Development of a Small-Scale Vertical Stack Oyster Purification Plant with Repeated Re-Use of Artificial Seawater

Seafish Report No.459

January 1991 (revised 1995)

The Sea Fish Industry Authority

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Summary

This report describes further development towards a standard design of small-scale vertical stack mollusc purification plant, and extended trials of the re-use of artificial seawater for the purification of pacific oysters in this type of plant.

The work was carried out at the premises of the Essex Oyster and Seafood Company Limited at Maldon using the prototype vertical stack purification plant developed earlier by Seafish and a more developed commercial prototype built for the company. Oysters from the nearby Goldhanger Creek were purified in the plant and the water re-used a total of 15 times over a 73 day period. Samples of the oysters were artificially contaminated to create a more severe test of purification.

Further detailed work is required to complete the standard design but the trials results indicate successful purification throughout the period. Following the trials the commercial prototype plant was granted a provisional operating license by the Department of Health.

Contents

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1. Introduction

To improve the conditions and efficiency under which bivalve molluscs are purified and reduce the cost and delay in obtaining operating licences, Seafish are developing the concept of three standard design high density purification systems of large, medium and finally small-scale (Refs: 1 to 5). These plants have the advantage of having a reduced volume enabling them to be housed in a building and have been developed also for use with artificial seawater (ASW). Small size and the use of ASW enables the systems to be sited in any commercial location, and not be tied to a suitable seawater source.

The main drawback of using ASW has been its cost as the operating criteria previously recommended by Ministry of Agriculture, Fisheries and Food (MAFF) allowed only three uses before being drained to waste. Seafish has already investigated the repeated re-use of ASW over long periods for the purification of mussels in order to substantially reduce this cost (Refs: 6 and 7).

A large-scale deep stacked mussel purification tank with extensive re-use of ASW has already been developed to a commercial stage (Refs: 1 and 2). A medium-scale deep stacked mussel purification tank has been similarly developed and this very high density tank uses only a small quantity of water but with limited re-use (Refs: 3 and 4).

A prototype small-scale vertical stack system has been under developed by Seafish as part of a programme investigating the purification criteria of pacific oysters (Ref: 5). Its small size means that it was particularly suited for oysters and other high value species which are normally handled in small quantities. There was a need to develop the prototype into a standard design and to investigate the re-use of ASW with oysters.

This report describes trials of the repeated re-use of ASW in the purification of oysters *Crasstostrea gigas* in the prototype vertical stacking purification plant, and further development towards a standard design for a small-scale vertical stack purification plant.

2. Objectives

2.1 To develop and prove a standard design of small scale vertical stack purification tank.

2.2 To investigate the repeated re-use of artificial sea water for an extended period with pacific oysters.

3. Outline of Trials Sequence

The sequence consisted of 15 consecutive oyster purification trials in the vertical stack purification plants over a period of 10.5 weeks in October to December 1990, re-using the artificial seawater but with the necessary make-up of new water after each purification cycle to replace the small proportion lost when flushing out the boxes. Trials 1 to 13 and Trial 15 were in the original prototype plant built by Seafish for the earlier trials (Ref: 5). Trial 14 was in a further developed plant built under Seafish Guidance for commercial operation by the Essex Oyster and Seafood Company Limited. The re-used water was transferred between the two plants. During the trials control samples were purified in freshly made ASW on the laboratory-scale purification plant set up alongside the trials plant and operating within the existing MAFF criteria for shellfish purification.

Comprehensive bacteriological, physical and chemical monitoring was carried out for each trial.

4. Trial Site and Oyster Supply

All the trials were carried out at the premises of the Essex Oyster and Seafood Company Limited situated on the Hythe Quay, Maldon, Essex. They also supplied the pacific oysters *(Crassostrea gigas)* for the trials from their lays in nearby Goldhanger Creek which is a relatively clean area. The oysters were relatively large in size, with a typical weight of 120 grams.

Before the start of the trials approximately 2,000 oysters (two purification plant loads) were harvested from the lays and placed in a holding pit at Goldhanger Creek. Following each purification trial the oysters were returned to the pit and subsequently used in rotation. However, for trial 4 to allow for losses in the trials and because of concern over the effects of handling prior to purification, a further purification load was taken directly from the lays and was subsequently added to the stock in the pit.

To achieve higher levels of initial contamination and hence a more severe test of the purification plants, oysters for trials 2 and 4 were relaid for a weekend in a sewage contaminated area of the river Crouch at Burnham prior to purification and oysters for trials 11,12,14 and 15 were artificially contaminated by immersion in a suspension of freeze dried E*scherichia coli (E. coli)* prior to purification.

5. Trials Equipment

5.1 The vertical stack purification plants

The prototype and further developed small-scale vertical stacked purification plants are shown in Figs 1 and 2. The specification, design, development and operation of the original prototype plant are described in detail in Appendix I. Likewise the further developed commercial prototype plant is described in Appendix II. This plant was not intended to be a fully developed standard design but was a step in that direction to suit the immediate commercial needs of the Essex Oyster and Seafood Company Limited.

The nominal capacity of the commercial prototype plant with two side-by-side stacks of boxes is approximately double that of the original single stack prototype. To retain continuity of water re-use during the trials one half of the commercial prototype was blanked off and it was run with only a single stack of boxes and the water capacity and flow rates were reduced to match.

It should be noted that although the water exchange rate of these prototype vertical stack units (1.5 times per hours) is well within the existing MAFF recommended range, as is their loading of oysters, the water flow rate past the oysters (approximately 11.50 m/hr) is high although no higher than that of the fully tested medium-scale mussel purification tank (Ref: 4). This high flow rate is a result of the vertical stack systems being, in effect, a tank seven or eight boxes long with an additional 50% of backup water in the sump, all of which is circulated. The backup water is required to allow for loss and to permit operation with only a part load of shellfish when additional water is required in the boxes to substitute for their displacement and to maintain flow throughout the system without the sump and circulation pump running dry.

Despite the additional sump water, at their nominal (MAFF recommended) loading of 530 oysters per square meter, the ratio of water/oysters in the vertical stack plants is not high (approximately 3.7 litres/kg for typical 80 gramme pacific oysters) in comparison to the water/mussel ratios of the fully tested medium and large-scale mussel purification tanks (3.5 litres/kg and 6.1 litres/kg respectively, Ref: 4). This is relevant to consideration of water re-use, as the build up of waste products in the water limits its re-use, although it is thought that weight-for-weight oysters are much less active than mussels. The water/shellfish ratio is comparatively low in the vertical stack plants because the water is constrained in a limited volume within the boxes rather than being a mass surrounding the boxes immersed in a tank.

5.2 Other trials equipment

The remaining trials equipment including the fully tested control purification tank used as a standard measure of purification effectiveness, the environmental chamber used for storage/mortality trials post-purification and the monitoring equipment for temperature, dissolved oxygen and water quality are detailed in Appendix III.

The control purification tank can be used with one or two trays of shellfish. For the control purification trials it was used in single tray mode with water capacity and flow rate adjusted to suit, but it was also used in the two tray mode for the artificial contamination of samples prior to purification.

6. Trials Procedure

6.1 Artificial seawater mixing and re-use

An initial batch of ASW was made up in a reservoir tank as described in Appendix IV. Following each purification cycle in the vertical stack plants up to 10% of the purification water was replaced to compensate for that left in the bottom of the boxes and flushed to waste together with the detritus from the oysters. New ASW was made up in the reservoir tank as required and the lost water made up before the start of each subsequent trial. The used ASW was transferred between the two prototype vertical stack units during the trials sequence.

The water in the control tank was completely replaced by freshly made ASW after each purification cycle.

6.2 Each purification cycle

The oysters were washed then loaded into the boxes which were then loaded into the vertical stack purification plant. The oysters were placed on the matting on the box base and were loaded in a single overlapping layer, which corresponded to approximately 100 oysters per box for the large pacific oysters used. Ensuring that the 'handed' boxes were correctly positioned in the stack and that all the drainage bungs and taps were closed the water circulation and u.v. sterilisation was then started. The water flow was set at the nominal 1.5 changes per hour and the heater thermostat to 13°C as earlier work (Ref: 5) had indicated that the purification temperature for pacific oysters should be within the range 8°C to 18°C.

The control purification tank was similarly loaded and started.

The salinity of the ASW was checked at the start of each purification cycle and water temperature and dissolved oxygen levels checked regularly during purification.

Each purification cycle was of approximately 48 hours including loading and unloading the plant, with a minimum immersion period of 42 hours.

At the end of the cycle the heater, u.v. and circulation pump in the vertical stack plants were turned off and the drainage bungs and taps opened to permit the water to drain back to the sump. When all but the small amount below the drainage level in the boxes had drained, the boxes were removed from the plant. The oysters were then removed from the boxes and washed again. The detritus left in the bottom of the boxes was flushed out and the boxes and matting cleaned.

The control tank was similarly emptied after each purification cycle but all the water was drained to waste and the tank itself had to be flushed out.

6.3 Water quality analysis

Before and after each trial a water sample was analysed from both the control tank and the re-use trial plant. The water was tested for levels of ammonia, nitrite, nitrate, pH and carbonate. The change in these levels during the whole time period of the trial was recorded.

6.4 Holding trials

After most trials, samples of oysters were taken from the vertical stack plant and the control tank and transported to Hull. The samples were usually of 20 oysters. In the vertical stack plant they were always taken from the bottom box and occasionally also from the top box. At Hull, the samples were put into shallow trays and held at 15°C, whilst kept moist in the environment chamber. Mortality in each sample was then recorded daily.

6.5 Bacteriological sampling and analysis

Several quantitative methods exist for the examination of bivalve molluscs for sewage contamination. These include roll tubes, pour plates and most probable number (MPN) techniques, but there is apparently no standard method. For the purpose of this trial an MPN method specified by P. A. West and M. R. Coleman was used (Ref: 9). The Chelmsford Public Health Laboratory were contracted to take samples throughout the trials. Oyster samples were taken at the start and end of each purification trial together with a water sample at the end of the trial. Oyster and water samples were examined for Total Coliforms, *Escherichia coli (E. coli)* and Group D Faecal Streptococci. Faecal Streptococci were to be used as an indication that purification had occurred in the absence of sufficient numbers of *E. coli.*

At the end of purification, counts of *E. coli* should all be less than 230 *E. coli*/100g oyster flesh and in water less than 2 *E. coli*/100ml. Counts of Streptococci in purified oysters are not well defined but more than 1000/100gm would be suspicious.

Each oyster sample taken for bacteriological analysis contained ten oysters. Oysters were taken from the four corners and centre of the box and placed in a clean, coded bag and sealed. Three post-purification samples were usually taken from the following locations:-

Top box in vertical stack
Bottom box in vertical stack

Control tank

The bottom box at the drainage end of the vertical stack is considered the most likely area for any possible problems as it represents the area where we might expect to see the lowest oxygen levels coupled with the maximum effect of any contaminant cascading down through the system.

The single water sample was taken just before the end of each purification cycle at the drainage end of the bottom box in the vertical stack.

6.6 Increasing the initial contamination

On trials 2 and 4 approximately 200 oysters were taken to Burnham on Crouch, in two nylon mesh bags. These bags were laid at the low water mark on the river bank close to a source of sewage contamination. They were left for two days and then returned to Maldon. One hundred were placed into the control tank and one hundred were split between the input end of the top box and the output end of the bottom box in the vertical stack plant. The rest of the plant was filled with oysters from the usual source and the system started running (Refs: 11 and 12).

On trials 11,12,14 and 15 the oysters were artificially polluted using a method of artificial pollution which was developed by the MAFF Fish Diseases Laboratory (Ref: 10). Three hundred oysters, two trays, were placed in the control tank and purified overnight. The oysters were than taken out of the tank and the u.v. was turned off. A vial of freeze dried *E. coli* was placed into the control tank and the water left to mix thoroughly for one hour. The two trays of oysters were then placed back in the control tank and left for four hours. The oysters were then removed and split into three lots of one hundred. One hundred went back into freshly made ASW in the control tank and 100 each went into the top and bottom boxes in the vertical stack purification plant.

7. Results and Discussions

7.1 Technical problems encountered when running the tanks

Both the original prototype and the further developed plant suffered technical problems which had to be remedied.

The only problem occurring with the prototype tank, which had been extensively used prior to these trials, was when the heater casing melted. This was caused by the heater being turned on at the same time as the water pump, not a few minutes later, leading to overheating through inadequate heat dissipation. This was remedied by replacing the in-line heater with heaters placed in the sump, which were always submerged, as used in the commercial prototype plant. However, this heating system was not without its own faults.

One of the heaters in the commercial prototype plant developed an electrical fault which caused a leak to earth which led to the fuses tripping out and the power being cut off to the purification tank. Thus stopping the power and the oysters being left in stationary water. The oxygen in the water was then used up by the oysters after which they closed up. This problem was remedied by replacement of the faulty heater.

Another design feature which created problems was location of the boxes in the racking. The boxes are 'handed' and also staggered in the racking to ensure the correct water flow and thus each box must be in the correct position in the rack and the correct way round. When the boxes were not located correctly various problems occurred. Usually the water would not cascade correctly and would splash all over the box below or miss the box below completely and splash onto the floor. On one occasion this occurred in the commercial prototype plant when the tank was not being monitored and it lead to the sump being emptied onto the floor and the pump running dry and seizing up. Fortunately, this did not occur during the trials sequence. The original pump was then replaced by a submersible type pump which does not have to be guarded against splashing and which also should be capable of running dry for short periods.

Continued practical development of the plant design is being carried out to overcome the remaining problems, as detailed in Appendix II, finally leading to a standard plant design.

7.2 Bacteriological purification

The results of the bacteriological analysis are summarised in Table 1.

The bacteriological results from the trials can be divided into two groups. Firstly the results of trials 1,2,8,9 and 10 which used oysters direct from Goldhanger Creek and which were relatively uncontaminated. Secondly, trials 2,4,11,12,14 and 15 used oysters which were additionally contaminated prior to putting into the purification tanks using either natural ore artificial means. In trial 2, oysters were tested from both direct from Goldhanger Creek and after being contaminated.

The results from the first group are inconclusive as in all cases, the oysters were <230 *E. coli* per 100 gms prior to purification indicating that the harvesting area was acceptably clean at the time of sampling. In all cases the post purification results were <20 *E. coli* per 100 gms but this inconclusive due to the low initial levels. Counts of Total Coliforms and Faecal Streptococci were low also.

The results from the second group are more significant as 17 of the 18 pre-purification results were >1000 *E. coli* per 100 gms. In four cases the results were >10,000 *E. coli* per 100 gms.

The results from the naturally contaminated oysters in trials 2 and 4 show that despite significant reductions in Total Coliforms and *E. coli* full purification did not occur in the vertical stack plant although one result from the control tank was satisfactory.

After trial 2 this was thought to have been caused by the additional handling that these oysters had been subject to and so for trial 4, the oysters were taken direct from the lays rather than the re-used oyster holding pit and then placed in the Crouch. However, the results were again poor and furthermore the post-purification mortality was high (see Section 7) indicating that the oysters had been stressed. It is concluded that the additional handling and/or the conditions in the Crouch were affecting the oysters level of activity. This highlights the need to ensure correct handling prior to purification.

With the artificially polluted oysters in trials 11,12,14 and 15 all thirteen samples of >1000 E. coli/gm reduced to levels of 20 or <20 *E. coli* within the 42 hour purification cycle, from as high as 18,000 *E. coli*. These results demonstrated that both the prototype and standard design tanks were capable of purifying oysters, at the end of an extended period of ASW re-use.

In all cases the post-purification water gave a zero count.

7.3 Water quality

The results of the water analysis are shown in Table 2 and 3 and Figs 3 to 8.

Prior to trial 7 the results are suspect because of the use of a deionisation bag and tap water to dilute the samples for the spectrophotometer. This water proved to be impure, containing nitrate and ammonia, and as most of the samples had to be diluted 10:1 to be within the range of the spectrophotometer, ammonia and nitrate in the water, multiplied up to 10 times, distorted the results. After run 6 deionised water from bottles was used to dilute the samples which showed no traces of ammonia or nitrate and therefore did not distort the results.

The control tank results for trial 6 are additionally suspect as for that particular trial a commercially available aquarium salt mix was used which appeared to give much higher levels of ammonia, nitrate and carbonate.

The remaining results appear to be satisfactory with no significant cumulative effects apparent as a result of continued water re-use and the results from the re-used water being of the same order as those from the control tank.

The biochemistry of the re-used water in purification systems is complex. The level of ammonia is increased by the waste products of the shellfish and that in turn is broken down into nitrite then nitrate by the action of nitrifying bacteria which develop within the system. Previous work has suggested that levels of ammonia above 40 ppm can start to affect mussel mortality (Ref: 16). Nitrate is also thought to be toxic to the shellfish but the critical level is uncertain. The levels of chemical accumulation indicated in these results are not thought to present a problem.

7.4 Mortality

Trials by Seafish with its environmental chamber have shown a relationship between mussel storage temperature and mortality. Storage for one day at 15°C approximates to three days storage at 5°C and 3.5 days storage at 0°C. (Ref: 13). It was assumed that oysters would display similar characteristics.

Results were not available from trials 1 to 3 as the environmental chamber defaulted and cooked the samples.

The results are shown in Table 4 and Figs 9 to 12. These show that there was no significant difference in the mortality between re-use and control oyster samples. However there were some differences between individual trials, in particular trial 4 in which the oysters did not purify effectively, showed the fastest mortality and this suggests that the shellfish had been stressed by their handling prior to purification.

7.5 Water temperature

The water temperature at the start and end of each trial are shown in Tables 2 and 3. The thermostatic heater controls ensured that a minimum temperature was maintained but it is clear that in warmer weather the temperatures could have risen well above the maximum desirable of 18°C. Some form of chilling will be required if the plant is to operate in high ambient temperatures.

7.6 Dissolved oxygen levels

The dissolved oxygen levels were monitored throughout the trial and rarely fell below 90% saturation. The recommended level is above 50% saturation, and therefore it is unlikely that levels which fall this low at the recommended temperatures and the loading densities used in this trial. On average there was only a 3% drop in oxygen across each box and this was largely made up in the cascade into the box below.

7.7 Overall consideration of results

The assessment of the activity of oysters during purification is more difficult than with mussels, as oysters use little oxygen and do not show external signs, such as the formation of byssus threads. It is necessary therefore to rely on the bacteriological, mortality and water quality results as indicators of purification activity and potential long-term water re-use problems. In all these indications the vertical stack plant proved satisfactory for 15 re-uses of ASW over a 73 days period despite the relatively low water/shellfish ratio for this design of plant. However, experience suggest that a cautious approach should be taken to water re-use with other species in this plant, particularly for mussels because of their high rate of activity.

8. Conclusions and Recommendations

1. Significant progress has been made toward producing a standard design of small-scale vertical stack purification plant. The fundamentals of its design and operation have been proven but detail design improvement is required and is underway.

2. Provision will have to be made in the standard design for chilling as well as heating if the required water temperature range is to be achieved in high ambient temperatures.

3. Given the above and the relatively high flow rates of the design (and hence high levels of oxygenation) the small-scale standard design should be capable of being set up for the purification of a wide range of mollusc species which require differing water conditions.

4. The bacteriological, post-purification mortality and water quality results of the trials all indicate successful operation of the plant for the purification of pacific oysters at the recommended loading density during 15 successive re-uses of artificial seawater (with 10% make-up after each purification cycle) over a period of 73 days.

5. The need for correct handling of the molluscs pre-purification to avoid stressing them and inhibiting their purification has been demonstrated yet again.

6. A loading density of a single overlapping layer of oysters and a maximum period of continuous water re-use of one month (15 re-uses), or of 10 re-uses over a longer period, are recommended. Further work will be necessary extended re-use could be recommended in this plant for other more active species such as mussels.

7. Following the trials the Department of Health granted the commercial prototype plant a provisional operating license on the above conditions.

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Tables

Table No. 1 - Oyster Trials - Bacteriological Results

Trial	Date 1990	Tank	Pre Purification			Post Purification Vertical Stack Tank			Post Purification Control Tank			Water	Comments
			Total Coliforms	*E. coli*	*F. Streptococci*	Total Coliforms	*E. coli*	*F. Streptococci*	Total Coliforms	*E. coli*	*F. Streptococci*	Total Coliforms	* AC/NC
1	2-4 Oct	S	<20	<20	<20	<20	<20	<20	<20	<20		0	
1	2-4 Oct	S	<20	<20	<20	<20	<20	<20					
1	2-4 Oct	S	<20	<20	<20	<20	<20	<20					
2	8-10 Oct	S	3500	1700	140	460	130	50	20	<20		0	NC
2	8-10 Oct	S	5400	1300	480	2200	490	330				0	NC
2	8-10 Oct	S	130	50	<20	<20	<20	<20					
2	8-10 Oct	S	80	80	<20								
4	17-19 Oct	S	18000	9200	140	2200	490	110				0	NC
4	17-19 Oct	S	18000	9200	210	1100	130	20				0	NC
8	30 Oct-1 Nov	S	<20	<20		<20	<20	<20	20	<20	<20		
9	5-7 Nov	S				<20	<20	<20	50	<20	<20	0	
9	5-7 Nov	S	320	20		<20	<20	<20					
10	12-14 Nov	S			<20	<20	<20	<20	<20	<20	<20	0	
10	12-14 Nov	S	20	<20		<20	<20	<20					
11	12-14 Nov	S	16000	16000	<20	20	20	<20	<20	<20	<20	0	AC
11	12-14 Nov	S	1700	1700	<20	<20	<20		<20			0	AC
11	12-14 Nov	S		2100			<20						AC
11	12-14 Nov	S		1700			<20						AC
11	12-14 Nov	S		80									AC
12	28-30 Nov	E O	5400	5400	<20	<20	<20	<20	170	170	20	0	AC
12	28-30 Nov	E O	18000	18000	<20	<20	<20	<20					AC

Trial	Date 1990	Tank	Pre Purification			Post Purification Vertical Stack Tank			Post Purification Control Tank			Water	Comments
			Total Coliforms	*E. coli*	*F. Streptococci*	Total Coliforms	*E. coli*	*F. Streptococci*	Total Coliforms	*E. coli*	*F. Streptococci*	Total Coliforms	* AC/NC
12	28-30 Nov	E O	18000	18000	<20								AC
14	3-6 Dec	E O	5400	5400		50	20	20	60	60	20	0	AC
14	3-6 Dec	E O	16000			20	<20	<20					AC
14	3-6 Dec	E O	2400	2400									AC
15	10-12 Dec	S	5400	5400		230	<20	50	<20	<20	<20		AC
15	10-12 Dec	S	1700	1700		<20	<20	<20					AC
15	10-12 Dec	S	5400	5400									AC

* Key	
NC	Naturally Contaminated
AC	Artificially Contaminated
S	Seafish
EO	Essex Oyster

Table No. 2 - Oyster Trials Re-Use Water Quality Results

Trial	Sample	Ammonia PPM	Nitrite PPM	Nitrate PPM	Carbonate PPM	pH	Salinity ‰	Temp °C	Comments
1	Pre	0.65	0.528	25.69			24	15	
1	Post	1.82	1.518	28.6			24	17	
2	Pre	1.924	1.52	37.4			27	11.8	
2	Post	24.7	2.059	129.25	148		27	14.6	Water
3	Pre	24.7	2.059	129.25	148		24	14.6	Quality
3	Post	15.6	2.11	27.98	130		26	16.5	Results
4	Pre	2.86	4.09	16.5	125	8.15	29	18	Suspect
4	Post	5.85	7.19	23.4	143	7.8	29	19	For Trials
5	Pre	5.85	7.19	23.4	143	7.8	29	19	1-6
5	Post	7.15	19.8	171.6	143	8.1	28	14.2	
6	Pre	7.15	19.8	171.6	143	8.1	28	14.2	
6	Post	9.62	10.29	10.56	117	7.75	28	15.5	
7	Pre	9.62	10.29	10.56	117	7.75	29	15.5	
7	Post	6.89	10.23	15.4	125	7.65	29	16	
8	Pre	6.11	8.65	5.19	135	7.8	28	11	
8	Post	10.66	12.21	16.72	143	7.65	28	12.6	
9	Pre	2.73	6.99	23.67	121	7.7	23.5	9.8	
9	Post	2.08	8.94	25.9	117	7.85	23.5	10.7	
10	Pre	4.68	3.99	20.43	121	7.65	24.5	11	
10	Post	0.78	6.6	26.4	121	7.8	24.5	14.9	
11	Pre	0.96	2.97	12.76	125	7.65	24.5	12.5	
11	Post	0.585	5.6	3.3	148	7.6	26	12.4	
12	Pre	1.64	0.838	0.88	140	7.9	30	13.4	
12	Post	3.276	3.102	3.52	117	7.75	30	14.5	
13	Pre	3.276	3.102	3.52	117	7.75	30	14.5	
13	Post	1.586	4.29	23.32	130	7.3	30	13.6	
14	Pre	1.586	4.29	23.32	130	7.3	30	13.6	
14	Post	0.481	0.356	30.8	112	7.5	29.5	13.5	
15	Pre	6.11	3.3	33.4	140	7.65	27.5	14	
15	Post								

	From	To	Multiply
Convert	Ammonia	Ammonia Nitrogen	0.77
	Nitrite	Nitrite Nitrogen	0.3
	Nitrate	Nitrate Nitrogen	0.23

Table 3 - OysterTrials Control Tank Water Quality Results

Trial	Sample	Ammonia	Nitrite	Nitrate	Carbonate	pH	Salinity	Temp	Comments
		PPM	PPM	PPM	PPM		‰	°C	
2	Post	2.16	0.16	52.8			27	15	Water quality
3	Post	5.2	0.627	32.16	130		26	17	
4	Post	3.25	1.32	20.24	140	7.85	24	19.5	suspect for
6	Pre	0	6.04	233	363	8.2	29	13.7	
6	Post	16.25	1.58	30.9	300	8.25	31	16.2	trials 1 - 6
7	Pre	0.52	0.36	16.24	153	8.1			
7	Post	0.91	1.815	7.26	273	8.15			
8	Pre	0.39	0.297	10.16	173	8.05			
8	Post	3.12	1.815	9.9	173	7.85			
9	Pre	0	0.396	11.35	193	8.25	22	11	
9	Post	0.39	0.924	13.29	153	7.9			
11	Pre	0.286	0.277	6.16	158	7.95			
11	Post	2.5	2.145	1.914	173	7.85			
12	Pre	0.79	0.211	1.67	125	7.9			
12	Post	2.6	1.386	3.256	135	7.9			
14	Pre	1.716	0.78	7.48	148	7.7			
14	Post	1	6.27	28.6	153	7.65		13	
15	Pre								
15	Post								

	From	To	Multiply
Convert	Ammonia	Ammonia Nitrogen	0.77
	Nitrite	Nitrite Nitrogen	0.3
	Nitrate	Nitrate Nitrogen	0.23

Table 4 - Days Storage at 15 °C to % levels of mortality in each sample

Trial	10% Re-Use	10% Control	50% Re-use	50% Control	90% Re-use	90% Control	100% Re-use	100% Control
1								
2								
3								
4	8	7	12	12	16	19	22	24
6	12	5	20	13	29	19	33	27
8	11	9	16	21	22	37	26	53
9	10	14	19	19	38	27	42	36
10	8	10	20	19	26	28	29	>50
11	13	10	18	18	22	23	23	24
12	14	9	19	16	24	21	>39	>39
14	9	11	15	16	19	21		
15	12	13						

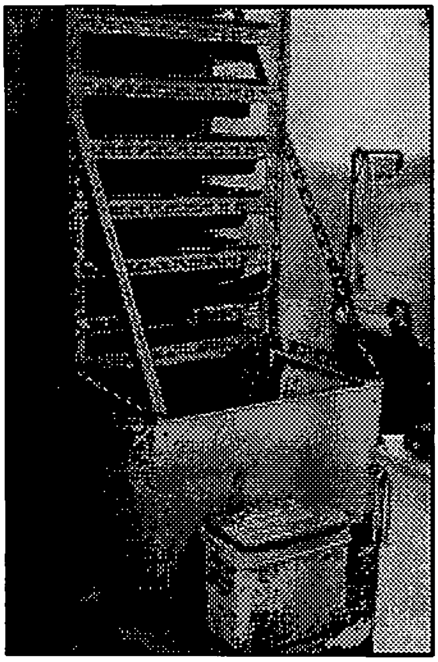


Figure 1 - Prototype Purification Plant

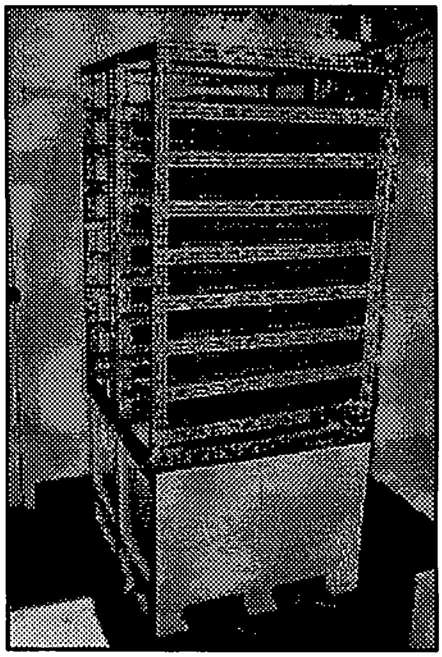


Figure 2a - Further Developed Standard Design Purification Plant

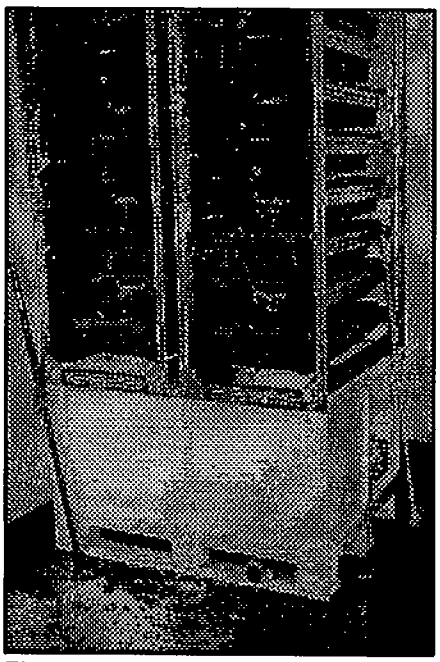
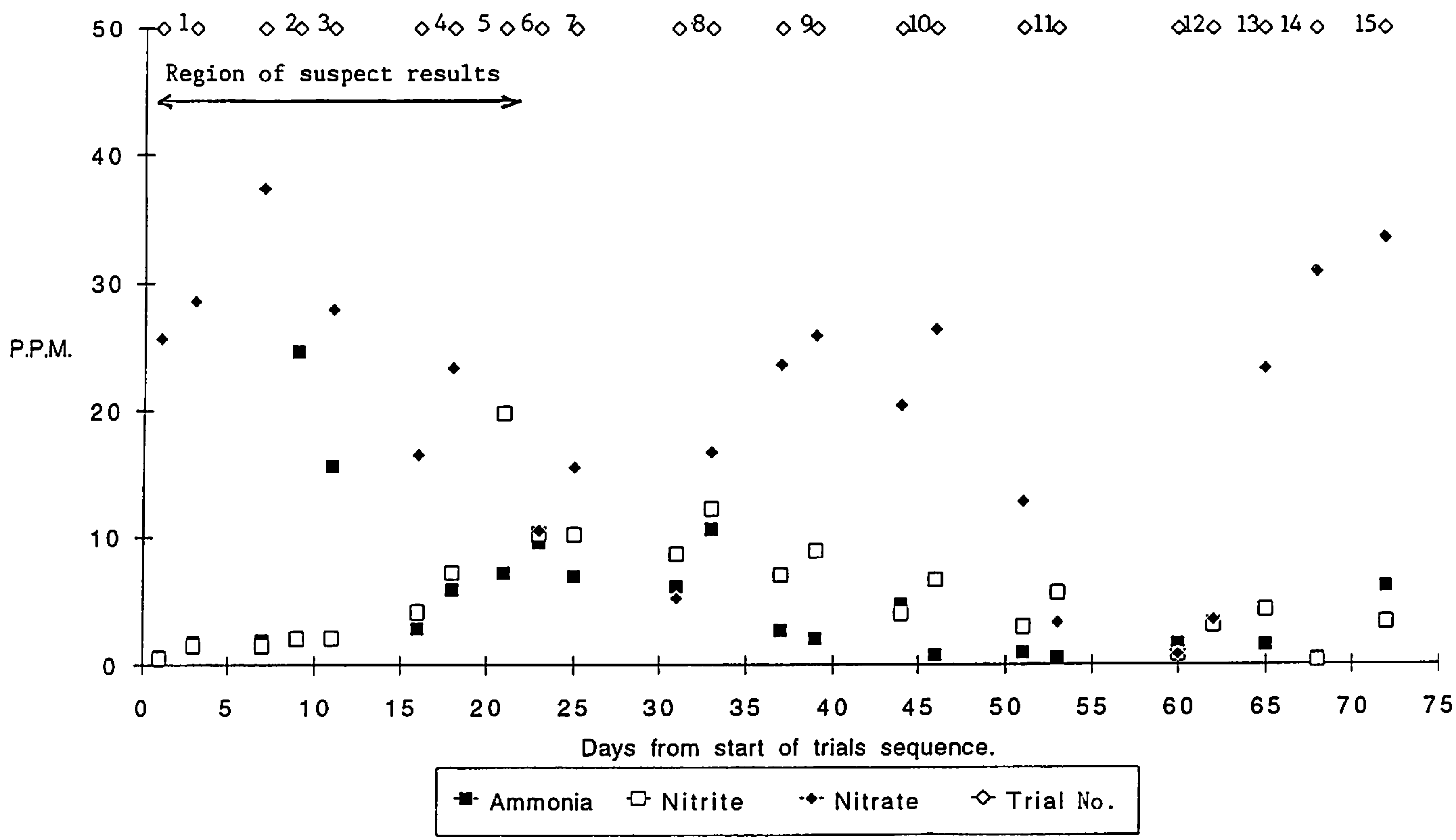


Figure 2b - Further Developed Standard Design Purification Plant

Figures



NB: Trial 2 and 5 Nitrate Results Post Purification off scale (see Table 2)

Figure 3 - Re-used Water Quality Results

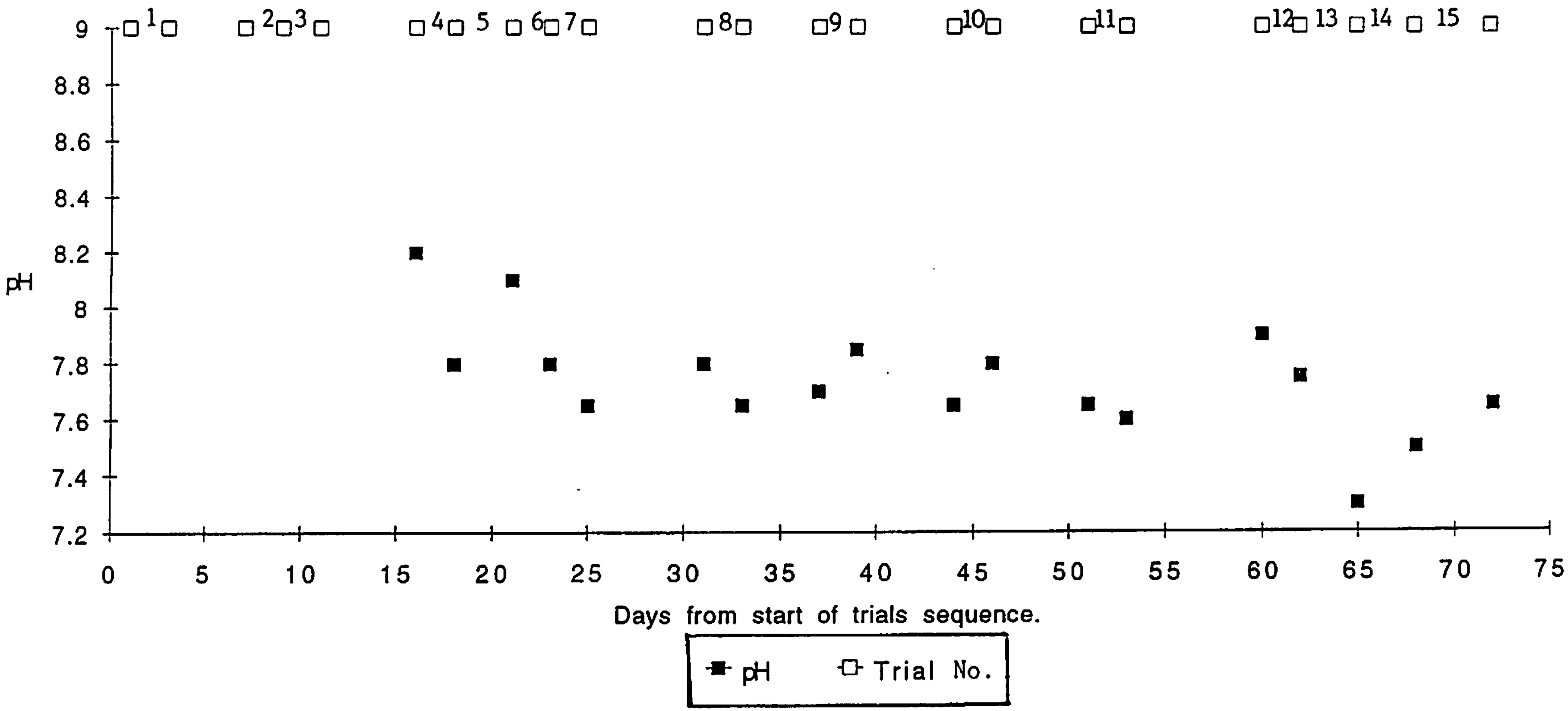


Figure 4 - Re-used Water pH Results

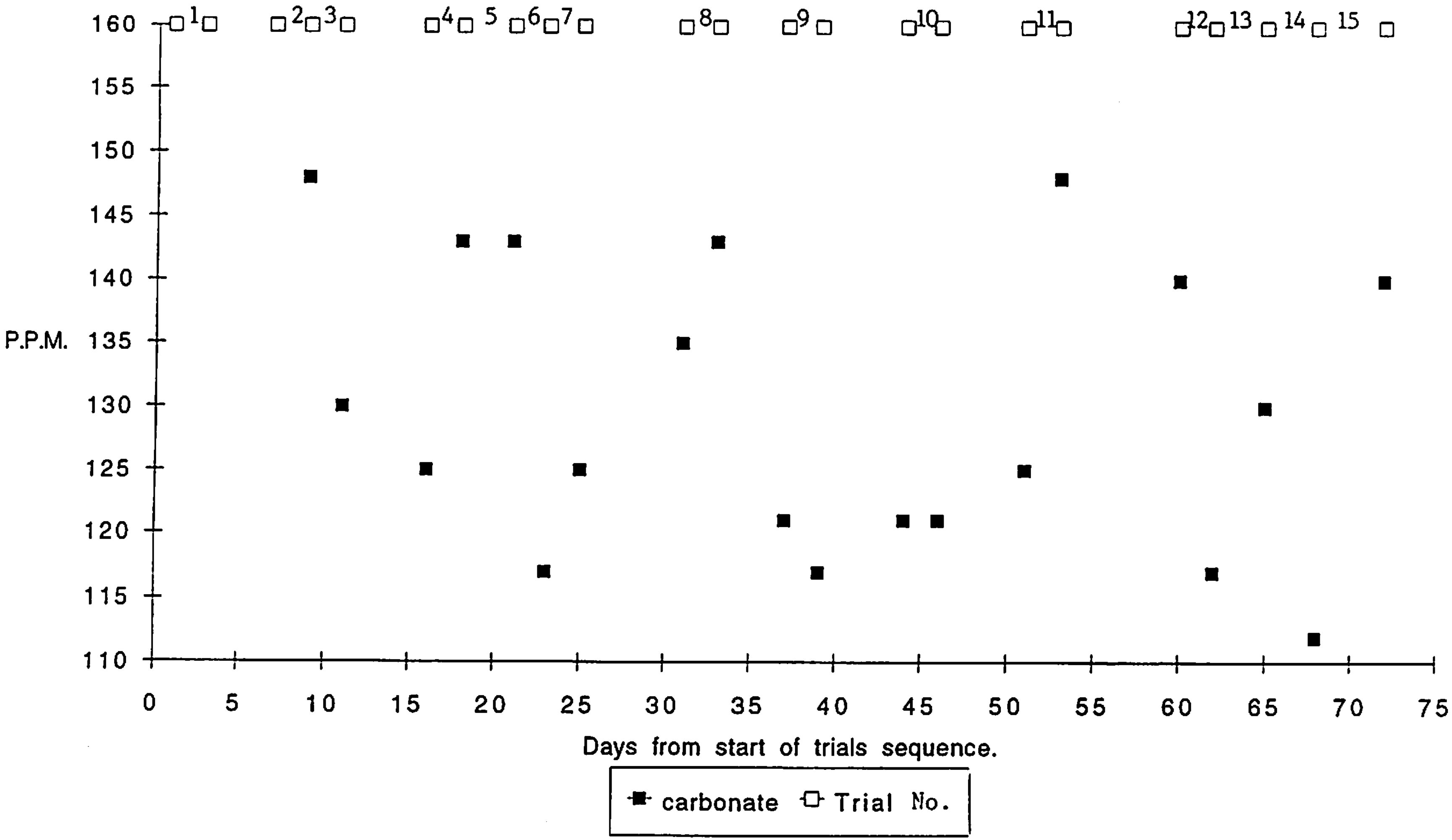
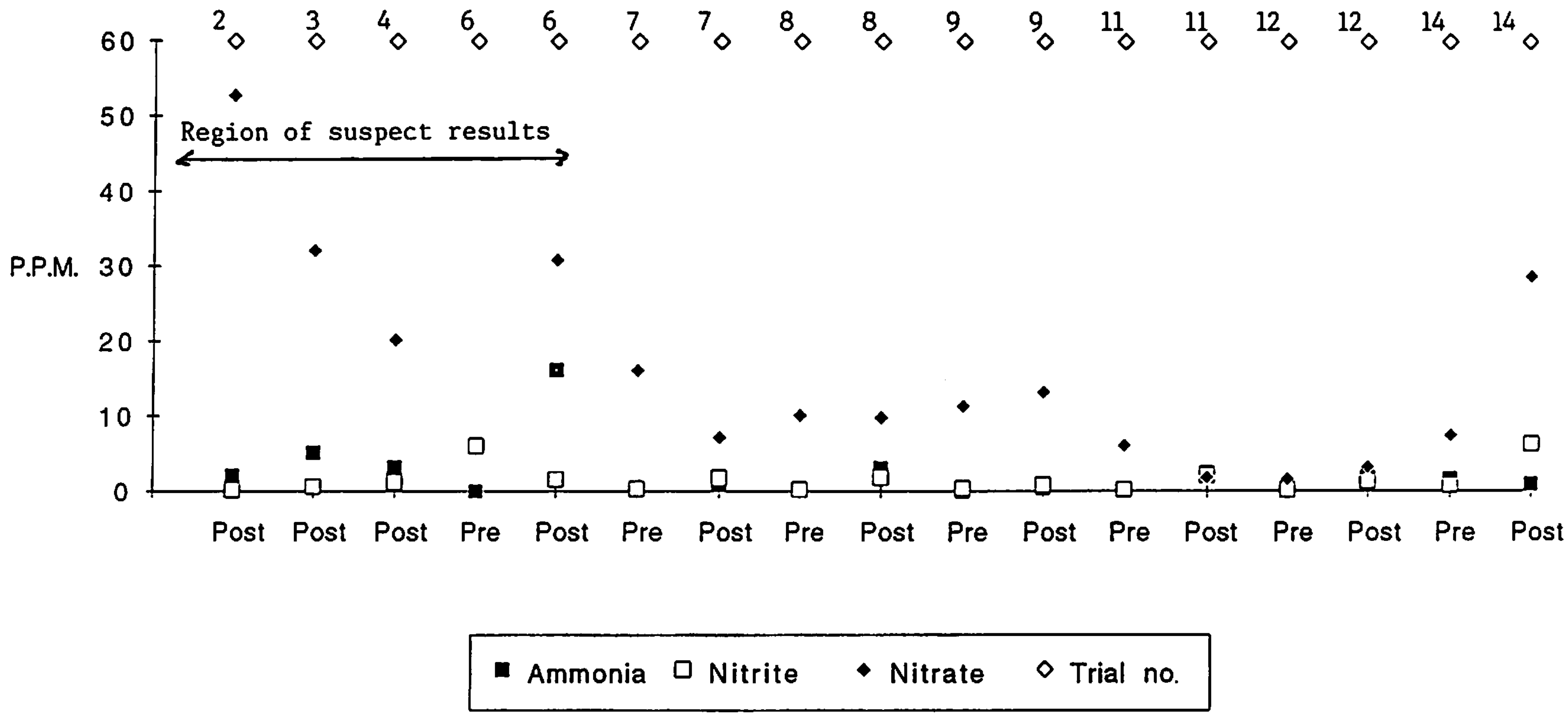


Figure 5 - Re-used Water Carbonate Results



N.B. Nitrate Level for Pre.Trial 6 Off Scale (See Table 2).

Figure 6 - Control Tank Water Quality Results

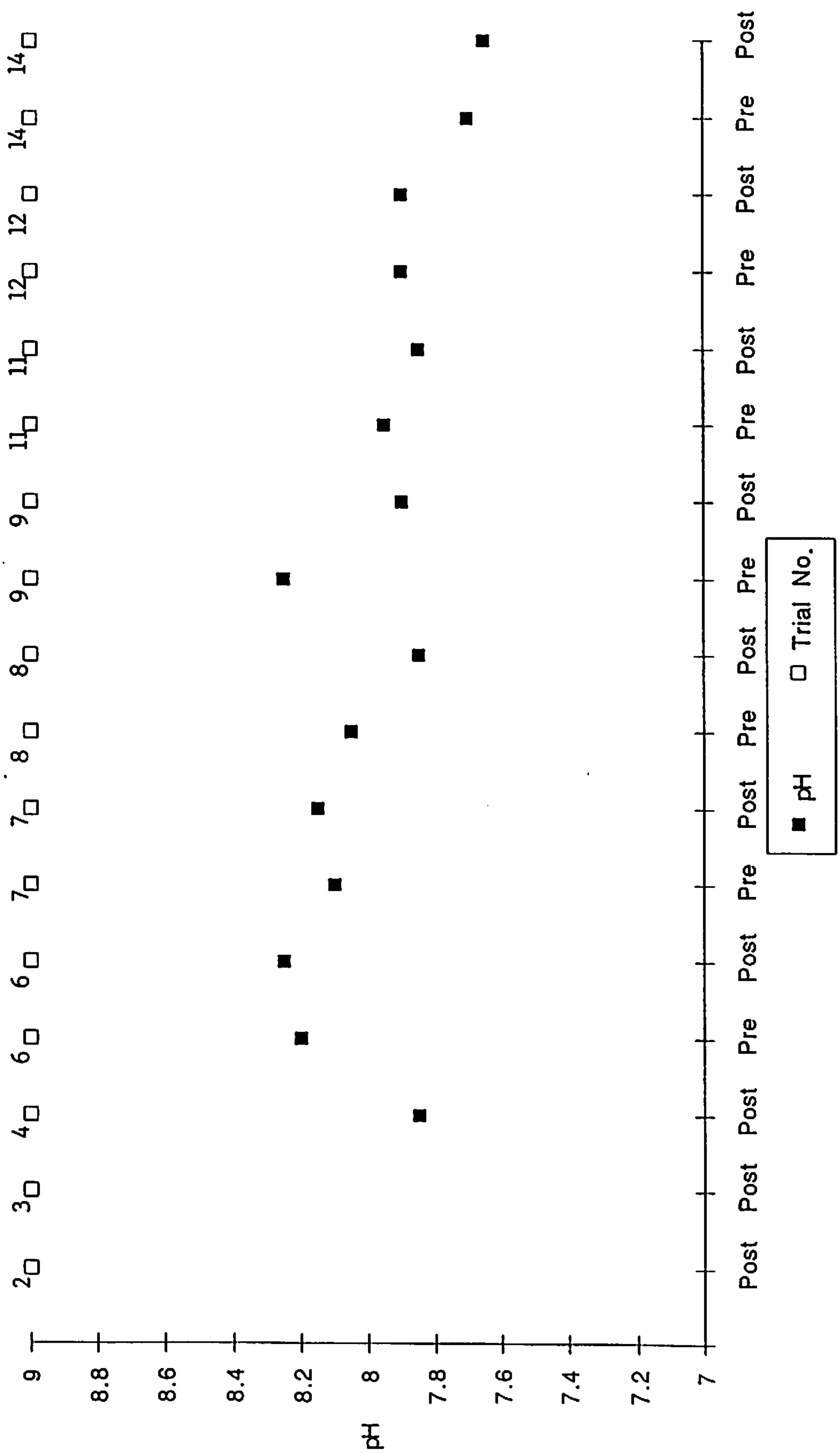


Figure 7- Control Tank pH Results

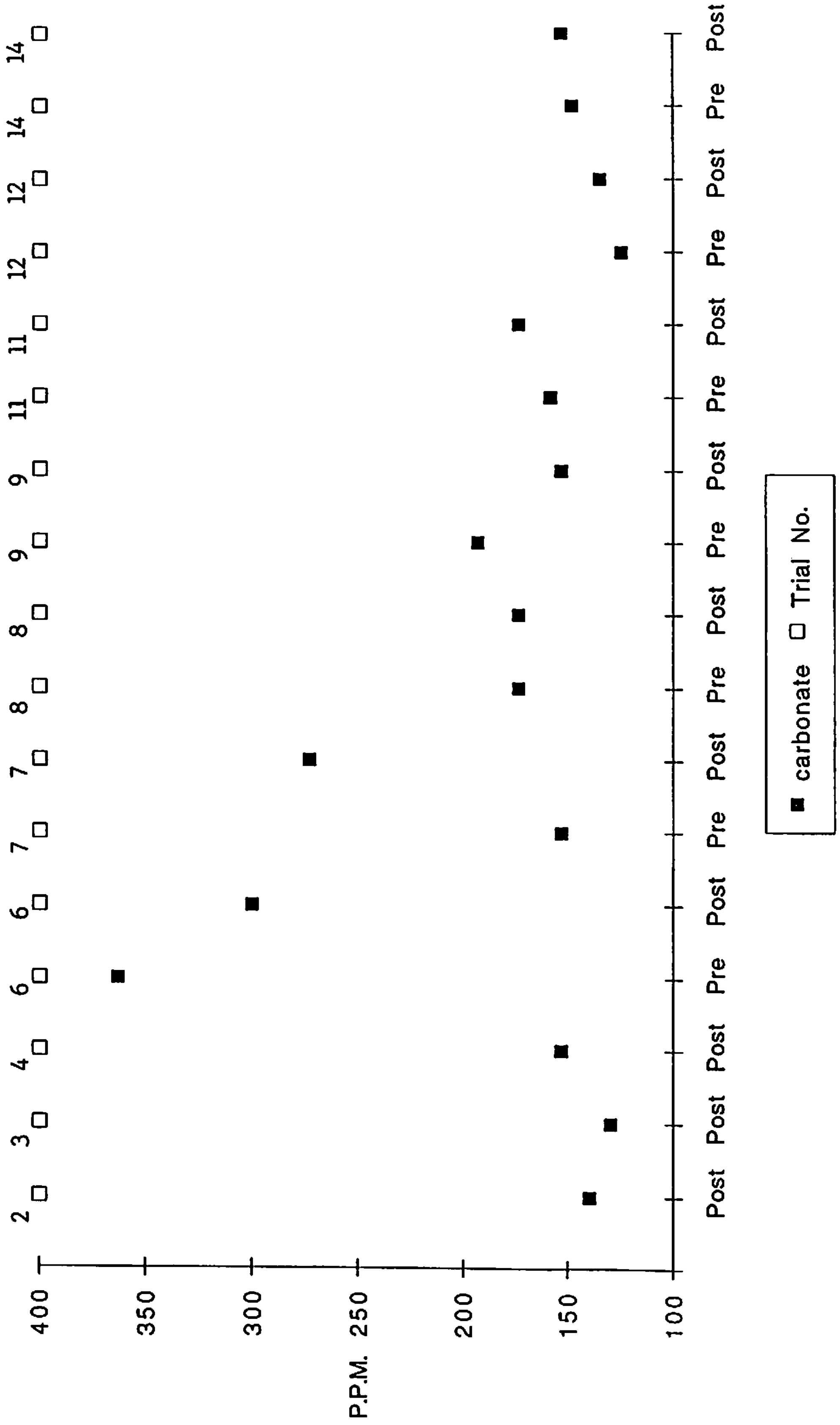


Figure 8 - Control Tank Carbonate Results

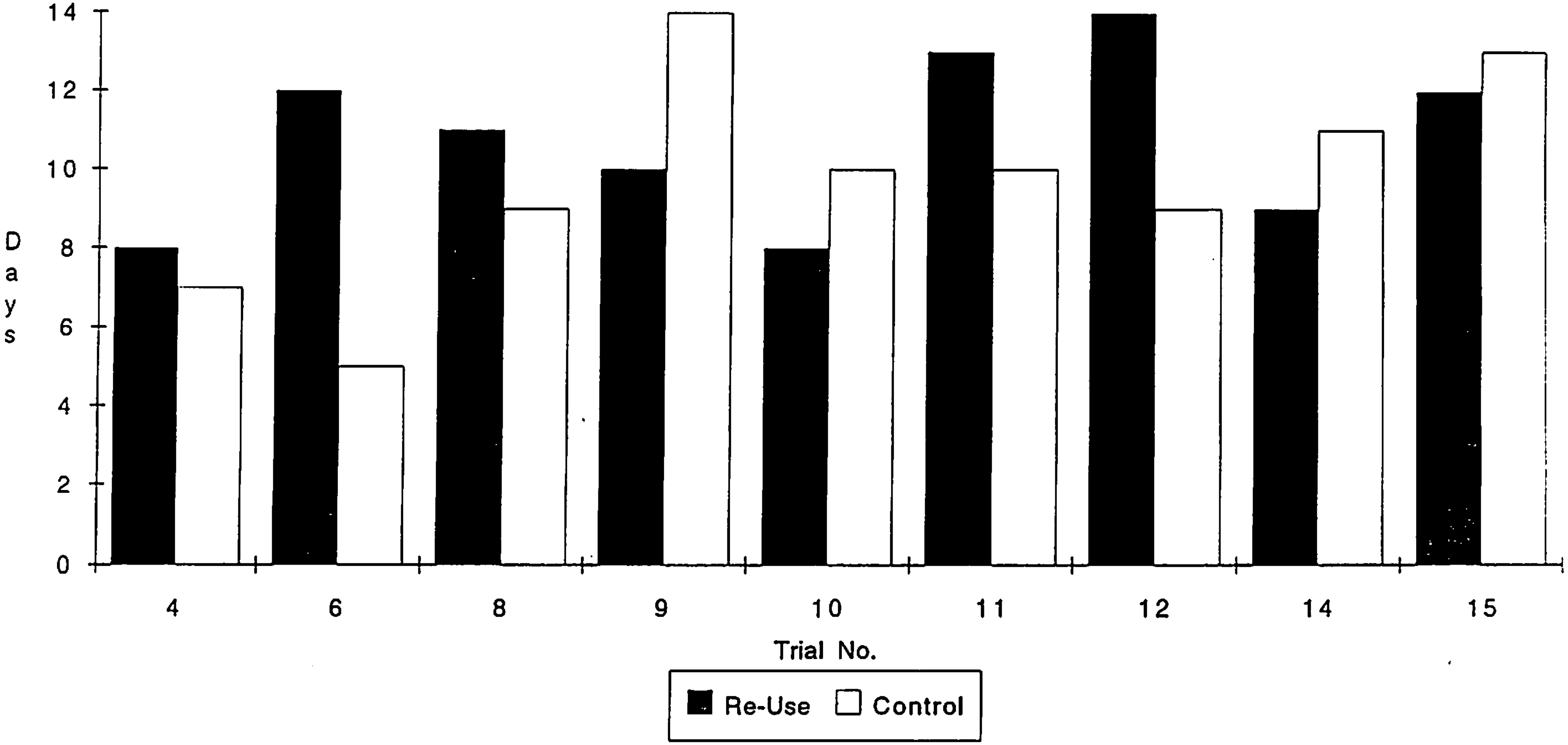


Figure 9 - Days Storage at 15°C to 10% Mortality

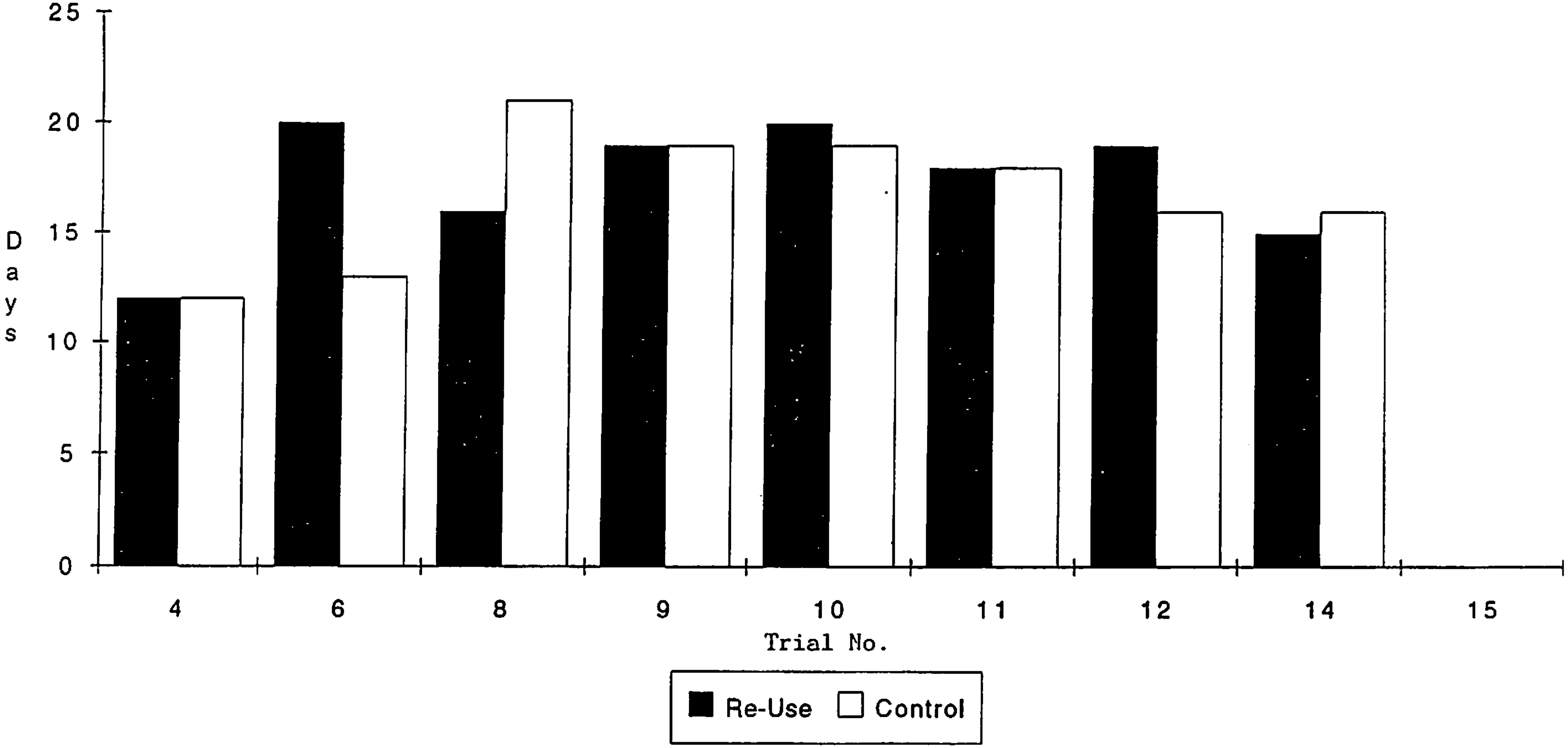


Figure 10 - Days Storage at 15°C to 50% Mortality

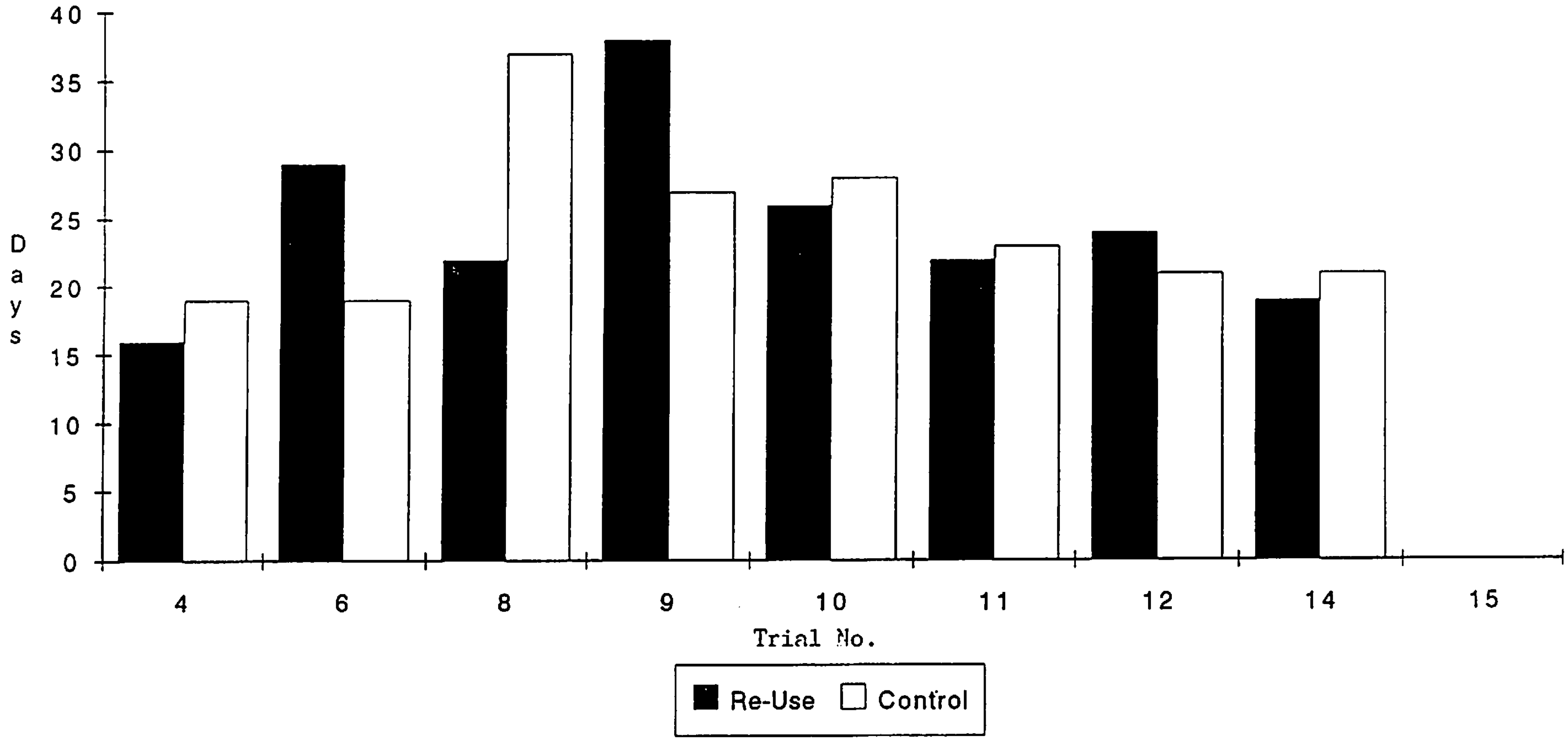


Figure 11 - Days Storage at 15°C to 90% Mortality

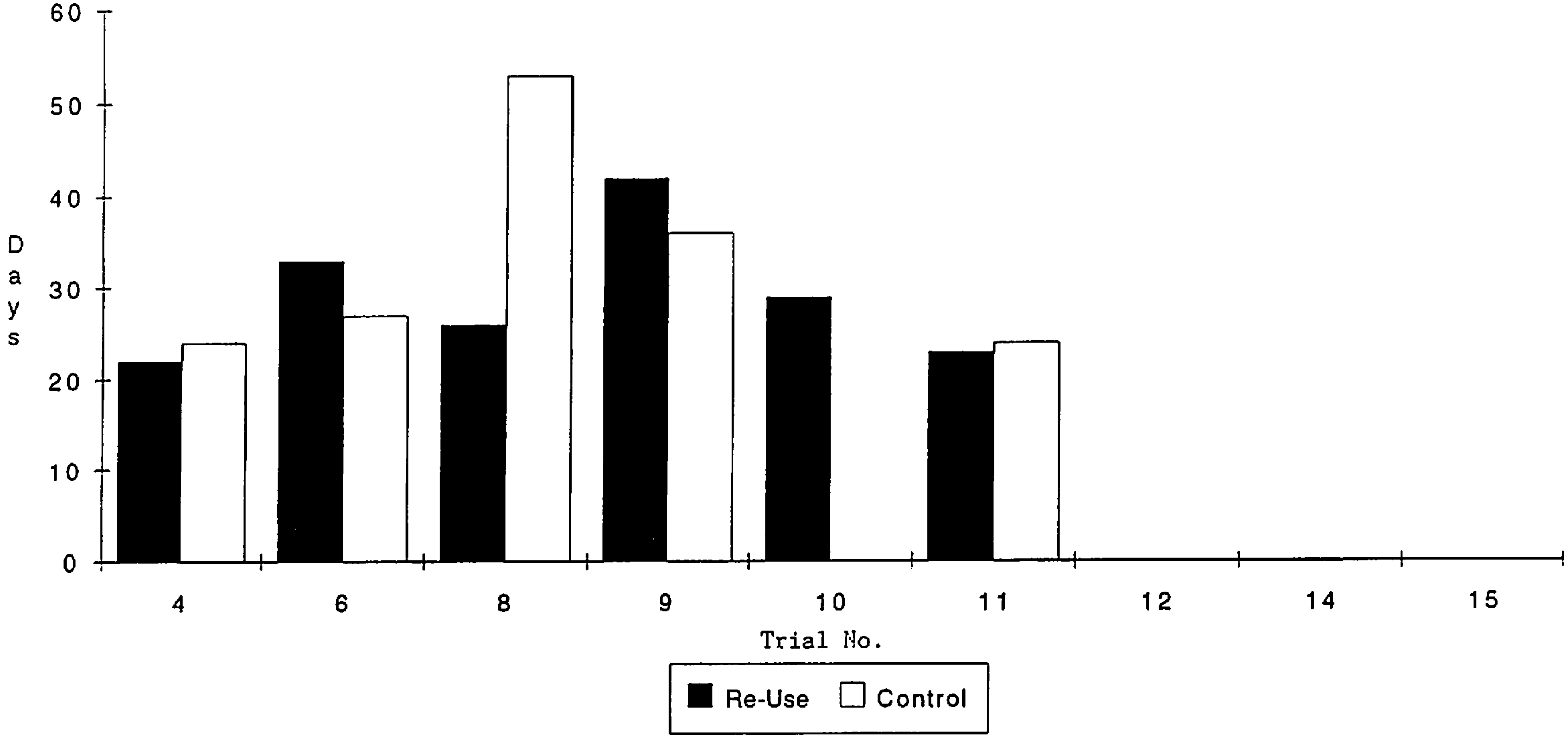


Figure 12 - Days Storage at 15°C to 100% Mortality

APPENDIX I
Development of Prototype Vertical Stack Purification Plant

1. Introduction

Where quantities of bivalve molluscs to be depurated are small a vertical stack system is often used. This consists of boxes containing the shellfish supported one above the other in a frame sat over a sump. Water is pumped up, via a u.v. sterilizer, to the top box from where it cascades down from one box to another until finally returning to the sump. In order to progress trials with oyster purification and to extend the range of standard plant designs, Seafish considered the development and construction of such a unit.

2. Existing Units

Vertical stack units are usually used for oyster depuration but in many cases are also used as storage facilities, whether or not purification is required. The basic design concept is good, it being a modular unit using a minimum of floor space, but there were several aspects of the water flow and method of operation that concerned Seafish.

2.1 Water cascade: in most systems water flows from one end of the box to the other, the water outlet consisting of two holes drilled in one end. In practice the water cascades directly over the oysters in the box below and may reduce the activity of individuals.

2.2 Water flow: adequate dissolved oxygen levels throughout the boxes is an essential factor for effective purification. There was some concern with regard to the potential for water 'dead spots' within the boxes and also the adequacy of the prescribed flow rates of 1 to 2 system water changes per hour.

2.3 Depth of water: from an operational viewpoint the height of the system is restricted by the need to remove the top box. In order to maximise on the number of boxes in a stack therefore the boxes are shallow. This could result in oysters not being totally immersed.

2.4 Bottom clearance: the oysters sit directly on the bottom of the boxes and are not kept clear of faeces, mud and silt.

2.5 Drainage: it is important when draining down the boxes that the faeces etc, are not disturbed which could cause recontamination of the oysters. In existing systems a small bleed hole is drilled in the bottom of each box. This drains continuously during purification but has little effect on the water cascade due to its low flow rate. Its purpose is twofold. If the pump failed it was considered preferable to let the system drain and to leave the shellfish in stagnant water. In practice this really applied to lobster storage for which these systems could sometimes be used and not mollusc purification. The bleed hole was also the means of draining the system down. In theory boxes were completely drained and the flow of water was such that faeces would not be disturbed from the bottom of the box. In practice this method of drainage is too slow and operators may pull boxes out of a stack with oysters still partly immersed, disturbing faeces and potentially recontaminating. As an alternative the operator may put a bung into the box end to allow more rapid drainage. This also increases the potential for re-contamination due to sudden change in water flow around the hold. The bleed hole itself, if used correctly, could also cause recontamination as any material drawn through the hole will fall onto a box of immersed oysters below.

2.6 Water temperature: this is an important factor in maintaining the balance between shellfish activity and dissolved oxygen levels. Pacific oysters *(C. gigas)* are now commonly farmed and purified in the United Kingdom. Recent work by Seafish has shown that a water temperature of 8°C is preferable to the 5°C currently specified by MAFF. Water heating may be required to maintain the temperature.

2.7 Handling: pacific oysters are easily damaged and difficult to wash. Seafish considered it worth considering means of reducing handling and therefore damage when operating the purification unit.

3. Development of Prototype Unit

3.1 Box type: to reduce cost it was decided that a standard plastic box be used. The requirements considered included internal depth, loading, water flow and ability to fit in a rack system. The Allibert box no. 12030 of 30 litres capacity and currently used in some stack systems was ultimately chosen (Fig. 1). This has internal working dimensions of 620 x 370 x 120mm.

3.2 Sump: the sump must have sufficient capacity to contain all the seawater with the boxes drained down and sufficient water when in use to maintain the circulation pump suction. For the prototype this was constructed in painted marine ply and glass reinforced plastic (GRP) (Fig 2). The sump was made to take two vertical stacks of boxes and was 1.24 m x 0.92 m x 0.6 m deep.

Although the sump could take two such stacks this was not considered necessary for trials purposes and consequently it was partitioned. The working volume, directly below the boxes then had a capacity of 300 litres.

3.3 Support frame: Dexion galvanised mild steel angle (75mm x 50mm) was bolted together to form a frame with a capacity of seven boxes in a vertical stack. The frame was mounted on top of the sump and gave the unit an overall height of 2.1 metres. The boxes were mounted on Dexion supports and could be removed individually from the stack (Figs 2 and 3).

3.4 Circulation system: a Berisford PV21 flooded suction pump with magnetic drive was used with flow control valve, flowmeter and 15 watt UVAQ ultra-violet light sterilizer. A heater (3.5) was also fitted. Pipework was in ¾" Acrylongitrile Butadiene Styrene (ABS) plastic with water pumped from the sump up to the tope of the unit and into the top box. The circulation system was mounted on a sheet of painted marine ply attached to one side of the unit and clear of any water spray or splashing (Fig. 4).

3.5 Heater and control: a 3KW in-line heater was fabricated and fitted into a water circulation system. This was made in 100mm ABS tube with a domestic, titanium, hot water element fitted. The required water temperature was maintained using a S digistat thermostatic control unit (Fig. 6).

3.6 Box modification - water flow: the problem was that of maintaining a positive water flow through each box without causing undue disturbance to the oysters. A number of different options were considered and tried. The one finally used was to cascade water from the handhold in one end of the box into the end of the box below from where it flows through the box and out of the opposite end and so on down the stack. This is shown diagrammatically in Fig. 5. This involved boxes having to be staggered in their vertical stack and also the fitting of fabricated stainless steel plates at each end of the box. To ensure that water cascading into the box did not fall directly onto the oysters a 'V' shaped plate was attached to the box at one end (Fig. 7). This contained the turbulence caused by the water cascade (Fig. 8) and created a water flow across the box. Where the water cascaded out at the opposite end a smaller plate was attached to direct water in a uniform cascade and prevent it from running under the box (Fig. 9). The plates were bolted onto the box with the handle areas sealed with mastic. The small drain holes in the box rim and stacking pillars were also blocked with mastic. These modifications allowed a suitable water depth when loaded of 120mm.

3.7 Box modification - false bottom: to keep oysters clear of faeces, mud etc., two options were considered. One was to use an open mesh plastic floor mat in the bottom of the box (Figs 1 and 10) and the other to insert a tray (Fig. 11), of open mesh design inside the purification box. Most existing floor mat is quite deep (25mm) and to deep for the limited water depth available in the boxes used. Allibert 'Allimat' was only 10mm deep and was used. An Allibert Tray No. 41015 was also found to fit inside the purification box. This had the advantage that with the system drained down the tray of oysters could be lifted clear of the faeces in the purification box bottom without direct handling of the oysters. Oysters could then be hosed down in the tray with the purification box washed out separately. The disadvantage of course was that it reduced the oyster capacity by up to 20%.

3.8 Box modification - drainage: the potential problems of box drainage are discussed in 2.5 and the use of a 'bleed' hole in the box bottom has been discounted as not necessary. A number of possible options were considered and the method chosen was one of drilling two 12mm holes in the bottom of the nesting pillars of the box at one end (Fig. 9). By splitting the drainage to two holes it was possible to have a reasonable drain down time of four minutes whilst minimising the potential for recontamination as a result of changes to flow conditions in each box. By inserting a section of plastic guttering beneath the drain holes from the box the water was sent directly to the sump (Figs. 12 and 13). This allowed for individual boxes to be drained down instead of the whole system. This is necessary if the purification unit is also to be used as a storage facility when molluscs from an individual box may be required.

The drainage holes were positioned such that in use, 8% of the water in the boxes did not drain down which represented 4% of the unit water capacity. Water is also lost through evaporation and some splashing and in practice a make up of between 5% and 10% is required if re-using seawater. The water remaining in the bottom of the box contained the faeces and mud resulting from purification (Fig. 14) and thus those contaminants did not drain down into the sump. They were removed with the boxes from the plant and were flushed out after the oysters had been taken from the boxes. Because the oysters were sat either on matting or a tray the water level in the box was below the oysters before the box was removed from the stack.

The drain holes were sealed by means of rubber bungs. The individual hole size of 12mm was such that if one of the two bungs came out during purification the water flow out of the hole to the sump was less than that running through the system. Therefore water would continue to flow through the cascade although at a reduced rate.

3.9 Unit capacity: using the MAFF recommended loading density of 530 oysters per square metre the Allibert box has a capacity of 125 oysters (at an average weight of 100gm) or 100 if the tray insert is used. The prototype with its single box stack has a nominal capacity of 875 oysters which would double to 1750 if both stacks were fitted.

3.10 Water flow rate: concern with water flow through the boxes is discussed in 2.2, and on the basis of water changes per hour is dependent upon the system water capacity. With a sump capacity of 300 litres the water flow through the boxes is 7.5m/hr at a single water change per hour and 11.2m/hr at one and a half. These compare well with flows in other proven systems developed by Seafish and coupled with the box modifications discussed in 3.6 provide a uniform water exchange with good re-oxygenation between boxes. Water change rates of two changes per hour with this system are not at present considered to be necessary when holding oysters.

4. Plant Operation

Clean boxes are filled with washed oysters (Fig. 15) clear of the box bottom using matting or an additional tray (3.7). The boxes are then slid into the frame, care being taken to orientate them correctly. In practice it was found that numbering the boxes 1 to 7 made the task more straightforward.

Before turning on the u.v. unit and pump, it is important to ensure that box drain bungs are inserted and that the sump is filled with sufficient seawater. If there is not enough seawater in the system then the sump and hence pump can run dry during filling, potentially damaging the pump. The flow valve can be turned open during filling but once complete must be turned down to the required water flow rate.

Under no circumstances should the heater be switched on until the system is running and the thermostat probe has been inserted into the water, usually in the top tray, otherwise the plastic heater casing would melt. This unit sufficed for the trials but in a commercial operation an alternative method, such as installing a heater in the sump, would be used. The Digistat control unit must be set to the required water temperature.

When draining down the heater must be switched off first, then the pump and u.v. The plastic guttering is inserted beneath the boxes to be emptied and the bungs removed. Once the water stops flowing out of the boxes the bungs should be replaced and the box removed from the frame. Oysters must be removed from the boxes before washing to avoid recontamination by the detritus remaining in the boxes.

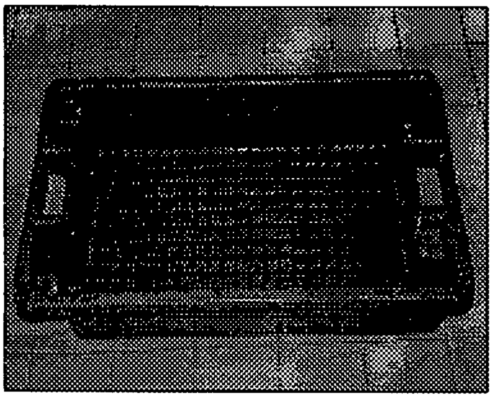


Figure 1 - Modified Allibert Box with Plastic Mat Insert

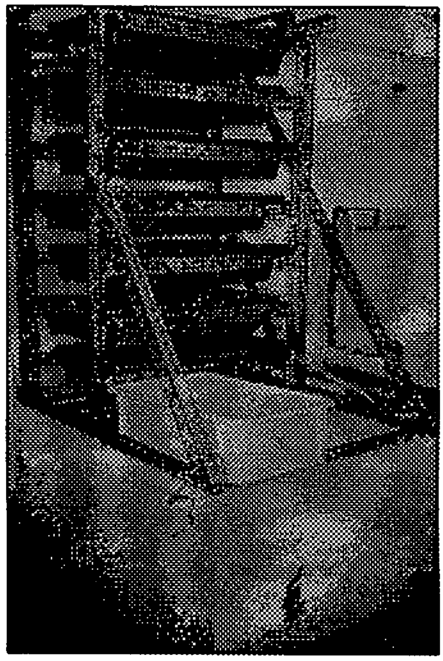


Figure 2 - Prototype Unit Sump and Support Frame

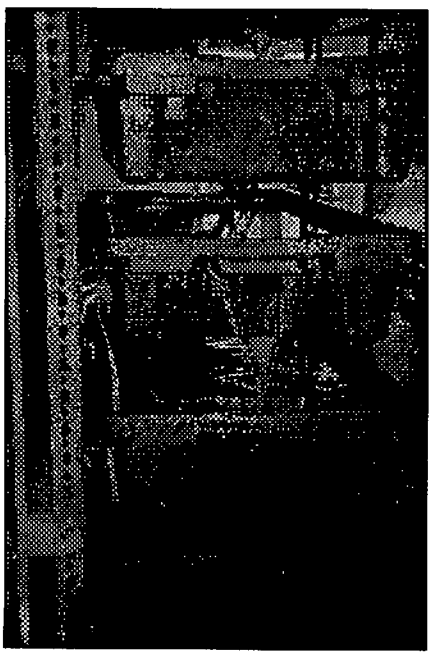


Figure 3 - Boxes Mounted on Frame

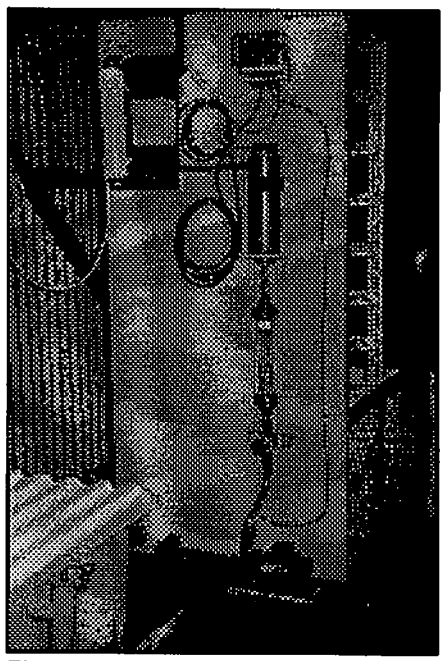


Figure 4 - Prototype Circulation System

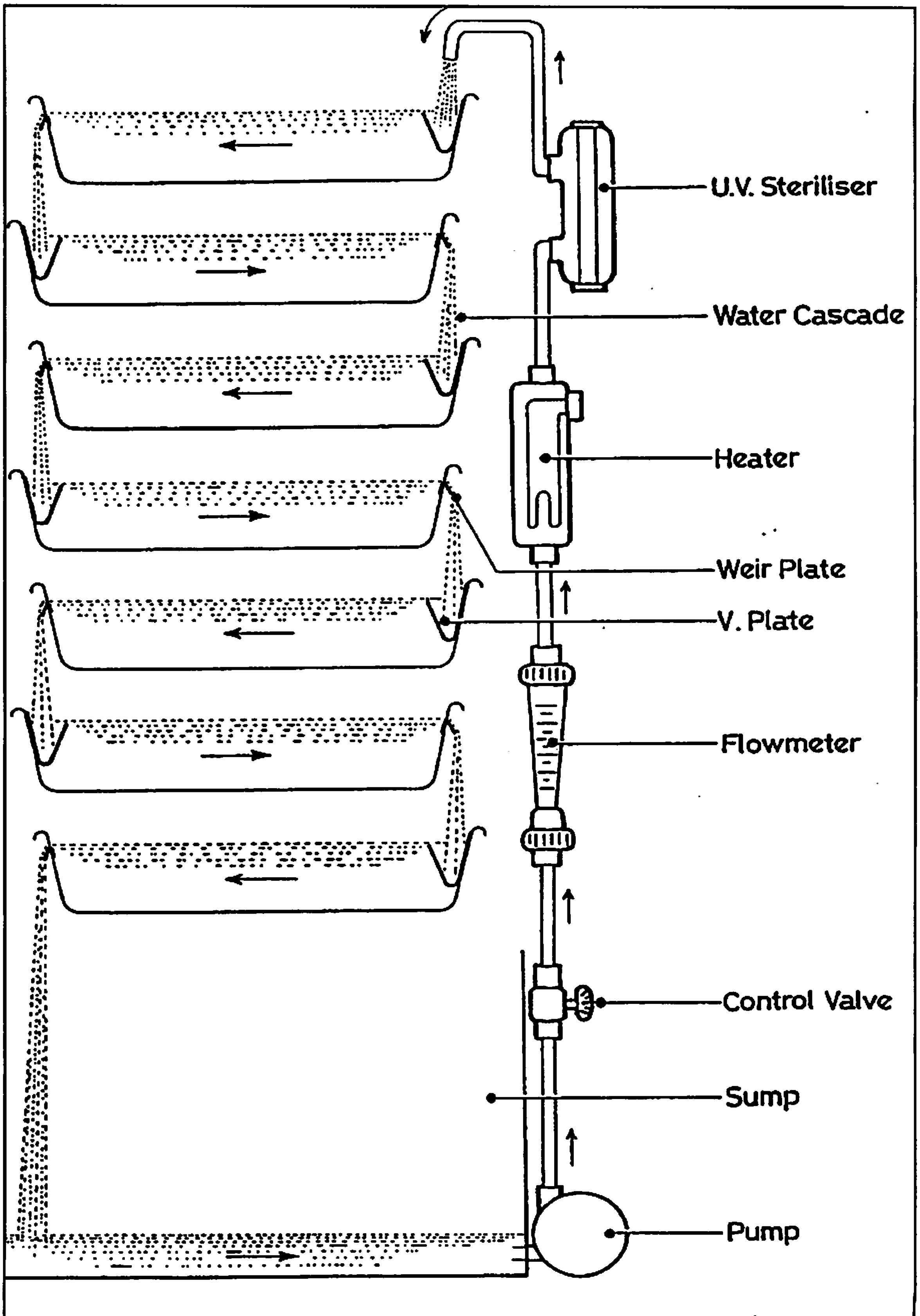


Figure 5 - Water Flow Through Purification Unit

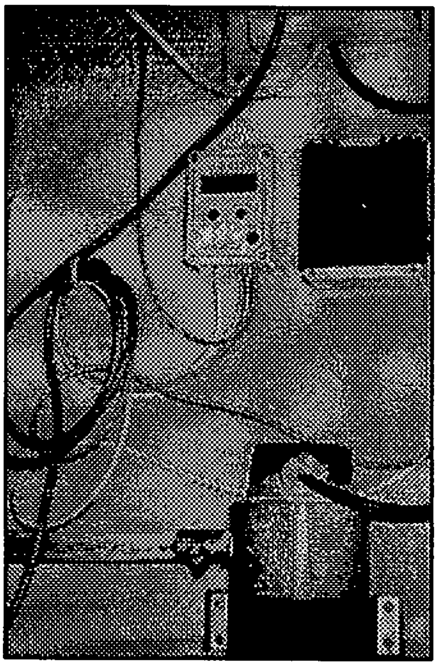


Figure 6 - Heater and Temperature Control Unit

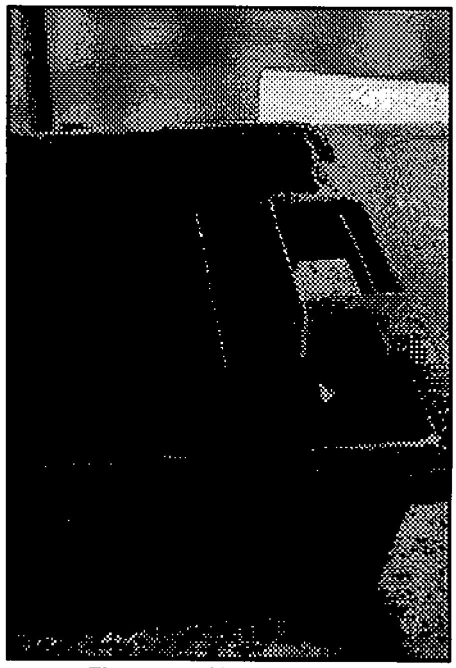


Figure 7 - 'V' Shaped Water Containment Plate

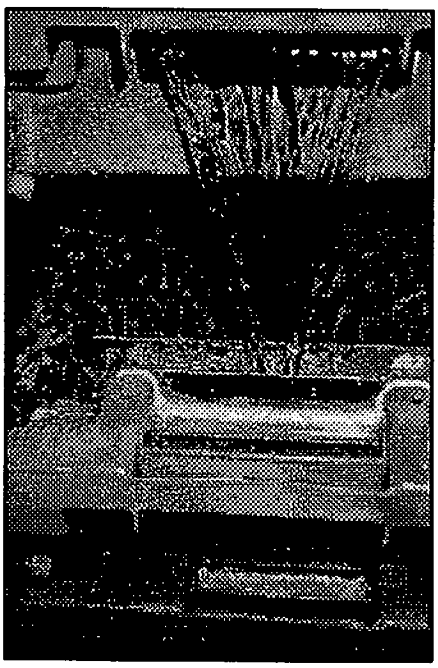


Figure 8 - 'V' Shaped Plate Contains Water Cascade

Figure 9 - Water Cascade Plate Note Bungs In Box Drains

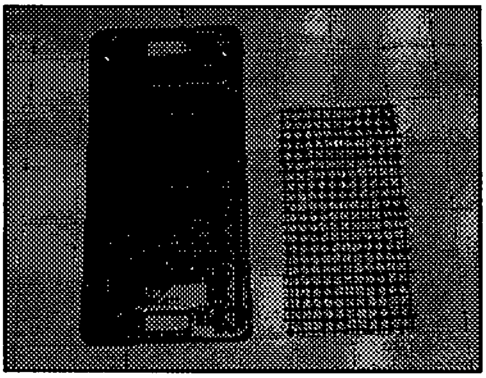


Figure 10 - Floor Mat Insert for Purification Box

Figure 11 - Box Tray Insert Option

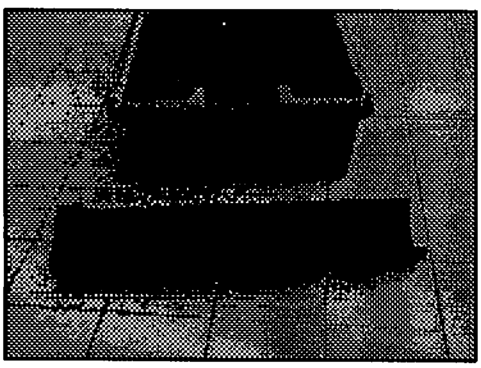


Figure 12 - Plastic Guttering for Draining Box Individual Boxes

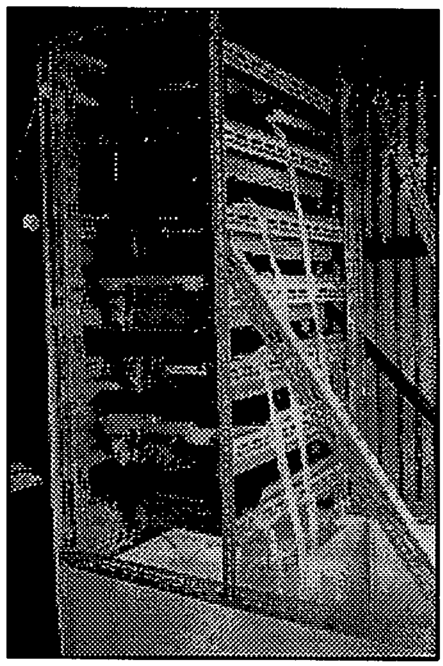


Figure 13 - Draining Boxes

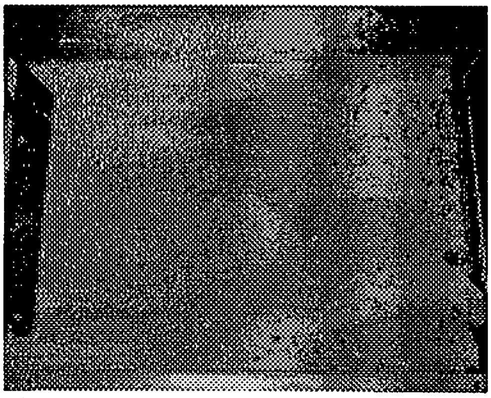


Figure 14 - Detritus in Bottom of Box after Purification

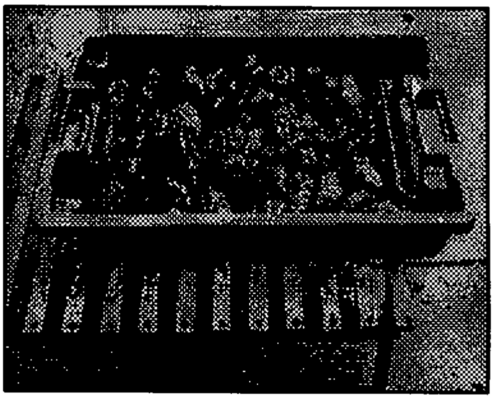


Figure 15 - Box Full of Oysters *(C. Gigas)*

APPENDIX II
Further Development of
A Vertical Stack Purification Plant

1. Introduction

A standard method of mollusc depuration is to support boxes of shellfish in a vertical stack and cascade water down through them from one box to another. Seafish have used this method when investigating oyster depuration and developed a prototype unit for these trials. Although not for commercial use the prototype did establish design criteria and these were used in the construction of a commercial unit by Essex Oyster and Seafood Company Limited at Maldon (Fig. 1). This unit was designed, developed and tested jointly by Essex Oyster and Seafish as part of further depuration trials. This is a description of the unit and those modifications made as part of the progress towards a standard design.

2. Prototype Unit

Seafish were concerned with the flow characteristics of existing vertical stack unit design during purification and subsequent draining down. There was a need to ensure sufficient water flow to maintain adequate dissolved oxygen levels whilst not disturbing molluscs to the extent that their activity was reduced. Methods of draining down were not satisfactory in minimising the chance of recontamination and there was a need to ensure that minimum water temperature requirements were met.

In the development of the prototype unit fabricated stainless steel plates were attached to the purification boxes to direct and contain water flow from one box to another (Fig. 2). Plastic matting was put into the boxes to keep molluscs clear of the bottom and a more satisfactory method for draining down used which allow boxes to be drained independently.

3. Commercial Unit

3.1 Box type

The Allibert Box No. 12030 was used with the fabricated stainless steel plates attached as with the prototype (Fig. 3). At one end of the box a 'V' shaped plate contains the turbulence of the water cascading into it and creates a water flow across the box. At the other end a small plate is attached to ensure a uniform flow where water cascades out at the box handle opening.

3.2 Sump

The sump unit must contain the total required water volume of 600 litres, have sufficient plan dimension to contain two stacks of boxes and also be able to support the framework when loaded at a weight approaching 650 kg. An Allibert plastic jumbox No. 21622 was considered suitable. This has a capacity of 650 litres and external dimensions of 1200 mm x 1000 mm x 765 mm.

A 50 mm plastic drain was fitted to the jumbox to allow for periodic draining down and cleaning.

3.3 Support frame

Dexion galvanised mild steel angle (75 mm x 50 mm) was again used to make a frame with a total capacity of 16 boxes in two vertical stacks. The frame was mounted on top of the jumbox sides and gave the unit a height of 2.34 m. Boxes were supported by Dexion runners at 180 mm vertical spacing.

3.4 Water circulation

A problem with using a flooded suction pump is that it needs to be at the floor level of the sump to maintain circulation and makes it vulnerable to water splashing. However, a small submersible and hence fully waterproof pump, was found which could be mounted externally and gave the required flow range of 10-15 litres per minute, representing one to one and a half system water changes per hour. Water flow through the boxes at this flow range is 7.5 - 11.2 m per hour and compares to flows used in other proven systems developed by Seafish. A strainer with removable foam filter was fitted to the suction pipe inside the sump. The pump used was an OASE Fountain Pump type USP 30 (Fig. 4).

A diaphragm type control valve, a flowmeter and a 15 watt UVAQ ultra-violet sterilizer completed the circuit which pumped artificial seawater from the sump up to the boxes at the top of the frame via 3/4" ABS plastic pipes (Fig. 5).

3.5 Heater and control

The heater needs to maintain a minimum water temperature of 8°C when purifying pacific oysters and the 3KW heater used on the prototype was considered well over capacity for this unit to be housed within a building. Instead standard aquarium type heaters connected to a temperature control unit (Fig. 6 - Rocon Electronics) were used. The heaters used were 300 watt titanium cased units (Schego) and not the normal glass type that could be broken easily. This approach gives the advantage that they are relatively low cost and can be installed in parallel in sufficient number to give the required heat input. Two were found adequate for maintaining water temperatures above 8°C.

3.6 Side panels
In use there was found to be some splashing from the unit onto the floor. This was subsequently found to be preventable when a clear acrylic panel was attached to the back of the frame.

3.7 Drainage
This unit contains eight boxes to a stack instead of the seven used with the prototype and in order to keep the overall height of the unit down, the boxes were vertically spaced at 180 mm instead of 210 mm. Although this had no apparent effect on dissolved oxygen levels three was not now sufficient space between the boxes to use the prototype drainage system of two small bungs in the box and a section of plastic guttering inserted under it (Fig. 7).

Several drainage options were tried using combinations of bungs and hose to direct water away from the boxes and into the sump. The option finally chosen was to fit a water butt tap in the box and connect this to a vertical down pipe with push fit plastic hose (Fig. 8). This allowed boxes to be drained independently but required a longer drain down time. The size of the tap opening is limited by the requirement that there must not be excessive changes in water flow within the box during drainage which may resuspend detritus and potentially recontaminate the molluscs. The tap chosen (Harcoster) has an opening of 12 mm, the same size as the drainage holes on the prototype, but with only one hole drainage time was doubled to approximately eight minutes. With this type of tap, due to it's size and location, 15.5% of the water remained in the box after draining down. This represents just under 10% of the unit water capacity of 600 litres and in practice a make up to 10% to 15% would be required if re-using seawater. This is 5% more than that required when using the rubber bungs.

3.8 Unit capacity
Using the MAFF recommended loading density of 530 oysters per square metre each box has a capacity of 125 oysters (at an average weight of 100 gm). With 16 boxes the unit has a capacity of 2,000 oysters.

4. Continued Development

In order to develop a standard design, the vertical stack unit needs not only to purify bivalve molluscs satisfactorily but also be cost effective in its construction. During the Seafish trials a number of minor problems were encountered with the commercial unit and were remedied as the trials progressed. The plant eventually received an operating licence from the

Department of Health (DoH), but there are some basic design changes that need to be considered in order to reduce the overall cost and simplify the design.

4.1 Box modification

The fabricated stainless steel plates attached to the boxes were very effective in creating a uniform water flow whilst containing the turbulence caused by the central cascade (Fig. 2). Unfortunately, they were expensive and difficult to fit and also required boxes to be staggered in the vertical stack, which required frame stops for each box to position them correctly. It is essential that the box modification are standard and repeatable and so the box manufacturer, Allibert, was asked if boxes could be provided already modified. Allibert considered this possible but cost effective only if the modifications involved the welding on of plastic parts. This approach was adopted and three types of modification were made and successfully tested. Two were plastic variants of the stainless steel 'V' plates, one consisted of a plastic partition welded across the box (Fig. 9) and the other a small plastic box welded outside the main box around the handle (Fig. 10). Both options retained the water cascade from the other box handle, simply replacing the stainless steel cascade with welded plastic. A third, and preferred option, was to fit plastic overflow pipes into the stacking pillars of the box (Fig. 11), replacing the cascade, and directing the water into the nesting recesses of the box below which were partitioned off, replacing the 'V' plates (Fig. 12). These options will be considered further with Allibert.

4.2 Support frame design

The use of Dexion angle, bolted together to construct the box support frame is laborious and it is difficult to maintain accuracy due to the limitation of the pre-formed bolt holes. It is also necessary to mount the frame across the top of the sump box sides and this makes it impossible to attach side panels in such a way that water will drain back into the sump. A solution is to make the frame in welded stainless steel and this is to be investigated further. This would give the required accuracy and allow side panels to be fitted correctly. It would also be corrosion resistant and easier to clean.

4.3 Box drainage

The water taps fitted to the boxes (3.7 - Fig. 8) were not ideal. Unless a more suitable tap is found, the use of rubber bungs as on the prototype is considered the best option (Fig. 7). This will require further consideration of the means of directing water back to the sump. The use of guttering on the prototype box requires a 60 mm spacing between boxes and limits the overall stack height to seven boxes.

4.4 Side panels

To contain any water splashing and reduce the effect of draughts on the water temperature within the unit, plastic sheet side panels should be fitted to the back and sides of the frame. The panels will need to be removable to allow for periodic thorough cleaning of the unit. If needed a plastic curtain should be fitted to the front of the unit.

4.5 Water temperature control

Maintenance of both maximum and minimum water temperatures is considered necessary in any purification system. With the assumption that this type of purification unit will be operated indoors, water heating is not considered to be a problem, the heating and control system used on the commercial unit giving sufficient flexibility. However, water chilling may well be necessary in hot weather and will need careful consideration as such equipment can be expensive, particularly for use in seawater systems.

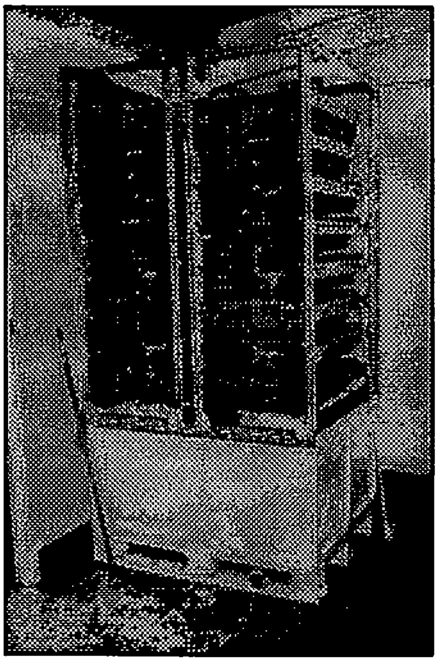


Figure 1 - Commercial Vertical Stack Unit at Essex Oyster and Seafood Company

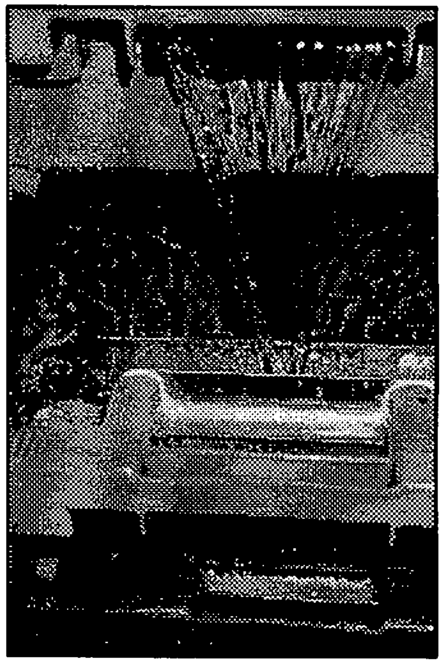


Figure 2 - 'V' Shaped Plates Direct and Contain Water Flow

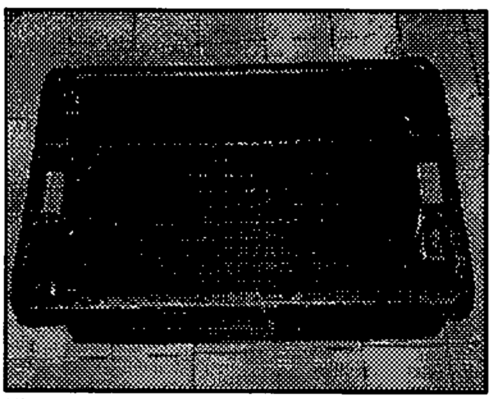


Figure 3 - Allibert 12030 Box with Stainless Steel Plates and Plastic Mat Insert

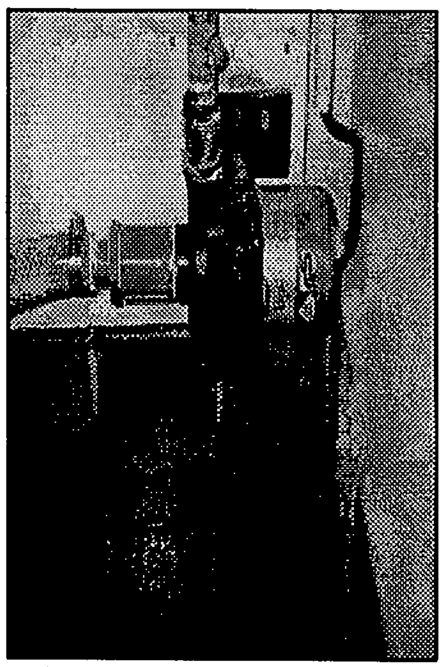


Figure 4 - Submersible Pump Unit

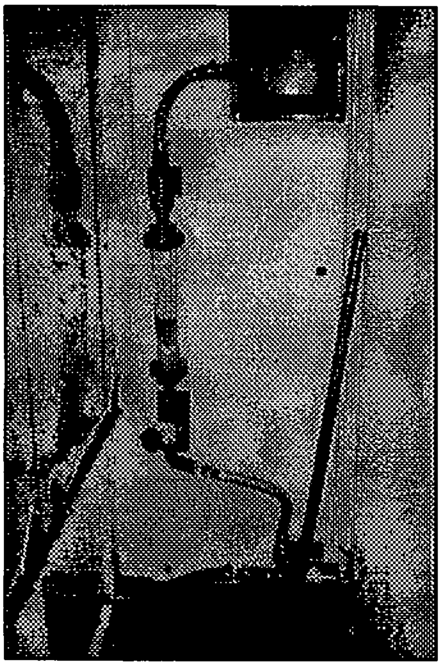


Figure 5 - Pump, Control, Valve, Flowmeter and UV Sterilizer

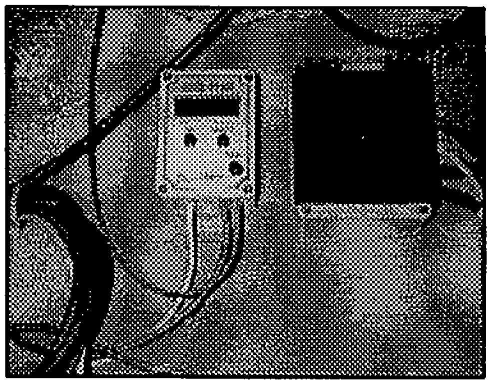


Figure 6 - 'Rocon' Temperature Control Unit

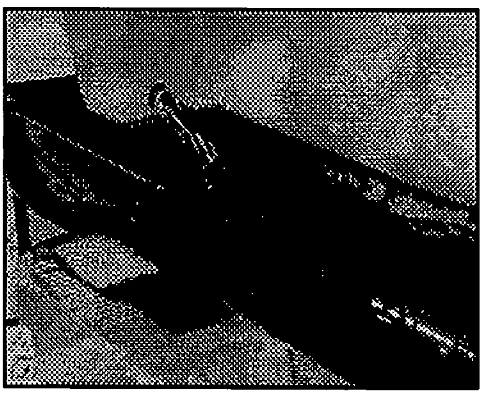


Figure 7 - Box Drainage Using Plastic Gutter

Figure 8 - Box Drainage Using Water Butt Tap and Hose

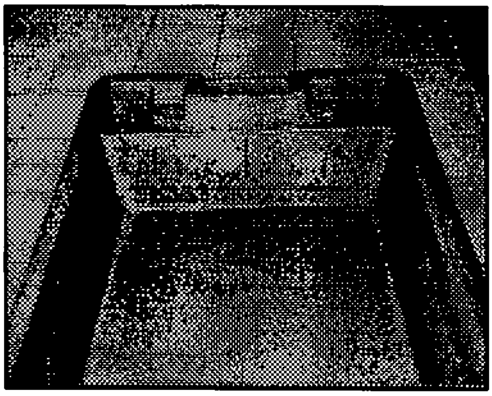


Figure 9 - Box with Welded Plastic Partition

Figure 10 - Box Unit Integral with Handle

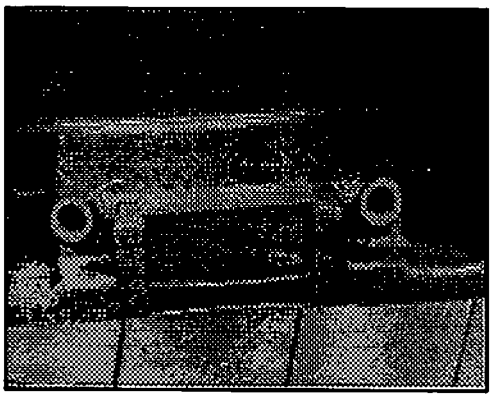


Figure 11 - Plastic Overflow Pipes Inserted into Box Stacking Locations

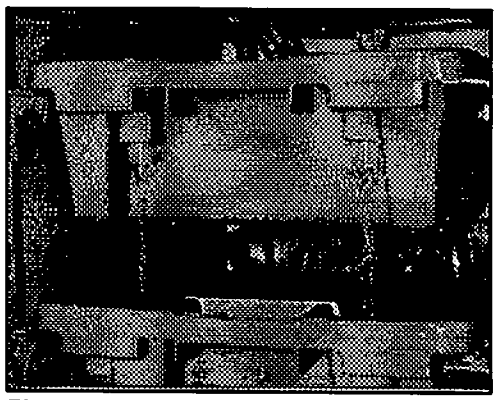


Figure 12 - Water Directed into Nesting Recesses of Blow Below

APPENDIX III
Trials Equipment

1. Control Purification Tank

Seafish installed on site a small control tank, capable of holding two fully immersed trays of oysters. The tank has its own u.v. steriliser, pump, control and aeration unit. It is designed to operate within the existing MAFF criteria for shellfish purification. (See Fig. 1 and 2).

2. Environmental Chamber Used for Storage Trial

Manufactured by Cee-Tel Thermal Equipment Limited, the test chamber installed at Seafish premises, Hull, has a 1000 mm x 1000 mm x 1000 mm chamber and any required temperature profile between -30°C to 100°C can be maintained. The accelerated spoilage so induced can be related to storage at lower temperatures and other comparable trials data. (See Fig. 3).

3. Temperature Measurement

Comark 9001 Digital Thermometer with probe and squirrel data logger connected to thermocouples.

4. Dissolved Oxygen Measurement

Oxyguard Handy Portable Oxygen meter with temperature compensation.

5. Water Quality

Palintest Portable Spectrophotometer with re-agents to measure:-

Ammonia measured in terms of total Ammonia PPM (NH_4)
Nitrite measured in terms of total Nitrite PPM (NO_2)
Nitrate measured in terms of total Nitrate PPM (NO_3)
pH
Carbonate

6. Salinity Measurement

A hydrometer and cylindrical glass jar used in conjunction with thermometer.

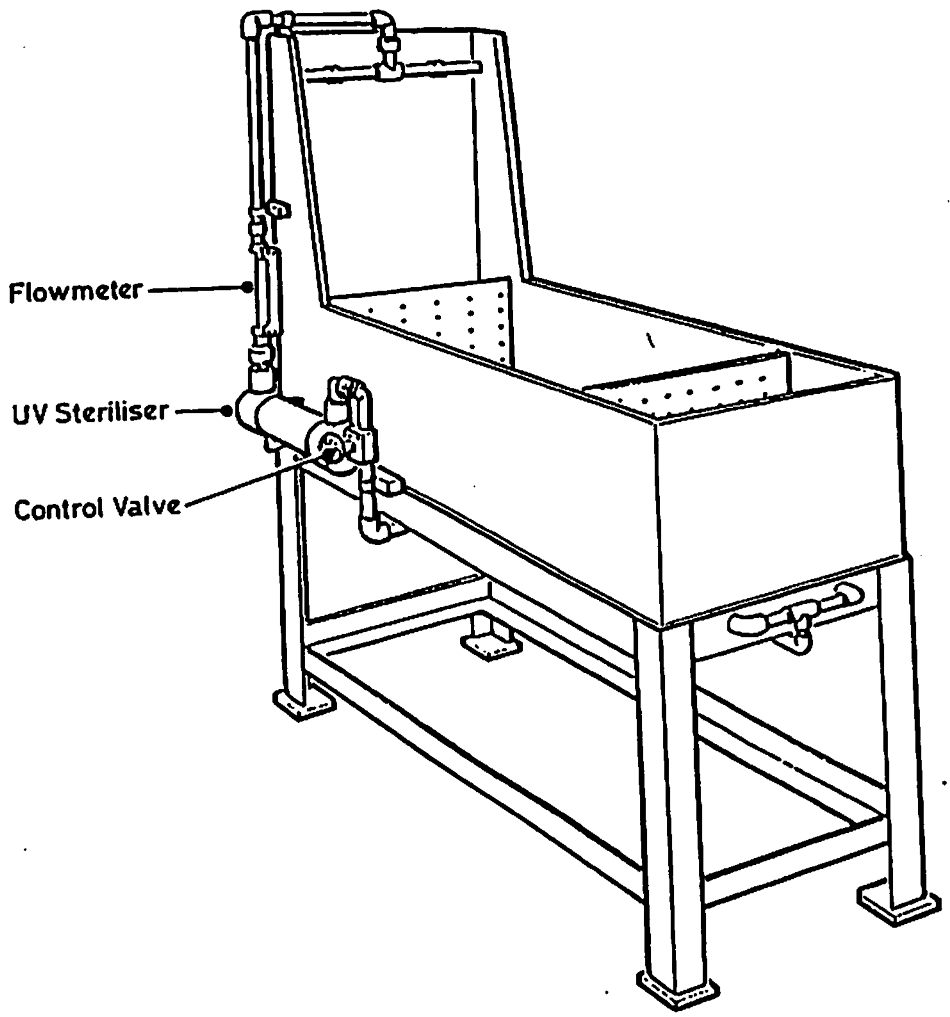


Figure 1 - *Control Purification Plant (MDP) - Equipment Specification*

Tank	Constructed in marine ply with light blue epoxy resin surface finish. Mild steel stand.
Pipework/Valves	1/2" A.B.S.
Pump	Nikkiso Magpan CPO3. Centrifugal pump with magnetic drive. Maximum capacity 6 l/min at 1 metre head. Mounted under tank.
Ultra Violet Sterilizer	UVAQ 15/3P with 15 watt tube.
Flowmeter	Paton PG1 - 10 litres/min.
Aeration	Atlantic B800 air pump mounted on back of tank feeding two 300mm diffuser blocks on tank base.
Water Capacity	At working depth of 180mm, 110 litres (24 gallons) and 340mm, 206 litres.
Tray	Up to two Allibert Type 41042 (752 x 448 x 167mm).
Heating	330 watt aquarium heater used with Digistat temperature controller.

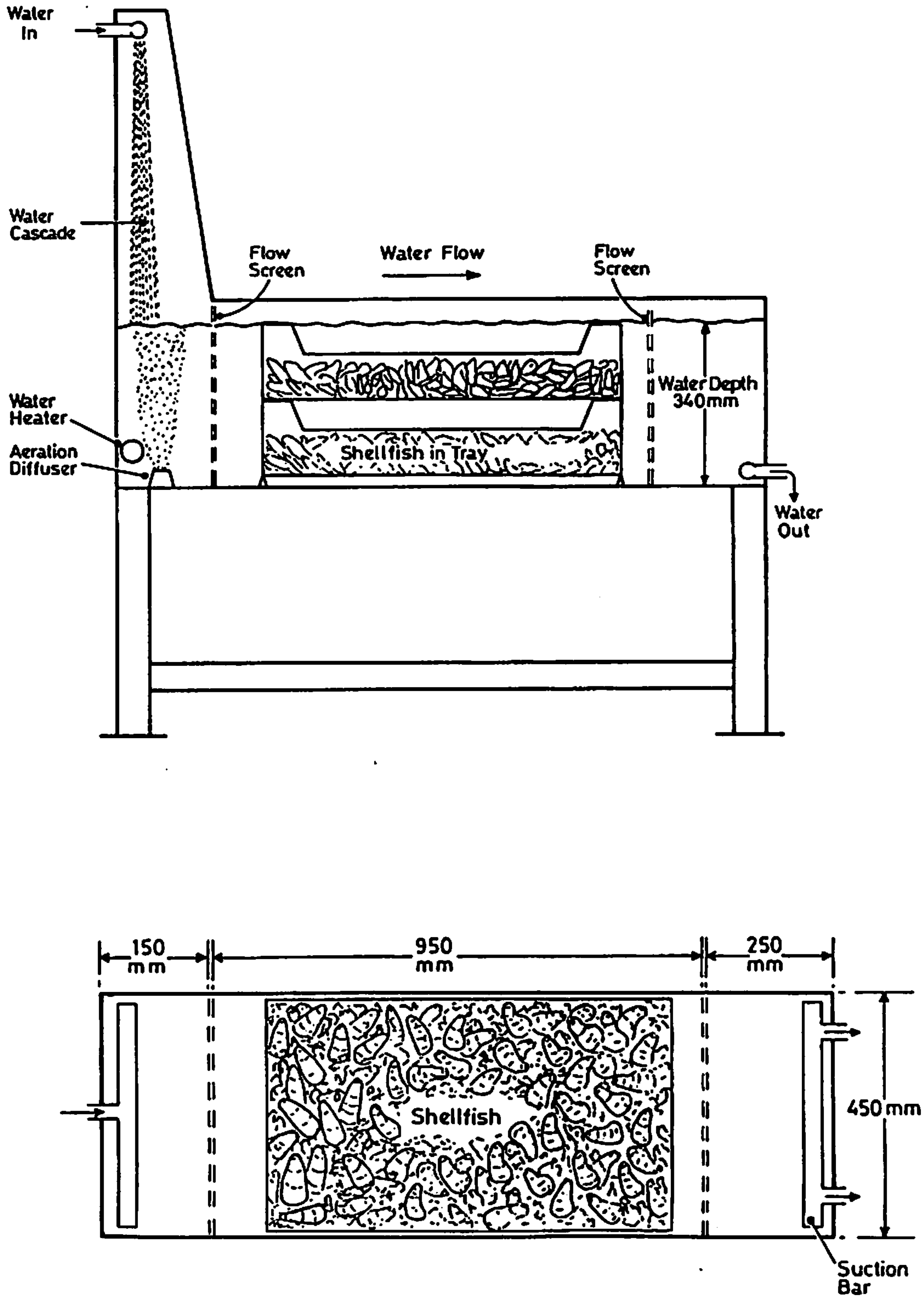


Figure 2 - *Control Tank - Schematic Layout in 2 Tray Mode*

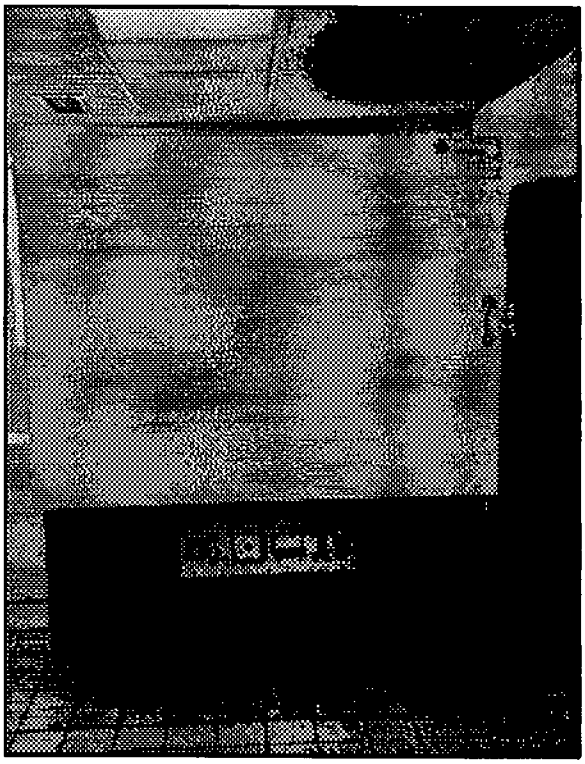


Figure 3 - Environmental Chamber

APPENDIX IV
Artificial Seawater

1. Salinity

The artificial seawater was made up using the five basic salts, as defined by MAFF Laboratory Leaflet No. 39. (Ref. No. 8). The salt content or salinity of seawater is usually expressed as number of parts by weight of salt in one thousand parts of weight of water. The unit 'parts per thousand' is indicated by the symbol ‰. Salinities of 22‰, 27‰ and 40‰ are specified all using five basic salts. The salinity of 27‰ was chosen for re-use even though a lower salinity of 20.5‰ is satisfactory. This was to allow a working margin for error (in a commercial environment) and avoid the danger that if salinity fell too low the oysters would not purify.

2. Mixture and Costs

The five basic salts were mixed in the following proportions to give a salinity of 27 parts per thousand in 1000 litres of tap water.

Sodium Chloride	NaC1	21.08 kg
Magnesium Sulphate	$MgSo_4$	5.18 kg
Magnesium Chloride	$MgC1_2$	4.12 kg
Flake Calcium Chloride	$CaC1_2$	1.06 kg
Potassium Chloride	KC1	0.5 kg

Commercial grade salts when obtained from a bulk supplier are in 50 kg sacks other than sodium chloride which comes in 25 kg sacks.

Costs are given below for sacks bought on individual and per tonne basis:-

	£ per sack (individual)	£ per pack (per tonne basis)
NaC1	5.40	4.20
$MgSo_4$	18.90	13.45
$MC1_2$	12.00	10.20
$CaC1_2$	19.43	13.90
KC1	40.15	12.35

If the sodium and magnesium salts are bought in bulk the salt cost per 1000 litres of water will be:-

	£
NaC1	3.54
$MgSo_4$	1.39
$MgC1_2$	0.84
$CaC1_2$	0.41
KC1	0.40
Total	6.58

Source: Ellis and Everard Chemicals - January 1991