous tests with the planar electrode cell, testing was carried out in the re-cycled batch mode.

Using 12.5mm square x 60mm rods, distilled water and a current density of 45 A/m$^2$, *E.coli* was destroyed with a residence time of 5.3 secs. This is similar to the results previously obtained with the planar electrode cell and a graphite anode. The effect of reducing the current density was to increase the required residence time as was the effect of introducing organic material (humic + fulvic acid).

## 2.5 Large Scale Rig Development

The encouraging results obtained from testing the bipolar cell in the re-cycling mode led to the building of a larger rig so that testing could be carried out in a batch mode and on a larger scale.

The performance of this cell was thoroughly investigated and included such parameters as current density, contact time, flow velocity, organic and nitrogen content, bacteria type, polarity reversal and chlorine generation. Due to the problem of supply of Ebonex, graphite was used in all these tests.

The results indicated that to disinfect water contaminated with *E.coli.* in the batch mode, a current density of 120–160 A/m$^2$ at a contact time of 5–8 secs. is required. It was also confirmed that the introduction of organics has a significant effect on cell performance. For instance, water with a Hazen No. 20 could require a 50% longer contact time. Work with water contaminated with settled sewage showed that the cell was effective in destroying bacteria other than *E.coli.*

## 2.6 Ebonex Plate Cell

Towards the latter stages of the work described above a number of Ebonex plates (approx. 2.5mm thick) became available. To gain some experience with this material, 6 plates, 56mm x 54mm, were stacked in an existing cell box in a parallel flow arrangement. Results from a limited number of tests using this cell indicated that with a current density of 120 A/m$^2$ a contact time as low as 1.5 sec. may be sufficient to disinfect water contaminated with *E.coli.*

With this cell configuration, useful life tests were carried out with a continuous supply of water through the cell at an operating current density of 245 A/m$^2$. The University water supply was used for this purpose. Initial tests resulted in a large deposit of calcium and magnesium hydrated oxides forming on the electrodes within a few days. Also there was considerable erosion of the electrodes. The problem of deposition was resolved by restarting the tests with new plates and reversing the polarity of the electrodes every 2 mins. Erosion of the electrodes was considered to be due to the current density being too high. This life test continued (operating at 108 $A/m^2$ and reversing polarity every 2 mins.) for 32 days with no significant deterioration of electrodes or deposition.

## 2.7 Ebonex Bipolar Cell with Rectangular Rods

When rectangular Ebonex rods became available a bipolar rod cell was built and tested. The results were very promising and confirmed the view that Ebonex was far better than graphite in this application. A limited number of tests were carried out to investigate the effect of polarity reversal on the performance of the cells. At a reversal rate of one per min. there was no significant change in performance. However, at the high rate of one per sec. a considerable drop in performance was observed.

## 2.8 Field Trials

When a supply of Ebonex square rods was available, a new bipolar cell was built. Another test rig was also manufactured, specifically designed for site testing, with a purpose built control box. The test rig was set up at Horsley Treatment Plant and field trials were carried out over a period of 5 weeks. Raw water was supplied mainly from the river Tyne. The initial performance of the cell was good even though the organic content of the water was very high. (Hazen numbers in excess of 100 were recorded). However, the effect of the high colour and turbidity was a dramatic drop in cell performance after 24 hours due to undissolved solids depositing on the electrode surfaces and also, possibly, to the "carry-through" of bacteria on the particles. It should be mentioned that there were abnormal storms during these tests and as a result the water carried heavy solids burden.

Close examination of the electrode surface showed that there was a surface coating. This had to be removed before the original performance was regained.

It was thought that the problem of surface contamination may be due to the high permeability of the Ebonex material and so might be avoided by using a non-porous electrode material. The field trials were therefore abandoned so that more laboratory tests could be carried out with the bipolar cell. One of these tests showed that having cleaned the Ebonex electrodes, the cell could operate continuously with the standard electrolyte solution for 6 days without detrimental effect on cell performance. The standard electrolyte solution is specified in Section 3.2.

## 2.9 Polarity Reversal

A series of tests was carried out with the Ebonex bipolar cell to study the effect of polarity reversal on cell performance under a variety of test conditions. Both *E.coli* and faecal Streptoccoci were used as indicator organisms.

The results showed that there is a period of instability after the current is reversed which manifests itself as a drop in cell current (at a constant voltage) and a momentary decrease in pH. The time over which this occurs and the precise characteristics of the instability seems to depend on the material of the electrode and not necessarily on the frequency of polarity reversal. This period of instability has a detrimental effect on the ability of the cell to kill bacteria and is thought to be caused by reversible chemical changes occurring at the electrode/electrolyte interface. Cell performance is dramatically reduced when the frequency of reversal is greater than 2 rev/min. At a frequency of 2 rev/hr., on the other hand, the period of low performance lasts for only a small proportion of the total running time. For Ebonex electrodes the time of instability lasts approx. 2 mins.

## 2.10 Material Investigation

A preliminary investigation was carried out to find alternative electrode materials which have similar electrode properties to Ebonex, i.e. high oxygen overpotential and the ability to generate chlorine, but which are non-porous.

Most metals were excluded from the investigation due to their instability as an anode. The more stable metals are either unacceptable in potable water, such as lead, or very expensive and only viable if used as a coating on another metal, e.g. platinised titanium. In general, these coatings are rapidly removed from their substrates when polarity is reversed.

Non-metals such as oxides, carbides, nitrides, borides and silicides were investigated together with several forms of carbon. Some were considered in bulk form and others as a coating laid on a substrate.

Tests showed that the electrodic properties of a material depend on its structure, how it has been manufactured and the presence of any trace elements. There are, therefore, a countless number of possibilities. However, from the number of tests carried out it was concluded that the carbides and carbon–carbon (a carbon/resin composite with a high fibre content) are the most promising types of materials.

All the nitrides tested proved to be anodically unstable being readily transformed to oxides. For a similar reason the suboxides can be ruled out except, of course, the suboxide of titanium, namely Ebonex.

A number of materials had not been made available by the time of completion of the project and the investigation has by no means exhausted all the possibilities. It is recommended that a further study be carried out to continue this investigation.

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# 3. Experimental Equipment, Cell Design, and Test Procedures

Below is a summary of the test procedures, test conditions, and the equipment manufactured. Table 1 : Test Conditions and Results, gives details of the individual tests. A description of the cells referred to in this table is also given below together with the equations used to calculate the main parameters of each cell.

## 3.1 Test Mode

The modes of testing referred to in Table I are as follows:

a) **Recirculating** (Recirc.)

In this mode, water is pumped from a small reservoir tank, usually about 2ℓ capacity, through the electrolytic cell, and returned to the same tank. Water is drawn from the inlet and outlet sampling valves for analysis at intervals during the test. The duration of the test would usually be about 3 hours, although some tests lasted over 6 hours.

b) **Batch**

In the batch mode, water is pumped from an inlet tank, through the electrolytic cell and then into a second tank. Normally a water sample would be taken for analysis from a sampling tap at the inlet to the cell at the beginning, in the middle and at the end of the test. Also a number of samples would be taken from a sampling valve at the cell outlet: approx. 10 samples would be taken for each test condition.

c) **Continuous Flow** (Con Flo)

For tests lasting more than a day, water was pumped from a continuous water source, through the electrolytic cell and dumped to drain. In the field trials carried out at Horsley Treatment Works, the water source was the raw water from the river Tyne. Similarly, in the laboratory, the Ebonex Plate Electrode Cell was connected directly to the mains water supply.

## 3.2 Electrolyte

In order to compare the performance of the various electrolytic cells and their electrode materials, a standard electrolyte was used in most laboratory tests. This consists of double distilled water with the addition of NaCℓ and $Na_2SO_4.10H_2O$ to give a chloride concentration of 20 ppm and an electrical conductivity typical of natural water. A standard solution of volume 60ℓ was made by diluting 396 ml of NaCℓ (5g/ℓ) and $Na_2SO_4.10H_2O$ (5 g/ℓ) with distilled water. To investigate the effect of parameters associated with natural water, such as colour, ammonium ion and chloride ion concentration, the standard solution was altered to vary the parameters one at a time. In these cases the modification to the standard solution is given in Table I.

### 3.3 Simulated Contaminated Water

For most of the bacteriological tests the indicator organism chosen was *Escherichia coli*. commonly used as an indicator of faecal pollution. On occasion faecal Streptococci was also used. To contaminate the water for test, it was inoculated with the bacteria to a concentration of approx. $10^6$ organisms/100 ml. Water samples for analysis were mixed with a small amount of thiosulphate to destroy any residual chlorine. Bacteriological analysis was carried out by colony count using the membrane filtration technique.

### 3.4 First Large Scale Test with Graphite Plates

Following the initial kinetic studies an undivided, bipolar, plane–parallel plate cell was constructed comprising five graphite electrodes. Each electrode was of area 225 mm$^2$, and the anode to cathode spacing was about 3mm. A drawing of the cell is shown in Fig. 1, a drawing of the test rig is shown in Fig. 2, and a photograph of the rig shown in Fig. 3. A charge of water of volume 220ℓ was passed batchwise through the cell. The charge contained 7.5g of NaCℓ, equivalent to 20 ppm of chloride ion, and 7.5g of $Na_2SO_4.10H_2O$. The latter was added not only to raise the conductivity to more realistic levels but also to introduce an additional anion so that the resulting solution would not be too dissimilar from typical drinking water.

### 3.5 Bench Scale Tests – Disc Anode

Initial bench scale tests were carried out with a 5mm dia. graphite or Ebonex disc anode, both rotating and static. Later, the anode was increased in size to 30mm dia.

A specially designed cell was manufactured for this purpose and is shown in the sketch, Fig. 4. The disc was fitted to a nylon carrier with a brass insert to mate with the spindle of a driving motor. Electrical contact with the disc was made by means of a spring loaded plunger. The rotating disc was positioned centrally over a Nafion membrane fitted to the bottom end of a perspex tube. The perspex tube, containing approx. 100 ccs of anolyte, was immersed in a beaker containing the catholyte. An 1/8" dia. stainless steel wire cathode formed in a loop was positioned below the membrane in such a way that the hydrogen gas evolved rose to the surface of the catholyte and was not trapped as an insulating blanket across the lower surface of the membrane.

The cell voltage was supplied by a Ministat 251 potentiostat rated at 25 Watts. Analysis of free chlorine was carried out with a Wallace and Tiernan DPD Residometer Type 100.

## 3.6 Bench Scale Tests – Plate Electrodes

The electrolytic cell designed for the plate electrodes consists of two polypropylene blocks sandwiching the anode and cathode plates, gaskets and, where applicable, a membrane and a turbulence promoter, as shown in Fig. 5. A sketch of the hydraulic circuit and a typical electrode is shown in Fig. 6. For part of the test programme, when there were no Ebonex plates large enough to manufacture a one piece electrode of this size, a small piece was fixed to a titanium plate with conducting Araldite.

For the condition where the cell is undivided, the membrane was removed and half of the flow circuit sealed off. The active area of the electrode was approx. 600 mm$^2$ and the gap between electrodes was approx. 1.0–1.5mm.

This cell was tested in the recirculating mode, the power supply and analysis equipment being identical to those described in Section 3.2. As well as graphite and Ebonex already mentioned, tin oxide coated glass and silicon carbide electrodes were also tested in this cell.

For the glass electrodes the exposed area was 75mm x 11mm giving an area of 825 mm$^2$. The gap was 1.5mm.

So

$$\text{Flow Velocity (m/s)} = \frac{0.28Q}{bt} = 0.017Q,$$

$$\text{Current Density (A/m}^2\text{)} = \frac{I \times 10^6}{b \times L} = 1212I,$$

$$\text{Contact Time (s)} = \frac{60 \times b \times L \times t \times T_K}{V_B \times 10^6} = \frac{0.074\ T_K}{V_B}$$

where $T_K$ = Running Time (min), $V_B$ = Total Volume of Water (ℓ)

b = width of electrode (mm)

L = length of electrode (mm)

t = gap (mm)

$Q$ = water flow rate ($\ell$/h)

$I$ = cell current (amps)

For the silicon carbide electrodes the exposed area was 60mm x 8mm and the gap was 1.4.

Therefore:

$$\underset{(\text{m/s})}{\text{Flow Velocity}} = \frac{0.28Q}{bt} = 0.025Q, \quad Q \text{ in } \ell/\text{hr}$$

$$\underset{(\text{A/m}^2)}{\text{Current Density}} = \frac{I \times 10^6}{b \times L} = 2083I, \quad I \text{ in Amps}$$

$$\underset{(\text{s})}{\text{Contact Time}} = \frac{b \times L \times t \times T_K}{V_B \times 10^6} = \frac{0.04\, T_K}{V_B} \quad \begin{array}{l} T_K \text{ in (min)} \\ V_B \text{ in } (\ell) \end{array}$$

## 3.7 The Bi-polar Rod Cell

The reasons for choosing the rod design for the larger scale cell have already been given in Section 2.4. A cell and rig were designed and manufactured to treat water at a rate of 50 $\ell$/hr. The cell consists of a perspex box in which the rod electrodes are stacked, as shown in Fig. 7. Water enters the cell at the bottom, passes between the electrodes, and then out through the top. The water is distributed on entry by a perforated graphite block which also acts as the anode. The stack of rods is held down by either a perforated stainless steel plate or a perforated graphite block which is conveniently made the cathode.

A number of such cells have been built to accommodate different rod sizes and shapes. The first cell was built for square sectioned rods 12.5 x 12.5mm or round sectioned rods 12.5mm dia., 60mm long. Graphite rods, with both round and square section, were separated by O-rings which fitted into grooves near the ends of each rod. The photograph in Fig. 8 shows the cell and a sample of the electrodes fitted.

The height of the rod stack can be altered to vary the contact time. As shown in Fig. 8, an extension was made so that there can be in excess of 12 rows of rods.

The following equations have been used to calculate the flow velocity, current density, and contact time.

**Flow Velocity, $V_F$** (m/s)

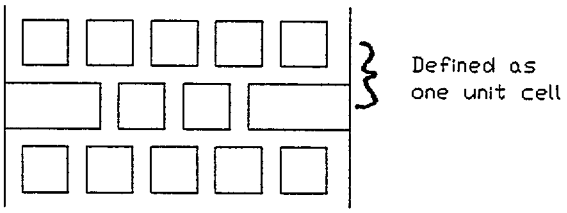
$$V_F = 0.28 \times \frac{Q}{6A_{xx}} \text{ (square sect.) or } 0.28 \times \frac{Q}{8A_{xx}} \text{ (round sect.)}$$

where Q = Flowrate (ℓ/hr)

$A_{xx}$ = L.t mm²

L = Rod Length (mm)

t = gap width (mm)



**Current Density, $D_I$**

$$D_I = \frac{I \times 10^6}{A_E \times N} \text{ A/m}^2$$

where I = Cell Current (Amps)

$A_E$ = Effective area of electrode (mm²)

= bL (square section)

= 0.1πDL (round section)

b = Rod width (mm)

D = Rod dia. (mm)

N = Number of rods per row (or unit cell)

**Contact Time, $T_c$**

a) <u>In batch mode</u>

$$T_c = 3.6 \times 10^{-3} \times \frac{V_E}{Q} \text{ sec}$$

where $V_E$ = Volume of water between effective area of electrodes at any one time.

= $A_{TE}$ x t (mm³)

and $A_{TE}$ = Total effective area

= $A_E$ x N x n (mm²)

n = Number of unit cells.

Q = Flow rate (ℓ/hr)

Therefore

$$T_c = 3.6 \times 10^{-3} \times \frac{bLNnt}{Q} \text{ sec (square rod)}$$

or

$$\frac{3.6 \times 10^{-4} \pi DLNnt}{Q} \text{ sec (round rod)}$$

b) In Recirculating Mode

$$T_c = 6 \times 10^{-5} \frac{V_E}{V_B} \times T_K \text{sec} \quad \text{where } V_B = \text{Batch Volume } (\ell)$$

$$T_K = \text{Running Time (min)}$$

$$= \frac{6 \times 10^{-5} b\ L\ Nnt\ T_K}{V_B} \text{ (square rod)}$$

$$= \frac{6 \times 10^{-6} \pi\ DLNn\ t\ T_K}{V_B} \text{ (round rod)}$$

The following are the parameters associated with the various cell assemblies tested.

a) **Graphite rods cell** (circular cross section) B(Cir)

$D = 12.5$mm

$L = 60$mm

$t = 1$mm

$N = 4$

$n = 8$

Flow Velocity = $5.8 \times 10^{-4}Q$ m/s

Current Density = $1060I$ A/m$^2$

Contact Time = $0.45\ T_K/V_B$ sec.

b) **Graphite rods cell** (square cross section)

$b = 12.5$mm

$L = 60$mm

$t = 1$mm

$N = 5$

$n = 4$ to $12$

Flow Velocity = $7.8 \times 10^{-4}Q$ m/s

Current Density = $267I$ A/m$^2$

Contact Time = $13.5\ n/Q$ sec.

c) **Ebonex rods cell** B(Squ)

$b = 12.5$mm

$L = 65$mm

$t = 1$mm

$N = 5$

$n = 6$

Flow Velocity = $7.2 \times 10^{-4}Q$ m/s

Current Density = $246I$ A/m$^2$

Contact Time = $14.6\ n/Q$ sec.

d) **Ebonex Rectangular rod cell** B(Rect)

$b = 12.5$mm

$L = 60$mm

$t = 1$mm

$N = 5$

$n = 6$

Flow Velocity = $7.8 \times 10^{-4}Q$ m/s

Current Density = $267I$ A/m$^2$

Contact Time = $81/Q$ sec.

e) **Tin Oxide rod cell** D(Rect)

$b = 17$mm  Flow Velocity $= 1.26 \times 10^{-3}Q$ m/s

$L = 37$mm  Current Density $= 397I$ A/m$^2$

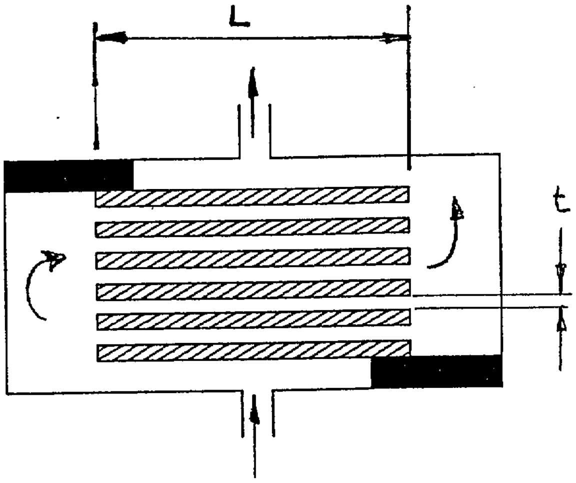
$t = 1$mm  Contact Time $= 63.4/Q$ sec.

$N = 4$

$n = 7$

## 3.8 Parallel Plate Cells

In order to test the performance of Ebonex and titanium plate electrodes they were arranged in the perspex box in such a way that the water passed between them in parallel paths, as shown below.



$b$ = plate width = 54mm

$L$ = plate length = 56mm

$t$ = gap = 1mm

$N_p$ = number of plates in parallel = 6

The plates are shown in the photograph, Fig. 9.

These cells were used in the batch mode and the calculations for flow velocity, current density, and contact time are as follows:

$$\underline{\text{Flow velocity}} = \frac{0.278Q}{(N_p-1)\ b\ t} = 1.03 \times 10^{-3}Q \text{ m/s, where } Q \text{ is in } \ell/\text{hr}.$$

$$\underline{\text{Current Density}} = \frac{I \times 10^6}{b \times L} = 330.6I \text{ A/m}^2\text{, where } I \text{ is in Amps}$$

$$\underline{\text{Contact Time}} = \frac{b \times L \times N_p \times t}{Q} = \frac{64.5}{Q} \text{ sec.}$$

### Ebonex Plate Tests

Two tests were carried out in the batch mode under the standard conditions and in both cases highly contaminated water was sterilised. The cell was connected to the mains water supply and left to run continuously, the water from the outlet running down to drain. After 4 days thick deposits covered the electrodes and the tests had to be aborted. New electrodes were fitted and the long term test continued with the polarity being reversed approx. 25 times per hour. This test ran for approx. 32 days., see photograph, Fig.9.

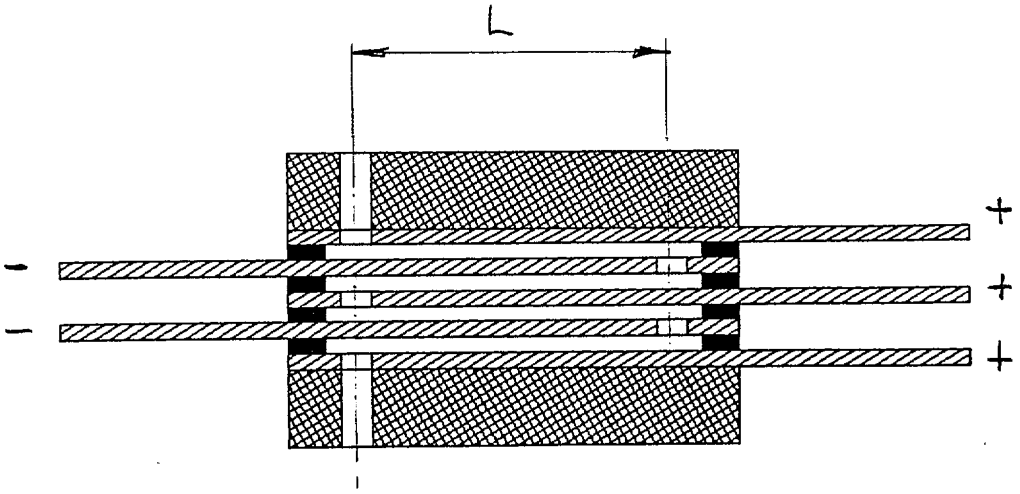
### Titanium Plate Cell

One test was carried out under the standard test conditions.

## 3.9 Series Plate Cell E(Plate)

This cell is similar to that described in Section 3.3 except that it provides a longer contact time by offering a longer flow path rather than by reducing flow rate and can therefore be used in the batch mode.

The electrodes are 5 tin oxide coated glass plates approx. 130mm x 20mm with a hole approx. 18mm from one end of each. These are stacked between two polypropylene blocks in such a way that water flows between each pair of electrodes, in series, serpentine fashion. The assembly is shown in the drawing below and the photograph Fig. 10. The cell is sealed with Neoprene gaskets. The exposed area of each electrode is approx. 104mm x 10mm and the gap is approx. 1.5mm. Because the electrodes are conducting on the surface only, electrical contact is made with each surface using crocodile clips as shown below.



$$\text{Flow Velocity(m/s)} = 0.28\ {}^{Q}/_{bt} = 0.0185Q\ ,\ Q \text{ in } \ell/\text{hr.}$$

$$\text{Current Density } (\text{A/m}^2) = \frac{I \times 10^6}{4 \times b \times L} = 240I,\ I \text{ in Amps}$$

$$\text{Contact Time (sec)} = \frac{b \times L \times t \times (N-1) \times 3.6 \times 10^{-3}}{Q} = \frac{22.5}{Q} \text{ sec,}$$

N is the number of plates.
L = active plate length (mm)
b = active plate width (mm)
t = gap (mm)

## 4. Results

Below is a summary of the results of the investigation. For details of all the tests carried out see Table I.

### 4.1 Chlorine Production

Initially the test programme was devoted to developing a method of producing chlorine from small concentrations of chlorides existing in natural waters by the method of electrolysis. The first electrolytic cell, designed on the basis of kinetic studies, produced no detectable chlorine. Experimentation with this cell was therefore suspended in favour of preparative bench scale studies of a diagnostic nature.

Initial tests were carried out with disc anode of 5mm dia. and 30mm dia. and the standard electrolyte solution described in Section 3.2. The results showed that at current densities below 80 A/m$^2$:

a) No significant chlorine was produced unless the anode was rotating.

b) No significant chlorine was produced when the anode was static and the electrolyte was stirred with a magnetic stirrer.

c) Chlorine was produced at a rate of approx. 1570 mg/m$^2$hr. with a rotating graphite anode and a graphite cathode in a cell divided by a Nafion membrane and a current density of 60 A/m$^2$.

d) Ebonex was found to be a more effective anode material than graphite. Chlorine was produced at a rate of approx. 3170 mg/m$^2$hr. with an Ebonex anode and a current density of 50 A/m$^2$ under conditions which were otherwise similar to (c).

e) No significant chlorine was produced in an undivided cell with a graphite or stainless steel cathode. With an Ebonex or Titanium cathode, however, the production rate was about a third of that experienced with a divided cell.

f) The chlorine production rate is little affected by chloride concentrations above 20 ppm.

g) The chlorine production rate increases with current density when the chloride concentration is greater than 20 ppm.

Further tests were carried out on a static anode using the divided plate cell described in Section 3.5. It was found that if the mass transfer coefficient was similar to that of the rotating disc, approx. $10^{-4}$ m/sec, then equivalent quantities of chlorine were produced. This was achieved by using a turbulence promoter and a fluid velocity of approx. 1m/s. These tests also demonstrated the characteristics described in (f) and (g) above.

Tests with the flow cell also showed that the take up of chlorine by any organic matter present in the electrolyte can exceed the rate of production of chlorine. Also, it was found that 1 ppm nitrogen present as ammonium ion in the anolyte halved the quantity of chlorine measured.

Later in the test programme and at higher current densities (over $100 A/m^2$) chlorine was produced with the Ebonex bipolar rod cell operating in the undivided mode. Chlorine concentrations of up to 5 ppm were measured with a water flow rate of 25 ℓ/hr. This represents a production rate of about 5000 $mg/m^2hr$.

## 4.2 Bacteriological Tests

The following is a summary of the results of a wide range of tests carried out to establish the performance of the electrolytic cell to destroy bacteria. In most cases simulated contaminated water was used as described in Section 3.3 and analysis was carried out by colony counts using the membrane filter technique. To obtain an indication of the bacteriological kill, a Kill Factor, KF, has been calculated where

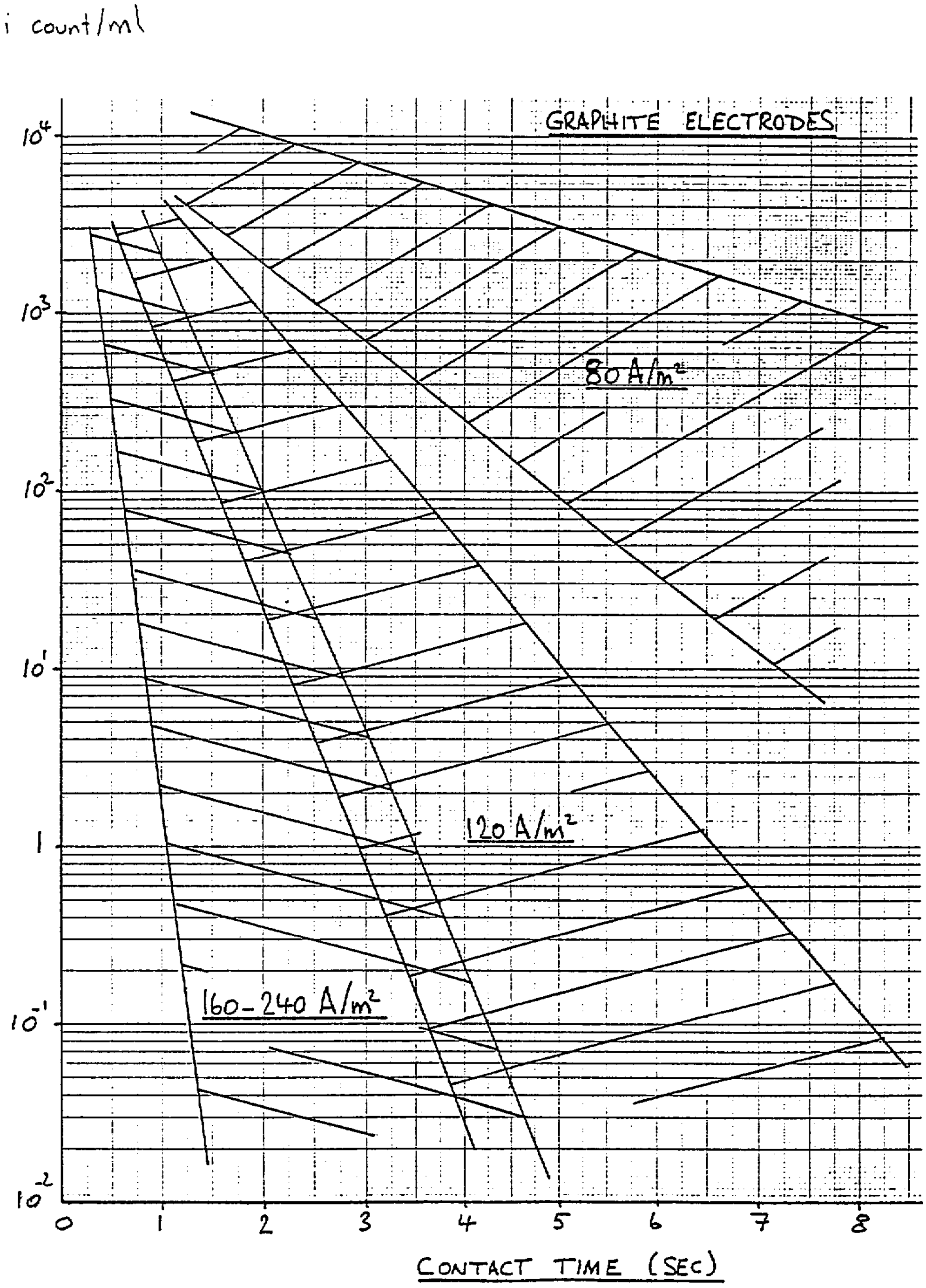
$$KF = \log \left(\frac{\text{Inlet count}}{\text{Outlet count}}\right)$$

### 4.2.1 Initial Tests with Plate Cell

Initial tests with the plate cell described in Section 3.5 showed that:

a) An electric current is necessary for there to be bacteriological kill.

b) In the absence of chlorides there can still be substantial kill, suggesting that the bacteria is killed not just by the chlorine, but by the electrolysis process itself, i.e. by direct anodic oxidation. Consequently, the need for separating anolyte and catholyte has


E. coli count/ml
GRAPHITE ELECTRODES
80 A/m²
120 A/m²
160-240 A/m²
10⁴
10³
10²
10¹
1
10⁻¹
10⁻²
0
1
2
3
4
5
6
7
8
CONTACT TIME (SEC)

been removed and most of the following work was carried out with an undivided cell.

c) Killing rate increases with current density and contact time.

d) Killing rate falls with the increase in the presence of organics.

e) Killing rate is unaffected by chloride concentration.

f) Ebonex is more effective than graphite as an anode material for the destruction of bacteria.

g) Killing rate is severely reduced during the time of instability immediately after the reversal of polarity.

### 4.2.2 Results with the Bipolar Rod Cell

Extensive testing has been carried out to investigate the effect of various parameters on the performance of the Bipolar Rod Cell to kill bacteria. The results show that, where analysis of bacteria is involved, there is a very high scatter, as much as three orders of magnitude for bacteria count. Consequently, a large number of results are required at each test condition to produce statistically sound results. It has been outside the scope of this project to carry out such a thorough investigation and so the conclusions drawn should be regarded as guidelines.

Below are summarised the main results:

a) **Current Density and Contact Time**

These are important factors which affect the cell performance as shown in the graph below.

This graph shows the effect of current density and contact time on the performance of the graphite square rod cell. It can be seen that to reduce the bacteriological count by six orders of magnitude, i.e. KF = 6 for instance, a contact time of at least 5 secs. at a current density of 160 A/m$^2$ is required.

With Ebonex square rods a kill factor of greater than 6 was achieved with a current density of 160 A/m$^2$ and a contact time of 3.6 sec. confirming previous conclusions that Ebonex is far superior to graphite as an anode electrode. This was also confirmed by a test with an Ebonex rectangular rod cell when a KF of > 7.2 was achieved with a current density of 121 A/m$^2$ and a contact time of 1.3 sec.

b) **Fluid Velocity**

Fluid velocities have been varied over the following range

| | |
|---|---|
| - Ebonex Cell Type A (Recir.) | 0.3 - 0.95 m/s |
| - Graphite Cell Type B (Recir.) | 0.016 - 0.093 m/s |
| - Graphite Cell Type B (Batch) | 0.011 - 0.077 m/s |

Earlier work showed that the mass transfer coefficient is an important factor in the production of chlorine from low concentrations of chlorides. It was thought, therefore, that fluid velocity, through its influence on mass transfer coefficient, would have an effect on the cell performance. However, no such effect has been detected within the range of velocities shown above. As discussed in the Field Trial Results the fluid velocity is nevertheless an important factor in keeping the electrode surfaces clean.

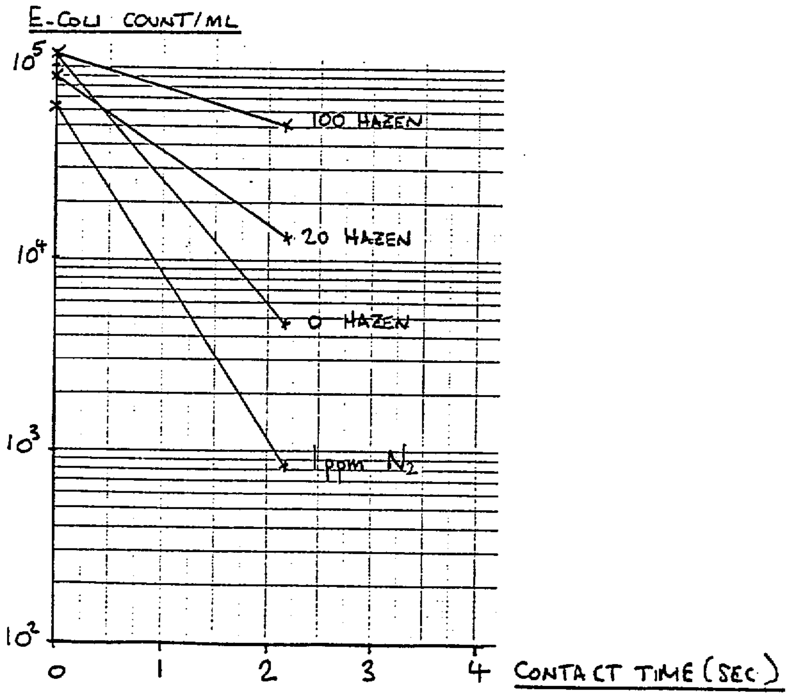
c) **Chloride Concentration**

The chloride concentration was varied between 0–40 ppm in earlier tests. Cell performance improves in terms of bacteria kill as chloride concentration rises to 10 ppm but with further increases remains unchanged. This behaviour is confirmed by later tests although the results are erratic when no chloride is present. Both high and low kill rates have been experienced in these cases, suggesting that by itself direct oxidation of the bacteria cells at the anode may not be a reliable mechanism for destroying the bacteria. For details of tests carried out in the absence of chlorides see Fig.11(a).

d) **Organic Material**

Organic material present in the electrolyte will be competing with the bacteria both for chlorine and in the direct oxidation process at the anode. For these reasons, therefore, it is expected that the effectiveness of the cell to kill bacteria will be impaired by the presence of organics.

This effect on the cell performance has been studied in the laboratory by adding humic and fulvic acid to the electrolyte, and the results confirm the above view, see graph below:



*See Table I for details of test conditions and results.
Graphite Electrodes
Current Density 120 A/$m^2$
Flow Rate 50 ℓ/hr.

An increase in contact time of at least 50% can be expected for water with 20° Hazen. The process may be impractical for water with 100° Hazen unless a highly efficient electrode material is found.

e) **Nitrogen**

The cell performance was not affected by the introduction of N in the form of Ammonium Sulphate at a concentration of 1 ppm, see graph above.

f) **pH**

As expected there was a drop in anolyte pH in the earlier tests when the cell was divided. Typically the pH dropped from approx. 6 to 4. Tests showed that a pH as low as 4 will contribute to the destruction of bacteria.

For the cell Type B, undivided cell, there was a smaller reduction in pH from approx. 6 to 5.

When reversing the polarity of the cell there is a period of instability immediately after the reversal during which the pH drops momentarily, ref 7. With the Ebonex square rod cell and a nominal current density of 170 A/m$^2$ and a contact time of 3.6 secs. the pH varied between 6.6 and 4 during each reversal cycle..

### g) Temperature

Most of the tests were carried out at room temperatures of 18–22°C. However, in the initial recirculating tests with cell Type A, a cooler was employed to ensure that the electrolyte temperature did not rise above 25°C, since separate tests had shown that temperatures around 34°C could increase the kill rate of bacteria.

### h) Other Bacteria

For the majority of bacteriological tests, suspensions of *E.coli* bacteria were introduced into the electrolyte. To investigate cell performance with other bacteria, a number of tests have been carried out with the introduction of faecal Streptococci and sewage.

Earlier laboratory tests with Ebonex cell Type A using sewage as source of bacteria, showed that the electrolytic cell was equally effective at destroying total coliforms as *E.coli*. This was confirmed with tests using the graphite cell Type B, and similar results were obtained when faecal Streptococci was introduced during laboratory tests with Ebonex cell Type B. For details of test conditions and results see Fig.11(b).

### j) Polarity Reversal

An investigation into the effect of polarity reversal on the cell performance showed that there is a period of instability immediately after the reversal during which time the cell current drops (with constant cell voltage) and there is a momentary drop in pH. It has also been shown that the efficiency of killing bacteria by means of the electrolytic process is adversely affected when the polarity of the electrodes is reversed. Typical results with the Ebonex square rod cell are shown in Fig.12. The duration of the instability and the precise characteristics of the instability seem to depend on the electrode material. With Ebonex electrodes the time of instability is approx. 2 mins. while with graphite electrodes it is about 6 secs. Although with the Ebonex and graphite the time is independent of the frequency of reversing this may not be so with other electrode materials, such as silicon carbide.

This period of instability is thought to be caused by redox effects occurring at the electrode/electrolyte interface but further work is necessary to establish this with certainty. The outcome is a reduction in the cell performance over the period of instability. In the case of Ebonex and graphite electrode cells operating with current reversal at 2 rev/hr. the period of time of instability is small in comparison with the time of steady state. On the other hand, the reduction in performance can be significant if the cell potential is reversing at 2 rev/min. With a frequency of 1 rev/sec. there is no significant bacteria kill. see Fig.13 for details of test conditions and results.

### k) Field Trials

A field trial was carried out with an Ebonex bipolar square rod cell using raw water, taken mainly from the river Tyne. A special test rig, see Fig.14, was built and installed at Horsley water treatment plant for the purpose. During the time of the trial the water had a very high organic content because of unusually heavy rainfall and consequently the colour and turbidity were very high. For the test conditions and results see Table I, tests 220688 to 150988.

Initially the cell performed well with a logarithmic reduction in bacteria of at least 3.7, but after 24 hrs. running no significant kill was detected. This deterioration was thought to be caused by a build-up of organic material on the surface and in the pores of the Ebonex by a filtering action, the type of Ebonex available being of a very permeable nature.

When the electrodes were cleaned and tested in the laboratory with the standard electolyte solution the initial cell performance was regained. Furthermore, after the cell had run continuously for 6 days in the laboratory under these conditions the cell still gave a good performance. See Fig.11(c) for details of test conditions and results.

## 4.3 Results of Material Investigation

The conclusion drawn from the field trials discussed above is that Ebonex electrodes become coated if there is undissolved material in the water, possibly by a filtering mechanism linked to its permeability. An investigation was carried out to find alternative electrode materials which have similar electrode properties to Ebonex (i.e. anodically stable, have a high oxygen over potential, and advantageously generate chlorine), but which are non-porous.

Further incentive for finding an alternative also arises from the reluctance of the manufacturer to give whole-hearted support to independent research into the use of Ebonex in the field of water treatment.

On the basis of the above criteria the following groups of materials were identified as possible candidates:

(a) Metals
(b) Carbon
(c) Oxides
(d) Carbides
(e) Nitrides
(f) Borides
(g) Silicides

Manufacturers were contacted to obtain samples which could be submitted to laboratory tests. These tests firstly involved an investigation of polarisation characteristics and if still promising were then employed in an existing electrolytic cell to test their effect in sterilising contaminated water. This latter stage was not always possible to undertake in the period of contract because they were not readily available in suitable form. The test conditions and results of tests carried out are shown in Fig. 15. The following conclusions can be drawn from the work done so far.

a) Most metals are unstable as an anode. Those which are relatively stable, such as lead, may release ions at concentrations that would be unacceptable in potable water.

b) Nitrides have proved to be anodically unstable.

c) Oxides are mainly electrically non-conducting. Some suboxides are conducting but vary in their stability. Tin oxide, for example, is unstable, whereas Ebonex, a suboxide of titanium, is very stable.

d) Of the carbides tested $\beta$-silicon carbide and boron carbide appear to be the most promising. Both have relatively high oxygen over potentials and over the short term were anodically stable, although the silicon carbide showed some crumbling of the surface which may, however, have been due to existing cracks. These materials are recommended for further consideration. Silicon carbide of the $\alpha$-type is non-electrically conducting, and some silicon carbide based materials developed for special purposes have additives which render them non-conducting.

e) A carbon-carbon material was tested. This is a carbon/resin composite with a high fibre reinforcing content. The anodic potential is similar to that of Ebonex and it is capable of chlorine production. Some etching of the surface was observed after 2 hrs. at 50 $A/m^2$, however, and the material was returned to the manufacturers for their comments. The manufacturers have since supplied a modified material which they think will be more suitable.

## 5. Conclusions

It has been shown conclusively that contaminated water can be sterilised by electrolysis without any additives. The exact mechanism by which bacteria is killed is not known but the laboratory test results indicate that bacteria are killed by a combination of direct oxidation at the anode surface and by chlorine generated from the natural chlorides existing in the water.

Most of the work has been carried out using graphite and Ebonex electrodes. Ebonex especially has proved to be very effective under laboratory conditions using artificially infected distilled and tapwater. However, this high performance rapidly deteriorated during field trials when subject to continuous operation with raw water. It is thought that due to its permeability undissolved solids lodged in the pores of the Ebonex thereby coating the surface. It should be noted, however, that due to unusually heavy storms the water carried an exceptionally high solids burden. Despite these unusual circumstances it would nevertheless be advantageous to find a non-porous material. With this in mind possible materials were surveyed and likely candidates submitted to simple laboratory polarisation investigations. Of these the most promising were $\beta$ silicon carbide, boron carbide and carbon fibre.

It is clear that until a suitable electrode material is found the method of sterilising raw water by electrolysis without additives is not practical.

The following are more specific conclusions that can be drawn from the extensive test programme undertaken.

### 5.1 Chlorine Generation at low chloride levels

a) A rotating electrode in a divided cell is required to generate chlorine at current densities less than 80 A/m$^2$.

b) The mass transfer coefficient is an important factor in the production of chlorine.

c) An Ebonex anode yields more chlorine than a graphite anode. Approx. 3170 mg/m$^2$hr. chlorine can be produced with an Ebonex rotating anode in a divided cell with a current density of 50 A/m$^2$ using the standard electrolyte solution of distilled water with NaC$\ell$ and $Na_2SO_4 10.H_2O$ added to give a chloride concentration of 20 ppm.

d) In an undivided cell with Ebonex anode and current density of 50 A/m$^2$ no significant chlorine was produced with a graphite or stainless steel cathode. With Titanium and Ebonex cathode, however, a low quantity of chlorine was produced.

e) Chlorine production rate was little affected by chloride concentration above 20 ppm.

f) Chlorine production rate increases with current density and contact time when chloride concentrations are greater than 20 ppm.

g) Organic matter can take up chlorine at a higher rate than that at which it can be produced.

h) 1 ppm Nitrogen content in the form of ammonium ion can halve the chlorine available.

j) A chlorine production rate of as much as 5000 $mg/m^2hr$. was achieved with an Ebonex bipolar cell (undivided) at a current density of over 100 $A/m^2$ and with the standard electrolyte solution.

## 5.2 Water Disinfection

a) Tests have shown that *E.coli.,* total Coliforms, and faecal Streptococci can be destroyed by the electrolytic process whether or not chlorides are present, although a more reliable result is achieved if chlorides are present. Most of the conclusions are based on tests with E.coli.

b) The ability to kill bacteria increases with current density and contact time but decreases when organics are present.

c) Using an Ebonex bipolar square rod cell operating at 160 $A/m^2$ and a contact time of 3.6 secs. a log reduction on bacteria count of around 6 can be expected with the standard electrolyte solution. To achieve the same result with an electrolyte containing organic material with a colour of $20^o$ Hazen the contact time would need to be 50% longer.

d) Cell performance was apparently not affected by the introduction of 1 ppm nitrogen. as ammonium ion.

e) The rate of kill was not improved by chloride concentration higher than 10 ppm.

f) Sterilisation was more effective with Ebonex as an anode than graphite.

g) Current reversal is necessary to prevent deposits of calcium and magnesium oxides at the cathode.

h) There is a drop in cell performance during a period of instability immediately after current reversal. For Ebonex and Graphite this period of instability is less than 2 mins. This is insignificant if the frequency of reversing is low, i.e. less then 2 rev. per hour, but will seriously affect the overall performance of the cell if the frequency is higher than 2 rev/min.

j) A field trial showed that an Ebonex bipolar cell will not operate successfully for more than a day with water which has high turbidity and colour. Ebonex is a porous material and it is thought that suspended matter gets caught up in the pores and coats the surface. A non-porous material similar to Ebonex may avoid this problem.

k) It is thought that particles in the electrolyte can cause carry-through or shielding of bacteria, thus reducing the effectiveness of the cell.

l) It has been shown that the Ebonex Bipolar Cell still operates satisfactorily after six days of continuous running in the laboratory using the standard electrolyte solution.

m) Cell performance was apparently unaffected by water flow rate over the range of 0.01 - 0.95 m/s.

### 5.3 Alternative Anode Materials

a) Most metals are anodically unstable.

b) Tests indicate that nitrides are also anodically unstable.

c) Most oxides are electrically non-conducting.

d) There are some sub-oxides which are electrically conducting. Some are apparently stable such as that of Ebonex. Others are anodically unstable such as that of Tin. No stable non-porous sub-oxide material was found.

e) Both $\beta$ silicon carbide and boron carbide gave a high oxygen overpotential and merit further investigation.

f) Hard Carbon and Carbon Fibre have low porosity and should be tested when material becomes available.

********

## ACKNOWLEDGEMENTS

Thanks are due to:

1) Ebonex Technologies for supplying Ebonex material for test.
2) Dynamic Ceramics for supplying Zirconia plates.
3) Tyne Tees Trans Tech. Ltd., Cleveland, for supplying glass coated with tin oxide and for coating Zirconia plates with tin oxide.
4) Tenmat, Manchester, for supplying Silicon Carbide pieces – both sintered and free Silicon.
5) Carborundum Co. for supplying Silicon Carbide pieces.
6) Kanthal, Inveralmond, for supplying $\alpha$ and $\beta$ silicon carbide pieces.
7) RTZ Chemicals (Borides) Ltd. for supplying boron carbide samples.
8) ASET, Newcastle upon Tyne, for providing hafnium nitride zirconium nitride and suboxide of titanium as coatings.
9) Borax Ltd., for supplying titanium dioxide samples.
10) Conradty, Germany for supplying tin oxide.
11) New Metals and Chemicals Ltd. for supplying some carbon-carbon material.
12) Newcastle and Gateshead Water Company, for allowing us to set up an experimental rig at their water treatment plant at Horsley, for providing some water analysis data, and also for supplying raw water.
13) Mr. Hunter of Mosswood Treatment Works, Consett, Co. Durham, for supplying a humic and fulvic acid solution.

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| TEST NO. | CELL[1] TYPE | ELECTRODE MATERIAL[2] AN./CATH. | TEST[3] MODE | CURRENT DENSITY A/M$^2$ | CONTACT TIME SEC. | FLUID VEL. M/S | CELL CURRENT mA | CELL GAP VOLTAGE V | TOTAL CELL VOLTAGE V | FLOW RATE L/HR | ELECTROLYTE[4] SEE * BELOW | pH | | TEMP $^O$C | FREE Cl$_2$ ppm | TOTAL Cl$_2$ ppm | BACTERIOLOGICAL COUNT COUNT/100ML | | | POLARITY REVERSING | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | IN | OUT | | | | INLET | OUTLET | LOG(INLET/OUTLET) | | |
| 170186 | A(PDMT) | EBON/ST.ST | RECIRC | 50 | 3.7 | 1.0 | 29.2 | 9.7 | 9.7 | 48 | 40ppmCl$^-$ | - | - | - | 1.68 | - | - | - | - | NO | CUM.Cl$_2$AFTER 105MIN |
| 170186 | A(PDMT) | EBON/ST.ST | RECIRC | 50 | 2.2 | 2.0 | 29.2 | 9.7 | 9.7 | 96 | 40ppmCl$^-$ | - | - | - | 0.75 | - | - | - | - | NO | CUM.Cl$_2$AFTER 61MIN |
| 170186 | A(PDMT) | EBON/ST.ST | RECIRC | 50 | 2.1 | 0.42 | 29.2 | 9.7 | 9.7 | 20 | 40ppmCl$^-$ | - | - | - | 0.87 | - | - | - | - | NO | CUM.Cl$_2$AFTER 60MIN |
| 200186 | A(PDMT) | EBON/ST.ST | RECIRC | 50 | 2.3 | 1.0 | 29.2 | 18.77 | 18.77 | 48 | STAND.SOL. | - | - | - | 0.93 | - | - | - | - | NO | CUM.Cl$_2$AFTER 64MIN |
| 200186 | A(PDMT) | EBON/ST.ST | RECIRC | 50 | 2.2 | 1.0 | 29.2 | 25.2 | 25.2 | 48 | 10ppmCl$^-$ | - | - | - | 0.99 | - | - | - | - | NO | CUM.Cl$_2$AFTER 62MIN |
| 200186 | A(PDMT) | EBON/ST.ST | RECIRC | 50 | 2.2 | 1.0 | 29.2 | 22.8 | 22.8 | 48 | 5ppmCl$^-$ | - | - | - | 0.3 | - | - | - | - | NO | CUM.Cl$_2$AFTER 62MIN |
| 200186 | A(PDMT) | EBON/ST.ST | RECIRC | 82.3 | 3.8 | 1.0 | 48.6 | - | - | 48 | STAND.SOL. | - | - | - | 1.05 | - | - | - | - | NO | CUM.Cl$_2$AFTER 108MIN |
| 200186 | A(PDMT) | EBON/ST.ST | RECIRC | 20 | 1.2 | 1.0 | 11.8 | - | - | 48 | STAND.SOL. | - | - | - | 0.13 | - | - | - | - | NO | CUM.Cl$_2$AFTER 35MIN |
| 200186 | A(PDMT) | EBON/ST.ST | RECIRC | 50 | 1.2 | 1.0 | 29.2 | - | - | 48 | STAND.SOL. | - | - | - | - | - | - | - | - | NO | - |
| 210186 | A(PDMT) | EBON/ST.ST | RECIRC | 20 | 2.1 | 1.0 | 11.8 | - | - | 48 | STAND.SOL. | - | - | - | 0.11 | - | - | - | - | NO | CUM.Cl$_2$AFTER 59MIN |
| 210186 | A(PDMT) | EBON/ST.ST | RECIRC | 40 | 4.1 | 1.0 | 23.6 | - | - | 48 | STAND.SOL. | - | - | - | 0.87 | - | - | - | - | NO | CUM.Cl$_2$AFTER 117MIN |
| 210186 | A(PDMT) | EBON/ST.ST | RECIRC | 50 | 1.6 | 1.0 | 29.5 | - | - | 48 | STAND.SOL. | - | - | - | 1.34 | - | - | - | - | NO | CUM.Cl$_2$AFTER 45MIN |
| 210186 | A(PDMT) | EBON/ST.ST | RECIRC | 20 | 2.1 | 1.0 | 11.8 | - | - | 48 | STAND.SOL. | - | - | - | 0.17 | - | - | - | - | NO | CUM.Cl$_2$AFTER 60MIN |
| 210186 | A(PDMT) | EBON/ST.ST | RECIRC | 40 | 3.8 | 1.0 | 23.6 | - | - | 48 | STAND.SOL. | - | - | | 0.74 | - | - | - | - | NO | CUM.Cl$_2$AFTER 108MIN |
| 210186 | A(PDMT) | EBON/ST.ST | RECIRC | 50 | 5.5 | 1.0 | 29.5 | - | - | 48 | STAND.SOL. | - | - | - | 1.73 | - | - | - | - | NO | CUM.Cl$_2$AFTER 154MIN |
| 210186 | A(PDMT) | EBON/ST.ST | RECIRC | 50 | 6.2 | 0.42 | 29.5 | - | - | 20 | 40ppmCl$^-$ | - | - | - | 2.27 | - | - | - | - | NO | CUM.Cl$_2$AFTER 175MIN |
| 210186 | A(PDMT) | EBON/ST.ST | RECIRC | 50 | 7.2 | 2.0 | 29.5 | - | - | 96 | STAND.SOL. | - | - | 32 | 2.8 | - | - | - | - | NO | CUM.Cl$_2$AFTER 204MIN |
| 080486 | A(PDMT) | EBON/ST.ST | RECIRC | 45 | 2.7 | 0.95 | 27 | - | - | 48 | STAND.SOL. | - | - | 26.5 | 0.63 | - | - | - | - | NO | CUM.Cl$_2$AFTER 75MIN |
| 080486 | A(PDMT) | EBON/ST.ST | RECIRC | 45 | 2.7 | 0.95 | 27 | - | - | 48 | 10ppmCl$^-$ | - | - | 25.0 | 0.70 | - | - | - | - | NO | CUM.Cl$_2$AFTER 75MIN |
| 080486 | A(PDMT) | EBON/ST.ST | RECIRC | 45 | 2.7 | 0.95 | 27 | - | - | 48 | 30ppmCl$^-$ | - | - | 24.0 | 1.10 | - | - | - | - | NO | CUM.Cl$_2$AFTER 75MIN |
| 090486 | A(PDMT) | EBON/ST.ST | RECIRC | 45 | 6.4 | 0.95 | 27 | 7.9 | 7.9 | 48 | STAND.SOL. | 4.7 | 3.5 | 24.0 | 0.01 | - | - | - | - | NO | CUM.Cl$_2$AFTER 240MIN |
| 100486 | A(PDMT) | EBON/ST.ST | RECIRC | 45 | 8.0 | 0.95 | 27 | 9.96 | 9.96 | 48 | 10ppmCl$^-$ | 5.1 | 3.5 | 23.0 | 0.01 | - | - | - | - | NO | CUM.Cl$_2$AFTER 300MIN |
| 110486 | A(PDMT) | EBON/ST.ST | .RECIRC | 45 | 10.4 | 0.95 | 27 | 9.5 | 9.5 | 48 | 30ppmCl$^-$ | 6.4 | 3.8 | 24.0 | 1.09 | - | - | - | - | NO | CUM.Cl$_2$AFTER 390MIN |
| 170486 | A(PDMT) | EBON/ST.ST | RECIRC | 45 | 0.76 | 0.95 | 27 | 9.7 | 9.7 | 48 | 30ppmCl$^-$ | 6.7 | 3.6 | 25.0 | 3.14 | - | 2.5E4 | <5 | >3.69 | NO | CUM.Cl$_2$AFTER 240MIN |
| 230486 | A(PDMT) | EBON/ST.ST | RECIRC | 45 | 0.38 | 0.93 | 27 | 9.5 | 9.5 | 48 | STAND.SOL. | 6 | 3.7 | 25.0 | 0.85 | - | 1.6E4 | <5 | >3.5 | NO | CUM.Cl$_2$AFTER 60MIN |
| 230486 | A(PDMT) | EBON/ST.ST | RECIRC | 45 | 0.76 | 0.93 | 27 | 12.15 | 12.15 | 48 | 10ppmCl- | 5.7 | 3.7 | 25.0 | 0.69 | - | 5.8E3 | <5 | >3.1 | NO | CUM.Cl$_2$AFTER 60MIN |
| 280486 | A(PDMT) | EBON/ST.ST | RECIRC | 45 | 4.0 | 0.95 | 27 | 9.78 | 9.78 | 40 | STAND.SOL. | 6.7 | 3.5 | 25.0 | 0.05 | - | 7.5E5 | <5 | >5.2 | NO | CUM.Cl$_2$AFTER 60MIN |
| 280486 | A(PDMT) | EBON/ST.ST | RECIRC | 45 | 3.8 | 0.79 | 27 | 10.26 | 10.26 | 40 | STAND.SOL. | 6.5 | - | 24.0 | 0.09 | - | - | - | - | NO | CUM.Cl$_2$AFTER 145MIN |
| 290486 | A(PDMT) | EBON/ST.ST | RECIRC | 45 | 0.33 | 0.73 | 27 | 8.7 | 8.7 | 37 | CRAM.SEWAGE | 6 | 3.7 | 27.0 | 0.50 | - | 7.2E3 | <5 | >3.2 E-C | NO | CUM.Cl$_2$AFTER 45MIN |
| 290486 | A(PDMT) | EBON/ST.ST | RECIRC | 45 | 1.49 | 0.73 | 27 | 8.7 | 8.7 | 37 | CRAM.SEWAGE | 6 | 3.7 | 27.0 | 0.50 | - | 1.4E6 | 2.5 | 5.7 TOT-C | NO | CUM.Cl$_2$AFTER 45MIN |
| 140586 | A(PDMT) | EBON/ST.ST | RECIRC | 45 | 0.38 | 0.63 | 27 | 9.6 | 9.6 | 32 | 1ppm N$_2$ | 5.7 | 4.0 | 27.0 | 0.77 | - | 1.5E5 | 1E2 | 3.2 | NO | CUM.Cl$_2$AFTER 330MIN |
| 150586 | A(PDMT) | EBON/ST.ST | RECIRC | 50 | 9.2 | 0.67 | 27 | 10 | 10 | 34 | HUMIC 20H$^O$ | 6 | 4.3 | 25.0 | 0.04 | 0.04 | - | - | - | NO | CUM.Cl$_2$AFTER 105MIN |
| 160586 | A(PDMT) | EBON/ST.ST | RECIRC | 45 | 0.38 | 0.69 | 27 | 10 | 10 | 35 | HUMIC 20H$^O$ | 5.7 | 5.7 | 25.0 | 0.07 | 0.24 | 1.8E5 | <10 | >4.2 | NO | CUM.Cl$_2$AFTER 360MIN |
| 210586 | A(PDMT) | EBON/ST.ST | RECIRC | 0 | 2.0 | 0.63 | 0 | 0 | 0 | 32 | STAND.SOL. | 6 | | 28.0 | 0.0 | - | 8.6E5 | 1.1E5 | 0.9 | NO | NO ELECTRIC CURRENT |
| 210586 | A(PDMT) | EBON/ST.ST | RECIRC | 45 | 0.5 | 0.63 | 27 | 12 | 12 | 32 | NO Cl$^-$ | 6.0 | 3.6 | 28.0 | 0.0 | - | 1.6E6 | 3.3E3 | 2.7 | NO | NO Cl$^-$ |
| 220586 | A(P) | EBON/ST.ST | RECIRC | 45 | 1.0 | 0.93 | 27 | 8.5 | 8.5 | 48 | STAND.SOL. | 6 | 7.6 | 28.0 | 0.0 | 0.89 | 2.2E6 | 8.2E3 | 3.4 | NO | NO MEMBRANE |
| 270586 | A(P) | EBON/ST.ST | RECIRC | 45 | 0.5 | 0.95 | 27 | 6 | 6 | 48 | 40ppmCl$^-$ | 5.9 | 6.7 | 27.0 | 0.0 | 0.27 | 1.0E4 | <10 | >3.0 | NO | NO MEMBRANE |
| 100686 | A(P) | EBON/ST.ST | RECIRC | 45 | 0.13 | 0.95 | 27 | 10 | 10 | 48 | 10ppmCl$^-$ | 6 | 6.7 | 28.0 | 0.0 | 0.00 | 1.1E6 | 2.0E3 | 2.7 | NO | NO MEMBRANE |
| 100686 | A(P) | EBON/ST.ST | RECIRC | 45 | 0.5 | 0.95 | 27 | 7 | 7 | 48 | 30ppmCl$^-$ | 6 | 6.8 | 28.0 | 0.0 | 0.14 | 6.5E5 | 3.9E2 | 3.2 | NO | NO MEMBRANE |
| 110686 | A(P) | EBON/ST.ST | RECIRC | 20 | 4.0 | 0.95 | 12 | 5 | 5 | 48 | STAND.SOL. | 6 | 6.6 | 28.0 | - | - | 2.3E6 | <10 | >5.4 | NO | NO MEMBRANE |
| 110686 | A(P) | EBON/ST.ST | RECIRC | 45 | 2.0 | 0.30 | 27 | 8 | 8 | 15 | STAND.SOL. | 6 | 7 | 28.0 | - | - | 3.6E6 | <10 | >5.6 | NO | NO MEMBRANE |
| 120686 | A(P) | EBON/ST.ST | RECIRC | 45 | 4.0 | 0.95 | 27 | 8 | 8 | 48 | HUMIC 100H$^O$ | 6 | - | 26.0 | 0.2 | 0.26 | 2.7E6 | 1.4E5 | 1.3 | NO | NO MEMBRANE |
| 160686 | A(P) | EBON/ST.ST | RECIRC | 45 | <10 | 0.95 | 27 | 8 | 8 | 48 | HUMIC 20H$^O$ | 6 | - | 26.0 | - | - | 3.2E4 | - | - | NO | NO MEMBRANE |
| 111186 | A(P) | EBON/ST.ST | RECIRC | 45 | 1.6 | 0.93 | 27 | 10.9 | 10.9 | 48 | STAND.SOL. | 5.9 | 6.0 | 25.4 | 0.0 | 0.7 | 1.6E5 | <10 | >4.2 | NO | NO MEMBRANE |
| 111186 | A(P) | GRAP/ST.ST | RECIRC | 45 | 1.6 | 0.93 | 27 | 10.9 | 10.9 | 48 | STAND.SOL. | 5.9 | 6.0 | 24.0 | 0.0 | 0.0 | 3.2E6 | 6.0E2 | 3.7 | NO | NO MEMBRANE |
| 081286 | B(Cir) | GRAPHITE | RECIRC | 24 | 27.0 | .093 | 22.3 | 2.8 | 25.0 | 160 | STAND.SOL. | 6.0 | 5.9 | 26.0 | 0.0 | 0.0 | 8.9E5 | 6.0E1 | 4.2 | NO | |
| 101286 | B(Cir) | GRAPHITE | RECIRC | 42/37 | 10.2 | .093 | 39/35 | 6.0 | 24.0 | 160 | STAND.SOL. | 6.2 | 5.9 | 24.0 | 0.0 | 0.0 | 1.3E6 | <10 | >5.1 | NO | |
| 270187 | B(Cir) | GRAPHITE | RECIRC | 42/37 | 5.1 | .093 | 39/35 | 6.0 | 24.0 | 160 | STAND.SOL. | 4.8 | 5.7 | 24.0 | 0.0 | 0.0 | 3.3E6 | 3.3E3 | 3.0 | NO | |
| 290187 | B(Cir) | GRAPHITE | RECIRC | 42/37 | 2.6 | .093 | 39/35 | 6.0 | 24.0 | 160 | STAND.SOL. | 5.5 | 4.5 | 23.0 | 0.0 | 0.0 | 1.2E5 | 8.0E2 | 2.2 | NO | |
| 030287 | B(Squ) | GRAPHITE | RECIRC | 21 | 27.0 | .062 | 81 | 9.0 | 18.0 | 80 | STAND.SOL. | 5.8 | 5.3 | 23.0 | 0.0 | 0.0 | 1.0E4 | 3.0E1 | 2.5 | NO | |
| 050287 | B(Squ) | GRAPHITE | RECIRC | 45 | 2.3 | .062 | 169 | 9.5 | 19.0 | 80 | STAND.SOL. | 4.9 | 4.1 | 23.0 | 0.0 | 0.0 | 1.3E6 | 6.4E3 | 2.3 | NO | |
| 090287 | B(Squ) | GRAPHITE | RECIRC | 45 | 6.8 | .016 | 169 | 10.0 | 20.0 | 20 | STAND.SOL. | 5.2 | 5.2 | 23.0 | 0.0 | 0.2 | 2.3E4 | 7.0E1 | 2.5 | NO | |
| 090287 | B(Squ) | GRAPHITE | RECIRC | 45 | 2.3 | .038 | 169 | 5.0 | 20.0 | 50 | STAND.SOL. | 5.3 | 4.8 | 23.0 | 0.64 | 0.0 | 4.5E4 | 6.0E1 | 2.9 | NO | |
| 120287 | B(Squ) | GRAPHITE | RECIRC | 45 | 14.0 | .038 | 168 | 5.0 | 20.0 | 50 | HUMIC 20H$^O$ | 5.5 | 5.4 | 24.0 | 0.0 | 0.1 | 5.5E6 | 4.0E1 | 5.1 | NO | |
| 120287 | B(Squ) | GRAPHITE | RECIRC | 45 | 27.0 | .038 | 168 | 5.3 | 21.0 | 50 | HUMIC 100H$^O$ | 5.6 | 5.4 | 23.0 | 0.14 | 0.14 | 8.4E6 | 4.2E3 | 3.3 | NO | |

1)SEE SECTION 3 2)SEE SECTION 3 3)SEE SECTION 3.1 4)SEE SECTION 3.2

*IN MOST CASES 2L OF ELECTROLYTE WERE CIRCULATED IN THE RECIRCULATING MODE

## TABLE 1 : TEST CONDITIONS AND RESULTS

SHEET 1

| TEST NO. | CELL[1] TYPE | ELECTRODE MATERIAL[2] AN./CATH. | TEST[3] MODE | CURRENT DENSITY A/M$^2$ | CONTACT TIME SEC. | FLUID VEL. M/S | CELL CURRENT mA | CELL GAP VOLTAGE V | TOTAL CELL VOLTAGE V | FLOW RATE L/HR | ELECTROLYTE[4] | pH | | TEMP $^0$C | FREE $Cl_2$ ppm | TOTAL $Cl_2$ ppm | BACTERIOLOGICAL COUNT COUNT/100ML | | | POLARITY REVERSING | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | IN | OUT | | | | INLET | OUTLET | LOG($\frac{\text{INLET}}{\text{OUTLET}}$) | | |
| 180387 | B(Squ) | GRAPHITE | BATCH | 20.1 | 1.08 | .0386 | 75.4 | 4.1 | 16.5 | 50 | STAND.SOL. | 5.4 | - | 18.5 | 0.0 | 0.0 | 4.7E3 | 1.1E3 | 0.64 | NO | OTHER BACT. PRESENT |
| 180387 | B(Squ) | GRAPHITE | BATCH | 45 | 1.08 | .0386 | 169 | 5.75 | 23.0 | 50 | STAND.SOL. | 5.5 | 5.3 | 18.5 | 0.0 | 0.0 | 4.7E3 | 8.0E2 | 0.77 | NO | OTHER BACT. PRESENT |
| 200387 | B(Squ) | GRAPHITE | BATCH | 20.1 | 1.08 | .0386 | 75.4 | 4.125 | 16.5 | 50 | STAND.SOL. | 5.9 | - | 21.5 | 0.0 | 0.0 | 4.8E5 | 3.1E5 | 0.20 | NO | |
| 200387 | B(Squ) | GRAPHITE | BATCH | 45 | 1.08 | .0386 | 169 | 5.5 | 22.0 | 50 | STAND.SOL. | 5.8 | 5.9 | 21.5 | 0.0 | 0.0 | 4.8E5 | 1.6E5 | 0.50 | NO | |
| 240387 | B(Squ) | GRAPHITE | BATCH | 45 | 2.16 | .0386 | 169 | 5.63 | 45.0 | 50 | STAND.SOL. | 5.4 | 5.2 | 21.0 | 0.0 | 0.0 | 2.5E5 | 9.0E4 | 0.40 | NO | |
| 240387 | B(Squ) | GRAPHITE | BATCH | 80 | 2.16 | .0386 | 300 | 7.38 | 59.0 | 50 | STAND.SOL. | 5.4 | 5.2 | 21.0 | 0.0 | 0.0 | 2.5E5 | 6.0E4 | 0.60 | NO | |
| 240387 | B(Squ) | GRAPHITE | BATCH | 100 | 2.16 | .0386 | 375 | 8.38 | 67.0 | 50 | STAND.SOL. | 5.4 | 5.2 | 21.0 | 0.0 | 0.0 | 2.5E5 | 5.8E3 | 1.6 | NO | |
| 010487 | B(Squ) | GRAPHITE | BATCH | 100 | 2.16 | .0386 | 375 | 8.125 | 65.0 | 50 | STAND.SOL. | 5.6 | 5.0 | 20.5 | 0.07 | 0.18 | 2.4E5 | 3.7E2 | 2.8 | NO | |
| 010487 | B(Squ) | GRAPHITE | BATCH | 60 | 2.16 | .0386 | 225 | 6.25 | 50.0 | 50 | STAND.SOL. | 5.6 | 5.0 | 20.5 | 0.07 | 0.18 | 2.4E5 | 2.3E4 | 1.02 | NO | |
| 010487 | B(Squ) | GRAPHITE | BATCH | 240 | 2.16 | .0386 | 900 | 14.25 | 114.0 | 50 | STAND.SOL. | 5.6 | 5.0 | 20.5 | 0.07 | 0.18 | 2.4E5 | <10 | 4.4 | NO | |
| 010487 | B(Squ) | GRAPHITE | BATCH | 187 | 2.16 | .0386 | 700 | 12 | 96.0 | 50 | STAND.SOL. | 5.6 | 5.0 | 20.5 | 0.07 | 0.18 | 2.4E5 | 1.0E1 | 4.4 | NO | |
| 010487 | B(Squ) | GRAPHITE | BATCH | 133 | 2.16 | .0386 | 500 | 9.5 | 76.0 | 50 | STAND.SOL. | 5.6 | 5.0 | 20.5 | 0.07 | 0.18 | 2.4E5 | 3.2E2 | 2.9 | NO | |
| 010487 | B(Squ) | GRAPHITE | BATCH | 80 | 2.16 | .0386 | 300 | 7.125 | 57.0 | 50 | STAND.SOL. | 5.6 | 5.0 | 20.5 | 0.07 | 0.18 | 2.4E5 | 1.0E5 | 0.4 | NO | |
| 010487 | B(Squ) | GRAPHITE | BATCH | 60 | 4.32 | .0193 | 225 | 6.0 | 48.0 | 25 | STAND.SOL. | 5.6 | 5.0 | 20.5 | 0.07 | 0.18 | 2.4E5 | 1.0E4 | 1.4 | NO | |
| 010487 | B(Squ) | GRAPHITE | BATCH | 80 | 4.32 | .0193 | 300 | 7.0 | 56.0 | 25 | STAND.SOL. | 5.6 | 5.0 | 22.0 | 0.07 | 0.18 | 2.4E5 | 6.3E3 | 1.6 | NO | |
| 010487 | B(Squ) | GRAPHITE | BATCH | 133 | 4.32 | .0193 | 500 | 9.75 | 78.0 | 25 | STAND.SOL. | 5.6 | 5.0 | 22.0 | 0.07 | 0.18 | 2.4E5 | <10 | 4.4 | NO | |
| 010487 | B(Squ) | GRAPHITE | BATCH | 187 | 4.32 | .0193 | 700 | 12.125 | 97.0 | 25 | STAND.SOL. | 5.6 | 5.0 | 22.0 | 0.07 | 0.18 | 2.4E5 | <10 | 4.4 | NO | |
| 010487 | B(Squ) | GRAPHITE | BATCH | 240 | 4.32 | .0193 | 900 | 14.25 | 114.0 | 25 | STAND.SOL. | 5.6 | 5.0 | 22.0 | 0.07 | 0.18 | 8.0E4 | 1.0E1 | 3.9 | NO | |
| 010487 | B(Squ) | GRAPHITE | BATCH | 240 | 1.08 | .072 | 900 | 14.25 | 114.0 | 100 | STAND.SOL. | 5.6 | 5.0 | 22.0 | 0.07 | 0.18 | 8.0E4 | 9.0E1 | 2.95 | NO | |
| 140587 | B(Squ) | GRAPHITE | BATCH | 80 | 2.16 | .0386 | 300 | 7.8 | 62.0 | 50 | STAND.SOL. | 6.0 | 5.1 | 20.0 | 0.01 | 0.12 | 1.2E5 | 4.7E2 | 2.41 | NO | |
| 140587 | B(Squ) | GRAPHITE | BATCH | 120 | 2.16 | .0386 | 450 | 10.0 | 80.0 | 50 | STAND.SOL. | 6.0 | 5.1 | 20.0 | 0.02 | 0.27 | 1.2E5 | 4.0E2 | 2.48 | NO | |
| 140587 | B(Squ) | GRAPHITE | BATCH | 160 | 2.16 | .0386 | 600 | 11.9 | 95.0 | 50 | STAND.SOL. | 6.0 | 5.1 | 20.0 | 0.04 | 0.37 | 1.2E5 | 4.0E1 | 3.48 | NO | |
| 140587 | B(Squ) | GRAPHITE | BATCH | 200 | 2.16 | .0386 | 750 | 13.9 | 111.0 | 50 | STAND.SOL. | 6.0 | 5.1 | 20.0 | 0.08 | 0.40 | 1.2E5 | 9.8E2 | 2.09 | NO | |
| 140587 | B(Squ) | GRAPHITE | BATCH | 80 | 4.32 | .0193 | 300 | 7.8 | 62.0 | 25 | STAND.SOL. | 6.0 | 5.1 | 20.0 | 0.10 | 0.16 | 1.2E5 | 5.7E3 | 1.32 | NO | |
| 140587 | B(Squ) | GRAPHITE | BATCH | 120 | 4.32 | .0193 | 450 | 9.9 | 79.0 | 25 | STAND.SOL. | 6.0 | 5.1 | 20.0 | 0.04 | 0.30 | 1.2E5 | 1.0E1 | 4.08 | NO | |
| 140587 | B(Squ) | GRAPHITE | BATCH | 160 | 4.32 | .0193 | 600 | 12.13 | 97.0 | 25 | STAND.SOL. | 6.0 | 5.1 | 20.0 | 0.03 | 0.47 | 1.2E5 | 7.0E1 | 3.23 | NO | |
| 140587 | B(Squ) | GRAPHITE | BATCH | 200 | 4.32 | .0193 | 750 | 13.8 | 110.0 | 25 | STAND.SOL. | 6.0 | 5.1 | 20.0 | 0.21 | 0.56 | 1.2E5 | 2.0E1 | 3.78 | NO | |
| 140587 | B(Squ) | GRAPHITE | BATCH | 200 | 1.08 | .0772 | 752 | 14.13 | 113.0 | 100 | STAND.SOL. | 6.0 | 5.1 | 20.0 | 0.31 | 0.20 | 1.2E5 | 9.0E4 | 0.13 | NO | |
| 140587 | B(Squ) | GRAPHITE | BATCH | 160 | 1.08 | .0772 | 600 | 12.25 | 98.0 | 100 | STAND.SOL. | 6.0 | 5.1 | 20.0 | 0.13 | 0.11 | 1.2E5 | 1.5E5 | 0.10 | NO | |
| 180587 | B(Squ) | GRAPHITE | BATCH | 120 | 3.6 | .0116 | 450 | 9.0 | 36.0 | 15 | STAND.SOL. | 6.4 | 5.2 | 21.0 | 0.02 | 0.13 | 9.7E4 | 3.3E3 | 1.47 | NO | E-C NOT TYPICAL |
| 180587 | B(Squ) | GRAPHITE | BATCH | 160 | 3.6 | .0116 | 600 | 11.25 | 45.0 | 15 | STAND.SOL. | 6.4 | 5.2 | 21.0 | 0.04 | 0.33 | 9.7E4 | 1.0E2 | 2.99 | NO | E-C NOT TYPICAL |
| 180587 | B(Squ) | GRAPHITE | BATCH | 200 | 3.6 | .0116 | 750 | 13.25 | 53.0 | 15 | STAND.SOL. | 6.4 | 5.2 | 21.0 | 0.08 | 0.38 | 9.7E4 | 6.0E2 | 2.21 | NO | E-C NOT TYPICAL |
| 180587 | B(Squ) | GRAPHITE | BATCH | 240 | 3.6 | .0116 | 900 | 14.75 | 59.0 | 15 | STAND.SOL. | 6.4 | 5.2 | 21.0 | 0.12 | 0.40 | 9.7E4 | 2.0E1 | 3.68 | NO | E-C NOT TYPICAL |
| 180587 | B(Squ) | GRAPHITE | BATCH | 80 | 2.16 | .0193 | 300 | | | 25 | STAND.SOL. | 6.4 | 5.2 | 21.0 | 0.11 | 0.06 | 9.7E4 | 4.5E4 | 0.33 | NO | E-C NOT TYPICAL |
| 180587 | B(Squ) | GRAPHITE | BATCH | 160 | 2.16 | .0193 | 600 | 11.0 | 44.0 | 25 | STAND.SOL. | 6.4 | 5.2 | 21.0 | 0.04 | 0.17 | 9.7E4 | 6.9E3 | 1.15 | NO | E-C NOT TYPICAL |
| 180587 | B(Squ) | GRAPHITE | BATCH | 200 | 2.16 | .0193 | 750 | 12.75 | 51.0 | 25 | STAND.SOL. | 6.4 | 5.2 | 21.0 | 0.04 | 0.22 | 9.7E4 | 2.2E3 | 1.64 | NO | E-C NOT TYPICAL |
| 180587 | B(Squ) | GRAPHITE | BATCH | 240 | 2.16 | .0193 | 900 | 14.75 | 59.0 | 25 | STAND.SOL. | 6.4 | 5.2 | 21.0 | 0.06 | 0.28 | 9.7E4 | 2.5E2 | 2.59 | NO | E-C NOT TYPICAL |
| 180587 | B(Squ) | GRAPHITE | BATCH | 240 | 1.08 | .0386 | 900 | 14.75 | 59.0 | 50 | STAND.SOL. | 6.4 | 5.2 | 21.0 | 0.05 | 0.14 | 9.7E4 | 3.0E4 | 0.51 | NO | E-C NOT TYPICAL |
| 180587 | B(Squ) | GRAPHITE | BATCH | 200 | 1.08 | .0386 | 750 | 12.75 | 51.0 | 50 | STAND.SOL. | 6.4 | 5.2 | 21.0 | 0.09 | 0.16 | 9.7E4 | 8.0E4 | 0.08 | NO | E-C NOT TYPICAL |
| 180587 | B(Squ) | GRAPHITE | BATCH | 280 | 1.08 | .0386 | 1050 | 16.25 | 65.0 | 50 | STAND.SOL. | 6.4 | 5.2 | 21.0 | 0.07 | 0.17 | 3.3E6 | 1.9E4 | 0.71 | NO | E-C NOT TYPICAL |
| 210587 | B(Squ) | GRAPHITE | BATCH | 120 | 10.8 | .0116 | 450 | 10.0 | 40.0 | 15 | STAND.SOL. | 5.5 | 5.0 | 21.0 | 0.05 | 0.15 | 3.3E6 | <10 | 5.52 | NO | E-C NOT TYPICAL |
| 210587 | B(Squ) | GRAPHITE | BATCH | 160 | 10.8 | .0116 | 600 | 11.5 | 46.0 | 15 | STAND.SOL. | 5.5 | 5.0 | 21.0 | 0.07 | 0.24 | 3.3E6 | <10 | 5.52 | NO | |
| 210587 | B(Squ) | GRAPHITE | BATCH | 200 | 10.8 | .0116 | 750 | 14.0 | 56.0 | 15 | STAND.SOL. | 5.5 | 5.0 | 21.0 | 0.12 | 0.33 | 3.3E6 | <10 | 5.52 | NO | |
| 210587 | B(Squ) | GRAPHITE | BATCH | 240 | 10.8 | .0116 | 900 | 16.0 | 64.0 | 15 | STAND.SOL. | 5.5 | 5.0 | 21.0 | 0.09 | 0.35 | 3.3E6 | <10 | 5.52 | NO | |
| 210587 | B(Squ) | GRAPHITE | BATCH | 120 | 6.5 | .0193 | 450 | 9.5 | 38.0 | 25 | STAND.SOL. | 5.5 | 5.0 | 21.0 | 0.04 | 0.10 | 3.3E6 | 2.5E4 | 2.12 | NO | |
| 210587 | B(Squ) | GRAPHITE | BATCH | 160 | 6.5 | .0193 | 600 | 11.75 | 47.0 | 25 | STAND.SOL. | 5.5 | 5.0 | 21.0 | 0.07 | 0.15 | 3.3E6 | 5.0E1 | 4.82 | NO | |
| 210587 | B(Squ) | GRAPHITE | BATCH | 200 | 6.5 | .0193 | 750 | 14.0 | 56.0 | 25 | STAND.SOL. | 5.5 | 5.0 | 21.0 | 0.06 | 0.20 | 3.3E6 | <10 | 5.52 | NO | |
| 210587 | B(Squ) | GRAPHITE | BATCH | 240 | 6.5 | .0193 | 900 | 15.75 | 63.0 | 25 | STAND.SOL. | 5.5 | 5.0 | 21.0 | 0.08 | 0.23 | 3.3E6 | <10 | 5.52 | NO | |
| 210587 | B(Squ) | GRAPHITE | BATCH | 240 | 3.25 | .0386 | 900 | 15.5 | 62.0 | 50 | STAND.SOL. | 5.5 | 5.0 | 21.0 | 0.06 | 0.13 | 3.3E6 | 6.0E1 | 4.74 | NO | |
| 210587 | B(Squ) | GRAPHITE | BATCH | 200 | 3.25 | .0386 | 750 | 13.5 | 54.0 | 50 | STAND.SOL. | 5.5 | 5.0 | 21.0 | 0.05 | 0.10 | 3.3E6 | <10 | 5.52 | NO | |
| 210587 | B(Squ) | GRAPHITE | BATCH | 280 | 3.25 | .0386 | 1050 | 17.0 | 68.0 | 50 | STAND.SOL. | 6.0 | 5.0 | 21.0 | 0.08 | 0.14 | 3.3E6 | 2.2E2 | 4.18 | NO | |
| 260587 | B(Squ) | GRAPHITE | BATCH | 80 | 2.16 | .039 | 300 | 7.75 | 62 | 50 | STAND.SOL. | 5.9 | 5.3 | 18.0 | 0.03 | 0.15 | 2.1E6 | 1.8E5 | 1.06 | NO | PINK COLONIES |
| 260587 | B(Squ) | GRAPHITE | BATCH | 120 | 2.16 | .039 | 450 | 9.63 | 77 | 50 | STAND.SOL. | 5.9 | 5.2 | 18.0 | 0.10 | 0.24 | 2.1E6 | 1.4E4 | 2.17 | NO | PINK COLONIES |
| 260587 | B(Squ) | GRAPHITE | BATCH | 160 | 2.16 | .039 | 600 | 11.63 | 93 | 50 | STAND.SOL. | 5.9 | 5.2 | 18.0 | 0.04 | 0.36 | 2.1E6 | 2.5E2 | 3.90 | NO | PINK COLONIES |
| 260587 | B(Squ) | GRAPHITE | BATCH | 200 | 2.16 | .039 | 750 | 13.38 | 107 | 50 | STAND.SOL. | 5.9 | 5.1 | 18.0 | 0.05 | 0.31 | 2.1E6 | 3.7E2 | 3.75 | NO | PINK COLONIES |

1)SEE SECTION 3 2)SEE SECTION 3 3)SEE,SECTION 3.1 4)SEE SECTION 3.2

TABLE 1 : TEST CONDITIONS AND RESULTS

SHEET 2

| TEST NO. | CELL[1] TYPE | ELECTRODE MATERIAL[2] AN./CATH. | TEST[3] MODE | CURRENT DENSITY $A/M^2$ | CONTACT TIME SEC. | FLUID VEL. M/S | CELL CURRENT mA | CELL GAP VOLTAGE V | TOTAL CELL VOLTAGE V | FLOW RATE L/HR | ELECTROLYTE[4] | pH | | TEMP $^0C$ | FREE $Cl_2$ ppm | TOTAL $Cl_2$ ppm | BACTERIOLOGICAL COUNT COUNT/100ML | | | POLARITY REVERSING | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | IN | OUT | | | | INLET | OUTLET | LOG(INLET/OUTLET) | | |
| 260587 | B(Squ) | GRAPHITE | BATCH | 80 | 4.32 | .019 | 300 | 7.5 | 60 | 25 | STAND.SOL. | 6.1 | 5.0 | 18.5 | 0.10 | 0.14 | 2.1E6 | 2.5E4 | 1.92 | NO | PINK COLONIES |
| 260587 | B(Squ) | GRAPHITE | BATCH | 120 | 4.32 | .019 | 450 | 9.75 | 78 | 25 | STAND.SOL. | 6.1 | 5.0 | 18.5 | 0.03 | 0.27 | 2.1E6 | 2.6E2 | 3.9 | NO | PINK COLONIES |
| 260587 | B(Squ) | GRAPHITE | BATCH | 160 | 4.32 | .019 | 600 | 11.88 | 95 | 25 | STAND.SOL. | 6.1 | 5.0 | 18.5 | 0.07 | 0.40 | 2.1E6 | 1.0E1 | 5.32 | NO | PINK COLONIES |
| 260587 | B(Squ) | GRAPHITE | BATCH | 200 | 4.32 | .019 | 750 | 13.5 | 108 | 25 | STAND.SOL. | 6.1 | 5.0 | 18.5 | 0.05 | 0.49 | 2.1E6 | <10 | 5.32 | NO | PINK COLONIES |
| 260587 | B(Squ) | GRAPHITE | BATCH | 200 | 1.44 | .058 | 750 | 13.38 | 107 | 75 | STAND.SOL. | 6.1 | 5.2 | 18.5 | 0.06 | 0.17 | 2.1E6 | 2.7E4 | 1.88 | NO | PINK COLONIES |
| 260587 | B(Squ) | GRAPHITE | BATCH | 240 | 1.44 | .058 | 900 | 14.75 | 118 | 75 | STAND.SOL. | 6.1 | 5.1 | 19.0 | 0.06 | 0.21 | 2.1E6 | 2.4E4 | 1.94 | NO | PINK COLONIES |
| 280587 | B(Squ) | GRAPHITE | BATCH | 80 | 6.48 | .0193 | 300 | 7.5 | 90 | 25 | STAND.SOL. | 6.1 | 5.0 | 21.5 | 0.00 | 0.13 | 3.1E6 | 1.9E5 | 1.22 | NO | |
| 280587 | B(Squ) | GRAPHITE | BATCH | 120 | 6.48 | .0193 | 450 | 9.6 | 115 | 25 | STAND.SOL. | 6.1 | 4.9 | 21.5 | 0.00 | 0.32 | 3.1E6 | 1.3E2 | 4.40 | NO | |
| 280587 | B(Squ) | GRAPHITE | BATCH | 80 | 3.24 | .0386 | 300 | 7.5 | 90 | 50 | STAND.SOL. | 6.1 | 5.3 | 21.5 | 0.00 | 0.05 | 3.1E6 | 6.4E4 | 1.70 | NO | |
| 280587 | B(Squ) | GRAPHITE | BATCH | 120 | 3.24 | .0386 | 450 | 9.6 | 115 | 50 | STAND.SOL. | 6.1 | 5.1 | 21.5 | 0.00 | 0.15 | 3.1E6 | 5.8E4 | 1.70 | NO | |
| 280587 | B(Squ) | GRAPHITE | BATCH | 133 | 3.24 | .0386 | 500 | 10.0 | 120 | 50 | STAND.SOL. | 6.1 | 5.1 | 21.5 | 0.00 | 0.20 | 3.1E6 | 9.9E3 | 2.50 | NO | |
| 280587 | B(Squ) | GRAPHITE | BATCH | 133 | 2.16 | .0579 | 500 | 10.0 | 120 | 75 | STAND.SOL. | 6.1 | 5.2 | 21.5 | 0.00 | 0.11 | 3.1E6 | 1.3E5 | 1.40 | NO | |
| 280587 | B(Squ) | GRAPHITE | BATCH | 120 | 2.16 | .0579 | 450 | 9.5 | 114 | 75 | STAND.SOL. | 6.1 | 5.2 | 21.5 | 0.00 | 0.09 | 3.1E6 | >2.0E5 | <1.2 | NO | |
| 280587 | B(Squ) | GRAPHITE | BATCH | 80 | 2.16 | .0579 | 300 | 7.5 | 90 | 75 | STAND.SOL. | 6.1 | 5.2 | 21.5 | 0.00 | 0.03 | 3.1E6 | >2.0E5 | <1.2 | NO | |
| 280587 | B(Squ) | GRAPHITE | BATCH | 53 | 6.48 | .0193 | 200 | 6.1 | 73 | 25 | STAND.SOL. | 6.1 | 5.1 | 21.5 | 0.00 | 0.05 | 3.1E6 | >2.0E5 | <1.2 | NO | |
| 040687 | B(Squ) | GRAPHITE | BATCH | 80 | 2.16 | .0386 | 300 | 7.4 | 59 | 50 | STAND.SOL. | 6.1 | 6.3 | 21.5 | 0.00 | 0.00 | 5.4E6 | >1.0E5 | <1.7 | AC 50HZ | |
| 040687 | B(Squ) | GRAPHITE | BATCH | 120 | 2.16 | .0386 | 450 | 11.0 | 88 | 50 | STAND.SOL. | 6.1 | 6.1 | 21.5 | 0.00 | 0.00 | 5.4E6 | 1.4E5 | 1.6 | AC 50HZ | |
| 040687 | B(Squ) | GRAPHITE | BATCH | 160 | 2.16 | .0386 | 600 | 14.8 | 118 | 50 | STAND.SOL. | 6.1 | 6.2 | 21.5 | 0.00 | 0.00 | 5.4E6 | >1.0E5 | <1.7 | AC 50HZ | |
| 040687 | B(Squ) | GRAPHITE | BATCH | 160 | 4.32 | .0193 | 600 | 14.4 | 115 | 25 | STAND.SOL. | 6.1 | 6.3 | 21.5 | 0.00 | 0.00 | 5.4E6 | >1.0E5 | <1.7 | AC 50HZ | |
| 040687 | B(Squ) | GRAPHITE | BATCH | 120 | 4.32 | .0193 | 450 | 10.9 | 87 | 25 | STAND.SOL. | 6.1 | 6.2 | 21.5 | 0.00 | 0.00 | 5.4E6 | >1.0E5 | <1.7 | AC 50HZ | |
| 040687 | B(Squ) | GRAPHITE | BATCH | 80 | 4.32 | .0193 | 300 | 7.1 | 57 | 25 | STAND.SOL. | 6.1 | 6.1 | 21.5 | 0.00 | 0.00 | 5.4E6 | >1.0E5 | <1.7 | AC 50HZ | |
| 040687 | B(Squ) | GRAPHITE | BATCH | 80 | 7.2 | .0116 | 300 | 7.3 | 58 | 15 | STAND.SOL. | 6.1 | 6.2 | 21.5 | 0.00 | 0.00 | 5.4E6 | >1.0E5 | <1.7 | AC 50HZ | |
| 040687 | B(Squ) | GRAPHITE | BATCH | 120 | 7.2 | .0116 | 450 | 10.9 | 87 | 15 | STAND.SOL. | 6.1 | 6.2 | 21.5 | 0.00 | 0.00 | 5.4E6 | >1.0E5 | <1.7 | AC 50HZ | |
| 040687 | B(Squ) | GRAPHITE | BATCH | 160 | 7.2 | .0116 | 600 | 13.8 | 110 | 15 | STAND.SOL. | 6.1 | 6.2 | 21.5 | 0.00 | 0.00 | 5.4E6 | >1.0E5 | <1.7 | AC 50HZ | |
| 220687 | B(Squ) | GRAPHITE | BATCH | 123 | 3.24 | .0386 | 460 | 10.0 | 120 | 50 | STAND.SOL. | 5.8 | 5.2 | 18.5 | 0.00 | 0.28 | 1.6E6 | 3.0E1 | 4.73 | NO | |
| 220687 | B(Squ) | GRAPHITE | BATCH | 123 | 2.16 | .0386 | 460 | 9.7 | 77.7 | 50 | STAND.SOL. | 5.8 | 5.9 | 19.0 | 0.00 | 0.14 | 1.6E6 | 5.2E4 | 1.50 | NO | |
| 220687 | B(Squ) | GRAPHITE | BATCH | 123 | 1.08 | .0386 | 460 | 9.6 | 38.5 | 50 | STAND.SOL. | 6.0 | 5.4 | 19.5 | 0.00 | 1.08 | 1.6E6 | 3.8E5 | 0.62 | NO | |
| 150787 | B(Squ) | GRAPHITE | BATCH | 123 | 3.24 | .0386 | 460 | 10.0 | 120 | 50 | STAND.SOL. | 5.9 | 5.5 | 20.0 | 0.00 | 0.00 | 9.7E5 | <E2 * | >4.0 * | 12REV/HR | |
| 150787 | B(Squ) | GRAPHITE | BATCH | 123 | 3.24 | .0386 | 460 | 10.0 | 120 | 50 | STAND.SOL. | 5.9 | 5.5 | 20.0 | 0.00 | 0.00 | 9.7E5 | 6.6E5+ | 0.17 + | 12REV/HR | |
| 150787 | B(Squ) | GRAPHITE | BATCH | 123 | 2.16 | .0386 | 460 | 10.0 | 80 | 50 | STAND.SOL. | 5.9 | 6.0 | 21.5 | 0.00 | 0.00 | 9.7E5 | <E3 * | >4.0 * | 12REV/HR | |
| 150787 | B(Squ) | GRAPHITE | BATCH | 123 | 2.16 | .0386 | 460 | 10.0 | 80 | 50 | STAND.SOL. | 5.9 | 6.0 | 21.5 | 0.00 | 0.00 | 9.7E5 | 8.5E5+ | 0.06 + | 12REV/HR | |
| 150787 | B(Squ) | GRAPHITE | BATCH | 123 | 1.08 | .0386 | 460 | 9.8 | 39 | 50 | STAND.SOL. | 5.9 | 6.0 | 21.5 | 0.00 | 0.00 | 9.7E5 | <E3 * | >4.0 * | 12REV/HR | |
| 150787 | B(Squ) | GRAPHITE | BATCH | 123 | 1.08 | .0386 | 460 | 9.8 | 39 | 50 | STAND.SOL. | 5.9 | 6.0 | 21.5 | 0.00 | 0.00 | 9.7E5 | 7.5E4+ | 1.11+ | 12REV/HR | |
| 210787 | B(Squ) | GRAPHITE | BATCH | 123 | 2.16 | .0386 | 460 | 9.8 | 78 | 50 | STAND.SOL. | 6.0 | 5.2 | 18.6 | 0.00 | 0.23 | 7.3E5 | 5.7E4 | 1.10 | TOP $^{+}$VE | |
| 210787 | B(Squ) | GRAPHITE | BATCH | 123 | 2.16 | .0386 | 460 | 9.9 | 79 | 50 | STAND.SOL. | 6.2 | 5.2 | 19.0 | 0.00 | 0.13 | 7.3E5 | 3.2E4 | 1.40 | TOP $^{-}$VE | |
| 290787 | B(Squ) | GRAPHITE | BATCH | 123 | 2.16 | .0386 | 460 | 9.4 | 75 | 50 | STAND.SOL. | 5.9 | 5.3 | 20.5 | 0.00 | 0.00 | 6.9E5 | 4.2E4 | 1.20 | NO | |
| 290787 | B(Squ) | GRAPHITE | BATCH | 115 | 2.16 | .0386 | 430 | 15.0 | 120 | 50 | STAND.SOL. | 6.0 | 5.5 | 20.5 | 0.00 | 0.11 | 6.9E5 | 3.5E4 | 1.3 | 30REV/MIN | |
| 080987 | B(Squ) | GRAPHITE | BATCH | 123 | 2.16 | .0386 | 462 | 9.8 | 78 | 50 | STAND.SOL. | 6.0 | 5.3 | 19.5 | 0.00 | 0.13 | 1.9E5 | 1.1E4 | 1.24 | NO | |
| 080987 | B(Squ) | GRAPHITE | BATCH | 123 | 2.16 | .0386 | 462 | 9.8 | 78 | 50 | HUMIC 20H' | 6.1 | 5.4 | 19.5 | 0.00 | 0.14 | <1.E3 | <1E3 | - | NO | INIT. COUNT LOW |
| 140987 | B(Squ) | GRAPHITE | BATCH | 123 | 2.16 | .0386 | 462 | 10.3 | 82 | 50 | STAND.SOL. | 6.0 | 5.2 | 17.5 | 0.00 | 0.00 | 1.2E7 | 4.5E5 | 1.40 | NO | |
| 140987 | B(Squ) | GRAPHITE | BATCH | 123 | 2.16 | .0386 | 462 | 10.4 | 83 | 50 | HUMIC 20H' | 5.9 | 5.3 | 17.5 | 0.00 | 0.00 | 1.2E7 | 1.3E6 | 1.00 | NO | |
| 160987 | B(Squ) | GRAPHITE | BATCH | 123 | 2.16 | .0386 | 462 | 10.5 | 84 | 50 | STAND.SOL. | 6.0 | 5.2 | 18.0 | 0.00 | 0.00 | 9.0E6 | 4.4E5 | 1.30 | NO | |
| 160987 | B(Squ) | GRAPHITE | BATCH | 123 | 2.16 | .0386 | 462 | 10.5 | 84 | 50 | HUM 100H' | 6.2 | 5.6 | 18.0 | 0.00 | 0.00 | 9.0E6 | 5.1E6 | 0.25 | NO | |
| 091087 | B(Squ) | GRAPHITE | BATCH | 130 | 2.16 | .0386 | 488 | 10.4 | 83 | 50 | 1ppm $N_2$ | 5.9 | 5.2 | 19.0 | 0.00 | 0.00 | 6.3E6 | 8.1E4 | 1.90 | NO | |
| 161087 | B(Squ) | GRAPHITE | BATCH | 130 | 2.16 | .0386 | 488 | 10.6 | 85 | 50 | SET.SEWAGE | 6.2 | 5.4 | 19.0 | 0.00 | 0.24 | 4.7E5 | 3.7E4 | 1.10 | NO | E-C COUNT |
| 161087 | B(Squ) | GRAPHITE | BATCH | 130 | 2.16 | .0386 | 488 | 10.6 | 85 | 50 | SET.SEWAGE | 6.2 | 5.4 | 19.0 | 0.00 | 0.10 | 2.9E6 | 2.9E4 | 2.00 | NO | TOT-C COUNT |
| 131187 | C(Plate) | EBONEX | BATCH | 111 | 1.3 | .051 | 336 | 14.8 | 74 | 50 | STAND.SOL. | 6.0 | 6.0 | 19.0 | 0.00 | 2.00 | 1.7E7 | <8.1E3 | >3.30 | NO | |
| 231187 | C(Plate) | EBONEX | BATCH | 121 | 1.3 | .051 | 368 | 15.6 | 78 | 50 | STAND.SOL. | 6.0 | 6.2 | 20.0 | 1.00 | 2.80 | 1.6E7 | <1.0 | >7.20 | NO | |
| 050588 | B(Rect) | EBONEX | BATCH | 123 | 1.6 | .0386 | 462 | 13.5 | 81 | 50 | STAND.SOL. | 6.3 | 6.3 | 22.0 | 2.00 | 3.00 | 6.0E6 | 2.0 | 6.5 | NO | |
| 120588 | B(Rect) | EBONEX | BATCH | 120 | 1.6 | .0386 | 461 | 13.5 | 81 | 50 | STAND.SOL. | 7.0 | 7.8 | 21.0 | 2.00 | 1.50 | 5.0E6 | <1.0 | >6.7 | 1REV/MIN | |
| 120588 | B(Rect) | EBONEX | BATCH | 120 | 1.6 | .0386 | 461 | 13.5 | 81 | 50 | STAND.SOL. | 7.0 | 7.8 | 21.0 | 2.00 | 1.50 | 5.0E6 | 5.8E3 | 3.00 | 1REV/SEC | |
| 220688 | B(Squ) | EBONEX | CON FLO | 172 | 1.8 | .036 | 700 | 13.3 | 80 | 50 | HUM>100H' | 7.7 | - | 21.0 | - | - | 5.0E3 | <1.0 | >3.7 | 26REV/HR | HORSLEY TEST |
| 270688 | B(Squ) | EBONEX | CON FLO | 172 | 1.8 | .036 | 740 | 13.3 | 80 | 50 | HUM 100H' | - | - | - | - | - | 2.0E3 | 6.0E2 | 0.5 | 26REV/HR | HORSLEY TEST |
| 250788 | B(Squ) | EBONEX | CON FLO | 98 | 1.8 | .036 | 400 | 10/12 | 60/70 | 50 | HUM 140H' | 7.7 | - | - | - | - | 4.6E3 | 4.6E3 | 0.0 | 26REV/HR | HORSLEY TEST |

1)SEE SECTION 3 2)SEE SECTION 3 3)SEE SECTION 3.1 4)SEE SECTION 3.2 * LOWEST OUTLET COUNT + HIGHEST OUTLET COUNT

TABLE 1 : TEST CONDITIONS AND RESULTS SHEET 3

| TEST NO. | CELL$^1$ TYPE | ELECTRODE MATERIAL$^2$ AN./CATH. | TEST$^3$ MODE | CURRENT DENSITY A/M$^2$ | CONTACT TIME SEC. | FLUID VEL. M/S | CELL CURRENT mA | CELL GAP VOLTAGE V | TOTAL CELL VOLTAGE V | FLOW RATE L/HR | ELECTROLYTE$^4$ | pH | | TEMP $^0$C | FREE $Cl_2$ ppm | TOTAL $Cl_2$ ppm | BACTERIOLOGICAL COUNT COUNT/100ML | | | POLARITY REVERSING | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | IN | OUT | | | | INLET | OUTLET | LOG(INLET/OUTLET) | | |
| 270788 | B(Squ) | EBONEX | CON FLO | 160/219 | 1.8 | .036 | 660/900 | 22/23 | 130/138 | 50 | HUM 145H˙ | 6.9 | - | - | - | - | 4.6E3 | 3.6E3 | 0.1 | 26REV/HR | HORSLEY TEST |
| 280788 | B(Squ) | EBONEX | CON FLO | 142/184 | 1.8 | .036 | 580/750 | 22/23 | 134/140 | 50 | HUM 120H˙ | 7.3 | - | - | - | - | 7.4E3 | 3.0E3 | 0.4 | 26REV/HR | HORSLEY TEST |
| 080888 | B(Squ) | EBONEX | CON FLO | 170/245 | 1.8 | .036 | 700/1E3 | 17/18 | 102/108 | 50 | HUM 52H˙ | - | - | - | - | - | 1.1E3 | 0.4E3 | 0.4 | 26REV/HR | HORSLEY TEST |
| 080888 | B(Squ) | EBONEX | CON FLO | 170/245 | 1.8 | .036 | 700/1E3 | 17/18 | 102/108 | 50 | HUM 52H˙ | - | - | - | - | - | 1.5E3 | 0.7E3 | 0.3 | 26REV/HR | HORSLEY TEST |
| 130988 | B(Squ) | EBONEX | CON FLO | 130/160 | 1.8 | .036 | 530/680 | 18/19 | 106/110 | 50 | STAND.SOL. | - | - | - | - | - | 8.7E6 | 1.0E5 | 1.9 | 26REV/HR | HORSLEY TEST |
| 130988 | B(Squ) | EBONEX | CON FLO | 130/160 | 1.8 | .036 | 530/650 | 18/19 | 106/110 | 50 | HUM 23H˙ | - | - | - | - | - | 8.3E6 | 1.0E5 | 1.9 | 26REV/HR | HORSLEY TEST |
| 150988 | B(Squ) | EBONEX | CON FLO | 147/211 | 1.8 | .036 | 600/860 | 17/19 | 104/110 | 50 | STAND.SOL. | 7.7 | - | 20.0 | - | - | 0.0 | 0.0 | - | 26REV/HR | HORSLEY TEST |
| 150988 | B(Squ) | EBONEX | CON FLO | 147/211 | 1.8 | .036 | 600/860 | 17/19 | 104/110 | 50 | STAND.SOL. | 7.7 | - | 20.0 | - | - | 1.1E7 | 1.1E5 | 2.0 | 26REV/HR | HORSLEY TEST |
| 111088 | B(Squ) | EBONEX | BATCH | 118/167 | 1.8 | .036 | 480/680 | 12/13 | 74/77 | 50 | STAND.SOL. | 6.0 | * | 21.0 | 1.20 | 2.50 | 7.0E6 | 1.1E3* | 3.8* | 30REV/HR | |
| 111088 | B(Squ) | EBONEX | BATCH | 118/167 | 1.8 | .036 | 480/680 | 12/13 | 74/77 | 50 | STAND.SOL. | 6.0 | * | 21.0 | 1.20 | 2.50 | 7.0E6 | 3.1E5$^+$ | 1.4+ | 30REV/HR | |
| 131088 | B(Squ) | EBONEX | BATCH | 162/220 | 3.6 | .018 | 660/900 | 16/17 | 95/100 | 25 | STAND.SOL. | 6.4 | * | 23.0 | - | 5.30 | 2.5E6 | <2.0 | >6.1 | 30REV/HR | |
| 181088 | B(Squ) | EBONEX | BATCH | 115/172 | 3.6 | .018 | 470/700 | 13/14 | 78/81 | 25 | STAND.SOL. | 6.4 | * | 21.0 | 2.00 | 2.60 | 1.2E6 | 2.0 * | 5.8 * | 30REV/HR | |
| 181088 | B(Squ) | EBONEX | BATCH | 115/172 | 3.6 | .018 | 470/700 | 13/14 | 78/81 | 25 | STAND.SOL. | 6.4 | * | 21.0 | 2.00 | 2.60 | 1.2E6 | 6.0E2+ | 3.3 + | 30REV/HR | |
| 181088 | B(Squ) | EBONEX | BATCH | 69/123 | 3.6 | .018 | 280/500 | /10 | 58/61 | 25 | STAND.SOL. | 6.4 | * | 22.0 | 0.60 | 1.00 | 1.7E6 | <1E2 * | >4.2 * | 30REV/HR | |
| 181088 | B(Squ) | EBONEX | BATCH | 69/123 | 3.6 | .018 | 280/500 | /10 | 58/61 | 25 | STAND.SOL. | 6.4 | * | 22.0 | 0.60 | 1.00 | 1.7E6 | 1.2E4+ | 2.2 + | 30REV/HR | |
| 241088 | B(Squ) | EBONEX | BATCH | 162/220 | 1.8 | .036 | 660/900 | 16/17 | 95/100 | 50 | STAND.SOL. | 6.4 | * | 18.0 | 4.50 | 4.80 | 3.2E6 | <1.0 * | >6.5 * | 30REV/HR | |
| 241088 | B(Squ) | EBONEX | BATCH | 162/220 | 1.8 | .036 | 660/900 | 16/17 | 95/100 | 50 | STAND.SOL. | 6.4 | * | 18.0 | 4.50 | 4.80 | 3.2E6 | 5.8E3+ | 2.7 + | 30REV/HR | |
| 241088 | B(Squ) | EBONEX | BATCH | 115/172 | 1.8 | .036 | 470/700 | 13/14 | 78/81 | 50 | STAND.SOL. | 6.4 | * | 18.0 | 1.10 | 0.90 | 3.2E6 | 6.0E2* | 3.7 * | 30REV/HR | |
| 241088 | B(Squ) | EBONEX | BATCH | 115/172 | 1.8 | .036 | 470/700 | 13/14 | 78/81 | 50 | STAND.SOL. | 6.4 | * | 18.0 | 1.10 | 0.90 | 3.2E6 | 3.8E6+ | 0.0 + | 30REV/HR | |
| 241088 | B(Squ) | EBONEX | BATCH | 115/172 | 6.0 | .0096 | 470/700 | 13/14 | 78/81 | 15 | STAND.SOL. | 6.4 | * | 19.0 | 2.10 | 2.50 | 3.2E6 | <1E2 | >4.5 | 30REV/HR | |
| 261088 | B(Squ) | EBONEX | BATCH | 162/220 | 3.6 | .011 | 660/900 | 16/17 | 95/100 | 25 | NO Cl$^-$ | 6.4 | * | 23.0 | 0.00 | 0.00 | 2.1E6 | 3.8E2* | 3.7 * | 30REV/HR | |
| 261088 | B(Squ) | EBONEX | BATCH | 162/220 | 3.6 | .011 | 660/900 | 16/17 | 95/100 | 25 | NO Cl$^-$ | 6.4 | * | 23.0 | 0.00 | 0.00 | 2.1E6 | 1.6E5+ | 1.1 + | 30REV/HR | |
| 261088 | B(Squ) | EBONEX | BATCH | 115/172 | 3.6 | .011 | 470/700 | 13/14 | 78/81 | 25 | NO Cl$^-$ | 6.3 | * | 24.0 | 0.00 | 0.00 | 2.1E6 | 1.2E6* | 0.2 * | 30REV/HR | |
| 261088 | B(Squ) | EBONEX | BATCH | 115/172 | 3.6 | .011 | 470/700 | 13/14 | 78/81 | 25 | NO Cl$^-$ | 6.3 | * | 24.0 | 0.00 | 0.00 | 2.1E6 | 1.7E6$^+$ | 0.1 + | 30REV/HR | |
| 311088 | B(Squ) | EBONEX | BATCH | 115/172 | 3.6 | .011 | 470/700 | 13/14 | 78/81 | 25 | STAND.SOL. | 7.5 | * | 18.0 | 3.50 | 4.00 | 2.3E7 | <1E2 * | >5.4 * | 2REV/HR | |
| 311088 | B(Squ) | EBONEX | BATCH | 115/172 | 3.6 | .011 | 470/700 | 13/14 | 78/81 | 25 | STAND.SOL. | 7.5 | * | 18.0 | 3.50 | 4.00 | 2.3E7 | 3.5E3+ | 3.8 + | 2REV/HR | |
| 011188 | B(Squ) | EBONEX | BATCH | 73/122 | 3.6 | .011 | 280/480 | ±14 | ±82 | 25 | STAND.SOL. | 6.5 | 6.3 | 20.0 | 0.00 | 0.00 | 1.6E7 | 5.4E6 | 0.5 | 30REV/MIN | |
| 011188 | B(Squ) | EBONEX | BATCH | 73/122 | 3.6 | .011 | 280/480 | ±14 | ±82 | 25 | STAND.SOL. | 6.4 | 6.7 | 20.0 | 0.00 | 3.90 | 1.1E7 | 3.2E2 | 4.5 | 2REV/HR | FAECAL STREPT. |
| 011188 | B(Squ) | EBONEX | BATCH | 73/122 | 3.6 | .011 | 280/480 | ±14 | ±82 | 25 | STAND.SOL. | 6.4 | 6.7 | 20.0 | 0.00 | 3.90 | 1.6E7 | <10 | >6.2 | 2REV/HR | FAECAL STREPT. |
| 071188 | B(Squ) | EBONEX | BATCH | 115/172 | 3.6 | .011 | 470/700 | ±13 | +78/-81 | 25 | STAND.SOL. | 8.7 | | 20.0 | 0.00 | 3.20 | 1.3E7 | 1.0E3* | 4.1 * | 30REV/HR | $CaCO_3$ADDED |
| 071188 | B(Squ) | EBONEX | BATCH | 115/172 | 3.6 | .011 | 470/700 | ±13 | +78/-81 | 25 | STAND.SOL. | 8.7 | | 20.0 | 0.00 | 3.20 | 1.3E7 | 2.9E5+ | 1.7 + | 30REV/HR | $CaCO_3$ADDED |
| 141188 | B(Squ) | EBONEX | BATCH | 120 | 3.6 | .011 | 480/500 | -13 | -80 | 25 | STAND.SOL. | 6.2 | 7.1 | 21.0 | 3.00 | 4.30 | 1.9E7 | <10 | >6.3 | 2REV/HR | ELECTR. CLEANED |
| 141188 | B(Squ) | EBONEX | BATCH | 120 | 3.6 | .011 | 490/500 | +13 | +80 | 25 | STAND.SOL. | 6.2 | 6.1 | 21.0 | 4.50 | 5.00 | 1.9E7 | <10 | >6.3 | 2REV/HR | ELECTR. CLEANED |
| 171188 | B(Squ) | EBONEX | BATCH | 124 | 3.6 | .011 | -500 | -13 | -80 | 25 | STAND.SOL. | 6.2 | 6.8 | 21.0 | - | 4.20 | 1.7E7 | <1.0 | >7.2 | 2REV/HR | |
| 171188 | B(Squ) | EBONEX | BATCH | 124 | 3.6 | .011 | +500 | +13 | +80 | 25 | STAND.SOL. | 6.2 | 6.0 | 21.0 | - | 3.40 | 1.7E7 | <1.0 | >7.2 | 2REV/HR | |
| 171188 | B(Squ) | EBONEX | BATCH | 124 | 1.8 | .036 | +500 | +13 | +80 | 50 | STAND.SOL. | 6.2 | 6.2 | 21.0 | - | 2.20 | 1.7E7 | <1.0 | >7.2 | 2REV/HR | |
| 221188 | B(Squ) | EBONEX | BATCH | 118/124 | 1.8 | .036 | 520/600 | -13 | -80 | 50 | STAND.SOL. | 6.5 | | 20.0 | - | 2.30 | 1.6E7 | 9.5E3** | 3.2 | 2REV/HR | **CELL OUTLET |
| 221188 | B(Squ) | EBONEX | BATCH | 118/124 | 1.8 | .036 | 480/510 | +13 | +80 | 50 | STAND.SOL. | 6.5 | | 20.0 | - | 0.44 | 1.6E7 | <1.0 ** | >7.2 | 2REV/HR | **OUTLET TANK |
| 221188 | B(Squ) | EBONEX | BATCH | 118/124 | 1.8 | .036 | 480/510 | +13 | +80 | 50 | STAND.SOL. | 4.3 | | 21.0 | - | - | 1.6E7 | 6.0 ** | 6.4 | 2REV/HR | **CELL OUTLET |
| 281188 | B(Squ) | EBONEX | BATCH | 124 | 3.6 | .018 | -500 | -19 | -114 | 25 | STAND.SOL. | 6.1 | 5.7 | 20.0 | 1.60 | 3.20 | 1.7E7 | 1.8E3 | 4.0 | 2REV/HR | AFTER 6 DAYS |
| 281188 | B(Squ) | EBONEX | BATCH | 124 | 3.6 | .018 | +500 | +17 | +100 | 25 | STAND.SOL. | 6.1 | 5.7 | 20.0 | 3.20 | 4.30 | 1.7E7 | 1.0 | >7.2 | 2REV/HR | AFTER 6 DAYS |
| 281188 | B(Squ) | EBONEX | BATCH | 124 | 1.8 | .036 | +500 | +17 | +100 | 50 | STAND.SOL. | 5.4 | | 20.0 | 1.70 | 2.80 | 1.7E7 | 2.0 | 6.9 | 2REV/HR | AFTER 6 DAYS |
| 170588 | C(Plate) | TITANIUM | BATCH | 185/195 | 1.3 | .051 | 560/590 | 17.5 | 122 | 50 | STAND.SOL. | 6.9 | 7.5 | 22.0 | 0.00 | 0.00 | 7.0E6 | >1.0E5 | <1.8 | NO | |
| 270988 | D(Rect.) | TIN OXIDE | BATCH | 120 | 1.3 | .062 | 300/380 | 17.0 | 136 | 50 | STAND.SOL. | 6.9 | 7.5 | 21.0 | 0.00 | 0.00 | 6.4E6 | 4.0E6 | 0.2 | NO | PRECIPITATE |
| 300988 | D(Rect.) | TIN OXIDE | BATCH | 120 | 1.3 | .062 | 330 | 17.0 | 135 | 50 | STAND.SOL. | 6.7 | - | 20.0 | - | 0.00 | - | - | - | NO | PREC. AND Ω-UP |
| 121288 | A(P) | CON.GLASS | RECIRC | 115 | 0.5 | 0.3 | 95 | 17.4 | 17.4 | 18 | STAND.SOL. | 6.8 | 7.0 | 27.0 | 0.50 | 1.50 | 8.7E6 | <1.0 | >6.9 | NO | TURB. PROM. |
| 191288 | A(P) | CON.GLASS | RECIRC | 112 | 1.0 | 0.3 | 92 | 15 | 15 | 18 | STAND.SOL. | - | - | 23.0 | 0.00 | 0.90 | 3.0E4 | <1.0 | >6.9 | NO | |
| 060289 | E(Plate) | CON.GLASS | BATCH | 120/98 | 1.4 | 0.3 | 456/372 | -38 | -38 | 16 | STAND.SOL. | - | - | 22.0 | - | 2.30 | 1.9E7 | 16.0 | 6.1 | NO | |
| 060289 | E(Plate) | CON.GLASS | BATCH | 120/98 | 1.4 | 0.3 | 456/450 | -45 | -45 | 16 | STAND.SOL. | - | - | 22.0 | - | 2.50 | 1.9E7 | 1.0 | 7.3 | NO | |
| 060289 | E(Plate) | CON.GLASS | BATCH | 5.4 | 1.4 | 0.3 | 30 | +45 | +45 | 16 | STAND.SOL. | - | - | 22.0 | - | 0.00 | 1.9E7 | 6.0E6 | 0.5 | NO | OX. LAYER REMOVED |
| 200389 | E(Plate) | CON.GLASS | BATCH | 120 | 1.5 | 0.28 | 500 | 32/34 | 32/45 | 15 | NO Cl$^-$ | 6.2 | 6.1 | 16.0 | 0.00 | 0.00 | 1.1E7 | 1.9E6 | 0.76 | NO | |
| 200389 | E(Plate) | CON.GLASS | BATCH | 120 | 1.5 | 0.28 | 500 | 55/60 | 55/60 | 15 | STAND.SOL. | 5.8 | 6.0 | 17.0 | 0.00 | 0.00 | 1.1E7 | 1.6E5 | 1.8 | NO | OX. LAYER REMOVED |

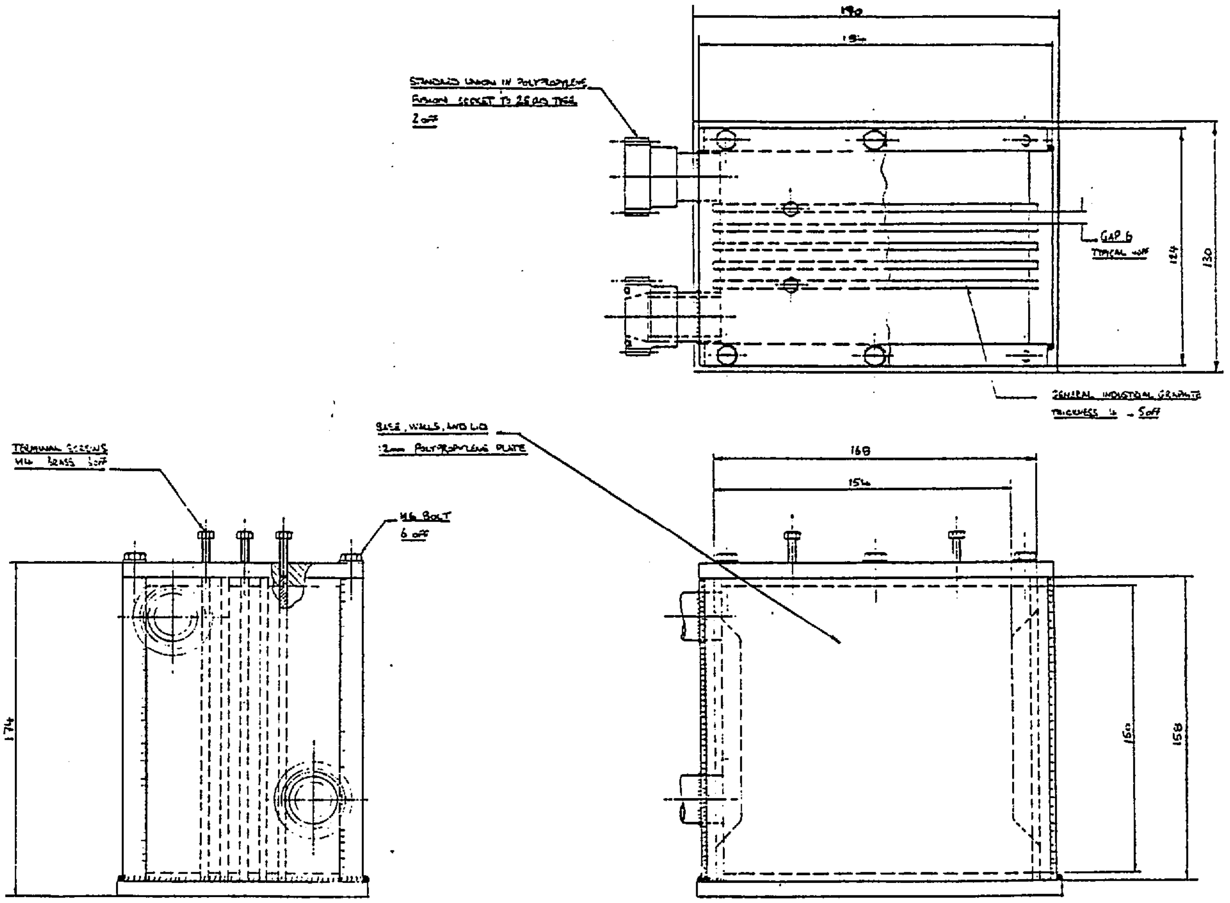
1)SEE SECTION 3 2)SEE SECTION 3 3)SEE SECTION 3.1 4)SEE SECTION 3.2 * LOWEST OUTLET COUNT + HIGHEST OUTLET COUNT

## TABLE 1 : TEST CONDITIONS AND RESULTS SHEET 4

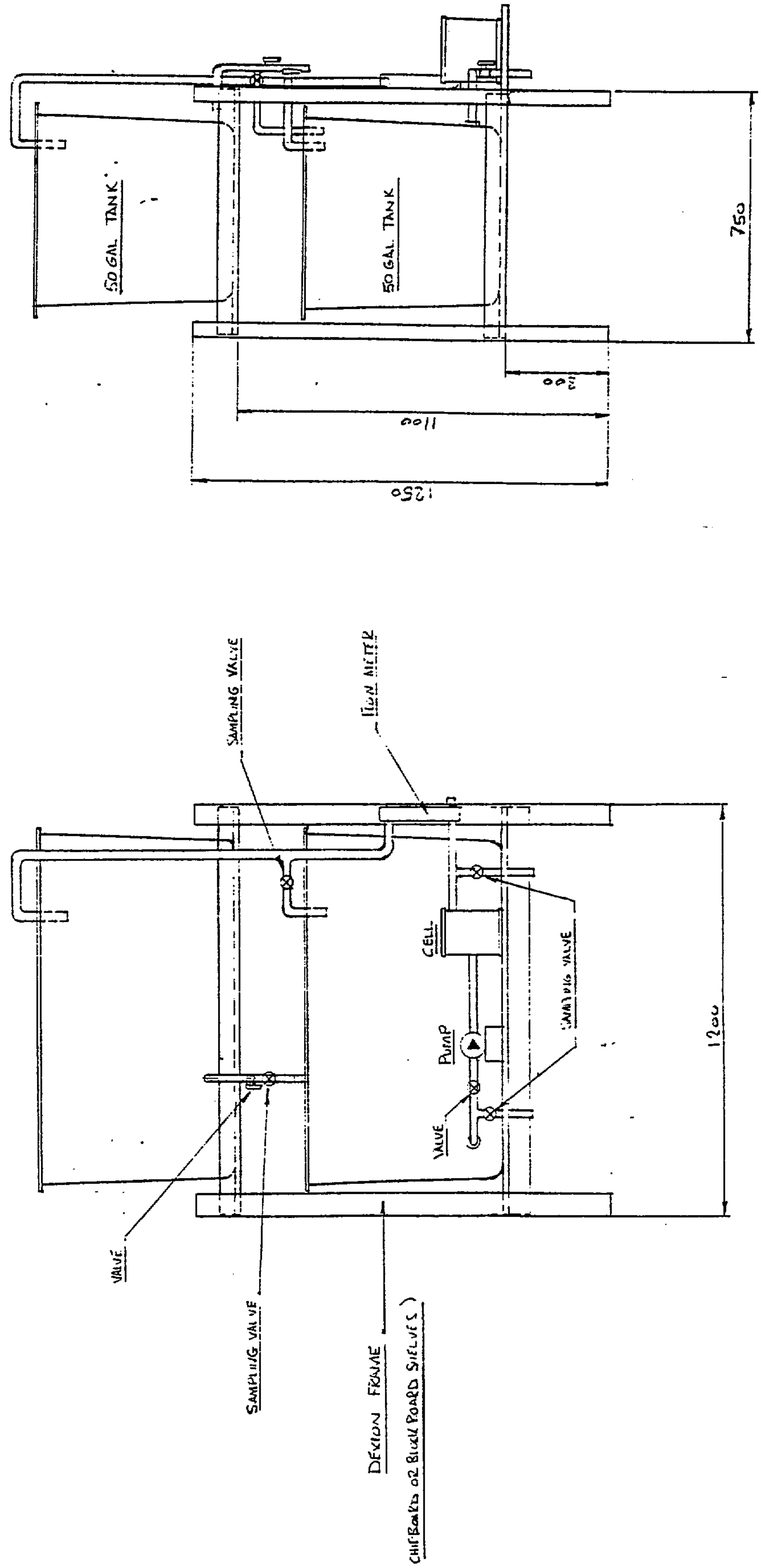
| TEST NO. | CELL$^1$ TYPE | ELECTRODE MATERIAL$^2$ AN./CATH. | TEST$^3$ MODE | CURRENT DENSITY A/M$^2$ | CONTACT TIME SEC. | FLUID VEL. M/S | CELL CURRENT mA | CELL GAP VOLTAGE V | TOTAL CELL VOLTAG V | FLOW RATE L/HR | ELECTROLYTE$^4$ | pH | | TEMP $^0C$ | FREE $Cl_2$ ppm | TOTAL $Cl_2$ ppm | BACTERIOLOGICAL COUNT COUNT/100ML | | | POLARITY REVERSING | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | IN | OUT | | | | INLET | OUTLET | LOG($\frac{INLET}{OUTLET}$) | | |
| 160589 | B(Squ) | GRAPHITE | BATCH | 120 | 3.25 | .039 | 450 | 9 | 110 | 50 | STAND.SOL. | 6.7 | 5.0 | 20.0 | 0.00 | 0.90 | 3.0E6 | <10 | >5.5 | NO | |
| 160589 | B(Squ) | GRAPHITE | BATCH | 120 | 6.5 | .019 | 450 | 9 | 110 | 25 | STAND.SOL. | 5.7 | 4.9 | 21.0 | 0.00 | 1.34 | 3.0E6 | <1 | >6.5 | NO | |
| 180589 | B(Squ) | GRAPHITE | BATCH | 120 | 3.25 | .039 | 450/435 | 11 | 129 | 50 | NO $Cl^-$ | 6.0 | 5.0 | 22.0 | 0.00 | 0.00 | 6.8E6 | <3.5E3 | >3.3 | NO | |
| 220589 | B(Squ) | GRAPHITE | BATCH | 120 | 3.25 | .039 | 450/425 | 10 | 120 | 50 | NO $Cl^-$ | 6.4 | 4.9 | 20.0 | 0.00 | 0.00 | 7.7E6 | <1.4E3 | >3.7 | NO | |
| 070689 | B(Squ) | GRAPHITE | BATCH | 120 | 3.25 | .039 | 450 | 10.7 | 128 | 50 | NO $Cl^-$ | 6.3 | 5.0 | 21.0 | 0.00 | 0.00 | 6.3E | 3.9E6 | 0.2 | NO | |
| 080689 | A(P) | SIL.CARB. | RECIRC. | 191 | 0.10 | .360 | 91.7 | 42/43 | 42/43 | 14 | STAND.SOL. | 6.0 | 4.0 | 23.0 | 0.00 | 0.00 | 1.7E7 | 6.5E2 | 4.4 | NO | |
| 120689 | A(P) | SIL.CARB. | RECIRC. | 10 | 1.76 | .148 | 4.8 | 6/21 | 6/21 | 5.8 | STAND.SOL. | 6.1 | 5.8 | 23.0 | 0.00 | 0.00 | 3.5E6 | 8.8E4 | 1.6 | ~1REV/HR | |
| 190689 | A(P) | SIL.CARB. | RECIRC. | 30 | 1.50 | .150 | 14.4 | 8/27 | 8/27 | 5.8 | STAND.SOL. | - | - | 25.0 | - | - | 1.0E7 | 4.8E6 | 0.3 | ~1REV/HR | |
| 220689 | A(P) | SIL.CARB. | RECIRC. | 190 | 1.40 | .360 | 91.8 | ±40 | ±40 | 14 | STAND.SOL. | - | - | 29.0 | - | - | 1.3E7 | 8.0E4 | 2.2 | NO | |
| 220689 | A(P) | SIL.CARB. | RECIRC. | 45 | 1.40 | .360 | 22/16 | 24/30 | 24/3 | 14 | STAND.SOL. | - | - | 27.0 | - | - | 2.2E7 | 5.9E5 | 1.6 | 1REV/MIN | |

1)SEE SECTION 3 2)SEE SECTION 3 3)SEE SECTION 3.1 4)SEE SECTION 3.2

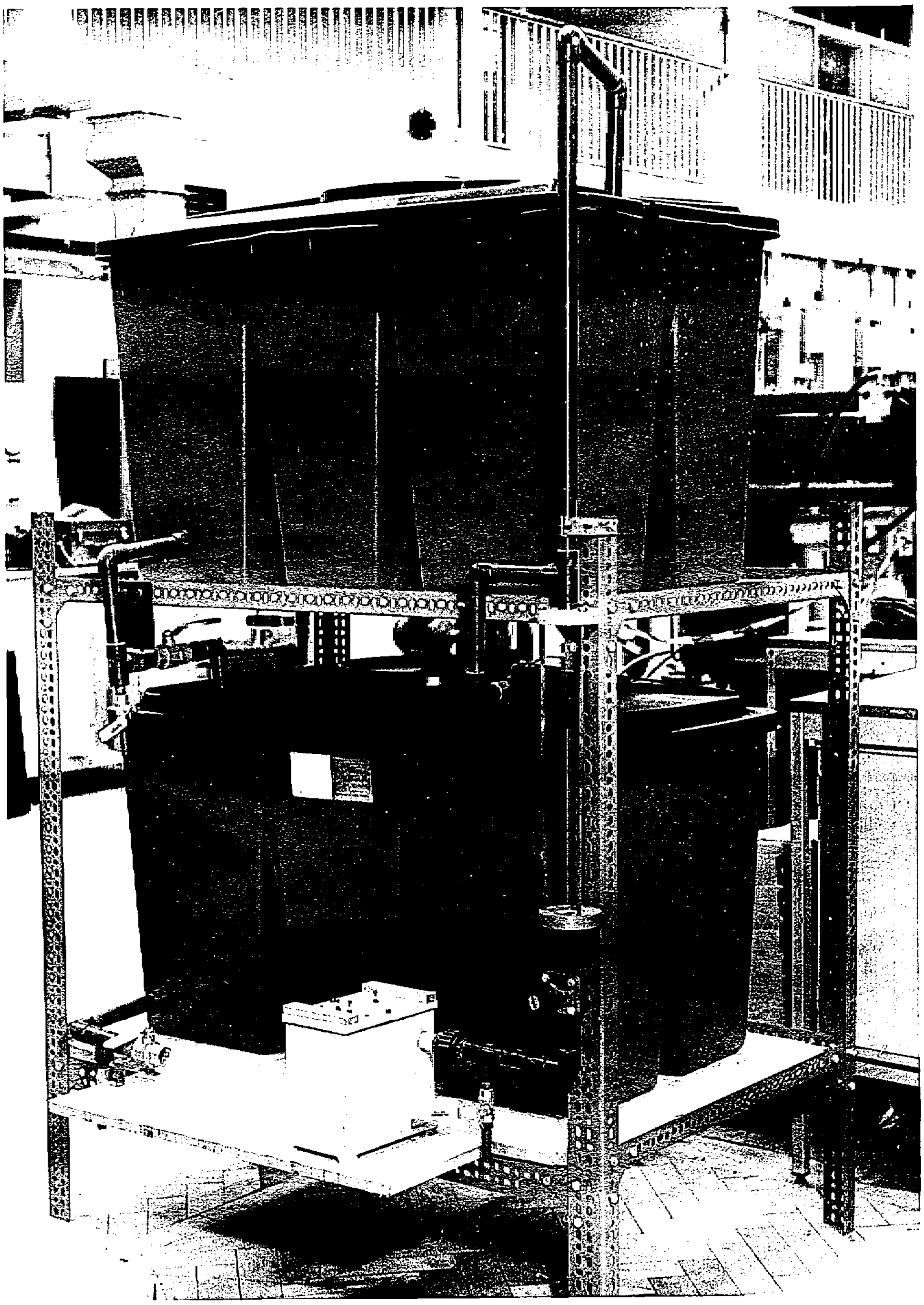
TABLE 1 : TEST CONDITIONS AND RESULTS SHEET 5



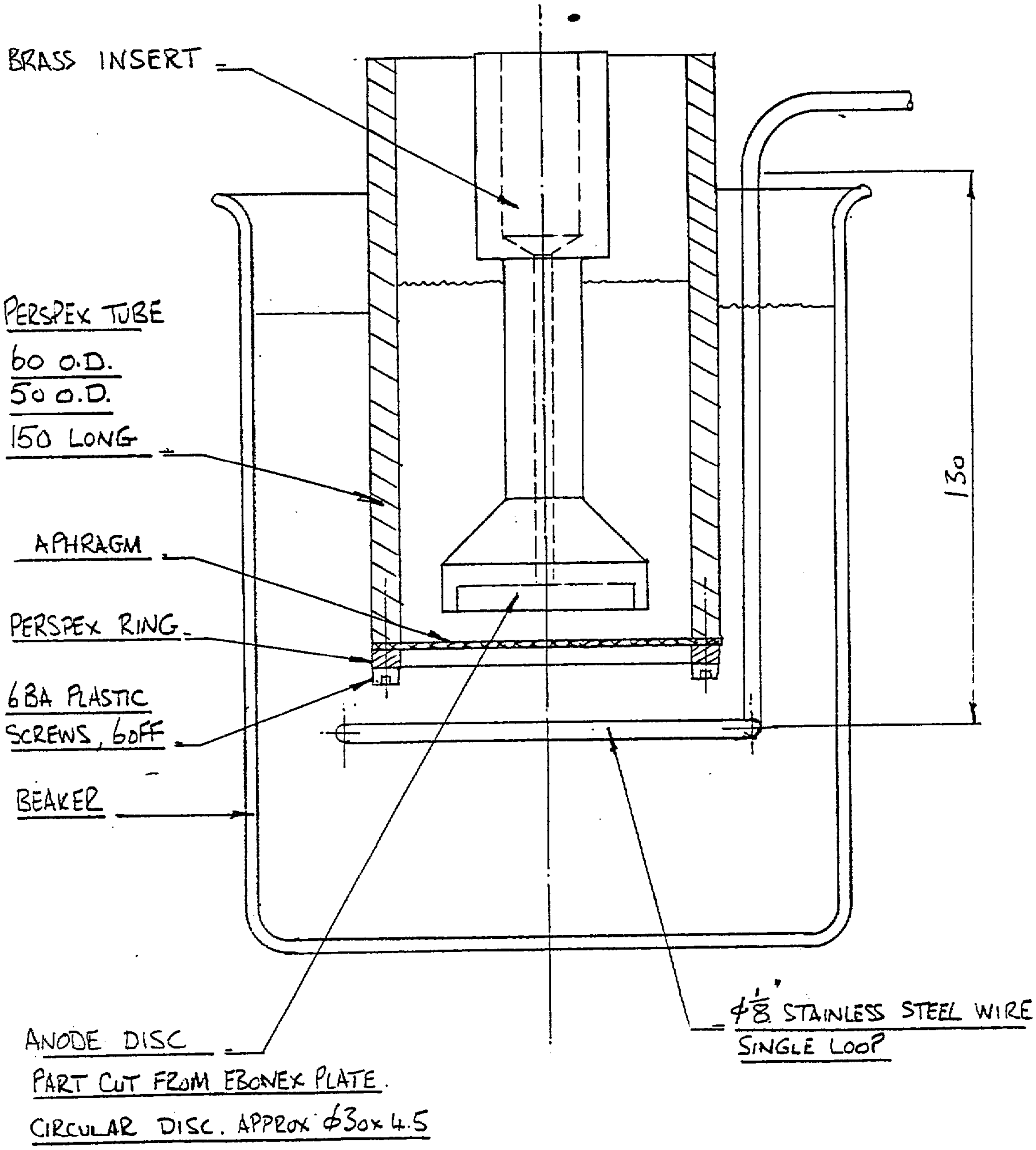
FIRST PROTOTYPE
ELECROLYTE CELL - GRAPHITE ELECTRODES FIG 1



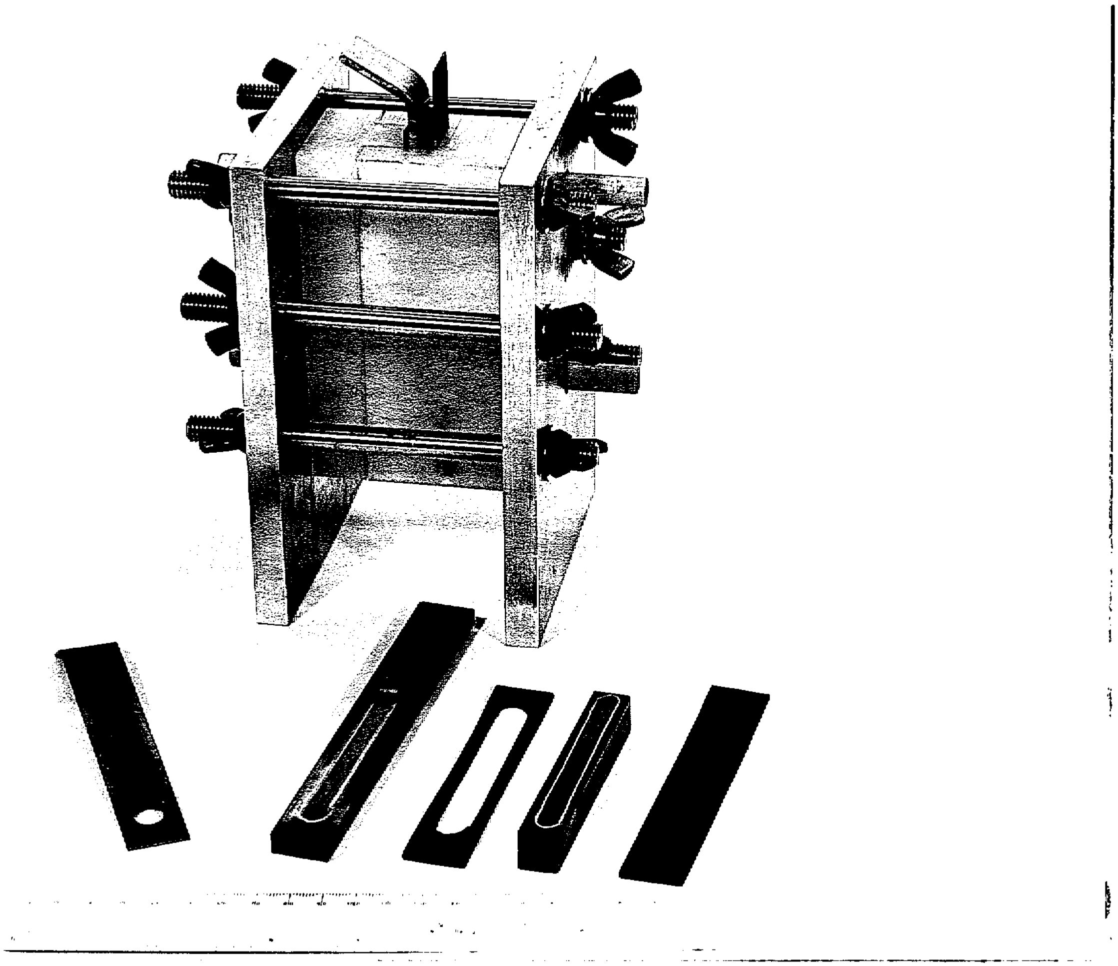
**FIRST PROTOTYPE - TEST RIG** **FIG 2**



PHOTOGRAPH OF FIRST PROTOTYPE TEST RIG FIG 3

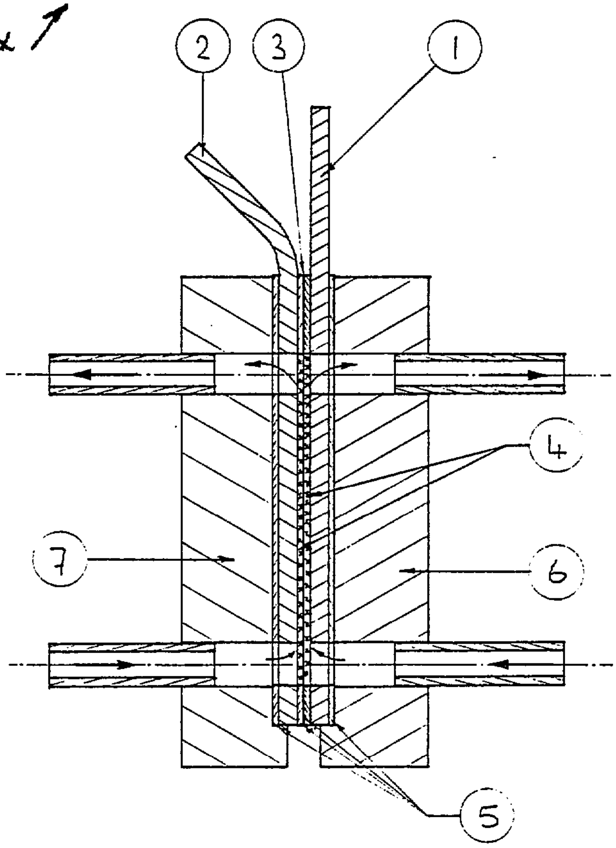


**BENCH SCALE TESTS**
**ELECROLYTIC CELL WITH DISC ANODE** **FIG 4**



EBONEX ↗

SILICON CARBONATE

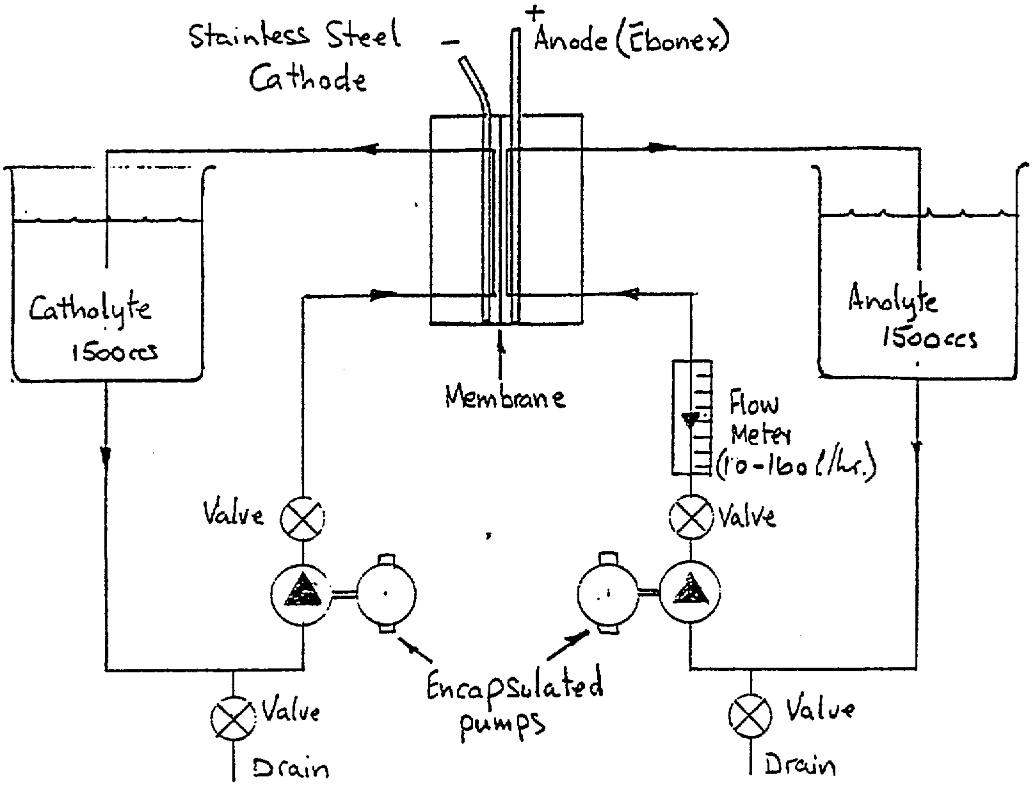


1. Ebonex Anode
2. Stainless Steel Cathode
3. Nafion Membrane
4. Mesh Turbulence Promoters
5. Rubber Seals

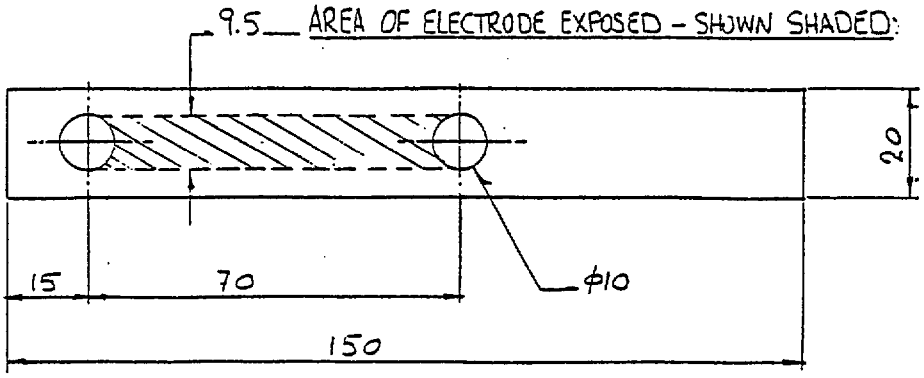
6. & 7. Polypropylene Plates

BENCH SCALE TESTS
PHOTOGRAPH AND DRAWING OF ELECTROLYTIC CELL
SHOWING COMPONENTS AND ELECTRODE TYPES

FIG 5

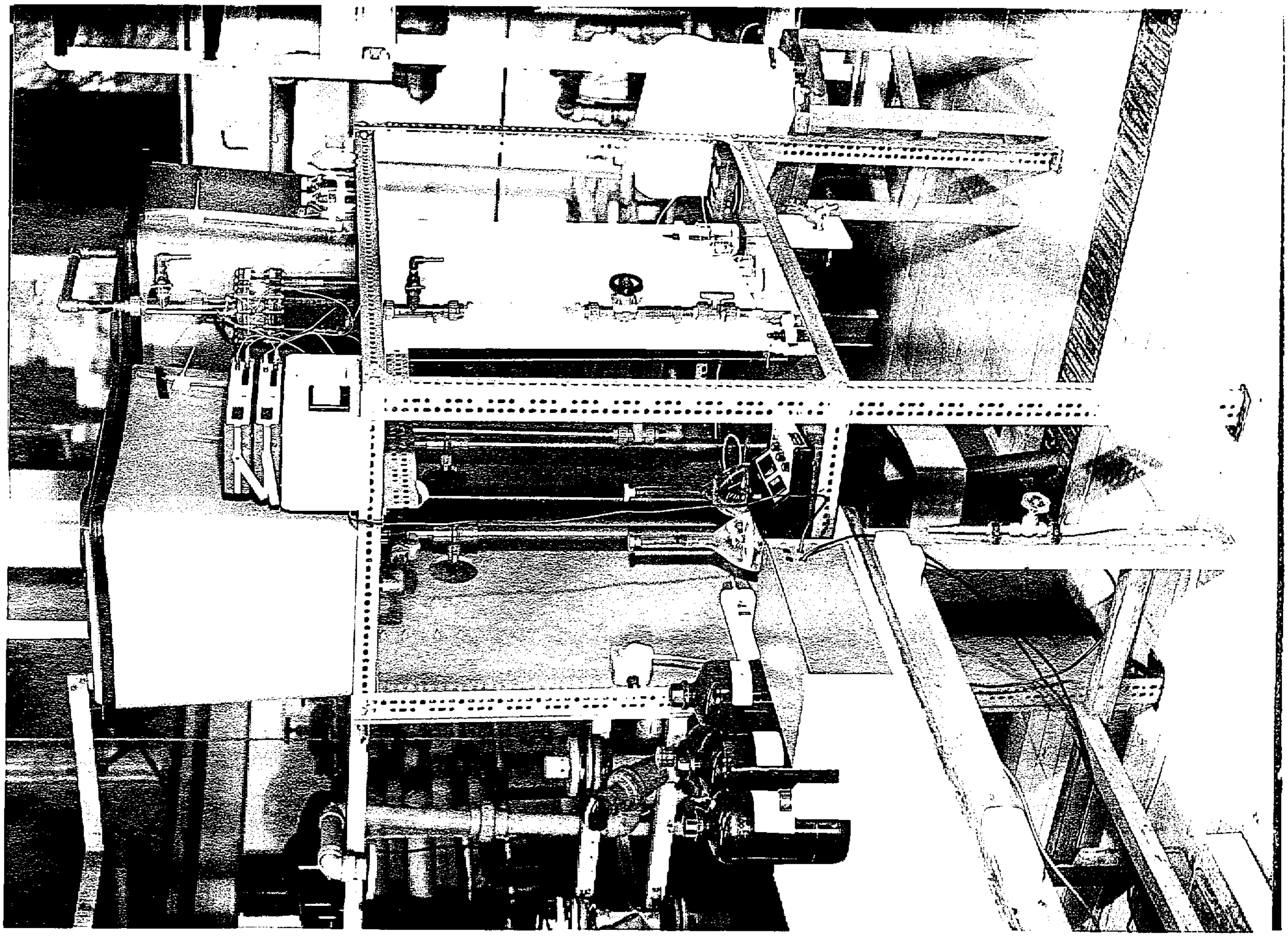


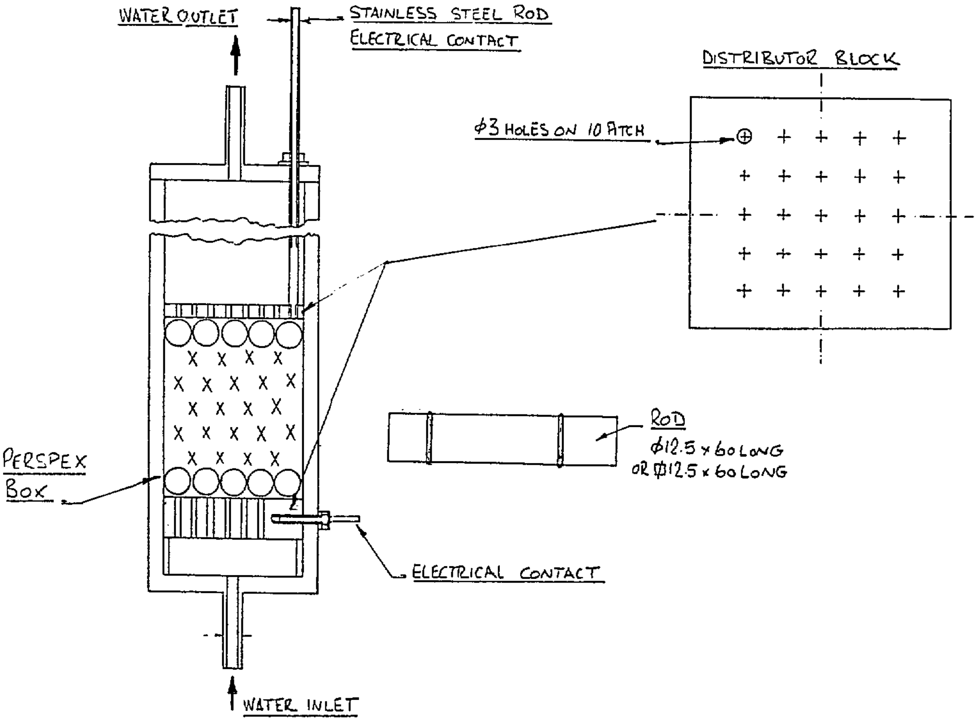
HYDRAULIC CIRCUIT



TYPICAL ELECTRODE DIMENSIONS IN (MM)

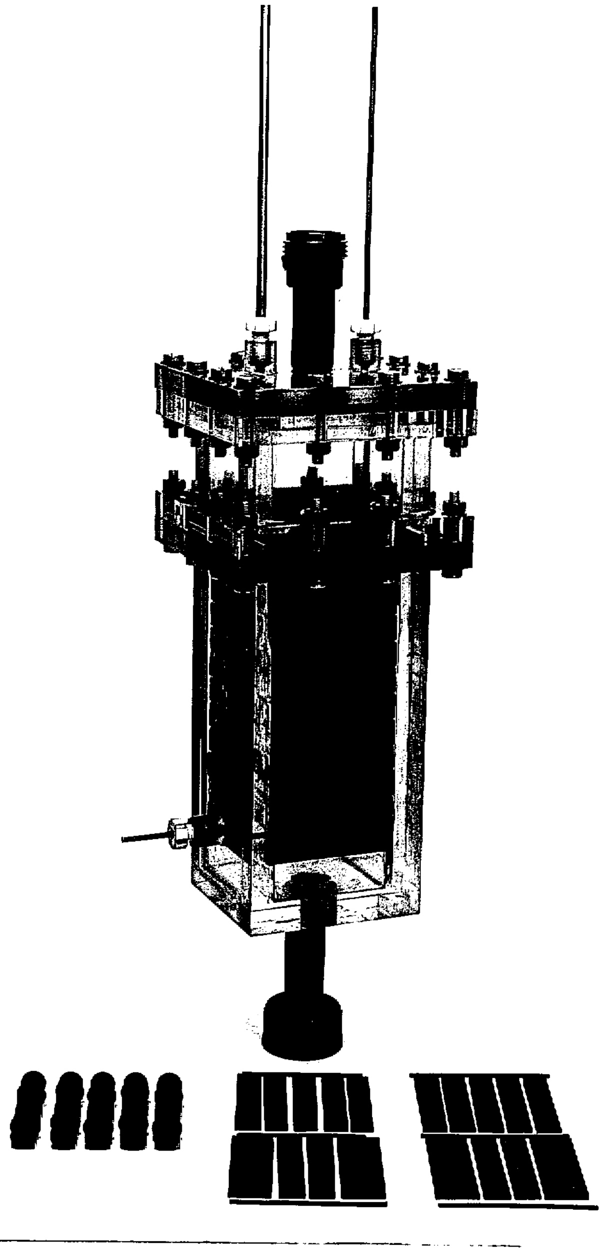
BENCH SCALE TESTS
HYDRAULIC CIRCUIT AND PLATE ELECRODE FIG 6



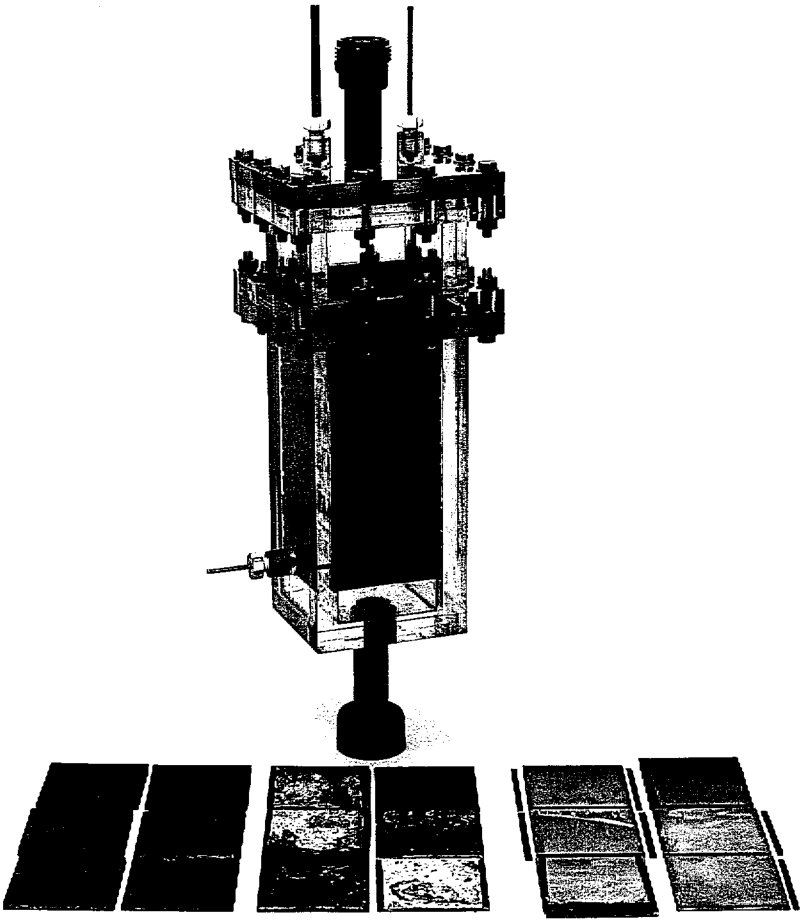


DRAWING SHOWING COMPONENTS OF BIPOLAR ROD CELL AND PHOTOGRAPH OF RIG

FIG 7



BIPOLAR ROD CELL SHOWING TYPES OF ROD USED FIG 8



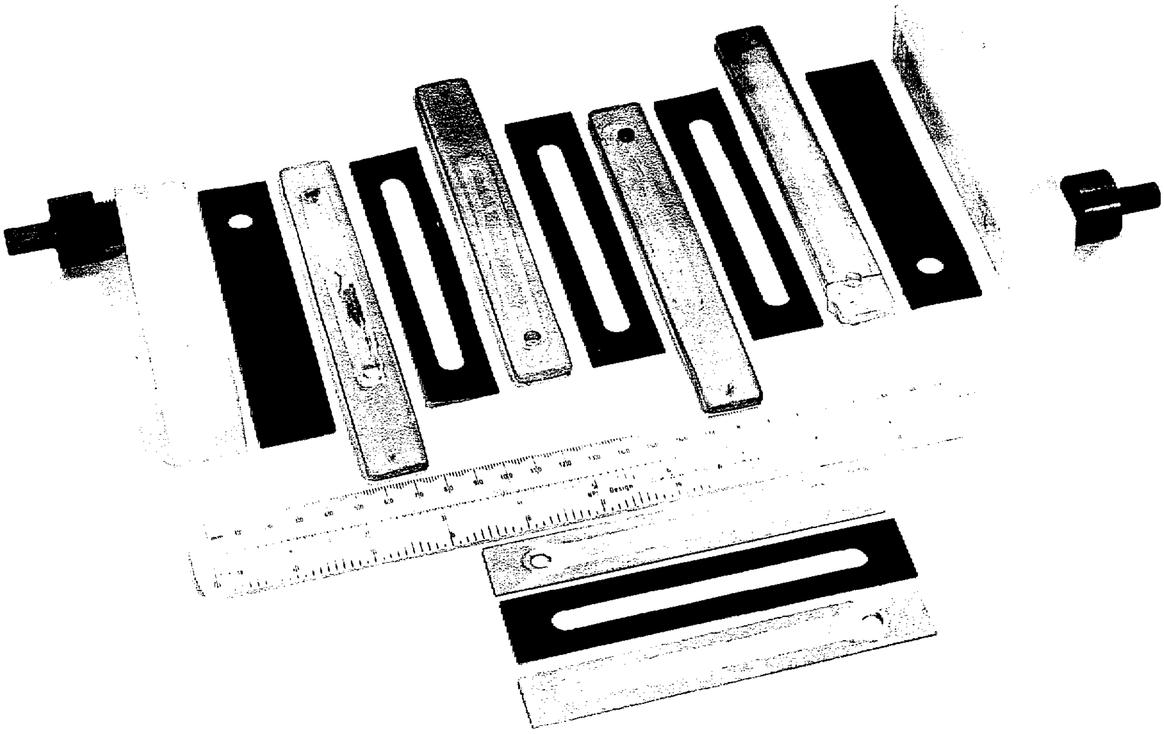
EBONEX (CURRENT REVERSED)

EBONEX (CURRENT NOT REV.)

TITANIUM (TEST 170588 )

PHOTOGRAPH SHOWING CELL BOX AND SOME OF THE PLATE ELECTRODES USED

FIG 9



PHOTOGRAPH SHOWING SERIES PLATE CELL FIG 10

## Fig 11 PERFORMANCE OF EBONEX SQUARE ROD CELL IN THE LABORATORY : A SUMMARY OF TEST CONDITIONS AND RESULTS

### (a) EFFECT OF NO CHLORIDES

| TEST NO. | CELL[1] TYPE | ELECTRODE MATERIAL[2] AN./CATH. | TEST[3] MODE | CURRENT DENSITY $A/M^2$ | CONTACT TIME SEC. | FLUID VEL. M/S | CELL CURRENT mA | CELL GAP VOLTAGE V | TOTAL CELL VOLTAGE V | FLOW RATE L/HR | ELECTROLYTE[4] | pH |  | TEMP °C | FREE $Cl_2$ ppm | TOTAL $Cl_2$ ppm | BACTERIOLOGICAL COUNT COUNT/100ML |  |  | POLARITY REVERSING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  |  |  | IN | OUT |  |  |  | INLET | OUTLET | LOG(INLET/OUTLET) |  |
| 131088 | B(Squ) | EBONEX | BATCH | 162/220 | 3.6 | .018 | 660/900 | 16/17 | 95/100 | 25 | STAND.SOL. | 6.4 | * | 23.0 | - | 5.30 | 2.5E6 | <2.0 | >6.1 | 30REV/HR |
| 181088 | B(Squ) | EBONEX | BATCH | 115/172 | 3.6 | .018 | 470/700 | 13/14 | 78/81 | 25 | STAND.SOL. | 6.4 | * | 21.0 | 2.00 | 2.60 | 1.2E6 | 2.0 * | 5.8 * | 30REV/HR |
| 181088 | B(Squ) | EBONEX | BATCH | 115/172 | 3.6 | .018 | 470/700 | 13/14 | 78/81 | 25 | STAND.SOL. | 6.4 | * | 21.0 | 2.00 | 2.60 | 1.2E6 | 6.0E2+ | 3.3 + | 30REV/HR |
| 181088 | B(Squ) | EBONEX | BATCH | 69/123 | 3.6 | .018 | 280/500 | /10 | 58/61 | 25 | STAND.SOL. | 6.4 | * | 22.0 | 0.60 | 1.00 | 1.7E6 | <1E2 * | >4.2 * | 30REV/HR |
| 181088 | B(Squ) | EBONEX | BATCH | 69/123 | 3.6 | .018 | 280/500 | /10 | 58/61 | 25 | STAND.SOL. | 6.4 | * | 22.0 | 0.60 | 1.00 | 1.7E6 | 1.2E4+ | 2.2 + | 30REV/HR |
| 261088 | B(Squ) | EBONEX | BATCH | 162/220 | 3.6 | .011 | 660/900 | 16/17 | 95/100 | 25 | NO $Cl^-$ | 6.4 | * | 23.0 | 0.00 | 0.00 | 2.1E6 | 3.8E2* | 3.7 * | 30REV/HR |
| 261088 | B(Squ) | EBONEX | BATCH | 162/220 | 3.6 | .011 | 660/900 | 16/17 | 95/100 | 25 | NO $Cl^-$ | 6.4 | * | 23.0 | 0.00 | 0.00 | 2.1E6 | 1.6E5+ | 1.1 + | 30REV/HR |
| 261088 | B(Squ) | EBONEX | BATCH | 115/172 | 3.6 | .011 | 470/700 | 13/14 | 78/81 | 25 | NO $Cl^-$ | 6.3 | * | 24.0 | 0.00 | 0.00 | 2.1E6 | 1.2E6* | 0.2 * | 30REV/HR |
| 261088 | B(Squ) | EBONEX | BATCH | 115/172 | 3.6 | .011 | 470/700 | 13/14 | 78/81 | 25 | NO $Cl^-$ | 6.3 | * | 24.0 | 0.00 | 0.00 | 2.1E6 | 1.7E6+ | 0.1 + | 30REV/HR |

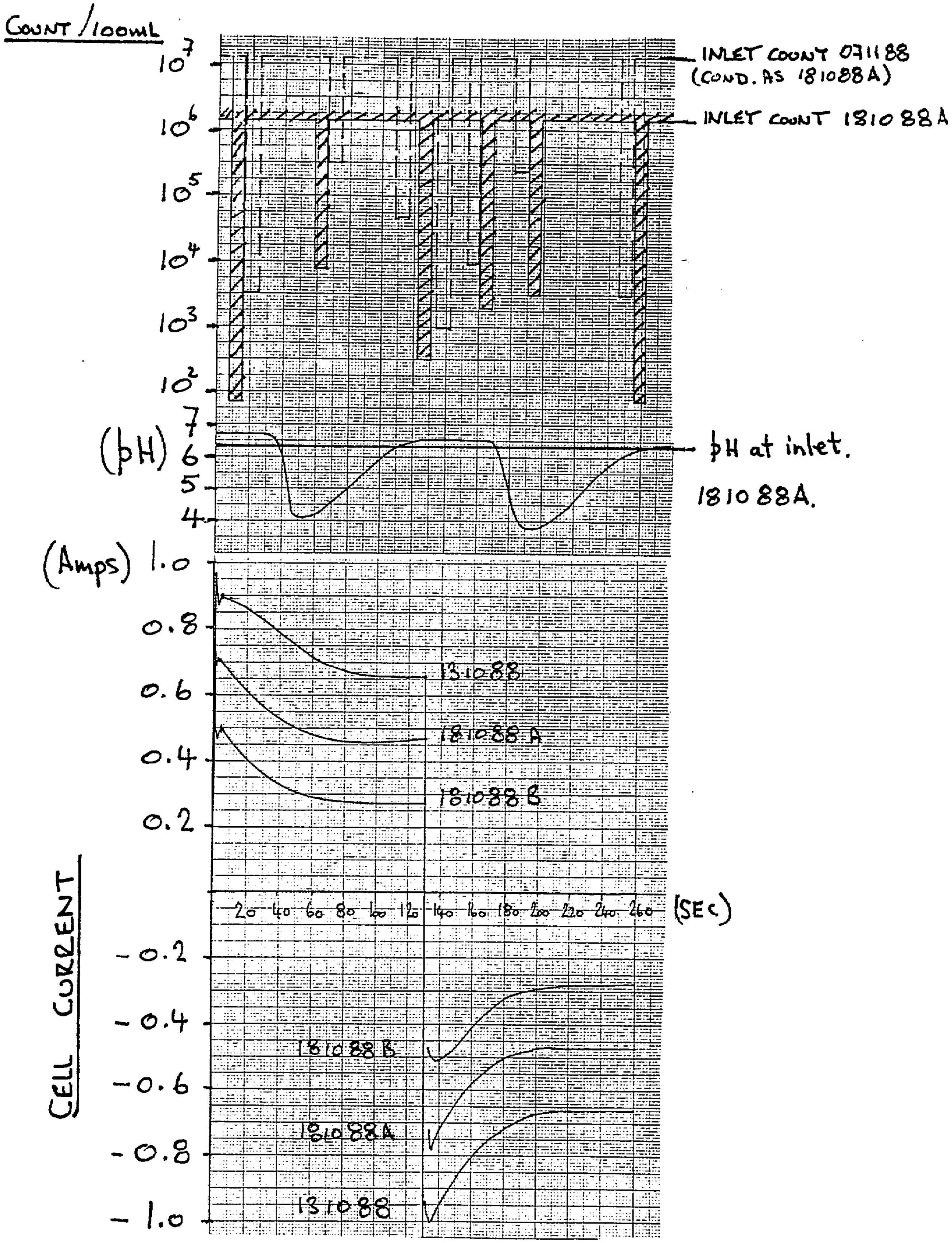
### (b) EFFECT ON FAECAL STREPTOCOCCI

| TEST NO. | CELL[1] TYPE | ELECTRODE MATERIAL[2] AN./CATH. | TEST[3] MODE | CURRENT DENSITY $A/M^2$ | CONTACT TIME SEC. | FLUID VEL. M/S | CELL CURRENT mA | CELL GAP VOLTAGE V | TOTAL CELL VOLTAGE V | FLOW RATE L/HR | ELECTROLYTE[4] | pH |  | TEMP °C | FREE $Cl_2$ ppm | TOTAL $Cl_2$ ppm | BACTERIOLOGICAL COUNT COUNT/100ML |  |  | POLARITY REVERSING | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  |  |  | IN | OUT |  |  |  | INLET | OUTLET | LOG(INLET/OUTLET) |  |  |
| 181088 | B(Squ) | EBONEX | BATCH | 69/123 | 3.6 | .018 | 280/500 | /10 | 58/61 | 25 | STAND.SOL. | 6.4 | * | 22.0 | 0.60 | 1.00 | 1.7E6 | <1E2 * | >4.2 * | 30REV/HR |  |
| 181088 | B(Squ) | EBONEX | BATCH | 69/123 | 3.6 | .018 | 280/500 | /10 | 58/61 | 25 | STAND.SOL. | 6.4 | * | 22.0 | 0.60 | 1.00 | 1.7E6 | 1.2E4+ | 2.2 + | 30REV/HR |  |
| 011188 | B(Squ) | EBONEX | BATCH | 73/122 | 3.6 | .011 | 280/480 | ±14 | ±82 | 25 | STAND.SOL. | 6.4 | 6.7 | 20.0 | 0.00 | 3.90 | 1.1E7 | 3.2E2 | 4.5 | 2REV/HR | FAECAL STREPT. |
| 011188 | B(Squ) | EBONEX | BATCH | 73/122 | 3.6 | .011 | 280/480 | ±14 | ±82 | 25 | STAND.SOL. | 6.4 | 6.7 | 20.0 | 0.00 | 3.90 | 1.6E7 | <10 | >6.2 | 2REV/HR | E-COLI |

### (c) SIX DAY TEST

| TEST NO. | CELL[1] TYPE | ELECTRODE MATERIAL[2] AN./CATH. | TEST[3] MODE | CURRENT DENSITY $A/M^2$ | CONTACT TIME SEC. | FLUID VEL. M/S | CELL CURRENT mA | CELL GAP VOLTAGE V | TOTAL CELL VOLTAGE V | FLOW RATE L/HR | ELECTROLYTE[4] | pH |  | TEMP °C | FREE $Cl_2$ ppm | TOTAL $Cl_2$ ppm | BACTERIOLOGICAL COUNT COUNT/100ML |  |  | POLARITY REVERSING | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  |  |  | IN | OUT |  |  |  | INLET | OUTLET | LOG(INLET/OUTLET) |  |  |
| 171188 | B(Squ) | EBONEX | BATCH | 124 | 3.6 | .011 | -500 | -13 | -80 | 25 | STAND.SOL. | 6.2 | 6.8 | 21.0 | - | 4.20 | 1.7E7 | <1.0 | >7.2 | 2REV/HR | PREVIOUS TEST |
| 171188 | B(Squ) | EBONEX | BATCH | 124 | 3.6 | .011 | +500 | +13 | +80 | 25 | STAND.SOL. | 6.2 | 6.0 | 21.0 | - | 3.40 | 1.7E7 | <1.0 | >7.2 | 2REV/HR |  |
| 171188 | B(Squ) | EBONEX | BATCH | 124 | 1.8 | .036 | +500 | +13 | +80 | 50 | STAND.SOL. | 6.2 | 6.2 | 21.0 | - | 2.20 | 1.7E7 | <1.0 | >7.2 | 2REV/HR |  |
| 221188 | B(Squ) | EBONEX | BATCH | 128/148 | 1.8 | .036 | 520/600 | -13 | -80 | 50 | STAND.SOL. | 6.5 |  | 20.0 | - | 2.30 | 1.6E7 | 8.7E3 | 3.3 | 2REV/HR |  |
| 221188 | B(Squ) | EBONEX | BATCH | 118/124 | 1.8 | .036 | 480/510 | +13 | +80 | 50 | STAND.SOL. | 6.5 |  | 20.0 | - | 0.44 | 1.6E7 | <1.0 ** | >7.2 | 2REV/HR | **OUTLET TANK |
| 221188 | B(Squ) | EBONEX | BATCH | 118/124 | 1.8 | .036 | 480/510 | +13 | +80 | 50 | STAND.SOL. | 4.3 |  | 21.0 | - | - | 1.6E7 | 7.1E3 | 3.4 | 2REV/HR |  |
| 281188 | B(Squ) | EBONEX | BATCH | 124 | 3.6 | .018 | -500 | -19 | -114 | 25 | STAND.SOL. | 6.1 | 5.7 | 20.0 | 1.60 | 3.20 | 1.7E7 | 1.8E3 | 4.0 | 2REV/HR | AFTER 6 DAYS |
| 281188 | B(Squ) | EBONEX | BATCH | 124 | 3.6 | .018 | +500 | +17 | +100 | 25 | STAND.SOL. | 6.1 | 5.7 | 20.0 | 3.20 | 4.30 | 1.7E7 | 1.0 | 7.2 | 2REV/HR | AFTER 6 DAYS |
| 281188 | B(Squ) | EBONEX | BATCH | 124 | 1.8 | .036 | +500 | +17 | +100 | 50 | STAND.SOL. | 5.4 |  | 20.0 | 1.70 | 2.80 | 1.7E7 | 2.0 | 6.9 | 2REV/HR | AFTER 6 DAYS |

## Investigation of Variation of Cell Current, pH, and Bacteriological Kill During the Current Reversal Cycle



Voltage Constant

EBONEX SQUARE ROD CELL
CONTACT TIME 3.6 SEC. CURRENT REVERSING 30 REV./HR. FIG12

## Fig13 PERFORMANCE OF EBONEX SQUARE ROD CELL IN THE LABORATORY WITH STANDARD ELECTROLYTE SOLUTION AND INOCULATED WITH STANDARD E-COLI CULTURE

### A SUMMARY OF TEST CONDITIONS AND RESULTS.

(a) CURRENT REVERSING 2/HR.

| TEST NO. | CELL$^1$ TYPE | ELECTRODE MATERIAL$^2$ AN./CATH. | TEST$^3$ MODE | CURRENT DENSITY A/M$^2$ | CONTACT TIME SEC. | FLUID VEL. M/S | CELL CURRENT mA | CELL GAP VOLTAGE V | TOTAL CELL VOLTAGE V | FLOW RATE L/HR | ELECTROLYTE$^4$ | pH | | TEMP $^0$C | FREE Cl$_2$ ppm | TOTAL Cl$_2$ ppm | BACTERIOLOGICAL COUNT COUNT/100ML | | | POLARITY REVERSING | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | IN | OUT | | | | INLET | OUTLET | LOG(INLET / OUTLET) | | |
| 141188 | B(Squ) | EBONEX | BATCH | 120 | 3.6 | .011 | 480/500 | -13 | -80 | 25 | STAND.SOL. | 6.2 | 7.1 | 21.0 | 3.00 | 4.30 | 1.9E7 | <10 | >6.3 | 2REV/HR | ELECTR. CLEA |
| 141188 | B(Squ) | EBONEX | BATCH | 120 | 3.6 | .011 | 490/500 | +13 | +80 | 25 | STAND.SOL. | 6.2 | 6.1 | 21.0 | 4.50 | 5.00 | 1.9E7 | <10 | >6.3 | 2REV/HR | ELECTR. CLEA |
| 171188 | B(Squ) | EBONEX | BATCH | 124 | 3.6 | .011 | -500 | -13 | -80 | 25 | STAND.SOL. | 6.2 | 6.8 | 21.0 | - | 4.20 | 1.7E7 | <1.0 | >7.2 | 2REV/HR | |
| 171188 | B(Squ) | EBONEX | BATCH | 124 | 3.6 | .011 | +500 | +13 | +80 | 25 | STAND.SOL. | 6.2 | 6.0 | 21.0 | - | 3.40 | 1.7E7 | <1.0 | >7.2 | 2REV/HR | |
| 171188 | B(Squ) | EBONEX | BATCH | 124 | 1.8 | .036 | +500 | +13 | +80 | 50 | STAND.SOL. | 6.2 | 6.2 | 21.0 | - | 2.20 | 1.7E7 | <1.0 | >7.2 | 2REV/HR | |

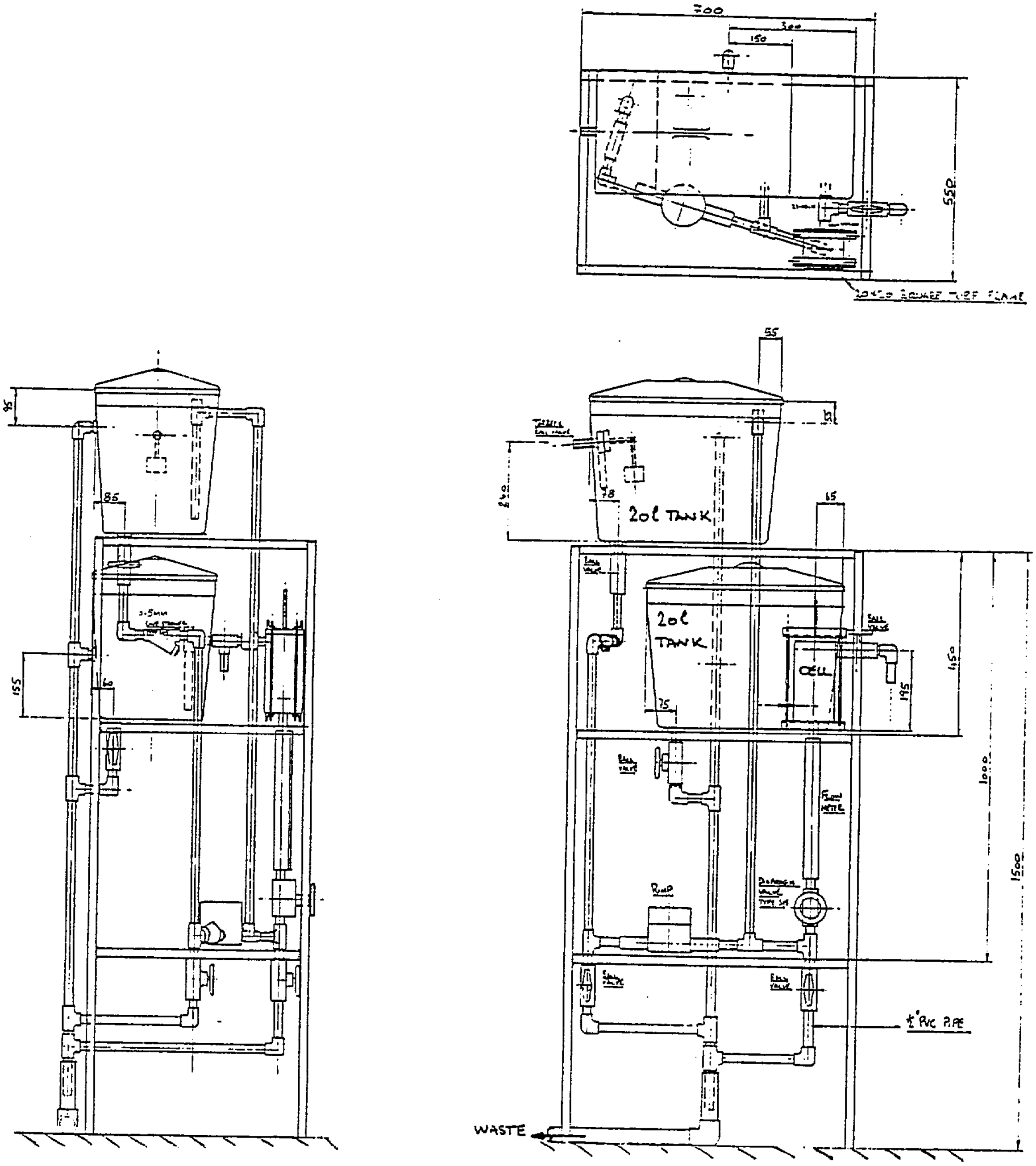
(b) CURRENT REVERSING 30/HR.

| TEST NO. | CELL$^1$ TYPE | ELECTRODE MATERIAL$^2$ AN./CATH. | TEST$^3$ MODE | CURRENT DENSITY A/M$^2$ | CONTACT TIME SEC. | FLUID VEL. M/S | CELL CURRENT mA | CELL GAP VOLTAGE V | TOTAL CELL VOLTAGE V | FLOW RATE L/HR | ELECTROLYTE$^4$ | pH | | TEMP $^0$C | FREE Cl$_2$ ppm | TOTAL Cl$_2$ ppm | BACTERIOLOGICAL COUNT COUNT/100ML | | | POLARITY REVERSING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | IN | OUT | | | | INLET | OUTLET | LOG(INLET / OUTLET) | |
| 111088 | B(Squ) | EBONEX | BATCH | 118/167 | 1.8 | .036 | 480/680 | 12/13 | 74/77 | 50 | STAND.SOL. | 6.0 | * | 21.0 | 1.20 | 2.50 | 7.0E6 | 1.1E3* | 3.8* | 30REV/HR |
| 111088 | B(Squ) | EBONEX | BATCH | 118/167 | 1.8 | .036 | 480/680 | 12/13 | 74/77 | 50 | STAND.SOL. | 6.0 | * | 21.0 | 1.20 | 2.50 | 7.0E6 | 3.1E5+ | 1.4+ | 30REV/HR |
| 131088 | B(Squ) | EBONEX | BATCH | 162/220 | 3.6 | .018 | 660/900 | 16/17 | 95/100 | 25 | STAND.SOL. | 6.4 | * | 23.0 | - | 5.30 | 2.5E6 | <2.0 | >6.1 | 30REV/HR |
| 181088 | B(Squ) | EBONEX | BATCH | 115/172 | 3.6 | .018 | 470/700 | 13/14 | 78/81 | 25 | STAND.SOL. | 6.4 | * | 21.0 | 2.00 | 2.60 | 1.2E6 | 2.0 * | 5.8 * | 30REV/HR |
| 181088 | B(Squ) | EBONEX | BATCH | 115/172 | 3.6 | .018 | 470/700 | 13/14 | 78/81 | 25 | STAND.SOL. | 6.4 | * | 21.0 | 2.00 | 2.60 | 1.2E6 | 6.0E2+ | 3.3 + | 30REV/HR |
| 181088 | B(Squ) | EBONEX | BATCH | 69/123 | 3.6 | .018 | 280/500 | /10 | 58/61 | 25 | STAND.SOL. | 6.4 | * | 22.0 | 0.60 | 1.00 | 1.7E6 | <1E2 * | >4.2 * | 30REV/HR |
| 181088 | B(Squ) | EBONEX | BATCH | 69/123 | 3.6 | .018 | 280/500 | /10 | 58/61 | 25 | STAND.SOL. | 6.4 | * | 22.0 | 0.60 | 1.00 | 1.7E6 | 1.2E4+ | 2.2 + | 30REV/HR |
| 241088 | B(Squ) | EBONEX | BATCH | 162/220 | 1.8 | .036 | 660/900 | 16/17 | 95/100 | 50 | STAND.SOL. | 6.4 | * | 18.0 | 4.50 | 4.80 | 3.2E6 | <1.0 * | >6.5 * | 30REV/HR |
| 241088 | B(Squ) | EBONEX | BATCH | 162/220 | 1.8 | .036 | 660/900 | 16/17 | 95/100 | 50 | STAND.SOL. | 6.4 | * | 18.0 | 4.50 | 4.80 | 3.2E6 | 5.8E3+ | 2.7 + | 30REV/HR |
| 241088 | B(Squ) | EBONEX | BATCH | 115/172 | 1.8 | .036 | 470/700 | 13/14 | 78/81 | 50 | STAND.SOL. | 6.4 | * | 18.0 | 1.10 | 0.90 | 3.2E6 | 6.0E2* | 3.7 * | 30REV/HR |
| 241088 | B(Squ) | EBONEX | BATCH | 115/172 | 1.8 | .036 | 470/700 | 13/14 | 78/81 | 50 | STAND.SOL. | 6.4 | * | 18.0 | 1.10 | 0.90 | 3.2E6 | 3.8E6+ | 0.0 + | 30REV/HR |
| 241088 | B(Squ) | EBONEX | BATCH | 115/172 | 6.0 | .0096 | 470/700 | 13/14 | 78/81 | 15 | STAND.SOL. | 6.4 | * | 19.0 | 2.10 | 2.50 | 3.2E6 | <1E2 | >4.5 | 30REV/HR |

(c) CURRENT REVERSING 30/MIN.

| TEST NO. | CELL$^1$ TYPE | ELECTRODE MATERIAL$^2$ AN./CATH. | TEST$^3$ MODE | CURRENT DENSITY A/M$^2$ | CONTACT TIME SEC. | FLUID VEL. M/S | CELL CURRENT mA | CELL GAP VOLTAGE V | TOTAL CELL VOLTAGE V | FLOW RATE L/HR | ELECTROLYTE$^4$ | pH | | TEMP $^0$C | FREE Cl$_2$ ppm | TOTAL Cl$_2$ ppm | BACTERIOLOGICAL COUNT COUNT/100ML | | | POLARITY REVERSING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | IN | OUT | | | | INLET | OUTLET | LOG(INLET / OUTLET) | |
| 011188 | B(Squ) | EBONEX | BATCH | 73/122 | 3.6 | .011 | 280/480 | ±14 | ±82 | ≈25 | STAND.SOL. | 6.5 | 6.3 | 20.0 | 0.00 | 0.00 | 1.6E7 | 5.4E6 | 0.5 | 30REV/MIN |

Fig. 13



HORSLEY FIELD TRIALS
DRAWING OF TREATMENT UNIT FIG 14

Fig 15 INVESTIGATION OF VARIOUS ELECTRODE MATERIALS A SUMMARY OF TEST CONDITIONS AND RESULTS

## (a) TIN OXIDE

| TEST NO. | CELL[1] TYPE | ELECTRODE MATERIAL[2] AN./CATH. | TEST[3] MODE | CURRENT DENSITY $A/M^2$ | CONTACT TIME SEC. | FLUID VEL. M/S | CELL CURRENT mA | CELL GAP VOLTAGE V | TOTAL CELL VOLTAGE V | FLOW RATE L/HR | ELECTROLYTE[4] | pH | | TEMP $^oC$ | FREE $Cl_2$ ppm | TOTAL $Cl_2$ ppm | BACTERIOLOGICAL COUNT COUNT/100ML | | | POLARITY REVERSING | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | IN | OUT | | | | INLET | OUTLET | LOG(INLET/OUTLET) | | |
| 270988 | D(Rect.) | TIN OXIDE | BATCH | 120 | 1.3 | .062 | 300/380 | 17.0 | 136 | 50 | STAND.SOL. | 6.9 | 7.5 | 21.0 | 0.00 | 0.00 | 6.4E6 | 4.0E6 | 0.2 | NO | PRECIPITATE |
| 300988 | D(Rect.) | TIN OXIDE | BATCH | 120 | 1.3 | .062 | 330 | 17.0 | 135 | 50 | STAND.SOL. | 6.7 | - | 20.0 | - | 0.00 | - | - | - | NO | PREC. AND Ω-UP |

## (b) CONDUCTING GLASS

| TEST NO. | CELL[1] TYPE | ELECTRODE MATERIAL[2] AN./CATH. | TEST[3] MODE | CURRENT DENSITY $A/M^2$ | CONTACT TIME SEC. | FLUID VEL. M/S | CELL CURRENT mA | CELL GAP VOLTAGE V | TOTAL CELL VOLTAGE V | FLOW RATE L/HR | ELECTROLYTE[4] | pH | | TEMP $^oC$ | FREE $Cl_2$ ppm | TOTAL $Cl_2$ ppm | BACTERIOLOGICAL COUNT COUNT/100ML | | | POLARITY REVERSING | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | IN | OUT | | | | INLET | OUTLET | LOG(INLET/OUTLET) | | |
| 121288 | A(P) | CON.GLASS | RECIRC | 115 | 0.5 | 0.3 | 95 | 17.4 | 17.4 | 18 | STAND.SOL. | 6.8 | 7.0 | 27.0 | 0.50 | 1.50 | 8.7E6 | <1.0 | >6.9 | NO | TURB. PROM. |
| 191288 | A(P) | CON.GLASS | RECIRC | 112 | 1.0 | 0.3 | 92 | 15 | 15 | 18 | STAND.SOL. | - | - | 23.0 | 0.00 | 0.90 | 3.0E4 | <1.0 | >6.9 | NO | |

## (c) CONDUCTING GLASS

| TEST NO. | CELL[1] TYPE | ELECTRODE MATERIAL[2] AN./CATH. | TEST[3] MODE | CURRENT DENSITY $A/M^2$ | CONTACT TIME SEC. | FLUID VEL. M/S | CELL CURRENT mA | CELL GAP VOLTAGE V | TOTAL CELL VOLTAGE V | FLOW RATE L/HR | ELECTROLYTE[4] | pH | | TEMP $^oC$ | FREE $Cl_2$ ppm | TOTAL $Cl_2$ ppm | BACTERIOLOGICAL COUNT COUNT/100ML | | | POLARITY REVERSING | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | IN | OUT | | | | INLET | OUTLET | LOG(INLET/OUTLET) | | |
| 060289 | E(Plate) | CON.GLASS | BATCH | 120/98 | 1.4 | 0.3 | 456/372 | -38 | -38 | 16 | STAND.SOL. | - | - | 22.0 | - | 2.30 | 1.9E7 | 16.0 | 6.1 | NO | |
| 060289 | E(Plate) | CON.GLASS | BATCH | 120/98 | 1.4 | 0.3 | 456/450 | -45 | -45 | 16 | STAND.SOL. | - | - | 22.0 | - | 2.50 | 1.9E7 | 1.0 | 7.3 | NO | |
| 060289 | E(Plate) | CON.GLASS | BATCH | 5.4 | 1.4 | 0.3 | 30 | +45 | +45 | 16 | STAND.SOL. | - | - | 22.0 | - | 0.00 | 1.9E7 | 6.0E6 | 0.5 | YES | OX. LAYER REMOVED |
| 200389 | E(Plate) | CON.GLASS | BATCH | 120 | 1.5 | 0.28 | 500 | 32/34 | 32/45 | 15 | NO $Cl^-$ | 6.2 | 6.1 | 16.0 | 0.00 | 0.00 | 1.1E7 | 1.9E6 | 0.76 | NO | |
| 200389 | E(Plate) | CON.GLASS | BATCH | 120 | 1.5 | 0.28 | 500 | 55/60 | 55/60 | 15 | STAND.SOL. | 5.8 | 6.0 | 17.0 | 0.00 | 0.00 | 1.1E7 | 2.0E4 | 2.7 | YES | OX. LAYER REMOVED |

## (d) SILICON CARBIDE

| TEST NO. | CELL[1] TYPE | ELECTRODE MATERIAL[2] AN./CATH. | TEST[3] MODE | CURRENT DENSITY $A/M^2$ | CONTACT TIME SEC. | FLUID VEL. M/S | CELL CURRENT mA | CELL GAP VOLTAGE V | TOTAL CELL VOLTAGE V | FLOW RATE L/HR | ELECTROLYTE[4] | pH | | TEMP $^oC$ | FREE $Cl_2$ ppm | TOTAL $Cl_2$ ppm | BACTERIOLOGICAL COUNT COUNT/100ML | | | POLARITY REVERSING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | IN | OUT | | | | INLET | OUTLET | LOG(INLET/OUTLET) | |
| 080689 | A(P) | SIL.CARB. | RECIRC. | 191 | 0.10 | .360 | 91.7 | 42/43 | 42/43 | 14 | STAND.SOL. | 6.0 | 4.0 | 23.0 | 0.00 | 0.00 | 1.7E7 | 6.5E2 | 4.4 | NO |
| 120689 | A(P) | SIL.CARB. | RECIRC. | 10 | 1.76 | .148 | 4.8 | 6/21 | 6/21 | 5.8 | STAND.SOL. | 6.1 | 5.8 | 23.0 | 0.00 | 0.00 | 3.5E6 | 8.8E4 | 1.6 | NO |
| 190689 | A(P) | SIL.CARB. | RECIRC. | 30 | 1.50 | .150 | 14.4 | 8/27 | 8/27 | 5.8 | STAND.SOL. | - | - | 25.0 | - | - | 1.0E7 | 4.8E6 | 0.3 | ~1REV/HR |
| 220689 | A(P) | SIL.CARB. | RECIRC. | 190 | 1.40 | .360 | 91.8 | ±40 | ±40 | 14 | STAND.SOL. | - | - | 29.0 | - | - | 1.3E7 | 8.0E4 | 2.2 | 1REV/MIN |
| 220689 | A(P) | SIL.CARB. | RECIRC. | 45 | 1.40 | .360 | 22/16 | 24/30 | 24/30 | 14 | STAND.SOL. | - | - | 27.0 | - | - | 2.2E7 | 5.9E5 | 1.6 | NO |

## (e) TITANIUM

| TEST NO. | CELL[1] TYPE | ELECTRODE MATERIAL[2] AN./CATH. | TEST[3] MODE | CURRENT DENSITY $A/M^2$ | CONTACT TIME SEC. | FLUID VEL. M/S | CELL CURRENT mA | CELL GAP VOLTAGE V | TOTAL CELL VOLTAGE V | FLOW RATE L/HR | ELECTROLYTE[4] | pH | | TEMP $^oC$ | FREE $Cl_2$ ppm | TOTAL $Cl_2$ ppm | BACTERIOLOGICAL COUNT COUNT/100ML | | | POLARITY REVERSING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | IN | OUT | | | | INLET | OUTLET | LOG(INLET/OUTLET) | |
| 170588 | C(Plate) | TITANIUM | BATCH | 185/195 | 1.3 | .051 | 560/590 | 17.5 | 122 | 50 | STAND.SOL. | 6.9 | 7.5 | 22.0 | 0.00 | 0.00 | 7.0E6 | >1.0E5 | <1.8 | NO |