CABIN WATER SPRAY SYSTEMS

COST ANALYSIS

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Prepared for the Civil Aviation Authority

by

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CONTENTS

1. EXECUTIVE SUMMARY

As a result of research conducted in the UK and USA the original concept of a Cabin Water Spray System in which water was sprayed throughout the entire length of the cabin has been radically altered.

This report analyses the possible costs of a reduced weight Cabin Water Spray System installation into three typical sizes of civil aircraft. To this end a theoretical design concept was established to which all costs could be related.

This report addresses the design costs, equipment costs, installation costs, maintenance costs and direct operating costs of such a system.

2. INTRODUCTION

This Study has been prepared in order to evaluate the possible cost implications of fitting civil aircraft with a Cabin Water Spray System (CWSS).

As a result of research conducted in the UK and USA the original concept of a Cabin Water Spray System in which water was sprayed throughout the entire length of the cabin in the event of a fire has been radically altered. It has been shown that the benefits of using a fine water mist can be satisfactorily obtained by spraying water only in the region of the fire. The original concept has therefore developed into a system that utilises discrete zones of approximately 8 to 10 feet cabin length each individually activated by sensors in the event of fire. This system makes extremely efficient use of the available water enabling, in comparison to the original full cabin spray system, a vast reduction in the total weight of the system.

In view of the large number of aircraft types, variants, operators' configurations, route structures, etc., the analysis must, out of necessity be restricted. To this end a Specification Ref. No. 9/40 : 26-20-02 Issue 2 dated 28 January 1993 was drawn up by the Civil Aviation Authority. This Specification forms the basis of a design concept discussed in Section 4.

Aim Aviation was commissioned by the Civil Aviation Authority to conduct a study to investigate cost aspects associated with a Cabin Water Spray System. During the course of the study, numerous airlines, manufacturers and associated aerospace companies collaborated in providing many of the costs and comments used in this report.

Aim Aviation wish to acknowledge the help and advice received from the following organizations (in alphabetical order):-

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3. STUDY REQUIREMENTS

3.1 SYSTEM SPECIFICATION

The following specification was drawn up by the CAA, it embodies two essential elements, firstly a series of requirements and specified parameters which prescribe the optimised water spray system that has been developed in full scale testing and has been shown to provide the fire suppression performance necessary. This part of the specification includes requirements that a Cabin Water Spray System would have to meet such as inertia loads, availability and reliability targets. The second part of the specification calls for the cost of this water spray system to be calculated for a number of variables, namely aircraft size, tank capacity, degree of crashworthiness and the possible use of potable water. The CAA considered that the information requested would enable a judgement to be made of the overall cost of such systems and also of the cost and benefit implications of individual requirements currently under discussion between the Authorities.

The information detailed below has been extracted from the CAA's specification 9/40 26-20-02 dated 28 January 1993. It defines the volume of water required per minute in each zone and the temperature which will initiate the spray. It also defines the parameters to be considered in the design, e.g. crash loads, reliability and flight crew interface.

For each aircraft under consideration CWSS must provide a water spray within the aircraft cabin. This should be achieved by dividing the cabin into a series of zones. A zone is the cabin volume defined by a cabin length of 8 feet and the associated cabin cross section.

The CWSS should be capable of filling the entire volume of each zone with a fine water spray. Each zone in regional and narrow body aircraft should contain eight nozzles whilst those in a wide body aircraft should contain 16 nozzles. Each nozzle should provide a water flow rate of 0.35 (US) gallons per minute (1.3 litres per minute). The same water flow rate should be maintained to each zone when the system is operating, and should be independent of the number of activated zones. (In a wide body aircraft, it is assumed that no more than six zones will be active at any one time.)

3.1.2 Each zone of the system must be automatically activated when the ambient cabin ceiling temperature in that zone is 150°C (302°F), or greater, and the aircraft is on the ground.

3.1.3 The CWSS must be capable of providing a fully developed spray in any one zone within 5 five seconds of system activation.

3.1.4 Information on the status of the system must be available to the flight crew.

3.1.5 Inadvertent operation of the system in flight is required to be extremely improbable, as required by JAR/FAR 25.1309.

3.1.6 The system must be capable of operation after having been subjected to the following inertia forces:

(i) Upward, 3.0 g
(ii) Forward, 9.0 g
(iii) Sideward, 3.0 g
(iv) Downward, 6.0 g
(v) Rearward, 1.5 g

3.1.7 The system must have an arm/disarm feature which prevents an in-flight operation of the system. During the course of the study, a number of operators indicated that they would require a cockpit controlled power supply switch. This has been costed in this study although it was not required by the CAA specification.

3.1.8 Design precautions must be taken to minimize the possible adverse effects of fire on the performance of the system.

3.1.9 The performance of the system shall not be adversely affected when the aircraft is in an attitude on the ground consistent with the collapse of one or more landing gear legs.

3.1.10 The probability of the system being inoperable when required should be no worse than 10^{-3} per flight hour.

3. SYSTEM SPECIFICATION (cont.)

3.2 AIRCRAFT TYPES

Significantly the study requires the analysis of 3 basic aircraft types, viz.

a) Regional Transport with a cabin length of 40 ft (12.2m). Typically a single aisle with 15 rows of seats at 31" (.79m) pitch, giving 45 passengers at 3 abreast or 60 passengers at 4 abreast.

b) Narrow Body Aircraft with a cabin length of 80 ft (24.4m). Typically a single aisle with 29 rows of seats at 32" (.81m) pitch, giving 174 passengers at 6 abreast.

c) Wide Body Aircraft with a cabin length of 136 ft (41.5m). Typically twin aisles with 40 rows of seats at 32" (.81m) pitch giving 360 passengers at 9 abreast.

Each of the three basic types is then divided into the following configurations:-

Regional Transport

1) One supply tank at the rear, capable of providing 8 US gallons of water to any one zone.

2) One central supply tank, capable of providing 8 US gallons of water to any one zone.

3) Two tanks, one at each end of the cabin, each capable of providing 4 US gallons of water to any one zone.

4) Two tanks, one at each end of the cabin, each capable of providing 8 US gallons of water to any one zone.

5) Using the onboard potable water supply.

Narrow Body

6) One supply tank at the rear, capable of providing 8 US gallons of water to any one zone.

7) One central supply tank, capable of providing 8 US gallons of water to any one zone.

8) Two tanks, one at each end of the cabin, each capable of providing 4 US gallons of water to any one zone.

9) Two tanks, one at each end of the cabin, each capable of providing 8 US gallons of water to any one zone.

10) Using the onboard potable water supply.

3.2 AIRCRAFT TYPES (cont.)

Wide Body

11) One supply tank at the rear, capable of providing 16 US gallons of water to any one zone.

12) One central supply tank, capable of providing 16 US gallons of water to any one zone.

13) Two tanks, one at each end of the cabin, each capable of providing 8 US gallons of water to any one zone.

14) Two tanks, one at each end of the cabin, each capable of providing 16 US gallons of water to any one zone.

15) Using the onboard potable water supply.

It should be noted that in all cases the amount of water carried is greater than that quoted above to cater for the filling of the distribution pipes. Exact details are shown in section 6 of this report.

4. DESIGN

4.1 CONCEPT

In order to meet the requirements of the Specification it was necessary to carry out a practical design study which was refined as discussions with industry progressed. A detailed weight analysis for each configuration has also been generated in order to evaluate the cost of ownership resulting from an increased aircraft weight.

In essence, the design consists of a water supply module, a main distribution pipe running the length of the aircraft, a network of nozzle feed pipes and a control module. Appendix A shows the concept in a schematic form and Appendix B shows an electrical schematic for its operation.

Water Supply Module
Three options have been considered in this study. Firstly a removable water supply, secondly a permanent tank and finally the existing potable water tank.

Distribution Pipe
Two concepts were considered as part of this study. Water can be fed to the nozzles from either a high or low pressure supply. There are advantages and disadvantages with both approaches. With a high pressure system the amount of water required to fill the distribution pipe is lower but each nozzle requires an additional and 'individually tuned' pressure regulator. A high pressure distribution system is also unsuitable for connection to a potable water supply without a major redesign of the aircraft tank/tanks.

A low pressure system requires a larger distribution pipe and therefore carries a greater volume of water. However it can be connected into the potable water supply and is less critical when it comes to the maintenance of nozzles. In general, the total costs and weights involved in both systems are similar. Detailed costings have therefore concentrated on the low pressure system.

Nozzle Feed
The aircraft is divided into 8ft. zones. Each zone is provided with a control valve and an eight way manifold together with flexible pipes connecting to the eight nozzles.

Control Module
As requested by a number of operators, the system should be capable of being armed/disarmed by the flight deck crew. Once armed it is fully automatic but cannot be actuated other than on the ground as the system is interlocked with multiple sensors, (radio altimeter, undercarriage micro switches, and possibly to the air speed indicator).

The system is triggered by heat sensors. Should a zone be triggered, the water container is pressurised and the primary feed valve on the water tank is opened, thus allowing the main distribution pipe to fill. The individual zone isolating valve is then opened providing water to the eight nozzles in this zone. A test facility is incorporated to ensure ease of maintenance and operational status.

4.1 CONCEPT (cont.)

Typical Operation
The operation of the system is expected to be along the following lines:-

The system is switched on prior to both take-off and landing by the flight deck crew. It is subsequently switched off as part of the "after departure" checks. As well as this manual control, the system will automatically dis-arm once the undercarriage sensors detect that the aircraft is airborne and conversely, will only re-arm when the aircraft is back on the ground.

The system is activated solely by Heat Sensors and only when the aircraft is on the ground.

Under normal circumstances, the components of the system are in the following conditions

1. All nozzles are sealed with dust caps.
2. All pipe runs are dry.
3. All zone control valves are in the closed position.
   (Therefore all nozzles are isolated from the main distribution pipe/pipes)
4. All frangible couplings are intact.
5. All available water is in a sealed, unpressurised tank.
6. The pressure bottle is fully charged.
7. The rechargeable battery is fully charged.

Should one of the heat sensors detect a temperature in excess of 150°C and the system has been armed (both by the flight deck crew and by virtue of being on the ground) then the CWSS will be activated. The sequence is as follows:-

1. The pyrotechnic start valve on the gas bottle will be operated.
2. The water tank will be pressurised.
3. The main control valve on the water tank will open and the distribution pipe will fill with water.
4. The zone control valve associated with the activated heat sensor will open.
5. The nozzle dust caps in the affected zone will be blown off.
6. The water spray will begin in the affected zone.

Should additional heat sensors be triggered, items 4, 5 and 6 are repeated.

Should the aircraft have suffered structural damage, sufficient to separate any of the frangible couplings, then there will be no loss of either pressure or water from the CWSS.

4.2 DETAIL

Base Assembly

As a result of the reduction in the amount of water required in the CAA's specification, a small and light storage tank could be used in some of the configurations. This tank could therefore be mounted on a removable base. Appendix C shows a typical assembly. Theoretically it could be located in the cabin behind the rearmost seat and be attached to the seat rails with standard seat rail fittings. Alternative positions could be under the floor, behind bulkheads or in wardrobes.

The mounting for the tank consists of a minimum of two aluminum alloy cradles attached to the base assembly. This base also provides mountings for the pressurisation bottle, control head, pressure reducing valve, primary stop valve, charging valves and batteries.

Where applicable the base has a carpeted, quick release cover to prevent damage or interference to either the tank, pressure bottle or the individual system components.

Tank

The tank is typically of cylindrical form with hemispherical ends. The size of a typical tank holding 10 US gallon would be 24" long by 12" in diameter. Four annular rings are formed in the cylindrical section providing two locations for the cradles and straps. Provision is made for connections to the pressurising and water feed unions. In the case of the latter this is via a valve assembly. There are also connections for a pressure relief valve and if applicable for remote filling/draining. The pressurisation is provided from a rapid discharge, high pressure stored gas cylinder, also mounted on the base assembly. To ensure that the system remains operational, irrespective of the aircraft attitude, the water in the tank is contained within a bladder. Once the tank is pressurised the bladder is compressed, thus ejecting the water.

Should the tank need to be a permanent installation, additional fittings and pipes are required to allow for draining and filling via the existing servicing points.

In the case of using the potable water supply, both a pumped and a pressurised system were considered. For a pumped system, it became clear that to provide the required pressure/flow rate and a reasonable spray duration, it would impose too great a weight penalty. It was therefore decided to cost a system requiring the pressurisation of the onboard potable water tank. This in turn requires more control valves to shut off the domestic water system, and where necessary, modifications to the potable water tank.

Distribution System

The water feed from removable tank/tanks is via a quick release coupling. Part of this coupling is mounted in a connection box recessed into the sidewall and closed with a decored panel. This box also provides access to the electrical connections. From this box, and behind the furnishings, a feed pipe runs up to the centreline of the aircraft and turns forward (or aft), until it reaches the first manifold. It then connects to the main distribution pipe which runs the length of the ceiling. See Appendix A.

4.2 DETAIL (cont.)

Distribution System (cont.)
The distribution pipe consists of a number of 8ft lengths of flexible pipe, connected together down the length of the cabin. The diameter of this pipe is determined by the number of zones on the aircraft, the location of the tank/s and the required operating pressure. Each 8ft length is joined together by a 'T' connector. In addition, to cater for crashworthy configurations, the 'T' connector is bracketed with either frangible couplings, solenoid valves or hydraulic fuses. Once again, there are advantages and disadvantages with each type. Frangible couplings introduce a pressure drop, solenoids require power to hold them open and hydraulic fuses take time to close thus allowing water to escape from a severed system .

Zone connections
Connected to the open end of the 'T' is an electrically operated solenoid valve and then an 8 way distribution manifold. As the zone solenoid valve is fed from the main distribution pipe, other zones can still be actuated, the only penalty being a reduction of spray time.

Manifold and Nozzle assembly
The manifold has eight threaded union connections for attachment to the nozzle supply pipes. There is also provision for mounting to the aircraft structure using insulating fittings. From the manifold run eight flexible narrow bore pipes, two feeding nozzles in the ceiling, three feeding nozzles on the port side and three feeding nozzles on the starboard side.

Each nozzle is held in a two part decorative holder which is attached to the aircraft structure. The holder has a connection to the flexible pipes mentioned above. Suitably positioned holes are provided in the furnishing panels, with protective bezels, bonded around the cut out. This allows the panels to be removed without disturbing the nozzles. All pipes are clipped to the aircraft structure at appropriate spacings. The clips are insulated from 'cold' areas and are provided with protective sleeving to prevent chafing of the pipes and fittings.

Heat Sensor
At least one linear heat sensor is located substantially over the centreline of the aisle, and above the ceiling panel. These sensors are set to activate three primary electrical circuits should the ambient temperature reach 150°C or greater at any point along the length of the sensor. A calibrated detection system for a given aircraft will be able to resolve this event into an individual cabin zone. Circuit one energizes (opens) the latching solenoid valve attached to the water tank. Circuit two fires the pressure bottle. Finally, circuit three opens the latching solenoid valve attached to the manifold of the zone containing the activated heat sensor.

The crashworthiness of the detection system can be enhanced by introducing a second control unit at the opposite end of the aircraft, and running its sensor "nose-to-tail" with the first system. In the event of a single fuselage break, detection capability is maintained in all zones.

Controls
Power for these circuits emanates from the battery bus-bar via a cockpit circuit breaker and flight deck instrumentation. See Appendix D. The circuit is prevented from airborne activation by the use of feeds from various sensors. Although the system is not considered 'despatch critical' a flight deck annunciator panel is provided with a "Press to Test" switch. Indication is restricted to "Armed and Serviceable". Appendix E shows a schematic of the test facility.

4.2 DETAIL (cont.)

Protection of Electrical Equipment

In the event of a legitimate activation, the water discharged by the CWSS must not impair the operation of other safety features, in accordance with JAR 25.1309 which states:-

> "The equipment, systems, and installations whose functioning is required by the JAR and national operating regulations must be designed to ensure that they perform their intended functions under any foreseeable operating conditions. (See AMJ 25.1309 and ACJ No. 2 to JAR 25.1309.) However, systems used for non-essential services need only comply so far as is necessary to ensure that the installations are neither a source of danger in themselves nor liable to prejudice the proper functioning of any essential system."

To that end, care and consideration must be given to the sealing of such systems due to either direct contact with the spray e.g. ingress through joints, or by more direct means i.e. migration of spray resulting in an accumulative volume of water.

Certain areas in the immediate vicinity of the tank/tanks would require special attention by way of sealing adjacent floor panels and possibly the shrouding of any electrical items behind or installed into the sidewall trim panel housing the water connection box. However it is believed that the protection afforded should not be vastly different to that adopted for the installations of a galley unit or lavatory.

The majority of systems can easily be protected, for example simply by the prudent application of a bead of sealant. One design of Floor Path Lighting features individual lens modules, housing a lamp, sealed by an 'O' ring which when installed into its floor track, becomes virtually self sealing and withstands 95% humidity. The addition of a sealant would obviously enhance its waterproof qualities.

Other systems which are above floor level, such as the Emergency Lighting and Passenger Address speakers, may again be easily sealed against the atmosphere/environment generated by the fine spray of the CWSS. For the lighting, the installation of a gasket between the lens and housing would suffice, for the speakers, a membrane between the bezel and speaker chassis.

5. CONFIGURATION VARIATIONS

5.1. REGIONAL TRANSPORT AIRCRAFT Configurations 1 to 5

Cabin length of : 40 ft.

Cabin height : 6½ ft.

Cabin width : 8½ft.

In each configuration for this aircraft type, the cabin is assumed to have 5 zones, each of 8 ft. length and therefore having a total of 40 nozzles throughout the cabin.

The design follows closely on the description in Section 4 with regard to the details incorporated. The main pipe is sized to ensure that the spray starts within 5 seconds. It should be noted that the difference between the total amount of water carried and the usable water is accounted for by the need to fill the main distribution pipe prior to the spray commencing.

Configuration 1
This has 10 US gallons of water (8 usable gallons) stored in a tank at the rear of the cabin. Typically this could be stowed on its base behind the last row of seats. It is assumed that an alternative location e.g. below floor, behind bulkheads or in wardrobes for example, does not materially affect the analysis.

Configuration 2
The tank is located close to the centre of the cabin, giving improved crashworthiness as a fracture of the main feed pipe will still supply to one side of the break. It should be noted that crashworthiness is also addressed by virtue of flexible pipe runs and frangible couplings.

Centre location of the tank means that the feed pipe diameter is smaller due to a reduced length to the furthest zone.

Configuration 3
This configuration improves the crashworthiness by providing 2 tanks with a combined total of 11 US gallons (8 usable gallons), such that water could be supplied to either side of a single break. Each tank has been designed to operate the entire system alone should there be a fuselage rupture. If the aircraft were to remain intact, the two tanks have the combined ability to provide a greater amount of usable water (in this case 9.5 US gallons).

Configuration 4
This is similar to Configuration 3, but having a total of 20 US gallons (18 usable gallons) can provide water for a longer period.

Configuration 5
This configuration uses the potable water system. Supply to the main feed pipe is controlled via a bi-directional valve. The heat sensing system redirects the domestic water to the CWSS and pressurizes the tank using a dedicated pressure cylinder.

5. CONFIGURATION VARIATIONS (cont.)

5.2. NARROW BODY AIRCRAFT Configurations 6 to 10

Cabin length of : 80 ft.

Cabin height : 7½ ft.

Cabin width : 12 ft.

In each configuration for this aircraft type, the cabin is assumed to have 10 zones each of 8 ft. length and therefore having a total of 80 nozzles throughout the cabin.

The design follows closely on the description in Section 4 with regard to the details incorporated. The main pipe is sized to ensure that the spray starts within 5 seconds. It should be noted that the difference between the total amount of water carried and the usable water is accounted for by the need to fill the main distribution pipe prior to the spray commencing.

Configuration 6
This has 12.5 US gallons of water (8 usable gallons) stored in a tank at the rear of the cabin. Typically this could be stowed on its base behind the last row of seats. It is assumed that an alternative location e.g. below floor, behind bulkheads or in wardrobes for example, does not materially affect the analysis.

Configuration 7
The tank is located close to the centre of the cabin, giving improved crashworthiness as a fracture of the main feed pipe will still supply to one side of the break. It should be noted that crashworthiness is also addressed by virtue of flexible pipe runs and frangible couplings.

Centre location of the tank means that the feed pipe diameter is smaller due to a reduced length to the furthest zone.

Configuration 8
This configuration improves the crashworthiness by providing 2 tanks with a combined total of 17 US gallons (8 usable gallons), such that water could be supplied to either side of a single break. Each tank has been designed to operate the entire system alone should there be a fuselage rupture. If the aircraft were to remain intact, the two tanks have the combined ability to provide a greater amount of usable water (in this case 12.5 US gallons).

Configuration 9 is similar to Configuration 8, but having a total of 25 US gallons (20.5 usable gallons) can provide water for a longer period.

Configuration 10 uses the potable water system. Supply to the main feed pipe is controlled via a bi-directional valve. The heat sensing system redirects the domestic water to the CWSS and pressurises the tank using a dedicated pressure cylinder.

5. CONFIGURATION VARIATIONS (cont.)

5.3. WIDE BODY AIRCRAFT Configurations 11 to 15

Cabin length of : 136 ft.

Cabin height : 8½ ft.

Cabin width : 17 ½ ft.

In each configuration for this aircraft type, the cabin is assumed to have 17 zones each of 8 ft. length. Using the stylistic concept of two narrow bodies in parallel each zone has 16 nozzles giving a total of 272 nozzles throughout the cabin.

The design follows closely on the description in Section 4, with regard to the details incorporated. The main pipe is sized to ensure that the spray starts within 5 seconds. The main feed pipes and heat sensors are duplicated above the ceiling and run over each aisle. Each manifold and nozzle distribution system still feeds 8 nozzles but 3 on each unit supply the centre area of the cabin. It should be noted that the difference between the total amount of water carried and the usable water is accounted for by the need to fill the main distribution pipes prior to the spray commencing.

In view of the specified volume of water carried, it is assumed that no more than 6 zones can be activated at any one time.

The volume of water in the tanks is too great for a removable system. The tanks are therefore filled and emptied using connections to existing water servicing points .

Configuration 11
This has 25 US gallons of water (16 usable gallons) stored in a tank at the rear of the cabin. Because of the size of the tank, it is possible that an alternative location may be required. This could be below floor, behind bulkheads or in wardrobes for example and does not materially affect the analysis.

Configuration 12
The tank is located close to the centre of the cabin, giving improved crashworthiness as a fracture of the main feed pipes will still supply to one side of the break. It should be noted that crashworthiness is also addressed by virtue of flexible pipe runs and frangible couplings.

Configuration 13
This configuration improves the crashworthiness by providing 2 tanks with a combined total of 34 US gallons (16 usable gallons), such that water could be supplied to either side of a single break. Each tank has been designed to operate the entire system alone should there be a fuselage rupture. If the aircraft were to remain intact, the two tanks have the combined ability to provide a greater amount of usable water (in this case 25 US gallons).

Configuration 14 is similar to Configuration 13, but having a total of 50 US gallons (41 usable) can provide water for a longer period.

Configuration 15 uses the potable water system. Supply to the main feed pipes is controlled via bi-directional valves. The heat sensing system redirects the domestic water to the CWSS and pressurises the tanks using dedicated pressure cylinders.

6. WEIGHT ANALYSIS

As part of the Cost Analysis we have considered 15 separate configurations covering three types of aircraft.

Weights of components are actual weights derived from specialised suppliers. Although future developments may lead to weight savings, existing technology and proven reliability has been chosen in order to meet the requirements of sections 3.1.5 and 3.1.10

The following is a brief description of the various configurations and the associated weight. A more detailed breakdown of the equipment is shown in Appendix F.

Configuration	System Weight (lbs)	(Kg)
Regional Transport		
1) 1 tank, 8 usable gallons, no crashworthiness	240	110
2) 1 central tank, 8 usable gallons, crashworthy	220	100
3) 2 tanks, 9.5 usable gallons, crashworthy	320	145
4) 2 tanks, 18 usable gallons, crashworthy	410	186
5) 1 tank, potable water only, crashworthy	140	63
Narrow Body		
6) 1 tank, 8 usable gallons, no crashworthiness	360	163
7) 1 central tank, 8 usable gallons, crashworthy	330	150
8) 2 tanks, 12.5 usable gallons, crashworthy	510	232
9) 2 tanks, 20.5 usable gallons, crashworthy	570	258
10) 1 tank, potable water only, crashworthy	240	109
Wide Body		
11) 1 tank, 16 usable gallons, no crashworthiness	950	431
12) 1 central tank, 16 usable gallons, crashworthy	980	444
13) 2 tanks, 25 usable gallons, crashworthy	1,280	581
14) 2 tanks, 41 usable gallons, crashworthy	1,450	658
15) 2 tanks, potable water only, crashworthy	930	422

Note 1. These figures include the weight of water.
Note 2. Where a central tank has been used, the diameter of the main pipes can be reduced. This is reflected in a lower weight.

7. COST ANALYSIS

Where prices from suppliers have been used, these are based on January 1993 figures. No trade weighted indices have been used.

Where information has been used with costs quoted in US dollars, these have been converted to £ sterling using an exchange rate of £1 sterling = 1.46 US dollars.

Information is as accurate as possible as of the date of this report. No guarantees can be given on future variations.

7.1. SYSTEM COSTS

As part of the Cost Analysis we have considered 15 separate configurations covering three types of aircraft. The following is a brief description of the various configurations and the associated cost. A more detailed breakdown of the equipment is shown in Appendix F. It should be noted that all costs are based on manufacture's retail prices.

Configuration	Equipment Cost (£ Sterling)
Regional	
1) 1 tank, 8 usable gallons, no crashworthiness	18,200
2) 1 central tank, 8 usable gallons, crashworthy	18,300
3) 2 tanks, 9.5 usable gallons, crashworthy	29,900
4) 2 tanks, 18 usable gallons, crashworthy	30,700
5) 1 tank, potable water only, crashworthy	15,300
Narrow body	
6) 1 tank, 8 usable gallons, no crashworthiness	28,700
7) 1 central tank, 8 usable gallons, crashworthy	28,600
8) 2 tanks, 12.5 usable gallons, crashworthy	45,600
9) 2 tanks, 20.5 usable gallons, crashworthy	42,700
10) 1 tank, potable water only, crashworthy	26,600
Wide body	
11) 1 tank, 16 usable gallons, no crashworthiness	73,700
12) 1 central tank, 16 usable gallons, crashworthy	78,500
13) 2 tanks, 25 usable gallons, crashworthy	107,500
14) 2 tanks, 41 usable gallons, crashworthy	109,800
15) 2 tanks, potable water only, crashworthy	99,800

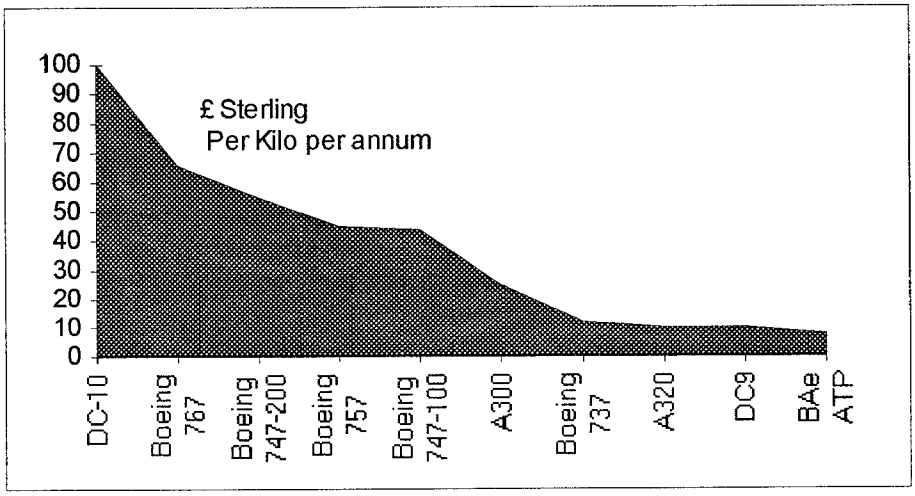
Note 1. Where a central tank has been used, the diameter of the main pipes can be reduced. This is reflected in a lower cost.

7. COST ANALYSIS (cont.)

7.2. DIRECT OPERATING COSTS

The chart below represents the cost of flying additional weight across a range of aircraft types. In a number of cases different airlines operate the same type of aircraft. Where their respective costs varied the higher figure has been used.

It should be noted that there can be large variations between Scheduled and Charter operations as well as between Long and Short Haul, again worst case figures have been used.



For the purpose of this study we have used the following figures when calculating the cost of carrying 1 Kilo of extra weight:

Regional Transport	£10	($14.6)
Narrow Body	£20	($29.2)
Wide Body	£55	($80.3)

Using these costs and the CWSS weights shown in section 6, we have the following Direct Operating Costs (D.O.C.) per annum for the various configurations.

Configuration No.	1	2	3	4	5
Regional Transport	£1100	£1000	£1450	£1860	£630
Configuration No.	6	7	8	9	10
Narrow Body	£3260	£3000	£4640	£5160	£2180
Configuration No.	11	12	13	14	15
Wide Body	£23,705	£24,420	£31,955	£36,190	£23,210

7. COST ANALYSIS (cont.)

7.3. MAINTENANCE COSTS

The following describes likely maintenance requirements for the hypothetical systems covered by this analysis.

As a maintenance aid, it is envisaged that a multiple function electronic test module would be used to connect to an electrical socket in the sidewall panel adjacent to the base assembly. This module is seen as being ground equipment and common to all aircraft types.

Its function is to test the electrical integrity throughout the system. The module would utilize the bite circuit in the system, driving a series of L.E.D. displays, thereby indicating the serviceability state of the respective circuit under test.

Daily Check/Test (per tank).
Remove base assembly cover and the dust cap from the maintenance connection in the sidewall.
Couple flying lead of test box to sidewall connector and carry out the function check.
Reverse the above operations.

1 man x 10 minutes @ £30 per hour. = £1825 p.a.

Monthly Check/Test
Remove base assembly cover and uncouple both water and electrical connectors.
Energise the primary stop valve and drain the contents. Flush through.
Remove power from valve and refill tank with clean and fresh domestic tap water.
Reverse procedure in paragraph (a).

2 men x 30 minutes @ £30 p.a. hour = £360 p.a.

Annual Check/Test

1. Remove base assembly cover, uncouple both water and electrical connections and inspect equipment. Connect pressure test equipment to both couplings, apply 100 psig air pressure and hold for 5 minutes, then allow to bleed off. (This tests the integrity of the main distribution pipe).
2. Remove and discard each nozzle assembly. Fit nozzle blanking caps. Pressure system to 100 psig. Open each zone in turn and hold for 2 minutes, then allow to bleed off.
3. Uncouple test equipment and remove from aircraft.
4. Remove nozzle blanking caps and replace with new nozzle/dust cap assemblies.
5. Perform continuity check on Pilots Annunciator Module.

Costs for the above items are:-

1.	1 man x 20 minutes.	=	£15 per tank
2.	1 man x 10 minutes.	=	£ 5 per zone
3.	1 man x 15 minutes.	=	£ 7 per tank
4.	1 man x 10 minutes.	=	£ 5 per zone
5.	1 man x 20 minutes.	=	£10 per aircraft

All costs are calculated at £30 per hour.

7. COST ANALYSIS (cont.)

7.3. MAINTENANCE COSTS (cont.)

Heavy Maintenance Check (Typically during a "C' Check).

Inspect security of mounting, wire locking and chafing of:

a. Sidewall connectors.
b. Sidewall feed pipe.
c. Zone Solenoid valves.
d. Manifold
e, All pipe connections especially frangible couplings.
f. Manifold to nozzle feed pipes
g. Nozzles.
h. Heat Sensor.
j. Wiring Harness
k. Bonding connections.
l. Integrity of adjacent airframe/floor sealing.

1 man approx. 1 hour/zone = £30 per zone

Summary of Maintenance Costs.

Configuration	Costs (£ Sterling) Per Annum	'C' Check
Regional		
1) 1 tank, 8 usable gallons, no crashworthiness	2,267	150
2) 1 central tank, 8 usable gallons, crashworthy	2,267	150
3) 2 tanks, 9.5 usable gallons, crashworthy	4,474	150
4) 2 tanks, 18 usable gallons, crashworthy	4,474	150
5) 1 tank, potable water only, crashworthy	1,907	150
Narrow body		
6) 1 tank, 8 usable gallons, no crashworthiness	2,317	300
7) 1 central tank, 8 usable gallons, crashworthy	2,317	300
8) 2 tanks, 12.5 usable gallons, crashworthy	4,524	300
9) 2 tanks, 20.5 usable gallons, crashworthy	4,524	300
10) 1 tank, potable water only, crashworthy	1,957	300
Wide body		
11) 1 tank, 16 usable gallons, no crashworthiness	2,557	1020
12) 1 central tank, 16 usable gallons, crashworthy	2,557	1020
13) 2 tanks, 25 usable gallons, crashworthy	4,764	1020
14) 2 tanks, 41 usable gallons, crashworthy	4,764	1020
15) 2 tanks, potable water only, crashworthy	4,044	1020

7. COST ANALYSIS (cont.)

7.4. RETROFIT INSTALLATIONS

Whilst it may be assumed that retrofit installation would be carried out during aircraft maintenance, typically 'C' checks, the actual work programme is simple enough against these specifications to be performed independently. For this reason the cost analysis includes this procedure. It is assumed that normal line maintenance practices are followed. The following tasks are required to install a CWSS:-

1) Remove seats as necessary

2) Remove furnishings

3) Remove insulation blankets where necessary

4) Modify insulation blankets to suit task 6

5) Carry out protection of electrical equipment

6) Install distribution and zone pipes etc.

7) Replace modified insulation blankets

8) Modify panels to accept nozzles, etc.

9) Fit heat detection system

10) Fit 'tank to ceiling' feed pipes

11) Modify potable water tank where necessary

12) Modify sidewall panels to incorporate connector box

13) Install looms and logic sensors

14) Install circuit breakers and flight deck arming module

15) Carry out inspection and system test

16) Replace sidewalls, ceiling, bins and P.S.U's. as appropriate

17) Install tank/tanks where necessary

18) Connect up system

19) Re-install seats

Appendix G part 1 shows the man hours required for these tasks together with costs calculated at a rate of £30 per hour.

7. COST ANALYSIS (cont.)

7.5. NEW BUILD INSTALLATIONS

For aircraft in build the fitting of this system can be carried out at various stations in the line assembly. Thus a number of the items listed in the 'retrofit section' are irrelevant. It is assumed that many components will be in stock and would therefore need modification. For convenience the same task numbers are used as listed in the Retrofit Installation Section.

1) Not required in new build

2) Not required in new build

3) Not required in new build

4) Modify existing insulation blankets to suit task 6

5) Carry out protection of electrical equipment

6) Install distribution and zone pipes etc.

7) Unnecessary task

8) Modify existing panels to accept nozzles, etc.

9) Fit heat detection system

10) Fit 'tank to ceiling' feed pipes

11) Modify potable water tank where necessary

12) Modify existing sidewall panels to incorporate connector box

13) Install test looms and logic sensors

14) Install circuit breakers and flight deck arming module

15) Carry out inspection and system test

16) Unnecessary task

17) Install tank/tanks where necessary

18) Connect up system

19) Unnecessary task

Appendix G part 2 shows the man hours required for these tasks together with costs calculated at a rate of £30 per hour.

7. COST ANALYSIS (cont.)

7.6. NEW DESIGN INSTALLATION

Whilst this installation will be similar to that of the 'existing build standard', it can be assumed that no modification tasks will be required as their manufacture will incorporate the necessary interface with the water spray system. Again, the task numbers are similar to those quoted in the Retrofit Installation section.

Only the following tasks will thus be necessary:-

6) Install distribution and zone pipes etc.

9) Fit heat detection system

10) Fit 'tank to ceiling' feed pipes

13) Install test looms and logic sensors

14) Install circuit breakers and flight deck arming module

15) Carry out inspection and system test

17) Install tank/tanks where necessary

18) Connect up system

Appendix G part 3 shows the man hours required for these tasks together with costs calculated at a rate of £30 per hour.

7. COST ANALYSIS (cont.)

7.7 DESIGN COSTS

New Design and New Build Aircraft.
The following section attempts to describe the process by which an aircraft manufacturer would proceed to design a Cabin Water Spray System for both NEW DESIGN and NEW BUILD scenarios. Although the actual process as listed was gleaned from discussions with manufacturers, the cost attributed to each of the activities is an approximation based on our own experience.

1) Technical Assessment: (15 man weeks)
Production of specification within confines of ruling. Proposes locations etc. for equipment . Takes account of interface if necessary with other systems.

2) Definition Document: (10 man weeks)
Defines items/components for in-house manufacture. Similarly, those items best bought-in with possible vendor list. Includes cost estimate.

3) Schematic Proposals: (20 man weeks)
Illustrates system layout (general assembly). Complete with relative notation i.e. fire hardening of components, segregated wiring.

4) Stress/Fatigue Analysis: (8 man weeks)
Use of Finite Element computer programme analysis etc.

5) Weight Analysis/Performance Chart: (4 man weeks)
Assesses system weight and its affect upon performance. Highlights recommendations for major components for siting with respect to weight and balance.

6) Hazard and Safety Assessment: (2 man weeks)
Ensures compliance with authoritative specifications, orders and notices etc.

7) Reliability and Maintainability Analysis: (5 man weeks)
Production of Failure Modes and Effects Analysis (FMEA). Minimum Equipment List generation. Maintenance Review Board Submission.

8) Flight Ops Approval: (1 man week)
Presentation of Flight Deck Module etc. Crew workload assessment.

9) Production Drawings: (49 man weeks)
Initiates buying, planning and programming etc.

Differing rates of non-recurring costs are applied to the above activities.
However, a Rough Order of Magnitude for the Regional and Narrow Body aircraft would be in the region of: **£215,000** and for the Wide Body **£240,000**

7. COST ANALYSIS (cont.)

7.7 DESIGN COSTS (cont.)

Retrofit Design.
For RETROFIT DESIGN, it is expected that no lesser procedure would be adopted. However, other factors must be considered and accounted for when assessing NON-RECURRING COSTS of this nature.

Outside the immediate and obvious design work required as detailed in Appendix H, further NRC's are incurred:-

1) Aircraft Survey - Establishing initial installations.
2) Evaluation - assessing generic applicability between aircraft models.
3) Development and Testing
4) Tooling for production manufacture
5) Qualification and Certification

The above does not only apply to each basic model in order to establish a generic design e.g. a Boeing 747 or an Airbus 320, but will also apply to different series of those models i.e. B747-100 or -200 etc. Individual tailoring to suit the options offered by the manufacturers e.g. interior trim types, will also generate a cost.

Summary of Additional Costs

1) Survey aircraft (assumed at 'heavy check'):-
Removal of furnishing panels
Inspection of configuration
Flight deck panel layouts
Potable tank plumbing (if necessary)
Modifications peculiar to operator

	Configurations	
Costs for:-	1 Tank	2 Tanks
Regional transport	£1,500	£1,750
Narrow Body	£1,800	£2,050
Wide Body	£2,250	£2,500

2) Evaluation:-
Identify and process problem area's
Evaluate differences within type, i.e. between variants

Cost for all configuration types £500

7. COST ANALYSIS (cont.)

7.7 DESIGN COSTS (cont.)

Retrofit Design. (cont.)

3) Design:-

Production of drawings (see Appendix H)

	Configurations	
Costs for:-	1 Tank	2 Tanks
Regional transport	£48,000	£50,000
Narrow Body	£50,000	£52,000
Wide Body	£55,000	£57,000

4) Addition procedural costs:-

Items 1 to 8 in section 7.7 refer.

	Configurations	
Costs for:-	1 Tank	2 Tanks
Regional & Narrow Body	£73,000	£78,000
Wide Body	£75,000	£80,000

These costs are at £30 per hour reflecting typical rates of retrofit design organisations.

Total Design Costs for RETROFIT:-

	Configurations	
	1 Tank	2 Tanks
Regional	£123,000	£130,250
Narrow Body	£125,300	£132,550
Wide Body	£132,750	£140,000

Other NRC considerations which are knowingly omitted from the above are Aircraft Manual Generation, development and testing (both discussed separately) and Certification Agency costs.

7. COST ANALYSIS (cont.)

7.8 MANUALS & SUPPORTING DOCUMENTATION

Part of the non-recurring costs to be assessed in the analysis is the generation of the various aircraft manuals. It is anticipated that the following list of affected manuals, and the time involved in their compilation or amendment, is common to all design configuration criteria.

Illustrated Parts Catalogue: Comprising lists of components by part number and locations.	£2400
Maintenance Manual: General description, operation, removal/re-installation, and testing of system.	£3600
Wiring Diagram Manual: Electrical Schematic and System Circuit Diagrams.	£1200
Maintenance Planning Document Schedule: Frequency of inspections, servicing and overhaul.	£2400
Operations Manuals: Flight Manual: - System Description and Limitations. Crew Manual: - System Description, Management, - Ground Servicing and Emergency Procedures. - Weight & Balance	£1200
Minimum Equipment List/Despatch Deviation: Permitted despatch unserviceabilities and serviceabilities	£300
Vendor Manual: List of equipment/component vendors.	£750
Engineering Training Manual: System Theory of Operation, testing and servicing techniques.	£3000
Passenger Address Video: Pre-flight passenger information.	£1000
Total cost of manual preparation:	**£15,850**

7. COST ANALYSIS (cont.)

7.9 OTHER NON RECURRING COSTS

Tooling Costs
Intrinsically, the system is modular. The majority of variation in installations between aircraft models and their type variants, can simply be accommodated in quantities and sizes.

When considering the components required as listed throughout Appendix F, and due to their interface requirements some tooling is required. This will take the form of drill jigs, assembly jigs, wiring peg boards etc. This will ensure commonality and address the large quantities involved.

Qualification Costs
New items not on the market and designed specifically for the CWSS will follow a process for qualification, with a view to certification by the airworthiness authorities. Any new products will naturally be tested and proven. If required, testing would encompass structural, flammability and reliability etc.

Test Facilities & Mock-ups
As described previously, whilst the CWSS is of modular design, it is the installation to the differing interior trim styles and cabin configurations etc. which significantly affects system criteria such as spray patterns.

It is envisaged that a full size cross sectional area mock up would be manufactured and sufficient in length to prove a 'zone' in constant section as well as in tapering fuselage sections. The mock up would simulate the interior trim with partitions and stowages etc. relevant to the aircraft configuration.

This facilitates tailoring of the system in order to produce the correct spray pattern and nozzle positions prior to production. It naturally also proves the tank installations and electrics etc.

Rough Order of Magnitude for manufacture and testing would be in the region of:- £30,000

8. CONCLUSIONS

Total Cost of a Cabin Water Spray System for a **Regional Transport** type aircraft.

Configuration No.1 - 1 tank, 8 usable gallons, no crashworthiness

	Procurement/ Installation	D.O.C.	Maintenance	Non Recurring
Retrofit	£30,275	£1,100	£2,267	£192,050
New Build	£25,445	£1,100	£2,267	£284,050
New Design	£22,940	£1,100	£2,267	£284,050

Configuration No.2 - 1 central tank, 8 usable gallons, crashworthy

	Procurement/ Installation	D.O.C.	Maintenance	Non Recurring
Retrofit	£30,375	£1,000	£2,267	£192,150
New Build	£25,545	£1,000	£2,267	£284,150
New Design	£23,040	£1,000	£2,267	£284,150

Configuration No.3 - 2 tanks, 9.5 usable gallons, crashworthy

	Procurement/ Installation	D.O.C.	Maintenance	Non Recurring
Retrofit	£42,440	£1,450	£4,474	£211,000
New Build	£37,610	£1,450	£4,474	£295,750
New Design	£35,030	£1,450	£4,474	£295,750

Configuration No.4 - 2 tanks, 18 usable gallons, crashworthy

	Procurement/ Installation	D.O.C.	Maintenance	Non Recurring
Retrofit	£43,240	£1,860	£4,474	£211,800
New Build	£38,410	£1,860	£4,474	£296,550
New Design	£35,830	£1,860	£4,474	£296,550

Configuration No.5 - 1 tank, potable water only, crashworthy

	Procurement/ Installation	D.O.C.	Maintenance	Non Recurring
Retrofit	£27,735	£630	£1,907	£189,150
New Build	£22,695	£630	£1,907	£281,150
New Design	£19,980	£630	£1,907	£281,150

Note 1. The Direct Operating Costs are based on £10 per Kilo per annum.
Note 2. The Maintenance Costs exclude the 'C' Checks shown in section 7.3

8. CONCLUSIONS (cont.)

Total Cost of a Cabin Water Spray System for a **Narrow Body** type aircraft.

Configuration No.6 - 1 tank, 8 usable gallons, no crashworthiness

	Procurement/ Installation	D.O.C.	Maintenance	Non Recurring
Retrofit	£51,553	£3,260	£2,317	£204,750
New Build	£42,125	£3,260	£2,317	£294,450
New Design	£37,190	£3260	£2,317	£294,450

Configuration No.7 - 1 central tank, 8 usable gallons, crashworthy

	Procurement/ Installation	D.O.C.	Maintenance	Non Recurring
Retrofit	£51,653	£3,000	£2,317	£204,850
New Build	£42,025	£3,000	£2,317	£294,550
New Design	£37,090	£3,000	£2,317	£294,550

Configuration No.8 - 2 tanks, 12.5 usable gallons, crashworthy

	Procurement/ Installation	D.O.C.	Maintenance	Non Recurring
Retrofit	£69,018	£4,640	£4,524	£229,000
New Build	£59,490	£4,640	£4,524	£311,450
New Design	£54,480	£4,640	£4,524	£311,450

Configuration No.9 - 2 tanks, 20.5 usable gallons, crashworthy

	Procurement/ Installation	D.O.C.	Maintenance	Non Recurring
Retrofit	£66,118	£5,160	£4,524	£226,100
New Build	£56,590	£5,160	£4,524	£308,550
New Design	£51,580	£5,160	£4,524	£308,550

Configuration No.10 - 1 tank, potable water only, crashworthy

	Procurement/ Installation	D.O.C.	Maintenance	Non Recurring
Retrofit	£49,913	£2,180	£1,957	£202,750
New Build	£40,175	£2,180	£1,957	£292,450
New Design	£35,030	£2,180	£1,957	£292,450

Note 1. The Direct Operating Costs are based on £20 per Kilo per annum.
Note 2. The Maintenance Costs exclude the 'C' Checks shown in section 7.3

8. CONCLUSIONS (cont.)

Total Cost of a Cabin Water Spray System for a **Wide Body** type aircraft.

Configuration No.11 - 1 tank, 16 usable gallons, no crashworthiness

	Procurement/ Installation	D.O.C.	Maintenance	Non Recurring
Retrofit	£132,053	£23,705	£2,557	£257,300
New Build	£115,223	£23,705	£2,557	£364,550
New Design	£98,750	£23,705	£2,557	£364,550

Configuration No.12 - 1 central tank, 16 usable gallons, crashworthy

	Procurement/ Installation	D.O.C.	Maintenance	Non Recurring
Retrofit	£136,853	£24,420	£2,557	£262,100
New Build	£120,023	£24,420	£2,557	£369,350
New Design	£103,550	£24,420	£2,557	£369,350

Configuration No.13 - 2 tanks, 25 usable gallons, crashworthy

	Procurement/ Installation	D.O.C.	Maintenance	Non Recurring
Retrofit	£166,468	£31,955	£4,764	£298,350
New Build	£149,638	£31,955	£4,764	£398,350
New Design	£133,090	£31,955	£4,764	£398,350

Configuration No.14 - 2 tanks, 41 usable gallons, crashworthy

	Procurement/ Installation	D.O.C.	Maintenance	Non Recurring
Retrofit	£168,768	£36,190	£4,764	£300,650
New Build	£151,938	£36,190	£4,764	£400,650
New Design	£135,390	£36,190	£4,764	£400,650

Configuration No.15 - 2 tanks, potable water only, crashworthy

	Procurement/ Installation	D.O.C.	Maintenance	Non Recurring
Retrofit	£159,218	£23,210	£4,044	£290,650
New Build	£141,728	£23,210	£4,044	£390,650
New Design	£125,000	£23,210	£4,044	£390,650

Note 1. The Direct Operating Costs are based on £55 per Kilo per annum.
Note 2. The Maintenance Costs exclude the 'C' Checks shown in section 7.3

9. INSURANCE IMPLICATIONS

It is possible that insurance premiums could be reduced should a CWSS be installed.

However, insurers have always been reactive rather than proactive to technical advances in safety within aerospace industry. Until and unless a stable premium base is achieved, providing insurers with not only adequate premiums to cope with day to day losses but also to allow them to build up reserves for catastrophic claims, their attitude to premium savings is likely to be cautious.

Statistics are available, derived from major accidents where cabin fire was the main contributory cause of loss of life. It can be demonstrated that the cost to the insurance market of passenger death and injury claims arising out of this type of accident has over the last ten years amounted to 2.78% of the total airline premiums and 2.95% of total airline claims.

In the current state of the aviation insurance market there is unlikely to be any automatic saving in premiums but it is believed that this market will respond favourably over a period following the general acceptance of CWSS. However this would only follow a perceived reduction in cabin fire fatalities and injuries and a corresponding reduction in the cost to aviation insurers.

In most of the claims referred to there has been a contribution from the aircraft manufacturers either as a result of their direct legal liability or as a result of an agreed cost sharing arrangement with the airlines to avoid formal legal action either directly from passengers or from airlines' insurers. Knowing that manufacturers are normally able to obtain indemnification from their customers in respect of damage to aircraft resulting from a manufacturing or design defect it is believed that the major part of manufacturers contributions to these losses will be in respect of passenger claims.

The view taken is that the elimination of the manufacturers contribution to cabin fire claims is obviously significant and would be recognised over a period, by way of their overall level of claim settlements and consequent premium savings.

However the most important factor may be the ability of manufacturers to show crashworthiness. In many legal jurisdictions particularly in the USA the ability to demonstrate to a court of law that you have taken every step to ensure passenger survival in the event of a crash is a vital part of a manufacturers defence particularly in jurisdictions where strict liability rules are in force.

The failure to install a safety system that is readily available may in itself be held to be a product defect leading not only to compensatory claims for death or injury to passengers but also opening up the possibility of punitive damages.

It is believed by the insurers that manufacturers will rapidly see the advantages of such a system and its contribution to not only diminishing claims against them but also of protecting them from even greater claims with the consequent probability of greatly increased premium costs.

The same argument on punitive damages could also apply to airlines who fail to specify a Cabin Water Spray System.

10. GENERAL COMMENTS AND OBSERVATIONS

Landing fees

During our discussions with UK based airlines, the subject of landing fees arose with respect to costs incurred due to the extra weight penalty. Examining the landing fee structure of the BAA shows that at Heathrow there is a banding that straddles 50 metric tonnes (110,229 lbs). The Boeing 737 family can fall either side of this figure. In simple terms, the difference between one band and the next is approximately £130 per movement. Assuming 2 movements per day it could be the equivalent of over £90,000 per annum per aircraft.

Potable Water

A number of operators either limit the amount of water onboard or run very close to using up all their potable water. Operators felt that the expense of having a CWSS which might be unavailable just when it was most needed was unacceptable. Taking this one stage further, if the potable water tank had to be modified to ensure there was minimum amount of water always present, then it would have no advantages over a dedicated water spray tank.

Most operators stated that if CWSS was mandated, then since it would be an emergency system, only a dedicated high quality configuration should be entertained.

Should a potable water installation in a wide body aircraft be considered, it should be noted that existing aircraft have tanks that are likely to be in a single location.

At least one foreign airline has a policy of dumping all onboard water prior to landing to avoid the possibility of freezing.

One operator commented that the tank/tanks should be mid fuselage for Centre of Gravity reasons.

Implementation Timescales

One airline advised us that their hangarage is pre-allocated for up to four years and most charter operations schedule their maintenance for the off peak season. Implementation timescales would need to be carefully considered to avoid an escalation of costs. One is loathed to allocate the cost of a new hangar to a CWSS. As an indication, the following represents the typical net loss of revenue by de-scheduling for one day (excluding Direct Operating Costs):-

Regional	£8,000
Narrow body	£25,000
Wide body	£95,000

All operators naturally require realistic compliance dates in order to embody the modification during phased heavy maintenance. This means that much of the work, removal of seats and trim panels etc., occurs during a major check and is therefore not an additional cost.

Fly-By-Wire Aircraft

An Airbus operator did not foresee any severe threat to the aircraft's Fly-by-Wire system if activation was limited to ground only. All electrical connectors are standard hermetically sealed types with no additional requirements.

10. GENERAL COMMENTS AND OBSERVATIONS

Revenue losses

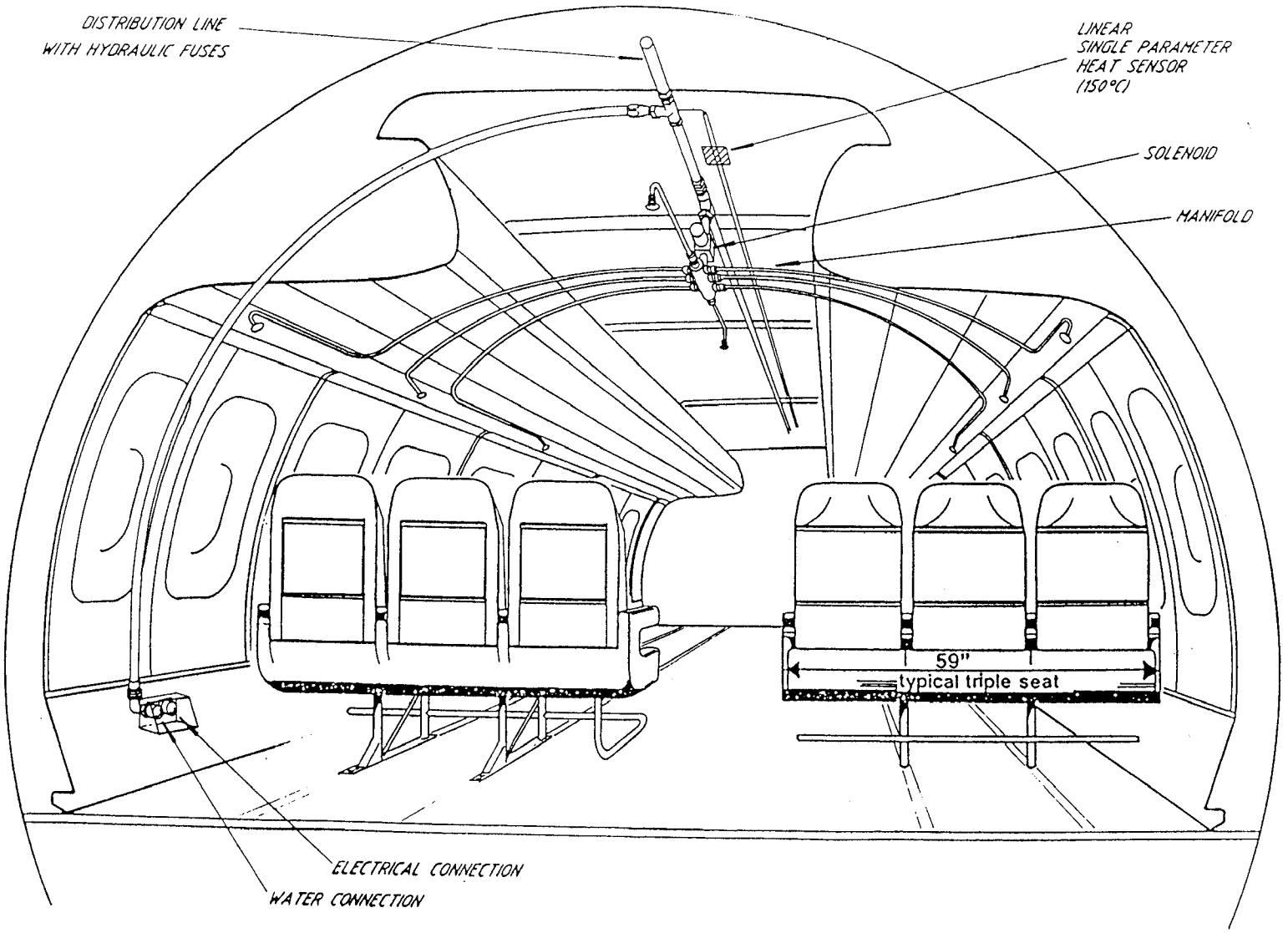
As part of the main analysis costs have been shown associated with flying an additional 'payload'. There are a few circumstances where this is inappropriate, for instance where an aircraft is using an airfield with a restricted runway length and is unable to operate with a maximum payload. In these cases, it is more appropriate to use the lost revenue as part of the cost of ownership. Using a worst case with a CWSS weight of say 1450lbs (the equivalent of 8 passengers) and a typical long haul fare from Kai Tak to Heathrow of £800, the revenue lost per flight would be £6,400.
It is possible to have a similar situation with charter operators. However in their case they cannot 'drop' passengers but have to introduce a Technical Stop to take on additional fuel. Extra costs are then associated with additional landing fees, greater fuel burn etc.

General Comments

Any modifications requiring a pressure hull rework was reported by one airline as incurring a manufacture's cost in the region of $1m.

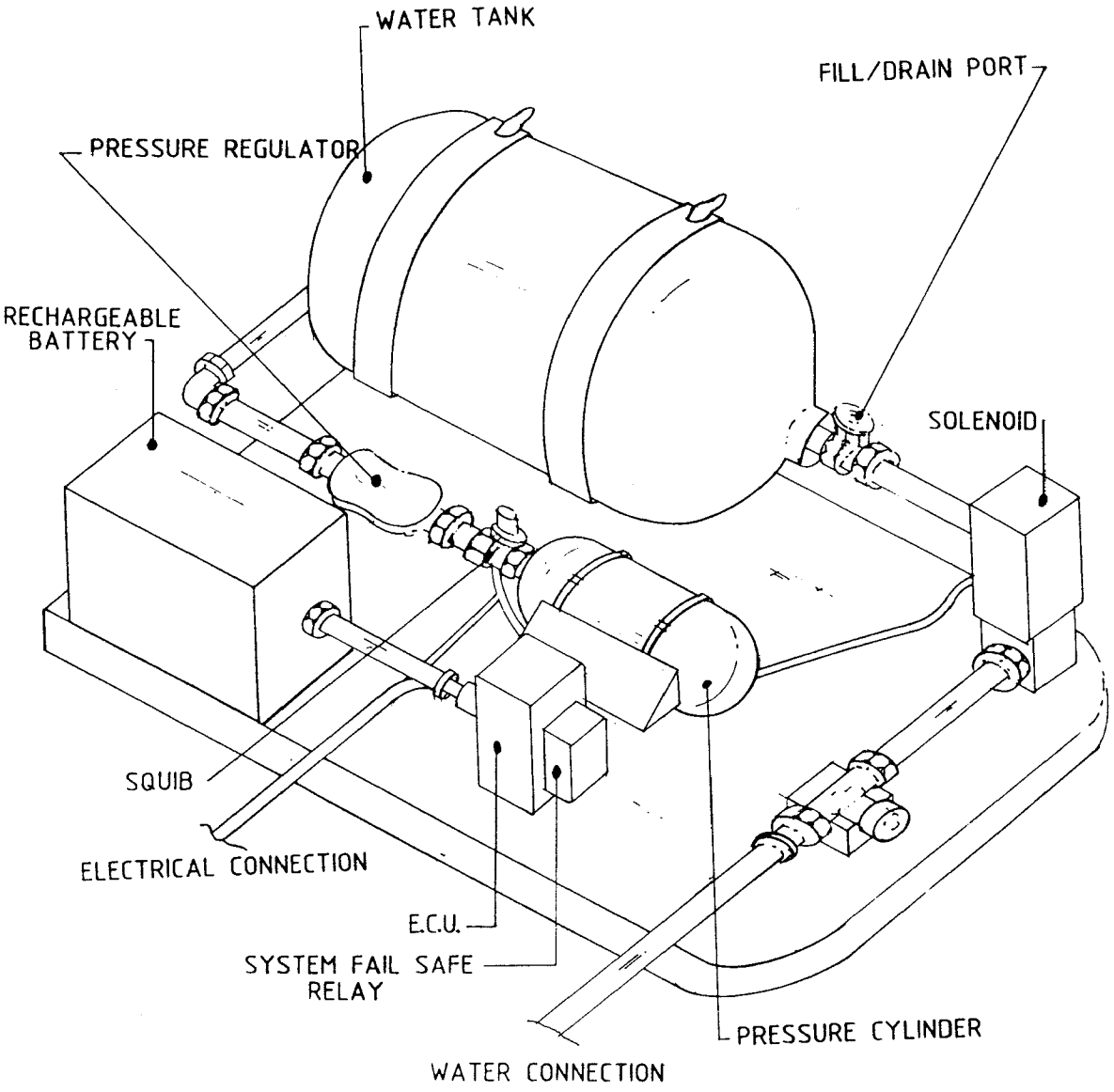
Some Charter Operators prefer not to have the cabin-installed tank base assembly due to their high density passenger configurations.

An equipment supplier commented that to provide a "Gauge Glass" on a pressurised gas bottle introduces a weak point in the equipment where pressure loss can occur.



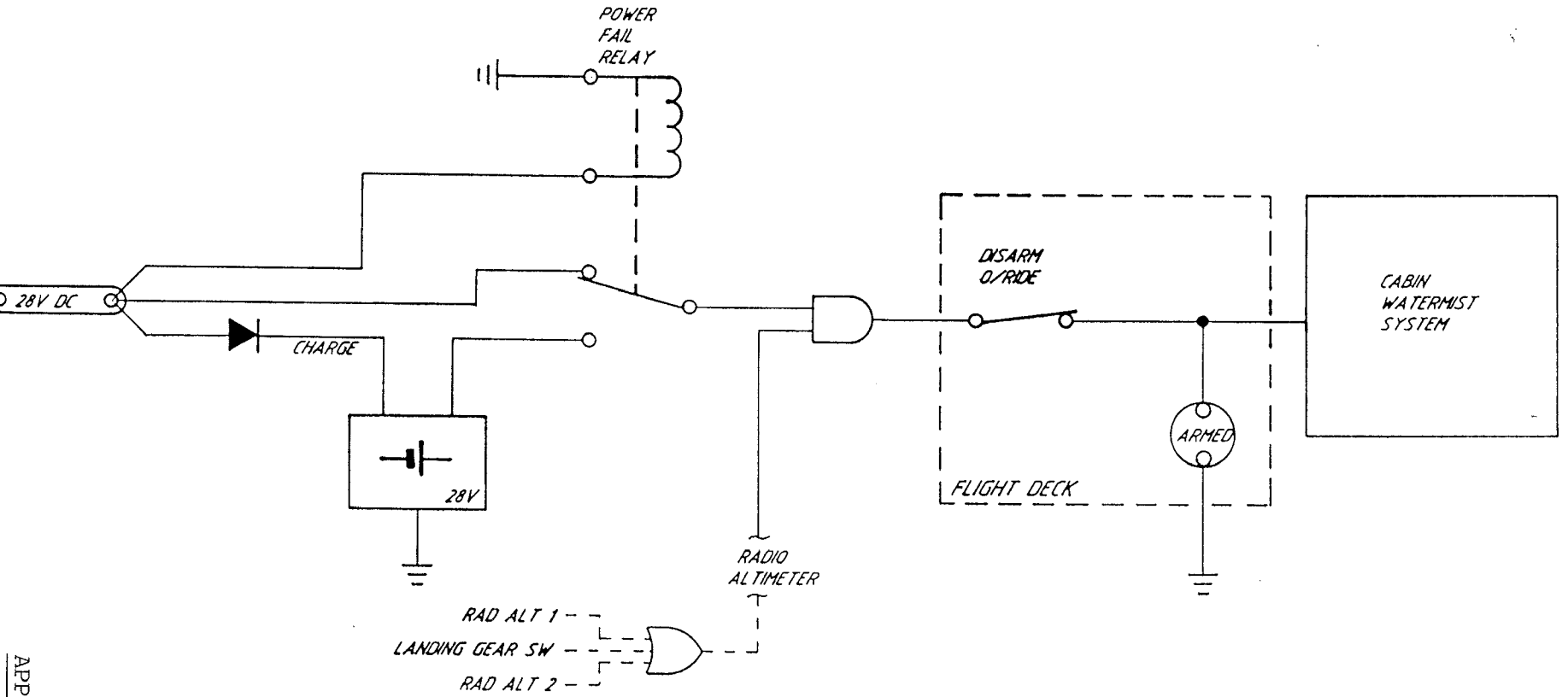
CONCEPTUAL LAYOUT OF SYSTEM

AIM AVIATION (R&D) LTD

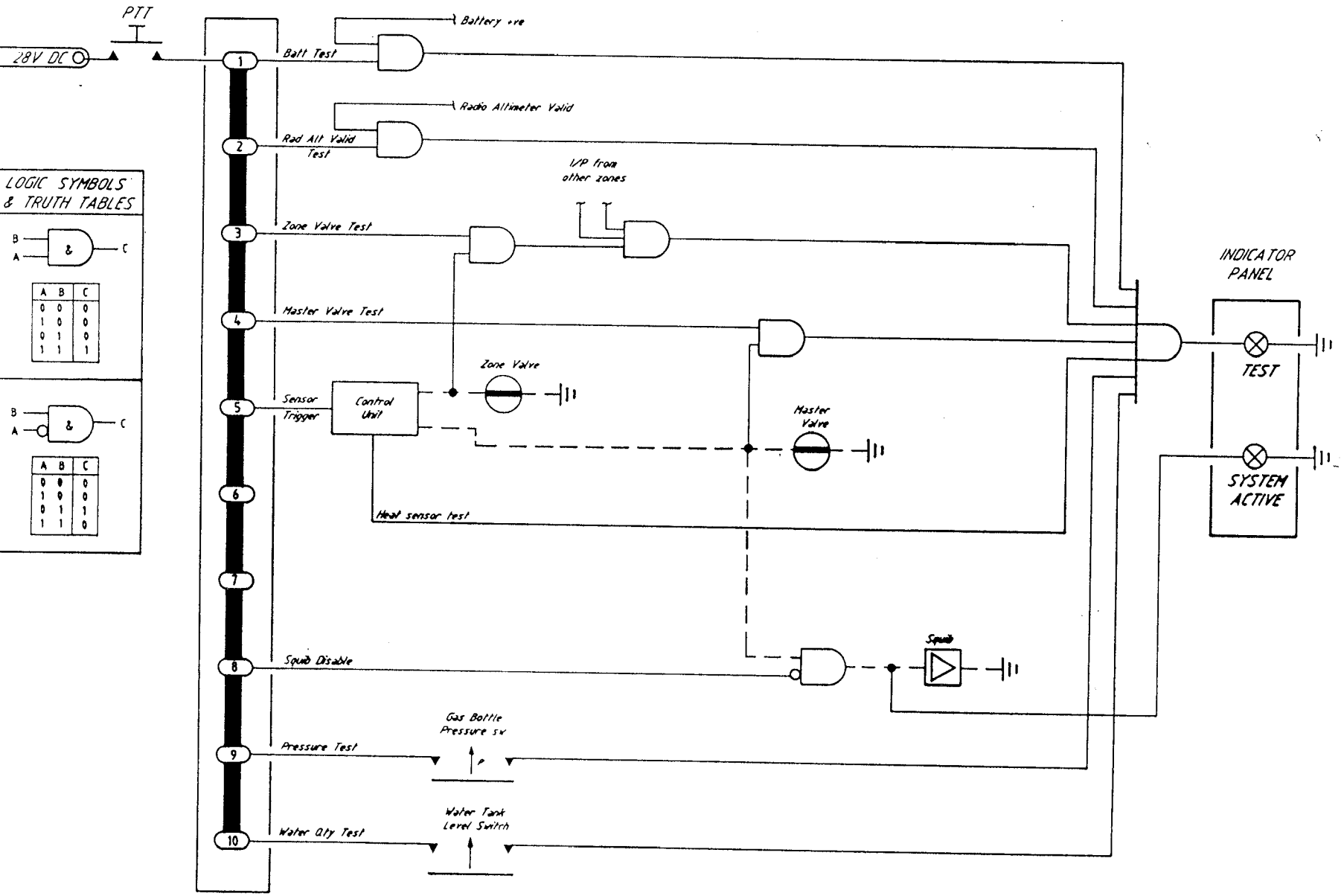


TYPICAL TANK INSTALLATION

APPENDIX C



POWER SUPPLY/BATTERY BACKUP



FLIGHT DECK ANNUNCIATOR SCHEMATIC

WEIGHT COST BREAKDOWN

	REGIONAL TRANSPORT	40' Length	5 Zones	1 Rear Tank - No crashworthiness		
	Configuration No. 1	Unit Cost	Unit Wt.	No.	Total Wt.	Total Cost
	1 Tank - 8 Usable US Gallons	(£)	(lbs)	off	(lbs)	(£)
1	Nozzle & Fittings	5.50	0.08	40	3.20	220.00
2	Narrow Bore Pipework (52' per Zone)	329.14	5.00	5	25.00	1645.70
3	8 Way Manifold	300.00	1.80	5	9.00	1500.00
4	Distribution Pipe 8' units (inc Fittings)	124.72	4.75	4	19.02	498.88
5	Tank to Ceiling Pipework (inc Fittings)	198.42	7.35	1	7.35	198.42
6	"T" Connector	50.00	0.47	5	2.35	250.00
7	Zone Solenoid Valve	420.00	0.70	5	3.50	2100.00
8	Frangible Coupling	0.00	0.00	0	0.00	0.00
9	Base Assembly & Floor Fittings	410.00	4.25	1	4.25	410.00
10	Base Cover	385.00	8.90	1	8.90	385.00
11	Water Tank & Fittings	3300.00	12.50	1	12.50	3300.00
12	Tank Mountings (2 per tank)	366.00	2.72	1	2.72	366.00
13	Water (10 US Gallons)	0.00	8.34	10	83.36	0.00
14	Quick release coupling	100.00	1.00	1	1.00	100.00
15	Check Valve	60.00	0.50	1	0.50	60.00
16	Drain Down/refill Facility	50.00	2.00	1	2.00	50.00
17	Pressure Cylinder & Fittings	815.00	11.00	1	11.00	815.00
18	Misc Attachments & Fittings	100.00	1.25	5	6.25	500.00
19	Heat Sensors	400.00	0.50	1	0.50	400.00
20	Control Panel & Test Facilities	1380.00	1.20	1	1.20	1380.00
21	Standby Batteries	1500.00	18.00	1	18.00	1500.00
22	Wiring Harness	2200.00	10.00	1	10.00	2200.00
23	Sidewall access Panel	145.00	1.25	1	1.25	145.00
24	Protection of Electrical Equipment	100.00	0.25	1	0.25	100.00
	TOTALS				233.10	18124.00

WEIGHT COST BREAKDOWN

	REGIONAL TRANSPORT	40' Length	5 Zones	1 Central Tank - Crashworthy		
	Configuration No. 2	Unit Cost	Unit Wt.	No.	Total Wt.	Total Cost
	1 Tank - 8 Usable US Gallons	(£)	(lbs)	off	(lbs)	(£)
1	Nozzle & Fittings	5.50	0.08	40	3.20	220.00
2	Narrow Bore Pipework (52' per Zone)	329.14	5.00	5	25.00	1645.70
3	8 Way Manifold	300.00	1.80	5	9.00	1500.00
4	Distribution Pipe 8' units (inc Fittings)	79.44	2.30	4	9.18	317.76
5	Tank to Ceiling Pipework (inc Fittings)	128.09	2.54	1	2.54	128.09
6	"T" Connector	45.00	0.30	5	1.50	225.00
7	Zone Solenoid Valve	400.00	0.60	5	3.00	2000.00
8	Frangible Coupling	140.00	0.80	4	3.20	560.00
9	Base Assembly & Floor Fittings	410.00	4.25	1	4.25	410.00
10	Base Cover	385.00	8.90	1	8.90	385.00
11	Water Tank & Fittings	3300.00	12.50	1	12.50	3300.00
12	Tank Mountings (2 per tank)	366.00	2.72	1	2.72	366.00
13	Water (10 US Gallons)	0.00	8.34	10	83.36	0.00
14	Quick release coupling	90.00	0.80	1	0.80	90.00
15	Check Valve	50.00	0.45	1	0.45	50.00
16	Drain Down/refill Facility	50.00	2.00	1	2.00	50.00
17	Pressure Cylinder & Fittings	815.00	11.00	1	11.00	815.00
18	Misc Attachments & Fittings	100.00	1.25	5	6.25	500.00
19	Heat Sensors	400.00	0.50	1	0.50	400.00
20	Control Panel & Test Facilities	1380.00	1.20	1	1.20	1380.00
21	Standby Batteries	1500.00	18.00	1	18.00	1500.00
22	Wiring Harness	2200.00	10.00	1	10.00	2200.00
23	Sidewall access Panel	145.00	1.25	1	1.25	145.00
24	Protection of Electrical Equipment	100.00	0.25	1	0.25	100.00
	TOTALS				220.05	18287.55

WEIGHT COST BREAKDOWN

	REGIONAL TRANSPORT	40' Length	5 Zones	Tanks Front & Rear - Crashworthy		
	Configuration No. 3	Unit Cost	Unit Wt.	No.	Total Wt.	Total Cost
	2 Tanks - 9.5 Usable US Gallons	(£)	(lbs)	off	(lbs)	(£)
1	Nozzle & Fittings	5.50	0.08	40	3.20	220.00
2	Narrow Bore Pipework (52' per Zone)	329.14	5.00	5	25.00	1645.70
3	8 Way Manifold	300.00	1.80	5	9.00	1500.00
4	Distribution Pipe 8' units (inc Fittings)	124.72	4.75	4	19.02	498.88
5	Tank to Ceiling Pipework (inc Fittings)	198.42	7.35	2	14.71	396.84
6	"T" Connector	50.00	0.47	5	2.35	250.00
7	Zone Solenoid Valve	420.00	0.70	5	3.50	2100.00
8	Frangible Coupling	150.00	1.00	8	8.00	1200.00
9	Base Assembly & Floor Fittings	400.00	3.50	2	7.00	800.00
10	Base Cover	345.00	7.60	2	15.20	690.00
11	Water Tank & Fittings	3000.00	11.00	2	22.00	6000.00
12	Tank Mountings (2 per tank)	366.00	2.72	2	5.44	732.00
13	Water (11 US Gallons)	0.00	8.34	11	91.70	0.00
14	Quick release coupling	100.00	1.00	2	2.00	200.00
15	Check Valve	60.00	0.50	2	1.00	120.00
16	Drain Down/refill Facility	50.00	2.00	2	4.00	100.00
17	Pressure Cylinder & Fittings	792.00	9.50	2	19.00	1584.00
18	Misc Attachments & Fittings	100.00	1.25	5	6.25	500.00
19	Heat Sensors	400.00	0.50	2	1.00	800.00
20	Control Panel & Test Facilities	1380.00	1.20	2	2.40	2760.00
21	Standby Batteries	1500.00	18.00	2	36.00	3000.00
22	Wiring Harness	2200.00	10.00	2	20.00	4400.00
23	Sidewall access Panel	145.00	1.25	2	2.50	290.00
24	Protection of Electrical Equipment	100.00	0.25	1	0.25	100.00
	TOTALS				320.51	29887.42

WEIGHT COST BREAKDOWN

	REGIONAL TRANSPORT	40' Length	5 Zones	Tanks Front & Rear - Crashworthy		
	Configuration No. 4	Unit Cost	Unit Wt.	No.	Total Wt.	Total Cost
	2 Tanks - 18 Usable US Gallons	(£)	(lbs)	off	(lbs)	(£)
1	Nozzle & Fittings	5.50	0.08	40	3.20	220.00
2	Narrow Bore Pipework (52' per Zone)	329.14	5.00	5	25.00	1645.70
3	8 Way Manifold	300.00	1.80	5	9.00	1500.00
4	Distribution Pipe 8' units (inc Fittings)	124.72	4.75	4	19.02	498.88
5	Tank to Ceiling Pipework (inc Fittings)	198.42	7.35	2	14.71	396.84
6	"T" Connector	50.00	0.47	5	2.35	250.00
7	Zone Solenoid Valve	420.00	0.70	5	3.50	2100.00
8	Frangible Coupling	150.00	1.00	8	8.00	1200.00
9	Base Assembly & Floor Fittings	410.00	4.25	2	8.50	820.00
10	Base Cover	385.00	8.90	2	17.80	770.00
11	Water Tank & Fittings	3300.00	12.50	2	25.00	6600.00
12	Tank Mountings (2 per tank)	366.00	2.72	2	5.44	732.00
13	Water (20 US Gallons)	0.00	8.34	20	166.72	0.00
14	Quick release coupling	100.00	1.00	2	2.00	200.00
15	Check Valve	60.00	0.50	2	1.00	120.00
16	Drain Down/refill Facility	50.00	2.00	2	4.00	100.00
17	Pressure Cylinder & Fittings	815.00	11.00	2	22.00	1630.00
18	Misc Attachments & Fittings	100.00	1.25	5	6.25	500.00
19	Heat Sensors	400.00	0.50	2	1.00	800.00
20	Control Panel & Test Facilities	1380.00	1.20	2	2.40	2760.00
21	Standby Batteries	1500.00	18.00	2	36.00	3000.00
22	Wiring Harness	2200.00	10.00	2	20.00	4400.00
23	Sidewall access Panel	145.00	1.25	2	2.50	290.00
24	Protection of Electrical Equipment	100.00	0.25	1	0.25	100.00
	TOTALS				405.63	30633.42

WEIGHT COST BREAKDOWN

	REGIONAL TRANSPORT	40' Length	5 Zones	1 Rear tank - Crashworthy		
	Configuration No. 5	Unit Cost	Unit Wt.	No.	Total Wt.	Total Cost
	Potable Water only	(£)	(lbs)	off	(lbs)	(£)
1	Nozzle & Fittings	5.50	0.08	40	3.20	220.00
2	Narrow Bore Pipework (52' per Zone)	329.14	5.00	5	25.00	1645.70
3	8 Way Manifold	300.00	1.80	5	9.00	1500.00
4	Distribution Pipe 8' units (inc Fittings)	124.72	4.75	4	19.02	498.88
5	Tank to Ceiling Pipework (inc Fittings)	198.42	7.35	1	7.35	198.42
6	"T" Connector	50.00	0.47	5	2.35	250.00
7	Zone Solenoid Valve	420.00	0.70	5	3.50	2100.00
8	Frangible Coupling	150.00	1.00	4	4.00	600.00
11	Potable Tank Modifications & Fittings	1175.00	13.30	1	13.30	1175.00
17	Pressure Cylinder & Fittings	970.00	11.00	1	11.00	970.00
18	Misc Attachments & Fittings	100.00	1.25	5	6.25	500.00
19	Heat Sensors	400.00	0.50	1	0.50	400.00
20	Control Panel & Test Facilities	1380.00	1.20	1	1.20	1380.00
21	Standby Batteries	1500.00	18.00	1	18.00	1500.00
22	Wiring Harness	2200.00	10.00	1	10.00	2200.00
24	Protection of Electrical Equipment	100.00	0.25	1	0.25	100.00
	TOTALS				133.92	15238.00

WEIGHT COST BREAKDOWN

	NARROW BODY	80' Length	10 Zones	1 Rear Tank - No crashworthiness		
	Configuration No. 6	Unit Cost	Unit Wt.	No.	Total Wt.	Total Cost
	1 Tank - 8 Usable US Gallons	(£)	(lbs)	off	(lbs)	(£)
1	Nozzle & Fittings	5.50	0.08	80	6.40	440.00
2	Narrow Bore Pipework (52' per Zone)	329.14	5.00	10	50.00	3291.40
3	8 Way Manifold	300.00	1.80	10	18.00	3000.00
4	Distribution Pipe 8' units (inc Fittings)	199.65	6.18	9	55.62	1796.83
5	Tank to Ceiling Pipework (inc Fittings)	323.93	9.58	1	9.58	323.93
6	"T" Connector	60.00	0.50	10	5.00	600.00
7	Zone Solenoid Valve	450.00	0.80	10	8.00	4500.00
8	Frangible Coupling	0.00	0.00	0	0.00	0.00
9	Base Assembly & Floor Fittings	410.00	4.25	1	4.25	410.00
10	Base Cover	385.00	8.90	1	8.90	385.00
11	Water Tank & Fittings	3400.00	15.00	1	15.00	3400.00
12	Tank Mountings (2 per tank)	366.00	2.72	1	2.72	366.00
13	Water (12.5 US Gallons)	0.00	8.34	13	104.20	0.00
14	Quick release coupling	125.00	1.10	1	1.10	125.00
15	Check Valve	80.00	0.60	1	0.60	80.00
16	Drain Down/refill Facility	50.00	2.00	1	2.00	50.00
17	Pressure Cylinder & Fittings	815.00	11.00	1	11.00	815.00
18	Misc Attachments & Fittings	100.00	1.25	10	12.50	1000.00
19	Heat Sensors	800.00	1.00	1	1.00	800.00
20	Control Panel & Test Facilities	1380.00	1.20	1	1.20	1380.00
21	Standby Batteries	1500.00	18.00	1	18.00	1500.00
22	Wiring Harness	4000.00	20.00	1	20.00	4000.00
23	Sidewall access Panel	145.00	1.25	1	1.25	145.00
24	Protection of Electrical Equipment	200.00	0.50	1	0.50	200.00
	TOTALS				356.82	28608.16

WEIGHT COST BREAKDOWN

	NARROW BODY	80' Length	10 Zones	1 Central Tank - Crashworthy		
	Configuration No. 7	Unit Cost	Unit Wt.	No.	Total Wt.	Total Cost
	1 Tank - 8 Usable US Gallons	(£)	(lbs)	off	(lbs)	(£)
1	Nozzle & Fittings	5.50	0.08	80	6.40	440.00
2	Narrow Bore Pipework (52' per Zone)	329.14	5.00	10	50.00	3291.40
3	8 Way Manifold	300.00	1.80	10	18.00	3000.00
4	Distribution Pipe 8' units (inc Fittings)	124.72	4.75	9	42.79	1122.48
5	Tank to Ceiling Pipework (inc Fittings)	198.42	5.27	1	5.27	198.42
6	"T" Connector	50.00	0.47	10	4.70	500.00
7	Zone Solenoid Valve	420.00	0.70	10	7.00	4200.00
8	Frangible Coupling	150.00	1.00	9	9.00	1350.00
9	Base Assembly & Floor Fittings	410.00	4.25	1	4.25	410.00
10	Base Cover	385.00	8.90	1	8.90	385.00
11	Water Tank & Fittings	3300.00	13.00	1	13.00	3300.00
12	Tank Mountings (2 per tank)	366.00	2.72	1	2.72	366.00
13	Water (10.5 US Gallons)	0.00	8.34	11	87.53	0.00
14	Quick release coupling	100.00	1.00	1	1.00	100.00
15	Check Valve	60.00	0.50	1	0.50	60.00
16	Drain Down/refill Facility	50.00	2.00	1	2.00	50.00
17	Pressure Cylinder & Fittings	815.00	11.00	1	11.00	815.00
18	Misc Attachments & Fittings	100.00	1.25	10	12.50	1000.00
19	Heat Sensors	800.00	1.00	1	1.00	800.00
20	Control Panel & Test Facilities	1380.00	1.20	1	1.20	1380.00
21	Standby Batteries	1500.00	18.00	1	18.00	1500.00
22	Wiring Harness	4000.00	20.00	1	20.00	4000.00
23	Sidewall access Panel	145.00	1.25	1	1.25	145.00
24	Protection of Electrical Equipment	200.00	0.50	1	0.50	200.00
	TOTALS				328.51	28613.30

WEIGHT COST BREAKDOWN

	NARROW BODY	80' Length	10 Zones	Tanks Front & Rear - Crashworthy		
	Configuration No. 8	Unit Cost	Unit Wt.	No.	Total Wt.	Total Cost
	2 Tanks - 12.5 usable US Gallons	(£)	(lbs)	off	(lbs)	(£)
1	Nozzle & Fittings	5.50	0.08	80	6.40	440.00
2	Narrow Bore Pipework (52' per Zone)	329.14	5.00	10	50.00	3291.40
3	8 Way Manifold	300.00	1.80	10	18.00	3000.00
4	Distribution Pipe 8' units (inc Fittings)	199.65	6.18	9	55.66	1796.83
5	Tank to Ceiling Pipework (inc Fittings)	323.93	9.58	2	19.17	647.86
6	"T" Connector	60.00	0.50	10	5.00	600.00
7	Zone Solenoid Valve	450.00	0.80	10	8.00	4500.00
8	Frangible Coupling	175.00	1.20	18	21.60	3150.00
9	Base Assembly & Floor Fittings	410.00	4.25	2	8.50	820.00
10	Base Cover	385.00	8.90	2	17.80	770.00
11	Water Tank & Fittings	3400.00	15.00	2	30.00	6800.00
12	Tank Mountings (2 per tank)	366.00	2.72	2	5.44	732.00
13	Water (17 US Gallons)	0.00	8.34	17	141.71	0.00
14	Quick release coupling	125.00	1.10	2	2.20	250.00
15	Check Valve	80.00	0.60	2	1.20	160.00
16	Drain Down/refill Facility	50.00	2.00	2	4.00	100.00
17	Pressure Cylinder & Fittings	815.00	8.50	2	17.00	1630.00
18	Misc Attachments & Fittings	100.00	1.25	10	12.50	1000.00
19	Heat Sensors	800.00	1.00	2	2.00	1600.00
20	Control Panel & Test Facilities	1380.00	1.20	2	2.40	2760.00
21	Standby Batteries	1500.00	18.00	2	36.00	3000.00
22	Wiring Harness	4000.00	20.00	2	40.00	8000.00
23	Sidewall access Panel	145.00	1.25	2	2.50	290.00
24	Protection of Electrical Equipment	200.00	0.50	1	0.50	200.00
	TOTALS				507.58	45538.09

	NARROW BODY	80' Length	10 Zones	Tanks Front & Rear - Crashworthy		
	Configuration No. 9	Unit Cost	Unit Wt.	No.	Total Wt.	Total Cost
	2 Tanks - 20.5 Usable US Gallons	(£)	(lbs)	off	(lbs)	(£)
1	Nozzle & Fittings	5.50	0.08	80	6.40	440.00
2	Narrow Bore Pipework (52' per Zone)	329.14	5.00	10	50.00	3291.40
3	8 Way Manifold	300.00	1.80	10	18.00	3000.00
4	Distribution Pipe 8' units (inc Fittings)	199.65	6.18	9	55.66	1796.83
5	Tank to Ceiling Pipework (inc Fittings)	323.93	9.58	2	19.17	647.86
6	"T" Connector	60.00	0.50	10	5.00	600.00
7	Zone Solenoid Valve	450.00	0.80	10	8.00	4500.00
8	Frangible Coupling	175.00	1.20	18	21.60	3150.00
9	Base Assembly & Floor Fittings	410.00	4.25	2	8.50	820.00
10	Base Cover	385.00	10.00	2	20.00	770.00
11	Water Tank & Fittings	3400.00	15.00	2	30.00	6800.00
12	Tank Mountings (2 per tank)	366.00	2.72	2	5.44	732.00
13	Water (25 US Gallons)	0.00	8.34	25	208.40	0.00
14	Quick release coupling	125.00	1.10	2	2.20	250.00
15	Check Valve	80.00	0.60	2	1.20	160.00
16	Drain Down/refill Facility	50.00	2.00	2	4.00	100.00
17	Pressure Cylinder & Fittings	815.00	11.00	2	22.00	1630.00
18	Misc Attachments & Fittings	100.00	1.25	10	12.50	1000.00
19	Heat Sensors	800.00	1.00	2	2.00	1600.00
20	Control Panel & Test Facilities	1380.00	1.20	1	1.20	1380.00
21	Standby Batteries	1500.00	18.00	1	18.00	1500.00
22	Wiring Harness	4000.00	20.00	2	40.00	8000.00
23	Sidewall access Panel	145.00	1.25	2	2.50	290.00
24	Protection of Electrical Equipment	200.00	0.50	1	0.50	200.00
	TOTALS				562.26	42658.09

WEIGHT COST BREAKDOWN

	NARROW BODY	80' Length	10 Zones	1 Rear tank - Crashworthy		
	Configuration No. 10	Unit Cost	Unit Wt.	No.	Total Wt.	Total Cost
	Potable Water only	(£)	(lbs)	off	(lbs)	(£)
1	Nozzle & Fittings	5.50	0.08	80	6.40	440.00
2	Narrow Bore Pipework (52' per Zone)	329.14	5.00	10	50.00	3291.40
3	8 Way Manifold	300.00	1.80	10	18.00	3000.00
4	Distribution Pipe 8' units (inc Fittings)	199.65	6.18	9	55.66	1796.83
5	Tank to Ceiling Pipework (inc Fittings)	323.93	9.58	1	9.58	323.93
6	"T" Connector	60.00	0.50	10	5.00	600.00
7	Zone Solenoid Valve	450.00	0.80	10	8.00	4500.00
8	Frangible Coupling	175.00	1.20	9	10.80	1575.00
11	Potable Tank Modifications & Fittings	1175.00	13.30	1	13.30	1175.00
17	Pressure Cylinder	970.00	11.00	1	11.00	970.00
18	Misc Attachments & Fittings	100.00	1.25	10	12.50	1000.00
19	Heat Sensors	800.00	1.00	1	1.00	800.00
20	Control Panel & Test Facilities	1380.00	1.20	1	1.20	1380.00
21	Standby Batteries	1500.00	18.00	1	18.00	1500.00
22	Wiring Harness	4000.00	20.00	1	20.00	4000.00
24	Protection of Electrical Equipment	200.00	0.50	1	0.50	200.00
	TOTALS				240.94	26552.16

WEIGHT COST BREAKDOWN

	WIDE BODY	136' Length	17 Zones	1 Rear Tank - No crashworthiness		
	Configuration No. 11	Unit Cost	Unit Wt.	No.	Total Wt.	Total Cost
	1 Tank - 16 Usable US Gallons	(£)	(lbs)	off	(lbs)	(£)
1	Nozzle & Fittings	5.50	0.08	272	21.76	1496.00
2	Narrow Bore Pipework (52' per Zone)	329.14	5.00	34	170.00	11190.76
3	8 Way Manifold	300.00	1.80	34	61.20	10200.00
4	Distribution Pipe 8' units (inc Fittings)	124.72	4.75	32	152.13	3991.04
5	Tank to Ceiling Pipework (inc Fittings)	240.12	9.95	2	19.91	480.24
6	"T" Connector	50.00	0.47	34	15.98	1700.00
7	Zone Solenoid Valve	420.00	0.70	34	23.80	14280.00
8	Frangible Coupling	0.00	0.00	0	0.00	0.00
9	Base Assembly & Floor Fittings	410.00	5.00	1	5.00	410.00
10	Base Cover	425.00	15.00	1	15.00	425.00
11	Water Tank & Fittings	3900.00	20.00	1	20.00	3900.00
12	Tank Mountings (4 per tank)	366.00	2.72	2	5.44	732.00
13	Water (25 US Gallons)	0.00	8.34	25	208.40	0.00
14	Quick release coupling	100.00	1.00	1	1.00	100.00
15	Check Valve	60.00	0.50	1	0.50	60.00
16	Drain Down/refill Facility	785.00	34.30	1	34.30	785.00
17	Pressure Cylinder & Fittings	970.00	11.00	1	11.00	970.00
18	Misc Attachments & Fittings	100.00	1.25	34	42.50	3400.00
19	Heat Sensors	1400.00	3.50	2	7.00	2800.00
20	Control Panel & Test Facilities	1380.00	1.20	1	1.20	1380.00
21	Standby Batteries	1500.00	18.00	1	18.00	1500.00
22	Wiring Looms	13000.00	113.00	1	113.00	13000.00
23	Sidewall access Panel	145.00	1.25	1	1.25	145.00
						0.00
24	Protection of Electrical Equipment	680.00	0.68	1	0.68	680.00
	TOTALS				949.05	73625.04

WEIGHT COST BREAKDOWN

	WIDE BODY	136' Length	17 Zones	1 Central Tank - Crashworthy		
	Configuration No. 12	Unit Cost	Unit Wt.	No.	Total Wt.	Total Cost
	1 Tank - 16 Usable US Gallons	(£)	(lbs)	off	(lbs)	(£)
1	Nozzle & Fittings	5.50	0.08	272	21.76	1496.00
2	Narrow Bore Pipework (52' per Zone)	329.14	5.00	34	170.00	11190.76
3	8 Way Manifold	300.00	1.80	34	61.20	10200.00
4	Distribution Pipe 8' units (inc Fittings)	124.72	4.75	32	152.13	3991.04
5	Tank to Ceiling Pipework (inc Fittings)	240.12	7.87	2	15.75	480.24
6	"T" Connector	50.00	0.47	34	15.98	1700.00
7	Zone Solenoid Valve	420.00	0.70	34	23.80	14280.00
8	Frangible Coupling	150.00	1.00	32	32.00	4800.00
9	Base Assembly & Floor Fittings	410.00	5.00	1	5.00	410.00
10	Base Cover	425.00	15.00	1	15.00	425.00
11	Water Tank & Fittings	3900.00	20.00	1	20.00	3900.00
12	Tank Mountings (4 per tank)	366.00	2.72	2	5.44	732.00
13	Water (25 US Gallons)	0.00	8.34	25	208.40	0.00
14	Quick release coupling	100.00	1.00	1	1.00	100.00
15	Check Valve	60.00	0.50	1	0.50	60.00
16	Drain Down/refill facility	785.00	34.30	1	34.30	785.00
17	Pressure Cylinder & Fittings	970.00	11.00	1	11.00	970.00
18	Misc Attachments & Fittings	100.00	1.25	34	42.50	3400.00
19	Heat Sensors	1400.00	3.50	2	7.00	2800.00
20	Control Panel & Test Facilities	1380.00	1.20	1	1.20	1380.00
21	Standby Batteries	1500.00	18.00	1	18.00	1500.00
22	Wiring Harness	13000.00	113.00	1	113.00	13000.00
						0.00
23	Sidewall access Panel	145.00	1.25	1	1.25	145.00
						0.00
24	Protection of Electrical Equipment	680.00	0.68	1	0.68	680.00
	TOTALS				976.89	78425.04

WEIGHT COST BREAKDOWN

	WIDE BODY	136' Length	17 Zones	Tanks Front & Rear - Crashworthy		
	Configuration No. 13	Unit Cost	Unit Wt.	No.	Total Wt.	Total Cost
	2 tanks - 25 Usable US Gallons	(£)	(lbs)	off	(lbs)	(£)
1	Nozzle & Fittings	5.50	0.08	272	21.76	1496.00
2	Narrow Bore Pipework (52' per Zone)	329.14	5.00	34	170.00	11190.76
3	8 Way Manifold	300.00	1.80	34	61.20	10200.00
4	Distribution Pipe 8' units (inc Fittings)	124.72	4.75	32	152.13	3991.04
5	Tank to Ceiling Pipework (inc Fittings)	240.12	9.95	4	39.82	960.48
6	"T" Connector	50.00	0.47	34	15.98	1700.00
7	Zone Solenoid Valve	420.00	0.70	34	23.80	14280.00
8	Frangible Coupling	150.00	1.00	64	64.00	9600.00
9	Base Assembly & Floor Fittings	410.00	5.00	2	10.00	820.00
10	Base Cover	385.00	8.90	2	17.80	770.00
11	Water Tank & Fittings	3400.00	15.00	2	30.00	6800.00
12	Tank Mountings (2 per tank)	366.00	2.72	2	5.44	732.00
13	Water (34 US Gallons)	0.00	8.34	34	283.42	0.00
14	Quick release coupling	100.00	1.00	2	2.00	200.00
15	Check Valve	60.00	0.50	2	1.00	120.00
16	Drain Down/refill Facility	475.00	18.00	2	36.00	950.00
17	Pressure Cylinder & Fittings	970.00	11.00	2	22.00	1940.00
18	Misc Attachments & Fittings	100.00	1.25	34	42.50	3400.00
19	Heat Sensors	1400.00	3.50	4	14.00	5600.00
20	Control Panel & Test Facilities	1380.00	1.20	2	2.40	2760.00
21	Standby Batteries	1500.00	18.00	2	36.00	3000.00
22	Wiring Harness	13000.00	113.00	2	226.00	26000.00
23	Sidewall access Panel	145.00	1.25	2	2.50	290.00
24	Protection of Electrical Equipment	680.00	0.68	1	0.68	680.00
	TOTALS				1280.43	107480.28

WEIGHT COST BREAKDOWN

	WIDE BODY	136' Length	17 Zones	Tanks Front & Rear - Crashworthy		
	Configuration No. 14	Unit Cost	Unit Wt.	No.	Total Wt.	Total Cost
	2 Tanks - 41 Usable US Gallons	(£)	(lbs)	off	(lbs)	(£)
1	Nozzle & Fittings	5.50	0.08	272	21.76	1496.00
2	Narrow Bore Pipework (52' per Zone)	329.14	5.00	34	170.00	11190.76
3	8 Way Manifold	300.00	1.80	34	61.20	10200.00
4	Distribution Pipe 8' units (inc Fittings)	124.72	4.75	32	152.13	3991.04
5	Tank to Ceiling Pipework (inc Fittings)	240.12	9.95	4	39.82	960.48
6	"T" Connector	50.00	0.47	34	15.98	1700.00
7	Zone Solenoid Valve	420.00	0.70	34	23.80	14280.00
8	Frangible Coupling	150.00	1.00	68	68.00	10200.00
9	Base Assembly & Floor Fittings	410.00	5.00	2	10.00	820.00
10	Base Cover	425.00	15.00	2	30.00	850.00
11	Water Tank & Fittings	3900.00	17.50	2	35.00	7800.00
12	Tank Mountings (4 per tank)	366.00	2.72	4	10.88	1464.00
13	Water (50 US Gallons)	0.00	8.34	50	416.80	0.00
14	Quick release coupling	1.00	1.00	2	2.00	2.00
15	Check Valve	68.00	0.50	2	1.00	136.00
16	Drain Down/refill Facility	475.00	18.00	2	36.00	950.00
17	Pressure Cylinder & Fittings	970.00	14.50	2	29.00	1940.00
18	Misc Attachments & Fittings	100.00	1.25	34	42.50	3400.00
19	Heat Sensors	1400.00	3.50	4	14.00	5600.00
20	Control Panel & Test Facilities	1380.00	1.20	2	2.40	2760.00
21	Standby Batteries	1500.00	18.00	2	36.00	3000.00
22	Wiring Harness	13000.00	113.00	2	226.00	26000.00
23	Sidewall access Panel	145.00	1.25	2	2.50	290.00
27	Protection of Electrical Equipment	680.00	0.68	1	0.68	680.00
	TOTALS				1447.44	109710.28

WEIGHT COST BREAKDOWN

	WIDE BODY	136' Length	17 Zones	Tanks Front & Rear Crashworthy		
	Configuration No. 15	Unit Cost	Unit Wt.	No.	Total Wt.	Total Cost
	Potable Water only	(£)	(lbs)	off	(lbs)	(£)
1	Nozzle & Fittings	5.50	0.08	272	21.76	1496.00
2	Narrow Bore Pipework (52' per Zone)	329.14	5.00	34	170.00	11190.76
3	8 Way Manifold	300.00	1.80	34	61.20	10200.00
4	Distribution Pipe 8' units (inc Fittings)	124.72	4.75	32	152.13	3991.04
5	Tank to Ceiling Pipework (inc Fittings)	240.12	9.95	4	39.82	960.48
6	"T" Connector	50.00	0.47	34	15.98	1700.00
7	Zone Solenoid Valve	420.00	0.70	34	23.80	14280.00
8	Frangible Coupling	150.00	1.00	68	68.00	10200.00
11	Potable Tank Modifications & Fittings	1175.00	13.30	2	26.60	2350.00
17	Pressure Cylinder	970.00	14.50	2	29.00	1940.00
18	Misc Attachments & Fittings	100.00	1.25	34	42.50	3400.00
19	Heat Sensors	1400.00	3.50	4	14.00	5600.00
20	Control Panel & Test Facilities	1380.00	1.20	2	2.40	2760.00
21	Standby Batteries	1500.00	18.00	2	36.00	3000.00
22	Wiring Harness	13000.00	113.00	2	226.00	26000.00
24	Protection of Electrical Equipment	680.00	0.68	1	0.68	680.00
	TOTALS				929.86	99748.28

COST OF INSTALLATION
LABOUR ONLY

	MAN HOURS TAKEN TO RETROFIT A CABIN WATER SPRAY SYSTEM IN AN EXISTING AIRCRAFT															
		Regional					Narrow Body					Wide Body				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Remove seats	5	5	5	5	5	9.6	9.6	9.6	9.6	9.6	20	20	20	20	20
2	Remove Furnishings	58	58	58	58	58	116	116	116	116	116	200	200	200	200	200
3	Remove insulation blankets	2	2	2	2	2	4	4	4	4	4	8	8	8	8	8
4	Modify insulation blankets	25	25	25	25	25	50	50	50	50	50	170	170	170	170	170
5	Protection of Electrical Equipment	3	3	4	4	2	5	5	6	6	4	14.6	14.6	15.6	15.6	13.6
6	Install distribution & zone pipes etc	100	100	100	100	100	200	200	200	200	200	680	680	680	680	680
7	Replace insulation blankets	2	2	2	2	2	4	4	4	4	4	8	8	8	8	8
8	Modify panels	54	54	54	54	54	108	108	108	108	108	363	363	363	363	363
9	Fit heat detection system	8	8	8	8	8	16	16	16	16	16	35	35	35	35	35
10	Fit tank to ceiling pipe	5	5	10	10	5	5	5	10	10	5	8	8	16	16	16
11	Modify potable tank					15					15					30
12	Modify sidewall for connector	1.5	1.5	3	3	1.5	1.5	1.5	3	3	1.5	1.5	1.5	3	3	3
13	Install wiring looms	24	24	24	24	24	36	36	36	36	36	60	60	60	60	60
14	Install flight deck equipment	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
15	Inspection and system test	10	10	15	15	10	15	15	20	20	15	39	39	44	44	39
16	Re-install interior fittings	87	87	87	87	87	170	170	170	170	170	300	300	300	300	300
17	Install tanks	2	2	4	4	0	2	2	4	4	0	4	4	8	8	0
18	Connect up system	1	1	2	2	1	1	1	2	2	1	1	1	2	2	2
19	Re-install seats	7	7	7	7	7	14	14	14	14	14	25	25	25	25	25
	TOTAL MAN HOURS	402.5	402.5	418	418	414.5	765.1	765.1	780.6	780.6	777.1	1945	1945	1966	1966	1981
	TOTAL COST @ £30 PER HOUR	12075	12075	12540	12540	12435	22953	22953	23418	23418	23313	58353	58353	58968	58968	59418

APPENDIX G
Part 1

COST OF INSTALLATION
LABOUR ONLY

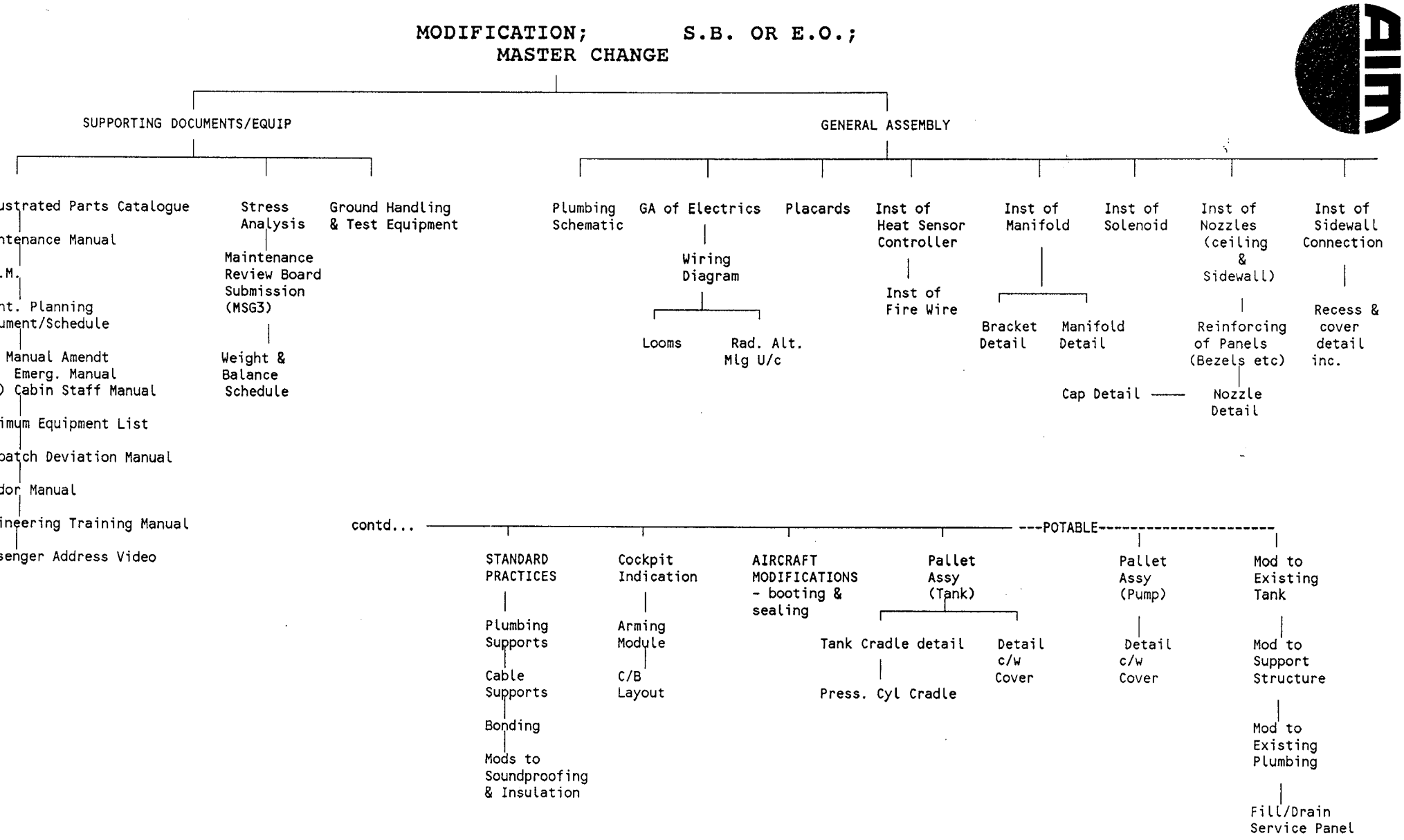
	MAN HOURS TAKEN TO INSTALL A CABIN WATER SPRAY SYSTEM IN A NEW BUILD AIRCRAFT															
		Regional					Narrow Body					Wide Body				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Remove seats															
2	Remove Furnishings															
3	Remove insulation blankets															
4	Modify insulation blankets	25	25	25	25	25	50	50	50	50	50	170	170	170	170	170
5	Protection of Electrical Equipment	3	3	4	4	2	5	5	6	6	4	14.6	14.6	15.6	15.6	13.6
6	Install distribution & zone pipes etc	100	100	100	100	100	200	200	200	200	200	680	680	680	680	680
7	Replace insulation blankets															
8	Modify panels	54	54	54	54	54	108	108	108	108	108	363	363	363	363	363
9	Fit heat detection system	8	8	8	8	8	16	16	16	16	16	35	35	35	35	35
10	Fit tank to ceiling pipe	5	5	10	10	5	5	5	10	10	5	8	8	16	16	8
11	Modify potable tank					8					8					16
12	Modify sidewall for connector	1.5	1.5	3	3	1.5	1.5	1.5	3	3	1.5	1.5	1.5	3	3	3
13	Install wiring looms	24	24	24	24	24	36	36	36	36	36	60	60	60	60	60
14	Install flight deck equipment	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
15	Inspection and system test	10	10	15	15	10	15	15	20	20	15	39	39	44	44	39
16	Re-install interior fittings															
17	Install tanks	2	2	4	4	0	2	2	4	4	0	4	4	8	8	0
18	Connect up system	1	1	2	2	1	1	1	2	2	1	1	1	2	2	2
19	Re-install seats															
	TOTAL MAN HOURS	241.5	241.5	257	257	246.5	447.5	447.5	463	463	452.5	1384	1384	1405	1405	1398
	TOTAL COST @ £30 PER HOUR	7245	7245	7710	7710	7395	13425	13425	13890	13890	13575	41523	41523	42138	42138	41928

APPENDIX G
Part 2

COST OF INSTALLATION
LABOUR ONLY

	MAN HOURS TAKEN TO INSTALL A CABIN WATER SPRAY SYSTEM IN A NEW DESIGN AIRCRAFT															
		Regional					Narrow Body					Wide Body				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Remove seats															
2	Remove Furnishings															
3	Remove insulation blankets															
4	Modify insulation blankets															
5	Protection of Electrical Equipment															
6	Install distribution & zone pipes etc	100	100	100	100	100	200	200	200	200	200	680	680	680	680	680
7	Replace insulation blankets															
8	Modify panels															
9	Fit heat detection system	8	8	8	8	8	16	16	16	16	16	35	35	35	35	35
10	Fit tank to ceiling pipe	5	5	10	10	5	5	5	10	10	5	8	8	16	16	16
11	Modify potable water tank															
12	Modify sidewall for connector															
13	Install wiring looms	24	24	24	24	24	36	36	36	36	36	60	60	60	60	60
14	Install flight deck equipment	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
15	Inspection and system test	10	10	15	15	10	15	15	20	20	15	39	39	44	44	39
16	Re-install interior fittings															
17	Install tanks	2	2	4	4	0	2	2	4	4	0	4	4	8	8	0
18	Connect up system	1	1	2	2	1	1	1	2	2	1	1	1	2	2	2
19	Re-install seats															
	TOTAL MAN HOURS	158	158	171	171	156	283	283	296	296	281	835	835	853	853	840
	TOTAL COST @ £30 PER HOUR	4740	4740	5130	5130	4680	8490	8490	8880	8880	8430	25050	25050	25590	25590	25200

APPENDIX G
Part 3



NON-RECURRING COST - FAMILY TREE