University of Southern Queensland

Faculty of Engineering & Surveying

Field Deployable Shower Unit
By Dual Membrane Filtration

A dissertation submitted by

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towards the degree of

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Abstract

Through the research and investigation of filtration systems both micro-filtration and ultra-filtration as well as reverse osmosis technology and techniques a conceptual a conceptual Field Deployable Shower Unit (FDSU) will be designed for the Department of Defence and for the potential use by humanitarian agencies and other Emergency Services during deployment to the field and whilst on disaster and humanitarian relief throughout the world. The FDSU will be designed to operate using supplied water or brackish water, dam water, bore or river water up to a TDS of 20,000 mg/L. The FDSU will also have the engineered redundancy to desalinate and process salt water on occasion as required.

The system will be designed based on current filtration and reverse osmosis technology as well as being based on current water purification equipment employed by the Department of Defence, whether the equipment is in general use or whether it is used as a subassembly in another system. The system will also be designed with the capability of being piggy backed directly on to the current water purification unit (WPU) employed by the Department of Defence. The DFSU design comprises of four main sections. These sections include the input or pre-filtration section, the micro-filtration section, the reverse osmosis membrane treatment section and the recycled/reclaimed water section. The water that is supplied from the WPU will bypass the input/pre-filtration, micro-filtration and reverse osmosis membrane sections.

The input / pre-filtration section pumps the water from the supplied water source whether it is in tanks or from a dam etc through a strainer to remove residual contaminants that may be in the water and greater than 800 microns in size through a

back flushable filter that is 400 microns in size to remove smaller contaminants. It is pumped to a micro-filtration feed tank where it is dosed with a chlorine solution en-route to disinfect the water prior to entering the micro-filtration section.

The micro-filtration section receives the chlorine dosed water via a pump which raises the pressure of the water to between one and a half and two bar in order to force the water through the micro-filtration section. The micro-filtration section has the capability to be reverse flushed for cleaning, de-scaling and de-fouling of the filter during operation. The water is then treated with a sodium bisulphate solution to neutralise the chlorine as the reverse osmosis membranes are sensitive to chlorine.

The reverse osmosis membrane section has the water fed to it via a high pressure pump which raises the water pressure to 45 bar based on a brackish water with a TDS of 20,00 mg/L in order to overcome the osmotic pressure and force the water through the reverse osmosis membrane. Based on the brackish water supply with a 60% permeate return for use in the shower, the system would require a constant supply of water at approximately 3,300 litres/hour once it has been run up and the recycled/reclaimed water is being processed and returned for use in the FDSU.

The recycled/reclaimed water section comprises of a back flushable filter with a pump that pumps the water from the shower sump through the back flushable filter through to the micro-filtration feed tank where it is dosed with a chlorine solution en-route to disinfect the water prior to entering the micro-filtration section.

The scope of this project has been limited to the design of a conceptual design employing the technologies and techniques of micro-filtration and reverse osmosis for the use in the Field Deployable Shower Unit. The construction and testing of a prototype and ultimately the project for the construction of the required amount of Field Deployable Shower Units will be solely reliant on the decision that the Department of Defence make in regards to whether the FDSU concept meets their requirements.

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ENG4111 Research Project Part 1 &
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Limitations of Use

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Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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Glossary of Terms

Absorption
(gen.) The taking in, incorporation or reception of gases, liquids, light or heat.
(phys/chem) Penetration of one substance into the inner structure of another (cf. adsorption, in which one substance is attracted and held on the surface of another). Occurs between a gas or vapour and a liquid.
(pharm.) The process of movement of a drug from the site of application into the extracellular compartment of the body.

Adsorption
Retention of gas, liquid, solid or a dissolved substance on a surface due to positive interaction (attraction) between the surface and the molecules of the adsorbed material. The interactive forces can be electrostatic (coulombic) or nonelectrostatic (dipole-dipole and hydrophobic). Adsorption to a membrane or filter device can occur in a specific manner (affinity) or non-specifically.

Air Scrubbing (AS)
AS is another way to clean the membrane hydraulically. During AS, air is injected into the bottom of the filter module. The combined water-air flow creates strong turbulent and shear forces to dislodge dirt deposited on the membrane surface. Forward flush or reverse flow are used to remove the solids dislodged during air scrubbing. Sometimes air scrubbing is combined with reverse filtration, termed as simultaneous air scrubbing and reverse filtration (SASRF), as the means of hydraulic cleaning.

Antigen
A foreign substance (usually proteinaceous or high molecular weight polysaccharide) which induces the formation of antibodies. Examples are bacteria, viruses, endo/exotoxins, pollen and vaccines.

Backwash
Reversing the flow of liquid through a filter in order to remove trapped solids.

Bacteria (Bacterium)
Free living simple celled, microscopic organisms having a cell wall and characteristic shape (e.g., round, rod-like, spiral or filamentous); lack a defined nucleus.

Bar
A unit of pressure. One bar = 14.5 psi.

Biomass
The total weight of living matter present in a specific area.

Blinding
The reduction or cut off of flow due to particles filling the pores of a filter.

Cartridge or Filter Cartridge
A filtration or separation device (usually in the shape of a cylinder) that is designed for easy installation and removal.

Clarification
To clear a liquid by filtration, by the addition of agents to precipitate solids, centrifugation, or by other means.

Coagulation
The destabilization and initial aggregation of finely divided suspended solids by the addition of a polyelectrolyte or a biological process.

Concentrate
Sample not filtered by a membrane. See Retentate.

Crossflow
Flow of solution parallel to the upstream surface of the membrane (see also Tangential Flow Filtration). This contrasts with direct flow seen in traditional filters, in which the liquid flows perpendicular to the surface of the filter.

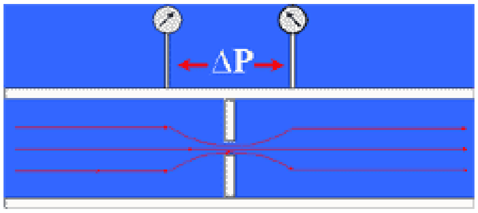
Crossflow (Tangential Flow) Filtration
A filtration system in which the feed stream flows across the filter media and exits as a retentate stream. The retentate stream is recycled to merge into the feed stream, while a portion of it passes through the filter media, resulting in concentration of the feed stream (referred to as retentate or concentrate). Tangential flow is by far the most effective way to perform ultrafiltration for samples greater than 150 mL. The Ultrasette™ tangential flow device can be used to purify and desalt protein solutions for most lab applications. TFF systems can easily be scaled up to larger scale process applications.

Cryptosporidium
A protozoan parasite that can live in the intestines of humans and animals.

Dead End (Conventional) Filtration
Feed stream flows in one direction only, perpendicular to and through the filter medium to emerge as product of filtrate. Sometimes referred to as "single pass" filtration. Syringe filters, disc membranes, capsules, and cartridges are used in this process.

Depth Filtration
Depth filtration is the process that traps contaminants both within the matrix and on the surface of the filter media. Depth filters are composed of random mats of metallic, polymeric, or inorganic materials. These filters rely on the density and thickness of the mats to trap particles, and generally retain large quantities of contaminants within the matrices. Media migration, which is the shifting of the filter medium under stress, and particulate unloading are potential problems.

Differential Pressure
Differential Pressure (Δ P) is the difference between the pressure in the system before the fluid reaches the filter (upstream pressure) and the system pressure after the fluid flows through the filter (downstream pressure). As the filter begins to clog, differential pressure increases.



Direct Flow Filtration
Filtration in which liquid flow is directly through the filter medium.

Distillation
The vaporization and subsequent condensation of a liquid. It is used to purify liquids and to separate liquid mixtures.

Feed
The unfiltered liquid. Often used in the phrase "feed stream", the flow of liquid into the filtration system.

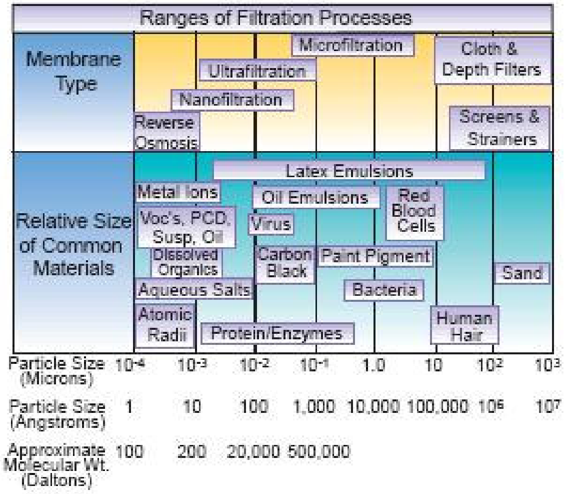
Filter (Noun)
An apparatus which performs filtration.

Filter (Verb)
To pass a fluid through a porous medium in order to remove solid particles.

Filter Element
A filter element is a single component, which includes filter media and any supporting materials and other hardware, which must be installed or replaced as a single unit. A common example is a filter cartridge.

Filtrate (Permeate)
Portion of the solution that has passed through the membrane.

Filtration
Process by which particles are removed from a fluid by passing the fluid through a permeable material. See Crossflow (Tangential Flow) Filtration, Dead End (Conventional) Filtration, Depth Filtration, Direct Flow Filtration, Nanofiltration, Reverse Osmosis (RO), Tangential Flow Filtration (TFF), Ultrafiltration.



Flow Decay
Decrease in flow rate as a result of filter plugging or clogging.

Flux
The amount of solution that passes through a unit of membrane area in a given amount of time. For instance, a filter might have a flux of 1 litre per minute per square centimetre. Flux decreases as the membrane fouls.

Fouling
Contamination (plugging) of the membrane, decreasing flux. Often requires chemical cleaning of the membrane.

Giardia Lamblia
A protozoan parasite responsible for giardiasis.

Head
An end closure for the filter Bowl, which contains one or more connections through which the fluid to be filtered passes. The component to which a filter cartridge is sealed.

Housing
The device that encloses a filter element and directs the flow of fluid through it. See Bowl.

Hypochlorite
A weak, unstable salt of hypochlorous acid used in aqueous solutions as a bleach, oxidizer, deodorant and disinfectant.

Integrity Test
A test to ensure that a sterilizing-grade filter is intact and will function as intended. Recommended integrity tests are the Forward Flow Test, Bubble Point test, and the Pressure Hold test. Integrity tests on sterilizing grade filters are correlated with bacterial challenge data.

Medium (Media)
The filter medium is the component of the filter system that actually permits the fluid to pass while retaining contaminants. In a typical drip coffee maker, the medium is the paper filter.

Membrane Recovery
Restoration of the original flux of a membrane after Fouling.

Microfiltration
Microfiltration is the process of removing particles from a liquid or gas by passing it through a porous medium. It generally involves removing particles between the sizes of 10 and 0.02 microns in liquids, and down to 0.003 microns in gases. [See Ultrafiltration, Nanofiltration, Reverse Osmosis (RO)].

Micro-filtration membranes
A low-pressure membrane filtration process that removes suspended solids and colloids larger than 0.1 microns.

Micron (Micrometer)
One one-millionth (0.000001) of one meter, or 0.00003937 inch. Bacteria are typically less than one micron in length. The smallest object visible to the naked eye is approximately 40 microns across. Human hairs are between 60 and 80 microns in diameter.

Microorganisms
Microscopic organisms such as bacteria, protozoans, yeast, viruses or algae. Typically refers to single-celled organisms that can only be observed under the microscope.

Microporous Membrane
A membrane is a thin, porous film that has flow paths or channels passing through it. The size of these channels is related to the pore size rating of the membrane (0.01 µm to 10 µm). Membranes can be used in the separation or filtration of suspended matter from liquids and gases.

Mil
A unit of measure equal to one thousandth of an inch. 1 mil = 0.001 in. = 0.025 mm. Commonly used to describe the thickness of a membrane or film.

Nanofiltration
Filtration that removes both particles and small dissolved molecules and ions. Finer than Ultrafiltration, not as fine as Reverse Osmosis (RO).

Operating Limits
Minimum and maximum parameters set for validation and processing pressures.

Osmosis
The net flow of solvent through a semi-permeable membrane from a region of high solute concentration to a region of low solute concentration. The flow continues across the membrane until the concentrations in both regions are the same.

Particle
Any discrete unit of material structure; a discernible mass having an observable length, width, thickness, size and shape. By size, the particles range: subatomic or fundamental (protons, neutrons, electrons, etc.); molecular (atoms and molecules, from angstroms to 0.5 µm); colloidal; microscopic (can be resolved by optical microscope, e.g., bacteria); macroscopic (can be resolved by the naked eye).
Particle Size Distribution (PSD)Refers to the number fraction or weight fraction of particles (in a fluid) falling into specified size ranges. For instance:

Size Range	# per Litre	% by Number (PSD)
5-15 µm	1000	20
15-25 µm	3000	60
25-50 µm	1000	20

Particulate
Relating to or occurring in the form of fine particles.

Permeability
The degree to which a fluid will pass through a permeable substance under specified conditions. The space or void volume between molecules allowing fluid flow.

Permeate
Fluid, which passes through a membrane. In ultrafiltration, this term is often used interchangeably with filtrate. To pass through the pores or interstices of something.
pH
The pH value of an aqueous solution is a number describing its acidity or alkalinity. A pH is the negative logarithm (base 10) of the concentration of hydrogen ions (equivalents per litre). The pH value of a neutral solution is 7. An acidic solution has a pH less than 7, while a basic solution has a pH greater than 7, up to 14.

Polyvinylidene Fluoride (PVDF)
PVDF membranes are naturally hydrophobic but can be modified to a hydrophilic nature. Useful for a wide range of applications: both aqueous and non-aggressive solvent based. It is typically low protein binding and used frequently for sterilizing filtration.

Purified Water, USP
Pharmaceutical water produced by distillation, reverse osmosis or deionization. Common uses are: a rinse for equipment, vials and ampoules, and as base for cosmetics and oral drugs. It is not used as raw material for parental drugs.

Recovery
Ability of a filter to retain bacteria, DNA or other biomolecules from a solution. Percentage of a chemical that can be recovered after processing.

Rejection
Amount (%) of a molecule that does not pass through a membrane.

Retentate
That which is retained on the upstream side of a membrane filter in a tangential or cross-flow system such as ultrafiltration or reverse osmosis. Often designated as concentrate.

Retention
Ability of a filter to retain particles (total number or those of a specific size) suspended in a gas or liquid. In the case of ultrafiltration, refers to the ability to concentrate molecules in solution. Expressed as percent of particles or molecules originally present.

Reverse Osmosis (RO)
Forcing a liquid through a nonporous membrane, removing particles, along with dissolved molecules and ions. Reverse Osmosis is the finest form of membrane separation and is used to desalinate water for drinking, and prepare ultrapure water for various industries.

Sanitization, Sanitize
To make clean by removing dirt and other extraneous materials with soap and general disinfectant so as to reduce possibility of growth and spread of pathogenic organisms. A common sanitization agent is 70% ethanol. Bleach is also commonly used.

Sedimentation
The removal of suspended solids from water or wastewater by gravity in a quiescent basin or clarifier.

Separation
Separation is the process of dividing a fluid stream (either liquid or gas) into separate components. This can include purification (removing something undesirable). This can include separation of two phases (liquid from gas), separation of soluble impurities (known as purification) or solids from a fluid (filtration). The products of a separation can themselves be separated further in many cases.

Serial Filtration
Filtration through two or more filters of decreasing pore size one after the other to increase throughput, filtration efficiency, or to protect the final filter.

Silt Density Index (SDI)
A measure of the fouling tendency of water based on the timed flow of a liquid through a membrane filter at a constant pressure.

Specifications
A detailed, precise description or parameter for identification of limits.

Standard (Normal) Pressure
A pressure of 1 atmosphere (1 bar, 14.70 psi or 760 mm of mercury) to which measurements of quantities dependent on pressure are often referred.

Tangential Flow Filtration (TFF)
Filtration in which liquid flows tangential to (along) the surface of the membrane while pressure is applied that forces liquid through the membrane. The sweeping action of TFF acts to minimize gel layer formation and fouling.

Throughput
The amount of solution which will pass through a filter prior to clogging.

Total Dissolved Solids (TDS)
Total Dissolved Solids are solids in water that can pass through a filter (usually with a pore size of 0.45 micrometers). TDS is a measure of the amount of material dissolved in water. This material can include carbonate, bicarbonate, chloride, sulfate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions. A certain level of these ions in water is necessary for aquatic life.

Total Suspended Solids (TSS)
The measure of particulate matter suspended in a sample of water or wastewater. After filtering a sample of a known volume, the filter is dried and weighed to determine the residue retained.

Transmembrane Pressure (TMP)
The force which drives liquid flow through a crossflow membrane. The upstream side (the side of the membrane the solution enters by) of a TFF system is under a higher pressure than the downstream side. This pressure difference forces liquid through the membrane.

Turbidity
Suspended matter in water or wastewater that scatters or otherwise interferes with the passage of light through the water.

Ultrafiltration
A low-pressure membrane filtration process that separates solutes in the 20 - 1000 angstrom (up to 0.1 micron) size range.

Upstream Side (of filter)
The feed side of the filter.

Virus
Simple life forms that require a host cell in order to reproduce. Consists of a small number of genes (DNA or RNA) encased in a coat of protein. Viral genes enter a host cell and are replicated by the host cell. The newly formed viral particles are then released to infect other cells. In some cases, the viral DNA becomes an integral part of the host cell chromosome. Viruses are commonly used as cloning vectors.

Nephelometric turbidity unit (NTU) is the unit of measure for the size or concentration of suspended particles based on the scattering of light transmitted or reflected by the medium.

Total organic carbon (TOC) represents the average number of organic particles per litre of water processed.

Chapter 1

Introduction

1.1 Project Aim

To research and design a safer, more reliable, robuster and more versatile Field Deployable Shower Unit (FDSU) than is currently available in the market place for the use of the Department of Defence, humanitarian agencies and other Emergency Services during deployment to the field and whilst on disaster and humanitarian relief throughout the world.

1.2 Project Objectives

To research information relating to field deployable shower units with an emphasis on utilizing reverse osmosis techniques and filtration methods.

To design a safe and versatile Field Deployable Shower Unit utilizing reverse osmosis and filtration techniques with a capability to enable eight persons to shower at any one time.

To evaluate the design for performance and make modifications where necessary in order to improve performance and efficiency. To identify components and manufacturers as well as suppliers that would be suitable for inclusion in the use of the Field Deployable Shower Unit.

1.3 Overview

Chapter 2

Contains information about the background and the current situation of the current bath system that is operated and utilised by the Department of Defence.

Chapter 3

Provides a detailed description of current technologies that are available for water disinfection and filtration.

Chapter 4

Contains and lists the requirements for the design of the Field Deployable Shower Unit that must be met to fulfil the project aim.

Chapter 5

Explains the way in which the project design methodology and objectives were undertaken.

Chapter 6

Contains the details of the FDSU design which includes the general concept of operation, the input system and treatment, the micro-filter system, the reverse osmosis system and the post reverse osmosis system.

Chapter 7

Lists the design modifications that were undertaken in the process of developing the final concept design of the FDSU.

Chapter 8

Contains details of the manufacturers and suppliers of products, parts, assemblies and sub-assemblies that are suitable for use in the FDSU.

Chapter 9

This chapter outlines the effects that may result from the design and development of the FDSU including environmental and safety effects.

Chapter 10

Contains the project conclusion and an outline of any further work that will be undertaken.

Chapter 2

Background

2.1 Current Bath Unit and Situation

2.1.1 Current Bath Unit

Currently the Department of Defence employ, operate and use a deployable field shower system known as the Shower System Field Mobile (SSFM). The purpose of the SSFM is for individual showering and personal hygiene whilst deployed in the field on military exercise, on operations or whilst on humanitarian operations in support of natural disasters or conflict. It is also able to provide limited Nuclear, Chemical and Biological decontamination for personnel and equipment. Defence states that water utilised for showering must be of a potable standard. The current system utilises a filtration system in conjunction with the heavy dosing of chemicals to the water supply to reach an uncertain standard that may be far from potable. The effect of dosing has caused Chlorine burns to the skin and eyes on several occasions to personnel whilst using and maintaining the system. Users must shower with their eyes and mouth closed to prevent irritation and ingestion of both the chlorine and unknown organisms. The SSFM has become an unreliable, maintenance consuming, burden to the department of Defence and its users. The fleet is continually being plagued with high maintenance costs due to equipment failure and spoiled membranes.

To exacerbate the problems above is the fact that water is such a needed commodity in the daily activities of personnel and a lot of the time it is in short supply. Personnel require drinking water ahead of the need of water to bathe. If the environment where personnel are operating is based around a constant water source, whether the water is fresh or not, then potable water can be obtained through Defence's current water purification units and it can be provided for the Field Deployable Shower Unit. In the event that the water purification units are not deployed and therefore not available and if water supplies do not extend to affording personnel a shower then the requirement will be a shower system that is self reliant in order to produce clean bathing water. To achieve this will require the replacement of the current Defence SSFM with a more reliable, safer and user friendly system. This system will be based on and designed around the current water purification unit employed by Defence. The system will wherever possible utilise the same parts, consumables, components and equipments as the in service water purification system allowing Defence to have commonality between systems.

2.1.2 Situation

The World Health Organisation (WHO) cites that freshwater is an important resource and will become more so in the future as the world population increases. Within the next fifty years, it is estimated that 40% of the world's population will live in countries facing water stress or water scarcity. The figure may actually be higher than 40%, because these data are calculated on a national basis, and therefore often do not take into account uneven distribution of water within national boundaries.

In many areas of the world, aquifers that supply drinking-water are being used faster than they recharge. Not only does this represent a water supply problem, it may also have serious health implications. Moreover, in coastal areas, aquifers containing potable water can become contaminated with saline water if water is withdrawn faster than it can naturally be replaced. The increasing salinity makes the water unfit for drinking and often also renders it unfit for irrigation. (http://www.who.int/water_sanitation_health/wastewater/wsh0308/en/index.html). It is in the interest of all individuals to maintain a sustainable approach to water use. The earth is our life support system and we have to live within its limitations. Limiting our activities because of the environment isn't something that comes naturally to us. We are clever creatures used to overcoming problems, and we are not used to accepting limits to our endeavours. In many ways this is a positive trait and has led to some incredible human achievements. On the other hand, if we get carried away with our own self importance and disregard the delicate balance of our ecosystem we will be heading for trouble (Budd 2000, p.41). As we develop our sustainable approach it is prudent to consider that even though over 70% of the earth is covered in water, 97% is in oceans, which are too salty for human use. Approximately 2% of the earth's water is trapped as ice in the polar ice caps or as glaciers. This leaves only about 1% of the world's water as fresh water, or water that can easily be used by humans. In Australia, the amount of available water is even more restricted because we have an extremely low annual rainfall. In addition, only 12% of the rainfall in Australia remains available as water in creeks, streams, lakes or rivers. This is because we have the highest rate of evaporation and transpiration in the world (Alafaci 1997, p.2). As well as this Australians use more water on average that nearly any other person in the world, except for North Americans. Every year, each person in Australia uses 1,000,000 litres of fresh water. In total

Australians use about 25,000 giga litres of water, or almost 50 times more water than Sydney Harbour, every year (Pelusey 2006, p. 8)

Chapter 3

Current Technologies

3.1 Current Disinfection Theory

3.1.1 Disinfection Technologies

Disinfection technologies kill or screen-out biological contaminants present in a water supply. Chlorination, micro-filtration, ozone and ultraviolet light are the four major technologies used to disinfect water (http://www.pure-pro.com/treating_the_water.htm).

Chlorination adds a concentration of the chemical chlorine or chloramine to the water supply, where the oxidizing ability of this chemical “burns up” the organic contaminants in the water. Chlorine can effectively treat biological pathogens like coliform bacteria and Legionella, though it is ineffective against hard-shelled cysts like those produced by Cryptosporidium. Chlorine also treats for organically related taste, colour and odour problems (http://www.pure-pro.com/treating_the_water.htm). Micro-filtration uses a filter media with a pore size smaller than 0.2 microns to physically prevent biological contamination from passing through. Ceramic and solid block carbon are commonly used to provide micro-filtration. Ceramic filters have an advantage in that they can often be cleaned and reused a number of times before they lose effectiveness. Carbon block media usually has to be disposed of after each use. This media, however, provides additional treatment for a variety of other health and aesthetic contaminants. Micro-filtration is effective for treating the full range of biological contaminants, including hard-shelled cysts like Cryptosporidium (http://www.pure-pro.com/treating_the_water.htm).

Ozone treatment has typically been used in large-scale commercial and industrial applications; however, there has been a recent growth in the number of ozone units designed for use in a single home or business application (eg swimming pools). Ozone treatment oxidizes organic contaminants in much the same way that chlorine does. An ozone generator converts the oxygen found in air to O3, or ozone. As with chlorination, proper concentrations and contact time is essential for disinfection. Ozone usually requires the use of a retention tank to accomplish this, and can be used to provide partial treatment in pools. Ozone is effective for treating pathogens like coliform bacteria and Legionella, but it is not effective against hard-shelled cysts like Cryptosporidium or Giardia Lamblia without using high contact times and concentrations (http://www.pure-pro.com/treating_the_water.htm).

Ultraviolet light has treated water since the beginning of time through natural sunlight. Modern ultraviolet treatment units use a UV bulb in clear quartz or plexiglass housing, around which flows the untreated water. The UV light destroys the genetic material of pathogens like coliform bacteria and Legionella, which effectively neutralizes them by preventing them from reproducing. UV is not effective for the treatment of hard-shelled cysts like Cryptosporidium and Giardia Lamblia (http://www.pure-pro.com/treating_the_water.htm).

3.2 Current Filtration Theory

3.2.1 Pre-filtration

Prior to micro-filtration, ultra-filtration and nano-filtration all of which can precede Reverse Osmosis depending on the type of system that is being designed there is a requirement to use a simple form of filtration in the form of either strainers, bag type, depth or fibre wound cartridges, and sand or diatomaceous earthmedia in order to remove larger particulate from the water source.

3.2.2 Micro-filtration

Micro-filtration is a low pressure cross-flow membrane process designed for the removal of smaller particulate i.e. particles or microbes that can be seen with the aid of a microscope such as cells, macrophage, large virus particles and cellular debris. It separates solids, bacteria, colloidal and suspended particle matter from a feedwater or waste stream, typically down to 0.1 microns in size to produce water with very high purity. Refer to figure 3.1 for the separation chart for micro-filtration separation.

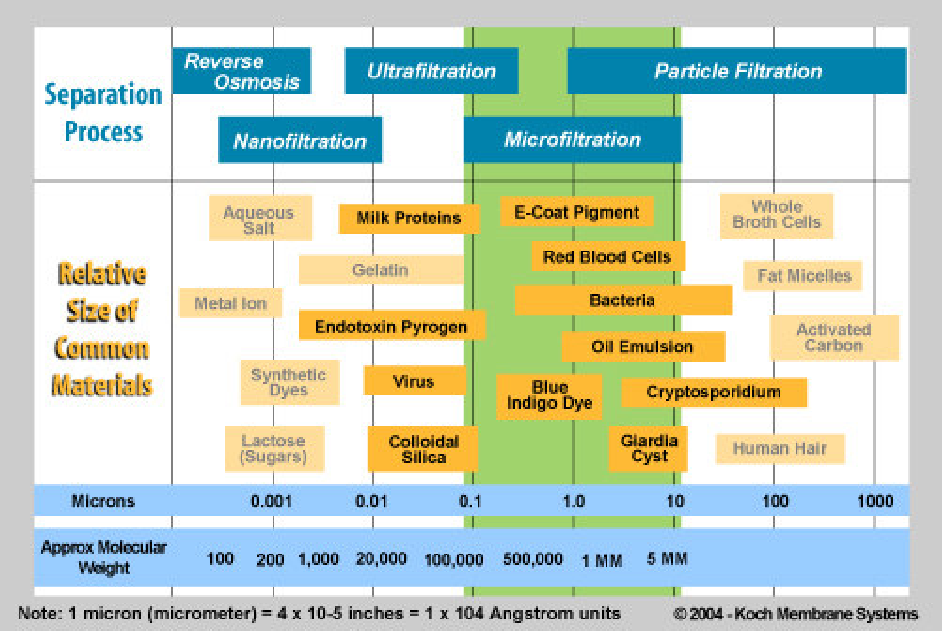


Figure 3.1 Separation Chart for Micro-filtration

Picture taken from(Koch Membrane Systems)

Micro-filtration is also used as a pre-treatment for surface water and seawater before reverse osmosis and other membrane systems as well as being used for fermentation, broth clarification and biomass clarification and recovery. Micro-filtration membranes are the most porous. As mentioned, these systems operate at moderate pressures and offer a variety of cleaning processes (using chemicals or back flush) to restore fouled membrane. Some membranes are fairly rugged and reusable after cleaning. Figure 3.2 shows a typical micro-filtration assembly. Micro-filtration technology is used industry wide in areas such as the pharmaceutical industry for cell harvesting and in the brewing industry for the cold sterilization of beer. By definition, micro-filtration refers to the removal of particles that range from 0.05 µm to less than 2.0 µm. Removal of bacteria from buffers or identification of particulate foreign matter in pharmaceutical products are examples of micro-filtration. This description justifies the need to remove the larger particles in the water to prevent the clogging of the reverse osmosis membranes.

Figure 3.2 Micro-filtration Assembly

Picture taken from (Pall Corporation)

Figures 3.3a and 3.3b show how the feed water is fed into the end of the micro-filtration membranes which are secured to the head of the housing. The water is forced down the hollow fibre members under approximately 1.5 Bar where the permeate/filtrate is forced out through the membrane and the concentrate reject is removed from the other end of the hollow fibre members.

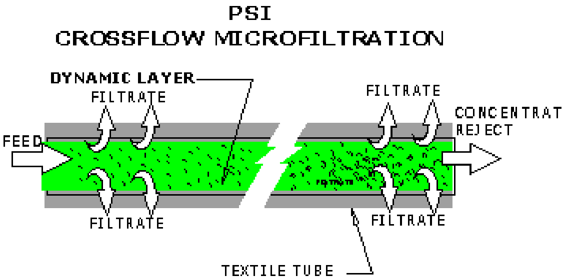


Figure 3.3a Micro-filtration Crossflow

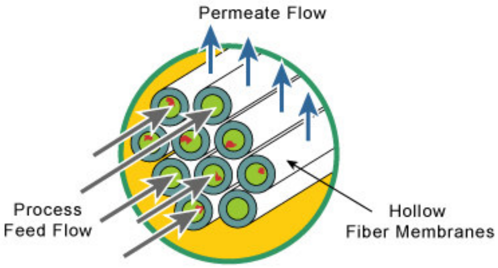


Figure 3.3b Feedflow Process

Picture taken from (Pall Corporation)

Micro-filtration is such an effective and robust medium in the filtration of feed waters and it is a cost effective option that it is being considered and put in place on a large scale in water treatment plants (Schaefer & Griffin 2001).

3.2.3 Ultra-filtration

Ultrafiltration (UF) is a pressure driven barrier to suspended solids. It removes oils, Colloidal solids, bacteria, viruses, endotoxins, other pathogens and other soluble pollutants and allows for recycling of industrial waters to produce water with a very high purity and low silt density. It works well on waste streams with compositional variability reducing, by up to 98%, the amount of waste to be treated or discharged. It serves as a pre-treatment for surface water and seawater before reverse osmosis. A micro-porous membrane filter removes particles according to pore size. By contrast, an ultrafiltration (UF) membrane functions as a molecular sieve. It separates dissolved molecules on the basis of size by passing a solution through an infinitesimally fine filter. The ultrafilter is a tough, thin, selectively permeable membrane that retains most macromolecules above a certain size including colloids, micro-organisms and pyrogens. Smaller molecules, such as solvents and ionized contaminants, are allowed to pass into the filtrate. Thus, UF provides a retained fraction (retentate) that is rich in large molecules and a filtrate that contains few, if any, of these molecules as displayed below in figure 3.4.

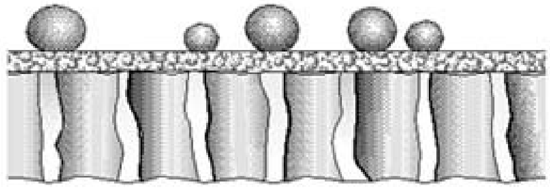


Figure 3.4 Molecular Structure of Ultrafiltration

Picture taken from (Free Drinking Water.com)

(http://www.freedrinkingwater.com/water-education/quality-water-filtration-method-ultrafiltration.htm). The removal of bacteria, viruses and pathogens makes the use of ultra-filtration ideal for the recycling of grey water.

3.2.4 Nano-filtration

Nano-filtration membranes have been developed that have retention capabilities of between 100 and 1000 molecular weight. Since a molecular weight of 200 equates to a large molecule of about 1 nanometer, these membranes are called nano-filtration membranes. Applied pressure requirement is between 75 and 450 psig, (far less than needed to achieve similar flow with reverse osmosis membranes). Ion-selectivity is a significant feature of nano-filtration. Salts with monovalent anions (e.g., Chlorides) are able to pass through the membrane, while salts with polyvalent anions (e.g., Sulphates or Phosphates) are retained. Nano-filters are used for processing surface waters to remove Matter Organic Water (MOW) such as humic and fulvic acids in order to preclude the formation of unwanted disinfection by-products (e.g., Trihalomethane). Nano-filtration technology can achieve a 98% recovery of water from waste. It is considered to be the state of the art in water purification. Membrane technology is rapidly gaining acceptance throughout the world as the most effective and economical water treatment method available. The degree of purification required generally determines what level of filtration is appropriate for a particular application.

3.3 Reverse Osmosis Theory

3.3.1 Osmosis

Osmosis is the natural process where water permeates through a membrane that excludes solids, dissolved salts and larger organic molecules. These semi-permeable membranes have pores of approximately 0.0005 microns in size. Figure 3.5 shows the natural process of osmosis where water flows through the semipermeable membrane from the pure solution to the salt solution in an effort to equalise the osmotic pressure of the two solutions.

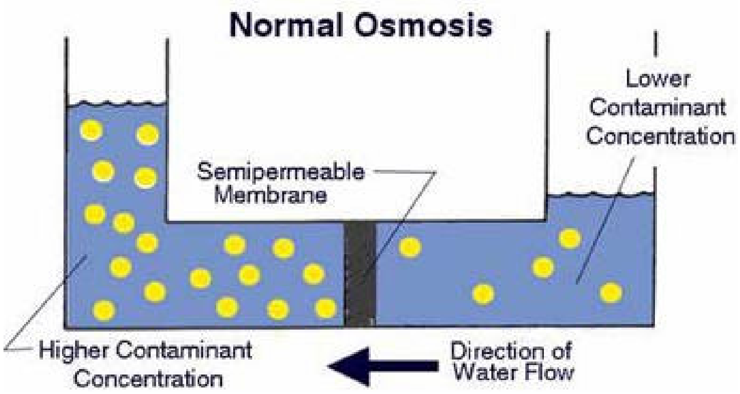


Figure 3.5 Osmosis

Picture taken from (Pure-Pro Water Corp)

3.3.2 Reverse Osmosis

Reverse Osmosis is a common treatment technology that produces high quality water. To understand reverse osmosis you have to understand the natural process of osmosis which occurs in all living cells, as previously explained. Figure 3.6 shows the separation chart for reverser osmosis. Water molecules have a stronger tendency to escape from pure water than from a salt solution. Water flows through a semipermeable membrane from the pure solution to the salt solution in an effort to equalise the osmotic pressure of the two solutions. The osmosis process may be reversed by applying pressure to the salt solution. In reverse osmosis water from the salt solution is forced back through the semipermeable membrane to the pure solution. The process stops when the osmotic pressure of the increasingly salty solution equals the applied pressure. In practise the salt solution must be continuously replaced before the osmotic pressure rises significantly. This is achieved using a cross flow mechanism where the surface of the semipermeable membrane is continuously flushed. Therefore commercial membranes have an inlet stream and two outlet streams. The inlet is known as the feedwater and the outlets are the Permeate (pure water) and the Concentrate (reject water).

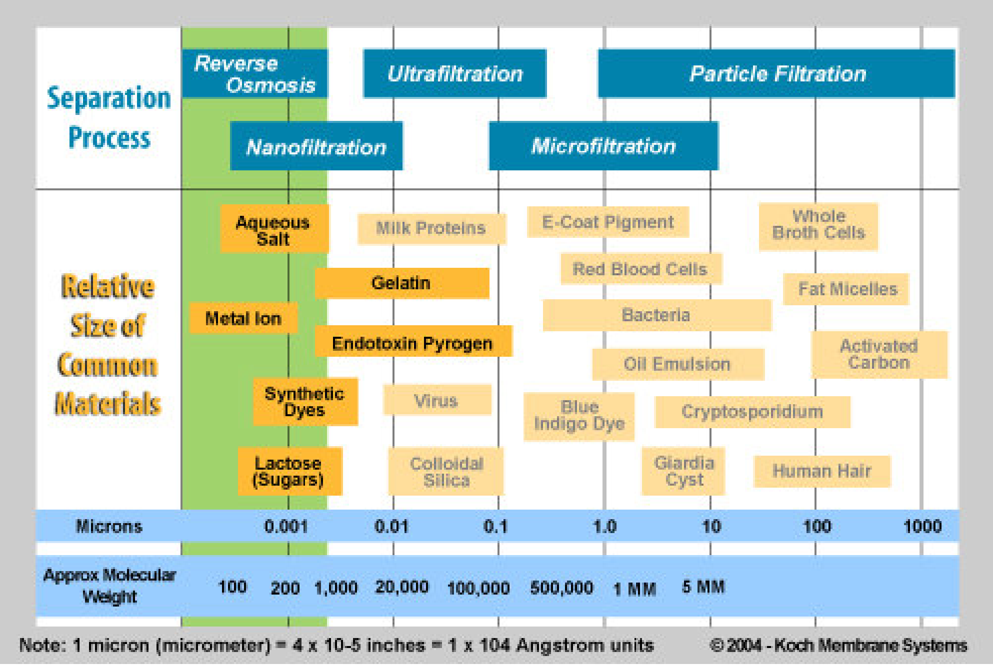


Figure 3.6 Reverse Osmosis Separation Chart

Picture taken from (Koch Membrane Systems)

Reverse Osmosis (RO) is used to reduce dissolved solids from feed waters with salinities up to 45,000 ppm TDS (total dissolved solids). Municipalities and industrial facilities are able to use RO permeate as a consistently pure drinking water supply and to transform drinking water to high purity water for industrial use at microelectronics, food and beverage, power, and pharmaceutical facilities. The technology is also very effective at removing bacteria, pyrogens, and organic contaminants. Reverse osmosis separation technology is used to remove dissolved impurities from water through the use of a semi-permeable membrane. As mentioned RO involves the reversal of flow through a membrane from a high salinity, or concentrated solution to the high purity, or "permeate", stream on the opposite side of the membrane. Pressure is used as the driving force for the separation. Reverse osmosis requires a high pressure to be exerted on the high concentration side of the membrane. The applied pressure (P) must be in excess of the osmotic pressure of the dissolved contaminants to allow flow across the membrane. This description of reverse osmosis summarises the concept of the technology that is the crux of the design concept of the FDSU. Figure 3.7 shows the reverse osmosis process. This process meets the minimum requirements of water treatment to produce potable water (ABCA Primary Standardization Office 1985). The amount and the quality of the filtrate/permeate/product water depends on the quality of the feedwater and on the chosen membrane.

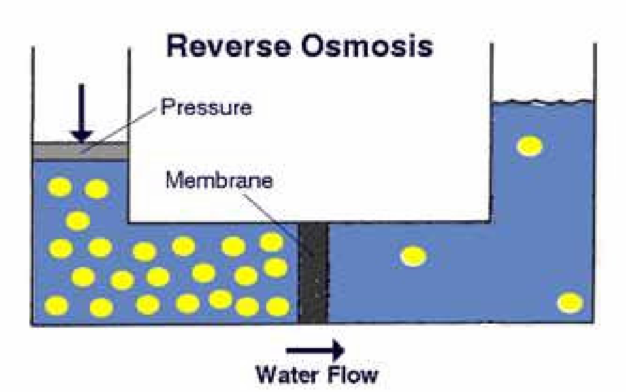


Figure 3.7 Reverse Osmosis

Picture taken from (Pure-Pro Water Corp)

3.3.3 Reverse Osmosis Membranes

The majority of the commercially manufactured reverse osmosis membranes are made from cellulose acetate, polysulfonate and polymide. Many other semipermeable membrane used in most Reverse Osmosis systems are cast polymer films of asymmetric density, they have a dense barrier layer which is very thin supported on a more porous substrate. The pores of the membranes that the concentrate will diffuse through are 0.0001 microns in diameter, for comparison the size of a human hair is close to 100 microns thick. There is four main types of Reverse Osmosis membranes available, they include the plate and frame, hollow fibre, tubular and spiral wound. Two of the more popular membrane configurations used in Reverse Osmosis and water purification is the spiral wound membrane and the tubular disc membrane (http://www.roconn.com/article8.html). Each of these two methods has their advantages and disadvantages which impact on their selection for specific use.

3.3.4 Spiral Wound Membranes

Spiral wound membrane technology is used to purify water for uses that include drinking, industrial processes, and medical applications. The highly efficient membranes produce high-quality product water from surface water, tap water, well water or seawater. Technology of spiral wound membranes - tightly packed filter material is sandwiched between mesh spacers and wrapped in a small-diameter tube - to desalt and demineralize process water. Figure 3.8 shows the make up of a spiral wound membrane. Feedwater is fed into the outer surface of the membrane, it then spirals inwards through the membrane to the centre where it is collected in the permeate tube as produce water (Amjad 1993). The membrane's operating conditions are fine-tuned to balance the amount of water which passes through the membrane, with the specific rejection rates of contaminants to achieve up to 99.8% salt rejection at low pressures and high flux rates.

Basic Construction of Spiral Wound Membranes

- Membrane cast as a film onto flat sheet
- Sandwiched together with:
  - Feed spacer thickness 0.028 - 0.10 inches
  - Permeate carrier
- Sealed at each edge and wound up around a perforated tube
- Finished diameter range 2.5" to 18"
- Length options 33" to 60"
- Membranes available with sanitary net outer wrap or standard hard outer wrap
- Microfiltration, Ultrafiltration, Nanofiltration and Reverse Osmosis separation ranges available
- Specially engineered high pH, high temperature and chemically resistant membranes available

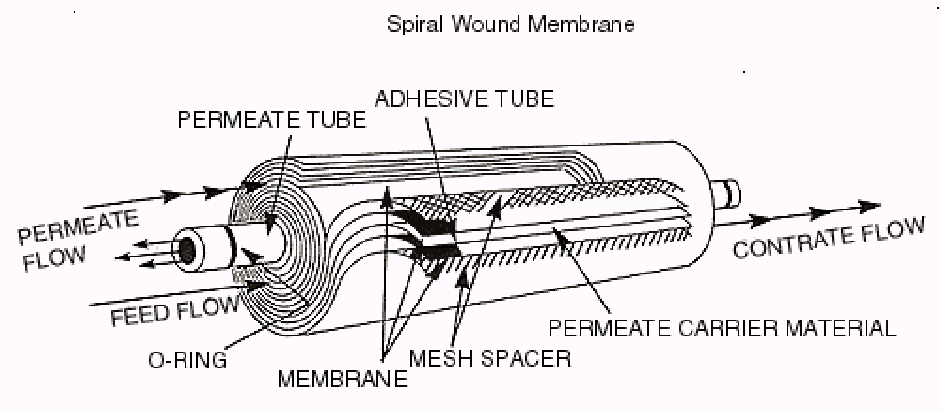


Figure 3.8 A Spiral Wound Membrane

Picture taken from (RO/CONN)

3.3.5 Disc Tube Membranes

Technology Description: The Disc Tube Module (DTM) technology is an innovative membrane separation process for removal of contaminants from liquid hazardous waste streams. Traditionally, membrane separation processes have been used as a secondary or polishing step in waste treatment schemes. However DTM technology uses an innovative process configuration which allows it to be the primary treatment for waste streams such as landfill leachate. The DTM technology is designed to treat waste that is higher in dissolved solids content, turbidity, and contaminant levels than waste treated by conventional membrane separation processes. The membrane module features larger feed flow channels and a higher feed flow velocity than other membrane separation systems. According to the technology developer, these characteristics allow the DTM greater tolerance for dissolved solids and turbidity and a greater resistance to fouling and scaling of the membranes. Suspended particulates are readily flushed away from the membrane during operation. The high flow velocity, short feed water path across each membrane, and the circuitous flow path create turbulent mixing to reduce boundary layer effects and minimize membrane fouling and scaling. The DTM design allows easy cleaning and maintenance of the membranes. Membrane material for the DTM is formed into a cushion with a porous spacer material on the inside. The membrane cushions are alternately stacked with hydraulic discs on a tension rod. The hydraulic discs support the membranes and provide flow channels to pass the feed liquid over the membranes. After passing through the membrane material, permeate flows through permeate collection channels to a product recovery tank. A stack of cushions and discs is housed in a pressure vessel. Flanges seal the ends of the module in the pressure vessel and provide the feed water input and the product and reject output connections. Figure 3.9a and 3.9b show the Disc Tube assembly and components. The number of discs per module, number of modules, and the membrane materials can be custom designed to suit the application. Modules are typically combined in a treatment unit or stage. The DTM technology can use reverse osmosis, ultrafiltration, or micro-filtration membrane materials. These membranes are more permeable to water than to contaminants or impurities. Water in the feed is forced through these membranes by pressure and becomes permeate consisting of a larger fraction of water with a lower concentration of contaminants. The impurities are selectively rejected by the membranes and are thus concentrated in the smaller fraction of the concentrate left behind. The percentage of water that passes through the membranes is a function of the operating pressure, membrane type, and concentration of the contaminants (http://www.p2pays.org/ref/09/08657.pdf).

Figure 3.9(a) A Disc Tube Assembly

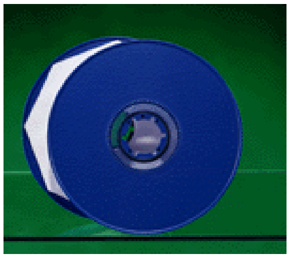


Figure 3.9(b) A Disc Tube Component

Picture taken from (Pall Corporation)

Some countries have desalination plants that use reverse osmosis. These countries have access to the sea and have dry climates. Australia has some small desalination plants, but as the country gets drier, newer and larger plants are being planned (Pelusey 2006, p.26).

Chapter 4

Dual Membrane Design Requirements

In order to meet the project aim of designing a safer, more reliable, robuster and more versatile Field Deployable Shower Unit than is currently available in the market place for use by the Department of Defence certain design requirements have been identified by Defence. These design requirements will dictate the design needs of the Deployable Field Shower Unit.

4.1 Feedwater Sources and Collection

Australia has limited inland surface water and groundwater resources suitable for human uses, so the protection of the quality of these waters is important. The major water quality threats to human uses of water and the health of aquatic ecosystems are: increasing instream salinity and land salination; saltation, nutrient enrichment and algal bloom; increasing water acidity; and pollutants such as metals and pesticides (Neal et al 2001, p44). The Field Deployable Shower Unit will be designed to accommodate feedwater that is available from water sources that include lakes, dams, bores, rivers and springs providing that the Total Dissolved Solids (TDS) of the feedwater does not exceed 20,000 mg/L. It will also be designed with an over engineered capability of being able to accept feedwater with a TDS of up to 35,000 mg/L which includes water sources of estuaries and open sea. This design concept is for as occasion dictates and it is not the primary role of the FDSU. The feedwater will initially be tested by an Army Engineer or Medical Corps personnel to ascertain the turbidity and the TDS levels of the water to ensure they are within the TDS level of 20,0000 mg/L for use. As well as this initial water test the FDSU system will conduct a full analysis of the water during run up and continually monitor the water condition from start to finish

4.2 Water Standards

The scope of the requirement states that the water at the shower head has to be to a potable standard. Therefore it has to meet drinking water standards. There are numerous water standards available to operators to adhere to, they include the AS/NZ Water Standard as well as the standards of many other countries. The FDSU however is most likely to be operated by Defence personnel whether in isolation or as part of a coalition force. The standard that will therefore be adopted is the drinking water standard of QSTAG – 245, Edition 2, a copy of QSTAG-245 is at Annex B. The FDSU also meets the World Health Organisation (WHO) Guidelines for Drinking Water Quality. WHO is an agency of the United Nations which is responsible for international and public health matters therefore defence can rest in the comfort that if the FDSU has to be deployed in support of the United Nation and they mandate that their Guidelines for Drinking Water Quality have to be met then it is achievable.

4.3 Production Requirements

The scope of requirement states that eight personnel have to be able to bathe at any one time and that the rate of 80 personnel per hour showering must also be achieved. On top of this requirement the FDSU must capable of operating continually for up to ten hours. Based on these requirements and assuming the worst case scenario of water with a TDS of 20,000 mg/L where the resultant permeate is 60% and concentrate is 40% of the feedwater through the Reverse Osmosis Membranes and the permeate is 90% and the concentrate is 10% of the feedwater through the micro-filter membranes then when the system is run up and operational there will be a requirement of 3,896 litres of feedwater per hour to be supplied to the FDSU. The feedwater supply requirements are varying in accordance with as to what the supply is and depending on the percentage of permeate that is produced through the Reverse Osmosis membranes and the Micro-filter membranes. Based on these requirements and the TDS of 20,000 mg/L the FDSU will require 8 Disc Tube modules for the Reverse Osmosis system and 3 Micro-filter modules for the Micro-filter system.

4.4 Operability

The FDSU is designed to be an automated system operated by Programmable Logic Controller (PLC). The whole system will be automated apart from the cleaning sequence which will be started manually and then fully PLC controlled after initiation of the sequence. The system under the operation of the PLC will continually monitor the standard of the water for pressure, chlorine, temperature, pH, conductivity, turbidity, TDS, salinity and flow through sensors that will transmit the information back to the PLC processor. The processor monitors the sensors and has a fail-safe control where the system turns off in the event of the following circumstances; feed water pressure at the high pressure pump inlet falls below 0.5 bar, the working pressure in the Reverse Osmosis module exceed 75 bar, electric motors overload, pressure in the permeate discharge line exceeds 3 bar, pressure in the concentrate discharge line exceeds 5 bar, malfunction of the motorized pressure control valve and excessive salinity of potable water. In the event of excessive salinity in the permeate water a diverter valve directs the water away from the shower system.

4.5 Maintenance

The maintenance and repair of the FDSU will be conducted by trained Royal Australian Electrical & Mechanical Engineers personnel in situ in the field and returned to contractor when back in barracks. The FDSU is designed with a large amount of commonality of sub-assemblies and parts with the water purification unit resulting in cross training that will benefit the maintainers. The majority of parts will be replaced by a one for one exchange. This will include sensors, small dosing pumps, instrumentation, valves, micro-filter membranes and Reverse Osmosis membranes that can not be repaired by the field repair kit.

4.6 Cleaning Regime

For the FDSU to meet its operational requirements it is paramount that it is cleaned and maintained on a regular basis. As the adage goes prevention is better than cure. In the majority of Reverse Osmosis systems, membrane blinding and fouling is the main cause of reduction in membrane life. The cross flow of the disc tube membrane help to alleviate a lot of this, however they still require chemical cleaning every 700 hours. The micro-filter membranes are air scrubbed and back flushed on a regular cyclic routine or when the differential pressure exceeds a pre-determined limit. They also require a chemical clean. The air scrubbing and back flushing of the micro-filters will be controlled by the PLC. The chemical cleaning of both the micro-filter and the disc tube modules will be controlled by the operator.

4.7 Sub-assemblies and Components

The FDSU will contain sub-assemblies as well as a number of components that will have to be monitored for their condition and replacement in line with the maintenance policy. Sub-assemblies such as generators, pumps and compressors will need to be technically inspected and serviced on a regular basis. This will mean down time of the FDSU which will need to be considered when the FDSU is in operation. Components are more along the lines of consumable which are easier to replace on a one for one basis. This would include membranes (micro-filter and disc tube), sensors, dosing pumps and valves. The consumption of the components will be largely dependant on the quality of the feed water that is being used and on the maintenance schedule that is adopted and adhered to.

4.8 Transportation and Containment

There may be a variety of transport modes by which the FDSU has to be moved. This may include air, rail ,sea or road. Which one of these modes that is going to be used will be dictated by the type of operation it will be supporting and the geographical area of operation. The FDSU will need to be contained in a container that provides adequate protection for the assembly and sub-assemblies yet it is still easily transported. Based on this criteria the FDSU will be designed around being contained within two ten foot ISO containers. One container will house the water treatment assemblies and the other container will house the shower system, hoses and change facilities.

4.9 Selected Micro-filtration Membrane

The micro-filter membrane that has been chosen for the FDSU is the Pall Microza membrane system. The features of the Microza membranes are that they were developed for treatment of water for process and municipal applications, replacement of multi-media and other filters, protection against bacteria and virus contamination, removal of organic and colloidal contaminants such as silica, and the protection of Reverse Osmosis system. The Microza membrane in micro-filtration is a PVDF 0.1 micron membrane, it has high permeability and throughput (recovery rates can be >95%), robust membrane fibre material, removes turbidity, oxidised iron and manganese, dependable barrier against Cryptosporidium, Giardia Lamblia, Legionella and other bacteria, resistant to chlorine and other oxidants, outside to inside flow capability, permits reverse filtration and air scrubbing removing membrane foulants, minimal pre-filtration required and minimal waste produced by minimizing chemical use and maximum recovery. Figures 4.1a and 4.1b show the microza micro-filter assembly.

Figure 4.1a Micro-filter Assembly Side View **….4.1b Micro-filter Assembly Front View**

Pictures taken from (Pall Corporation)

4.10 Selected Reverse Osmosis Membrane

The Reverse Osmosis membrane selected for use in the Field Deployable Shower Unit is the Pall Disc Tube™ Module System. It has been selected due to its major advance in Reverse Osmosis technology and also due to the fact that the Australian Navy use the system on their fleet of ships for water purification. This allows for commonality of parts between the FDSU and the Navy water purification/Desalination systems. The patented fluid dynamics and construction of the disc membrane stack result in an open channel, unrestricted and fully turbulent feedwater system. This means that suspended solids carried in the feedwater cannot be trapped or easily settle out inside the membrane module. In frequent maintenance, cleaning of the membranes can be successfully achieved using a standard, built-in system. Round-the-clock reliability and product water quality are also guaranteed. These are achieved through Pall's adherence to the highest standards in components, materials, and methods of design and construction. Advantages of the Disc Tube Module System include:

Minimization of membrane scaling and fouling. The system uses short feed flow paths, open channels and high-packing densities to minimize concentration polarization and physical flow impediments. Consequently, scaling and fouling are greatly reduced while high energy efficiency is maintained.

Long membrane life. The combination of low membrane scaling and fouling, highly stable membranes, and the simple built-in cleaning system means that membrane life-expectancy is not normally limited by feedwater pollution. Useful membrane life of five years or more can be expected.

Lower membrane replacement costs. Compared to spirally wound and hollow fibre membrane elements which are life-sealed at manufacture (so the complete element must be replaced at relatively high cost), the DT Module system allows the replacement of individual sheets of membrane at a fraction of the cost. Thus allowing the system to be repaired in the field.

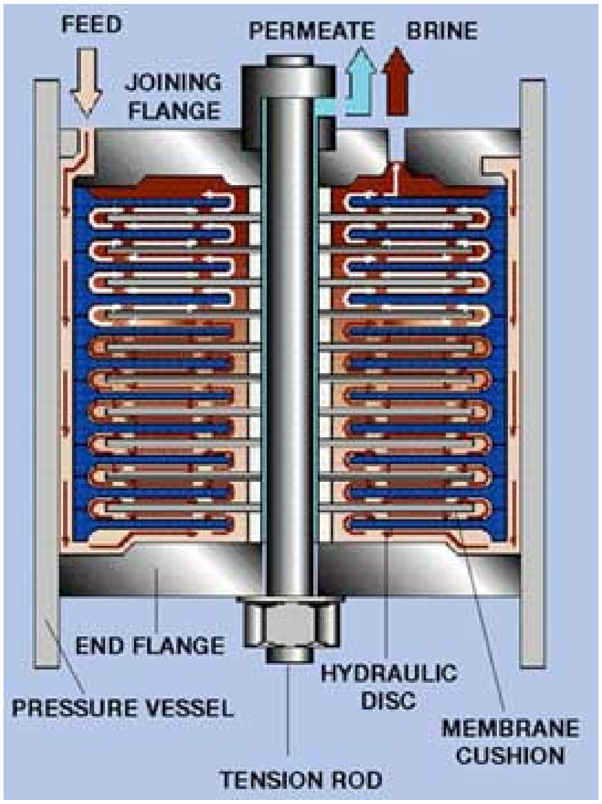


Figure 4.2 - Crosscut View of Disc Tube Assembly

Picture taken from (Pall Corporation)

Easy access to all membranes. Modules can easily be opened up to permit replacement or inspection of each membrane cushion.

Compact and flexible. Modular design and construction of all standard units simplifies transportation and installation, and enables efficient use of floor space. Also the DT modules can be installed in either the horizontal or the vertical position.

4.11 Pumps

The processes involved in the FDSU involves the use of water at low and high pressure. The lower pressure being the pump feeding the water to the micro-filter system at approximately 1.5 bar. The High Pressure pump feeds the water to the Reverse Osmosis system at 45 bar and can be operated up to 65 bar if it was going to be used to process sea water. This high pressure can pose a safety issue and therefore needs to be controlled. The design of the FDSU will need to incorporate this consideration into the concept in order to minimise risk to operators and maintainers. Safety mechanisms will be incorporated to reduce water pressure and control its exit from the system in the event of error or fault.

Chapter 5

Project Design Methodology

5.1 Project Research

A thorough, comprehensive and systematic investigation of technical manuals, engineering notes, technical and engineering electronic data bases as well as communication with industry professionals will be undertaken. To complement this investigation a general internet search will be conducted as well as a review of relevant regulations, Defence Manuals and notes. To correlate and consolidate all of the gathered information, meetings and discussions with industry group subject matter experts will be co-ordinated and conducted.

5.2 Conceptual Design of the Field Deployable Shower Unit

From the researched information a field deployable shower unit will be able to be designed to a block diagram level. From the block diagram level each block will be investigated to ascertain whether current technology, parts and equipment is already available to achieve the design requirements of that particular part of the system, thus preventing the replication of design technology and maximizing use of current and readily available technology, parts and equipment. The design will be based on supplied water with no greater than a TDS of 20,000 mg /L

Following the conceptual design of the FDSU the components, parts, consumables and equipment requirements can be fully investigated, identified and sourced based on the specifications which they must meet. As the FDSU will be part of the Department of Defence equipment fleet, specific items and equipments like pumps, motors, generators, membranes, filters, hoses etc will be selected to replicate current and existing parts and equipment being used within Defence. This will provide commonality of those parts and equipment throughout Defence and provide savings in the cost of parts, maintenance and training.

Chapter 6

Field Deployable Shower Unit

6.1 Concept of Operations

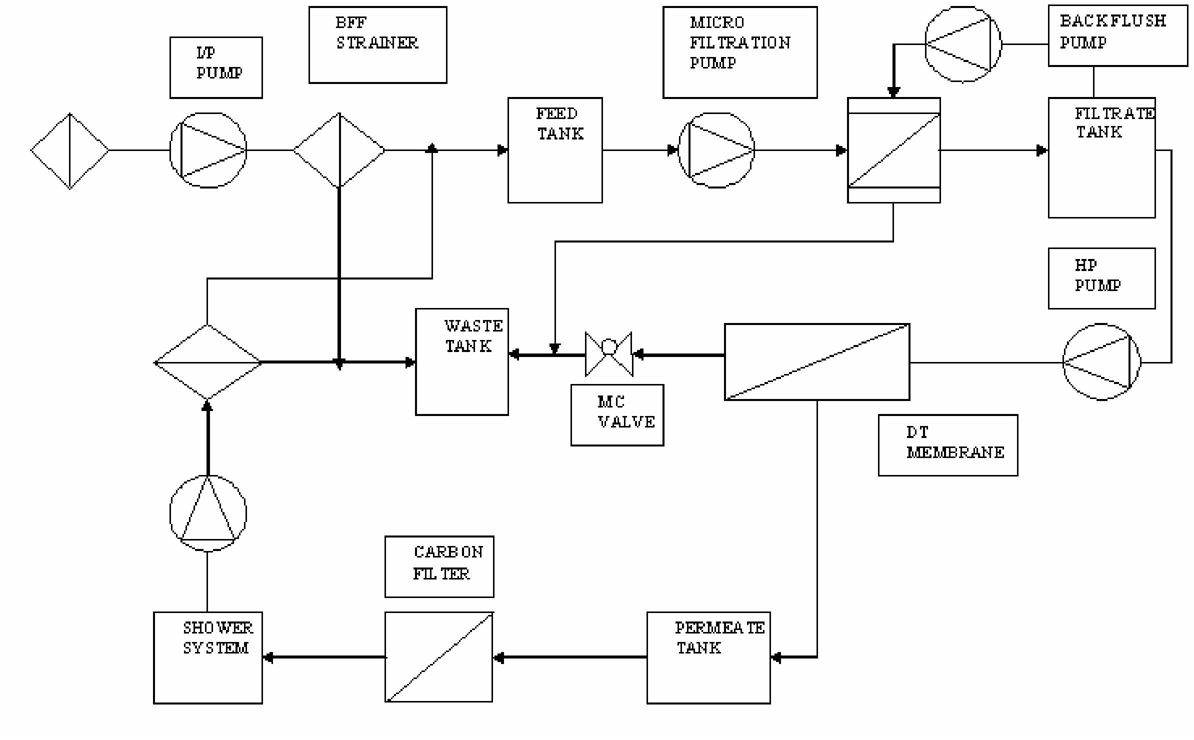


Figure 6.1 – FDSU General Concept of Operations

Referring to figure 6.1, the general concept of operation is as follows, the input pump draws the feedwater through the front end strainer which is an 800 micron strainer and feeds it to the feed tank via the 400 micron back flushable filter. The water en-route to the feed tank is dosed with a low level of chlorine. The water from the feed tank is pumped by the micro-filtration pump at 1.5 Bar through the micro-filter assembly and into the filtrate tank where it is dosed with sodium bisulphate to neutralise the chlorine as the chlorine is detrimental to the reverse osmosis Disc Tube membranes. The backflush pump is only operated during the clean cycle of the micro-filter assembly. The water is then pumped via the high pressure (HP) pump at 45 Bar under the control of the motor control valve to the permeate tank prior to passing through the carbon filter and onto the shower system.

6.2 Input System and Treatment

The input system is designed to remove any larger particulate, sediments, foliage or any other debris from the feed water and thus ensuring it does not make its way to the micro-filter membranes. The water is tested and assessed for its suitability prior to it being pumped into the FDSU. The onboard PLC will analyse the suitability of the water also to ensure it’s within TDS and turbidity parameters.

6.2.1 Input Design

Feedwater is fed from a source and pumped by P1 through strainer Sv1into the back flushable filter BFF1. V1 controls the flow of the feed water through Sv1 before it enters PFT1. The water is tested for its quality by S1 and S2 for TDS and turbidity levels. If the water quality is too poor for use in the FDSU, V1 will close and the system will redirect the water to the drain tank and then go through a shut down cycle. The operator will then assess the situation. If the water is suitable it passes through V1 and will be fed to feed tank PFT1. Along the way S3 and S4 will test the water for its pH and chlorine levels. Based on the readings from S3 and S4 the feedwater will be dosed with the required amount of Chlorine through DP1 and the Ph will be kept at a neutral pH (~7) by acid dosing through DP2. The level of the water in PFT1 will be monitored by level control S5. If the level of PFT1 is too low S5 will send a signal to the PLC which won't allow any feed water to be pumped from PFT1 by pump P2.

Refer to figure 6.2 for a sketch of the input system. Appendix C provides a component description.

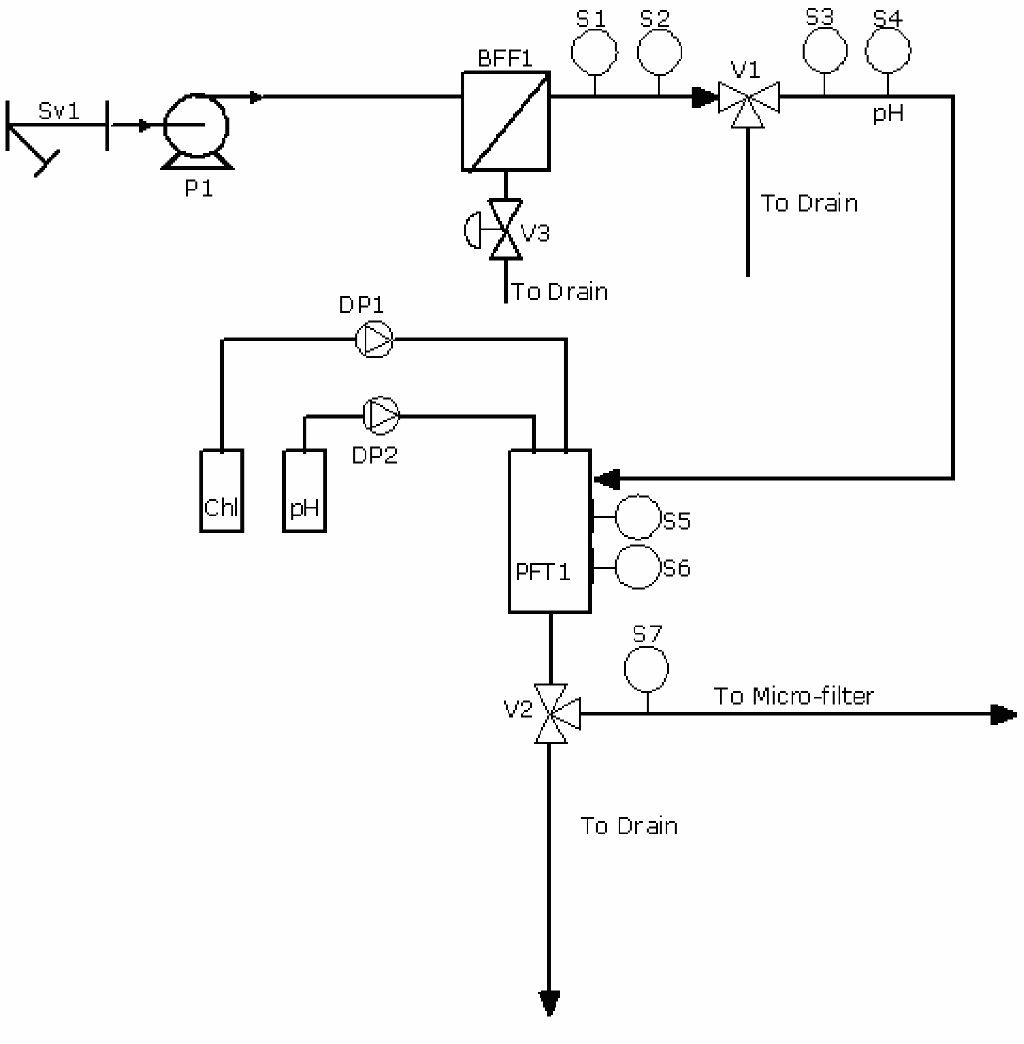


Figure 6.2 Input Design

6.2.2 Input Pump and Strainer

An external single stage centrifugal pump that is attached to an 800 micron strainer pumps the feed water to the FDSU. The pump has the capacity of pumping from up to 100m away and has a lift capacity of an elevation of five metres. The input strainer will be attached to a floating buoy if the feed water source is from a dam, lake or river. Once the feed water passes through the strainer it is pumped to the back flushable filter which filters up to 400 microns. The back flushable filter can be set to carry out a back flush and clean whenever a pre determined differential pressure is achieved or on a cleaning cycle to maximise operational time of the FDSU. The feed water is then pumped to the Micro-filter system by the Micro-filter pump at a pressure of 1.5 bar.

6.2.3 Chlorine and Acid Dosing

Before the water is dosed with Chlorine or an acid it is tested for its Chlorine and pH levels to ascertain the feed waters current levels of both. The Chlorine is added for an initial disinfection of the feed water. The micro-filter membranes are robust and are not affected by or damaged by the chlorine in the water. The feed water pH level is checked and dosed with an acid if required to maintain a neutral pH level of around about 7.

6.3 Micro-filtration System

The micro-filtration system is a crucial component of the FDSU. The micro-filter membranes remove particles down to 0.1 microns under the 1.5 bar pressure of the micro-filter pump. Particulate that is removed by micro-filtration includes turbidity, oxidised iron and manganese, colloids and is a dependable barrier against Cryptosporidium, Giardia Lamblia, Legionella and other bacteria.

6.3.1 Micro-filter System

The feed water is fed from the input system by P2. As the water is being pumped to the micro-filtration system it is tested by S10, S11, S12 and S13 which tests the pH, Chlorine level, temperature and inlet pressure of the water. P2 raises the water pressure to 1.5 bar. The water is pumped through V10. If the water is unsuitable P2 will stop and V10 will redirect the water to the drain disposal waste. If the water is suitable the feed water will pass through V10 en-route to the MF array of MFB1. The 1.5 bar pressure forces the feed water through MFB1 and the permeate flows through V11 to filtrate tank FT10. The concentrate is discarded to the drain disposal waste via V14and S14. The water enroute to FT10 is tested by S16 for the level of chlorine in the water and is then dosed with sodium bisulfite by DP11 to neutralise the chlorine prior to the feed water being pumped to the Reverse Osmosis system by high pressure pump HP1. If the differential pressure between S14 and S11 is greater than 3 bar an automatic backwash will be initiated on the micro-filter system. If the chlorine level sensed by S18 is too high then V13 will redirect the water to the drain tank and the PLC will initiate rectification action.

Refer to figure 6.3 for a sketch of the Micro-filter. Appendix D provides a component description.

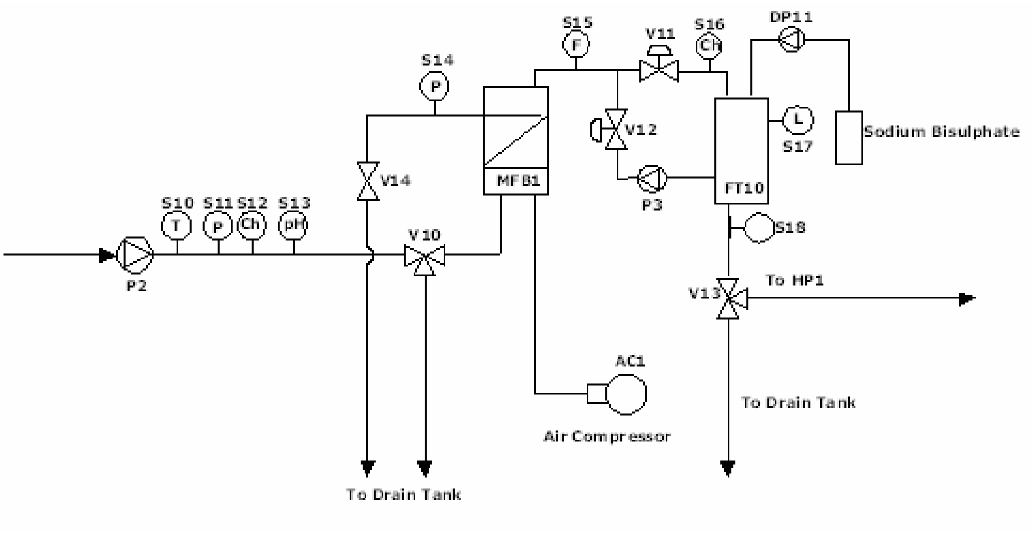


Figure 6.3 Micro-filter System

6.3.2 Micro-filter System Backwash Process

If there is a build up of dirt load bacteria, suspended solids and other insoluble matter larger than the pore size of the micro-filter then the pressure differential to filter the water through would also increase. When this pressure differential is sensed between S11 and S14 the automatic backwash is initiated. The first step is a combined air scrub and reverse filtrate flow. The compressed air is supplied by AC1 and is supplied to the feed inlet of the micro-filter modules of MFB1. As the air travels up the modules it generates a scrubbing action of air to the fibres and fibres against each other. At the same time a continuous stream of filtrate is pumped by P3 through the membranes from the clean side of MFB1 to the feed side and then to the drain tank through V14. At this time V11 closes and V12 opens. The dirt coating is scrubbed off of the membrane surface and ready to be flushed out of the module. The second step is the flushing of the feed side of MFB1 with feed water from P2 and disposed of to the drain tank through V14. During this second stage both V11 and V12 will be closed.

6.4 Reverse Osmosis System

The Reverse Osmosis system is the crucial component of the FDSU for the removal of the remaining particulate that is left in the feed water. The high pressure pump has raised the feed water pressure to 45 bar and forces the pre filtered and treated water through the Reverse Osmosis system.

6.4.1 Reverse Osmosis System Design

HP1 raises the pressure of the feed water to 45 bar. S21 tests the feed water for its Chlorine level. If the Chlorine level is too high then V20 and pressure reducing valve V31 will redirect the feed water away from HP1 and through to drain disposal tank DDT1. If the feed water is suitable it is forced into the Reverse Osmosis system RO1 through V21, V22, S22, S23 and S24. Initially the High Pressure Pump HP1 continuously delivers feed Water to RO1. The feed water is discharged from the system via a System Pressure Control Valve MCV1. After the system starts and feed water is delivered to RO1 no permeate flow occurs until after the pressure within RO1 rises above the Osmotic Pressure of the feed water. This is accomplished by closing MCV1, which builds up pressure within RO1. After the Osmotic Pressure of the feed water is overcome the membrane elements will split the feed water into a low saline solution permeate and a high saline brine concentrate. The concentrate is directed away to DDT1 through V30, MCV1 and V29. V28 is a safety pressure relief valve. V26 and V27 are also a safety pressure relief and pressure reducing valve for precaution in the event of the system failing. The Permeate flows through the membranes of RO1 and is then discharged from the system via S25, S26, S27, S28, S29, V23, V24 and a solenoid operated permeate Solenoid Valve SCV1. SCV1 directs the permeate either to the shower or to DDT1 depending upon the quality of the Permeate after it has been checked by the sensors for pH, TDS, salinity, conductivity and turbidity.

Refer to figure 6.4 for a sketch of the Reverse Osmosis system. Appendix E provides a component description.

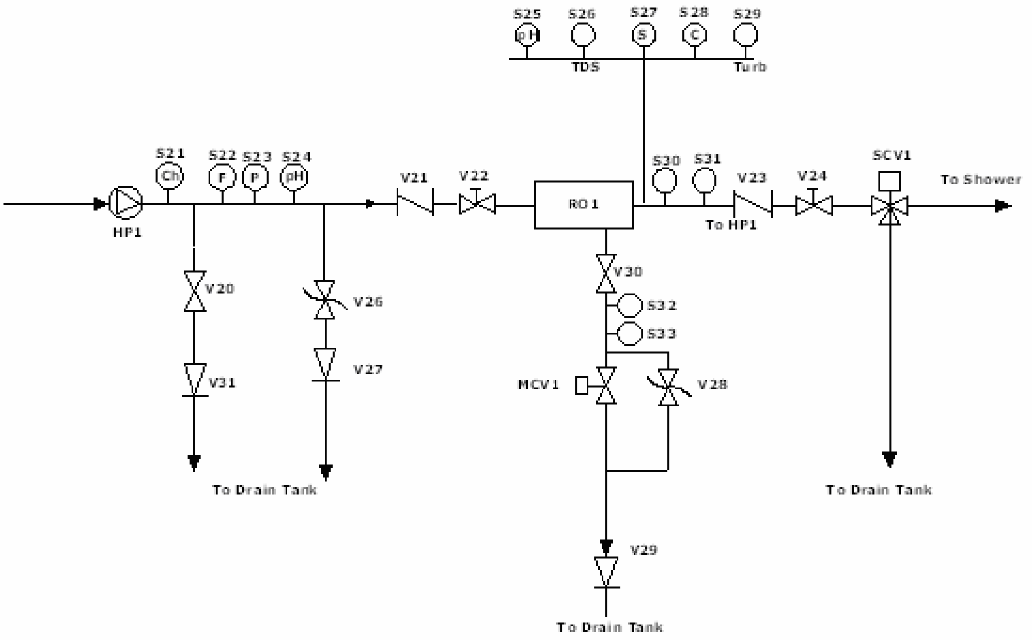


Figure 6.4 Reverse Osmosis System

6.4.2 Membrane System

As the feedwater enters the reverse osmosis system it passes through V21 which is a check valve it then passes through V22 which is a shut off valve. V24 at the output is also a shut off valve and these valves can be used to isolate an individual membrane to conduct maintenance on the selected membrane. V30 will also prevent water passing flowing back towards the membrane. If the input pressure of the feed water is too high

V26 will open and drain the water to the drain tank through the pressure reducing valve V27 which reduces the pressure to a safer operating pressure before it drains away. Once MCV1 allows the water to flow the permeate will be controlled by SCV1. If the sensors assess the pH, TDS, salinity, conductivity and turbidity to be of a potable standard then the water will be directed to the shower system. If the water is not of a potable standard then SCV1 will direct it to the drain tank. The concentrated waste will pass through V30, MCV1 and pressure reducing valve V29 which reduces the water pressure to a safe operating pressure and drains the water to the drain tank. The membrane system consists of 8 Disc Tube membranes which provides the calculated water requirements. Each of the Disc Tube membranes has its own individual input and output lines complete with shut off valves. This capability will enable the isolation of individual membranes to conduct maintenance and repairs as required.

6.5 Post Reverse Osmosis Treatment

The final part of the FDSU system is the post Reverse Osmosis treatment where the feed water goes through its final processing stage prior to being utilised in the shower system, to where it is then reclaimed and recycled to be passed back into the input stage to go through the complete FDSU process again. This process is going to be developed further in future work, however, a basic concept is provided below.

6.5.1 Post Reverse Osmosis Design

The feed water that leaves RO1 is fed to permeate tank PT1. The feed water is tested by S41 en-route to PT1 for its pH level. If the feed water pH level needs adjusting then dosing pump DP41 will dose the water with sodium hydroxide to bring the pH level of the water to a neutral level. The water from PT1 is pumped via P41 through a carbon cartridge filter CCF1 to the shower system where it is delivered to eight shower heads for use. The spent shower water is then drained to shower sump SS1. From the SS1 the water is pumped through P42 through back flushable filter BFF41 and V45 to the input feed tank MFT1 for re-use in the DFSO system. Figure 6.5 shows the post reverse osmosis system general concept

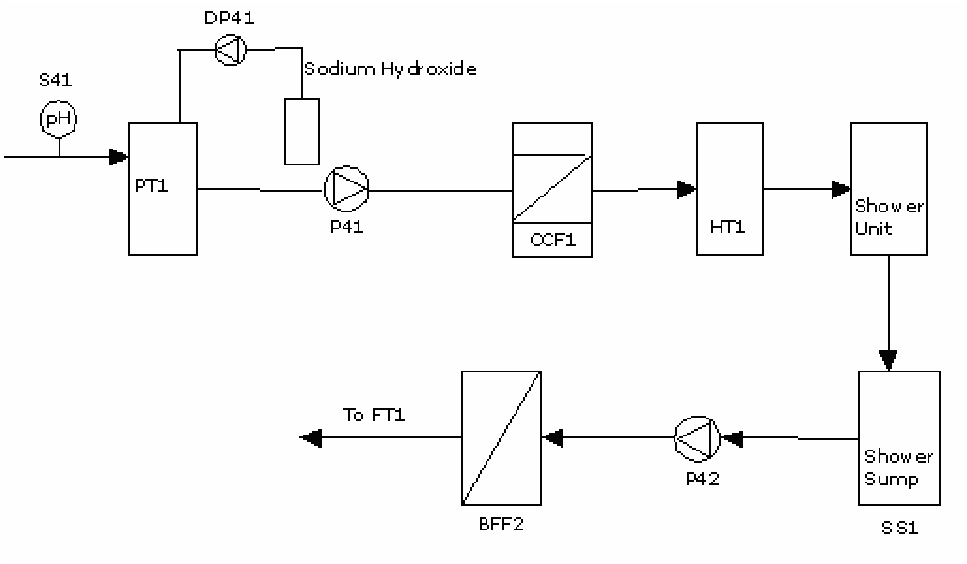


Figure 6.5 Post Reverse Osmosis System

6.6 Chemical Dosing and Cleaning

6.6.1 Chemical Dosing

The system requires that the feedwater is treated by various chemical to ensure that it is at a disinfected and potable standard at the end of the FDSU process. Variable dosing pumps are used to treat the water with Sodium Bisulphate, Chlorine and Sodium Hydroxide to ensure the water pH and Chlorine levels are correct. The complete process is controlled by the PLC. It senses the water condition through the respective sensors and adjusts the dosing based on the sensor reading. It is initiated and completed in real time.

6.6.2 Chemical Cleaning

In spite of the excellent flow conditions of the Disc Tube membranes, there will be some form of fouling of the membrane surface caused by the tendency of reverse osmosis membranes to adsorb colloidal matter. This is amplified by the increasing concentration of salts and suspended materials that is inherent in cross flow modes of filtration. The disc membrane stack results in an open feed channel, unrestricted, turbulent feed water system. The open channel enables optimal cleaning of the membranes in recirculation. During the cleaning process the contaminants on the surface of the membranes will be removed with special cleaning solutions and will be rinsed out of the module system as easily as the bigger particles. Periodical cleaning of the membranes should be carried out at about 700 hours of continuous operation or if the FDSU is being shut down for a period of time. The cleaning cycle will be fully automated through the PLC. It will be initiated once the cleaning injection device and the appropriate cleaning chemicals are connected to the injection device. If the FDSU is shut down for a prolonged time period then a disinfection procedure is carried out as well as the cleaning procedure described. This will ensure optimum protection of the FDSU against corrosion and bacterial growth in the Disc Tube membrane modules.

Chapter 7

Design Modification Additions

The FDSU design had certain design modifications added to it as the design process progressed before the final concept was decided upon. The modifications came about as a consequence of the thorough and comprehensive research that was undertaken. That is particular technologies that were researched after a particular technology had been selected for a particular function were found to be more suitable and appropriate for that particular function in the design.

7.1 Reverse Osmosis Membranes

Initially the spiral wound membranes were selected for the reverse osmosis system based on their large surface area and throughput of permeate. After significant research and assessing the application of the reverse osmosis membranes the Disc Tube membranes were selected. The Disc Tube membranes were selected due to their ease of use; practicality in their compactness and the fact that they can be installed either in the vertical or horizontal configuration, the open feed channel, unrestricted and turbulent feed water system assisting in its self cleaning which results in the Disc Tube membranes only requiring cleaning every 700 hours or more. This fact also means the life of the Disc Tube is extended.

7.2 Micro-filtration Membranes

The selection of the Microza micro-filtration membranes was undertaken due to their hardiness and robustness. By implementing the choice of the Microza Micro-filter membranes it allowed the option of reducing the variety of pre-filtration prior to the Micro-filter system which would have included using sand filters and other filtration systems at the input of the FDSU. By using the Microza Micro-filters an 800 micron strainer and a 400 micron back flushable filter can be placed at the input of the FDSU.

Chapter 8

Resource Analysis

The Field Deployable Shower Unit has been designed based on current technology and proven systems that are currently in service in industry. Based on these technologies and the current water purification unit that the Department of Defence has in service, components, parts and sub-assemblies that are common between the FDSU and the water purification unit will be sourced from Pall Australia who supply the water purification unit to the Department of Defence.

Where common parts are not available then suppliers of commercial of the shelf (COTS) parts have been sourced. All selected manufacturers and suppliers are well established within their respective industries and are at the forefront of their industry in technology and manufacturing. The majority of them are also global which will satisfy the requirement of obtaining parts if the FDSU has to be deployed away from Australia.

8.1 Micro-filtration Membranes (Pall Microza Membranes)

The micro-filtration membrane filters that have been sourced and investigated are the Pall Microza Membranes and they will be procured and supplied from Pall Australia who are part of a very large international company at the forefront of water processing and purification in the area of filtration and separation. Micro filtration is a pressure driven barrier to solids and bacteria to produce water with very high purity. It is also used as pre-treatment for surface water and seawater before reverse osmosis and other membrane systems, (http://www.gewater.com/products/equipment/mf_uf_mbr/mf.jsp). Microza high permeability 0.1 micron hollow fibre membranes offer a major advantage in drinking water filtration applications, including the protection of RO systems used in harsh conditions or with difficult feed waters. The surface filtration membrane prevents pore plugging across a high surface area, has good chemical and mechanical strength and with its own self cleaning backwash system, typically provides up to five years service life. Systems are modular and therefore adaptable to any flow requirement and space restriction.

Figure 8.1 Pall Microza Micro-filter Assembly

Picture taken from (Pall Corporation)

8.2 Reverse Osmosis Membrane Filters (Pall)

The reverse osmosis membrane filters that have been investigated and sourced are the Pall Disc Tube Membranes. They will be procured and supplied from Pall Australia which is part of a very large international company at the forefront of water processing and purification in the area of filtration and separation.

Figure 8.2 Pall Disc Tube Module

Picture taken from (Pall Corporation)

The Pall DT Module is designed to overcome many of the problems associated with existing reverse osmosis desalination systems (http://www.pall.com/Aerospace_24350.asp).

Features include:

- High performance and low operating costs.
- Modular construction for installation into available spaces.
- Worldwide service network with 20 years experience on membrane systems.
- Unrestricted, open channel, turbulent feedwater flow.
- No chemical pre- treatment required.
- High permeate recovery rates.
- Low environmental impact.
- Integrated self cleaning system.
- Simple and flexible maintenance procedures.
- Expected membrane life - 5 years plus.

- Quick, simple installation.

8.3 Valves and Pneumatic Actuators

The check and shut off valves will be sourced from Crane Australia (http://www.craneaus.com.au/index.html). The valve product is a bronze cast valve and contains approximately 90% copper, 6% tin and 4% zinc making it ideal for its use in the DFSU due to its resistance to wear and corrosion.

Figure 8.3 Crane Check and Shut Off Valves

Picture taken from (Crane Australia)

The pneumatic valve actuators will be sourced through a company by the name of Hytork. Hytork develops and manufacturers actuators for the automation of industrial valves. Their product range includes pneumatic actuators and a wide range of control accessories. Hytork was established in 1972 Initially as a valve automator. The company soon specialised in the manufacture of pneumatic actuators. The growing need for process automation led to the development and production of accessories, such as switch boxes and specialised solenoid valves In 1999 Emerson Electric, an American multinational conglomerate consisting of more than 300 companies and divisions, acquired the company in 1999 (http://www.emersonprocess.com/valveautomation/hytork/). Some examples of Hytorks actuators are displayed in figure 8.4.

Figure 8.4 Pneumatic Actuators

Picture taken from (Hytork)

8.4 Pumps

The high pressure pump will be sourced from Cat Pumps and will be a high pressure pump that is designed specifically for use in water purification and reverse osmosis systems. CAT PUMPS is a major supplier of stainless steel pumps for high pressure desalination reverse osmosis systems. Our complete line of 316L and Duplex Stainless Steel high pressure desalination pumps are used on large ships, offshore platforms, island support and remote location seawater desalination systems. All NATO countries have a compulsory reverse osmosis use requirement for specific CAT PUMPS. Each model is matched with Relief Valves and Pulsation Dampeners or can be customized into a Power Unit designed specifically for your high pressure desalination system (http://www.catpumps.com/pages/Pumps_ss_desal.asp). Figure 8.5 shows the 6767 pump that will be used. These pumps are also used on the Australian Navy's desalination units.

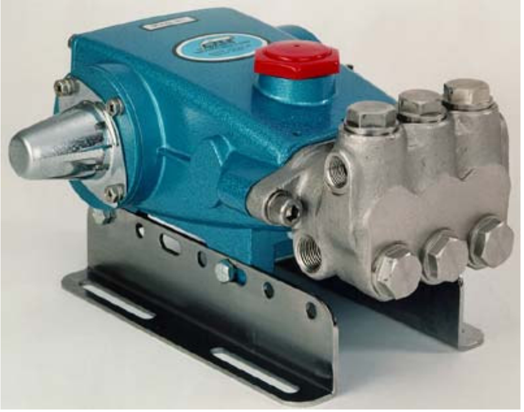


Figure 8.5 Cat Model 6767 High Pressure Pump

Picture taken from (Cat Pumps)

8.5 Pressure Relief and Reducing Valves

The pressure relief and reducing valves will be sourced from Mack valves. Mack Valves has made its name providing strong engineered and reliable valves which perform safely in extreme conditions in a variety of industries. Mack Valves operates from a modern manufacturing and head office facility in 30 Burgess Rd, Bayswater, Victoria and supports branch offices throughout Australia. With our lean and responsive operations, engineering know-how and a global team of experienced sales staff, agents and approved distributors, Mack Valves offers customers the highest levels of technical support and customer service (http://www.mackvalves.com.au).

They are fabricated from bronze and stainless steel and are specifically designed for use in saltwater conditions. This may appear to be over engineering with the FDSU but as the system is designed to operate with brackish water this is not detrimental in fact it will increase its life of type.

Figure 8.6(a) Mack Pressure Reducing Valves.

Figure 8.6(b) Mack Pressure Relief Valve

Picture taken from (Mack Valves)

8.6 Power Requirements

The power requirements for the FDSU will be provided for by a 16kVA generator that is currently available and utilised by Defence. The generator is supplied by Advanced Power 33 Sheperd Street, Liverpool, NSW. Advanced Power has been in partnership with and supplying Defence with generators for over ten years. The specification sheet for the generator is as per Annex B. The reasons for the selection of the Advanced Power generator are outlined below.

DURABILITY

Constructed for rugged conditions and developed to stringent military requirements for the Australian Army, the APD 016 has undergone comprehensive testing and survived extremes in temperature, humidity, salt laden atmospheres, vibration, and drop tests.

POWER OUTPUT

The APD 016 is a skid-mounted field deployable diesel generator capable of delivering 16 kVA for any application in the harshest of environmental conditions. With exceptional motor-starting capability, the APD 016 is able to start 3-phase motors up to 12 kW DOL and will also provide up to 8 kVA on any single-phase.

POWER QUALITY

It provides exceptional power quality which exceeds the military requirements of QSTAG299 under all load conditions. Low harmonics make it ideal to supply power to sensitive electronic equipment such as radios and computers. Precise voltage regulation is achieved using digital technology and real RMS sensing to maintain the output voltage to within 1.0% of its preset value.

RELIABILITY

The microprocessor based control system has proven to be a most reliable method of regulating the output voltage and monitoring all areas of the generator. If a fault occurs the equipment is shut down before any damage is caused. A diagnostic message appears on the control panel indicating what fault caused the shutdown.

SILENT OPERATION

The Hatz 4-cylinder silent pack diesel engine™s noise proof capsule further reduces the engine noise levels down to 68 dB(A) at 7 m.

PORTABILITY

Compact in design with convenient lifting eye, forklift pockets, and tube frame construction provides easy handling.

EASY TO USE

The APD 016 has electric start and an automatic refuelling system that tops up the on-board tank from an external bulk supply. The digital instrument panel displays voltage, frequency and load for each phase, and engine temperature, oil pressure and battery volts.

MAINENANCE

Modular design allows for rapid fault diagnosis and repair in the field by module replacement. Minimal servicing is required with scheduled maintenance only once every 500 hours. Non technical operators can perform all minor preventative and scheduled maintenance using only the tools supplied in the accessory box which also contains spare fuel and air filters, oil strainer, and the user manual. A complete workshop manual and spare parts book written to comply with DEF(AUST) 5629A is also available (http://www.apower.com.au/military/apd016.htm). Figure 8.7 displays the selected 16kVA generator. Appendix F provides a Data Summary for the generator.

Figure 8.7 The APD016 16kVA Generator

Picture taken from (Advanced Power)

8.7 Piping

The piping that is going to be used will be stainless steel 316L pipes, fitting and flanges and will be supplied through Stainless Pipe and Fitting Australia (SPF), 17-21 Coulson Way, Canning Vale, Western Australia. SPF have proven themselves in the field of supplying quality components for water treatment as supported by SPF supplying Stainless Steel 316L pipes, fittings and flanges to the West Australian Water Corporations $150 Million upgrade of its Woodman Point Wastewater Treatment Plant. SPF is your integral link to opportunity in a range of industries including -

- Oil and Gas
- Mining and Mineral Processing
- Chemical and Petrochemical
- Water Treatment and Desalination

- Nuclear Power
- Defence

Figure 8.8 316 Stainless Steel Piping

Grade 316 is the standard molybdenum-bearing grade, second in importance to 304 amongst the austenitic stainless steels. The molybdenum gives 316 better overall corrosion resistant properties than Grade 304, particularly higher resistance to pitting and crevice corrosion in chloride environments. It has excellent forming and welding characteristics. It is readily brake or roll formed into a variety of parts for applications in the industrial, architectural, and transportation fields. Grade 316 also has outstanding welding characteristics (http://www.spfa.com.au/pages/meeting.asp).

Corrosion Resistance – Excellent in a range of atmospheric environments and many corrosive media – generally more resistant than 304. Subject to pitting and crevice corrosion in warm chloride environments, and to stress corrosion cracking above about

60°C. Considered resistant to potable water with up to about 1000mg/L chlorides at ambient temperatures, reducing to about 500mg/L at 60°C.

316 is usually regarded as the standard “marine grade stainless steel”, but it is not resistant to warm sea water. In many marine environments 316 does exhibit surface corrosion, usually visible as brown staining. This is particularly associated with crevices and rough surface finish.

8.8 Programmable Logic Control

The PLC system that has been selected to control the operation of the FDSU is an Allen-Bradley system. Allen-Bradley systems set the industry standard and are operated in the Department of Defence’s water purification unit. Allen-Bradley control solutions set the standard – from the invention of the programmable logic controller nearly 30 years ago to today’s open and highly integrated control platforms. They offer highly integrated control solutions to assure that your control system will be available to solve your challenges. The benefit to you comes in time savings, cost savings and faster start-ups that result from pre-integrated products designed to work together as well as from services available to you from initial conception to ongoing maintenance.

Figure 8.9 Allen-Bradley Programmable Logic Controller

The SLC 500 System has been chose from the Allen-Bradley suite of PLC’s. The Allen-Bradley SLC 500 is Rockwell Automation's small, chassis-based, modular family of programmable controllers and I/O. The SLC's smaller size means that you can use an SLC in applications where you can't afford the size and overhead of a traditional, full-size PLC. With its multiple processor choices, numerous power supply options and extensive I/O capacity, the modular SLC 500 controller allows you to create a system specifically designed for your application.

The SLC 500 was one of the first full-featured small controllers on the market, and it remains the gold standard in small logic controllers more than a decade after its introduction. In fact, the SLC 500 provides cost-effective, reliable control in hundreds of thousands of applications around the world — everything from amusement park rides to pharmaceutical and food processes.

The SLC 500 line offers a range of choices in memory, I/O capacity, instruction set, and communication ports to allow you to tailor a control system to your exact application requirements. These products have a strong reliability history covering hundreds of thousands of installations in a broad range of applications. (http://www.ab.com/programmablecontrol/plc/slcsystem/index.html).

8.9 Instrumentation and Sensors

The instrumentation and sensors chosen for the FDSU are from Yokogawa. Yokogawa is a reputable company in the field of testing and instrumentation. The company states that for many years to come, the Yokogawa Group will strive to realize a healthy and profitable operation and to remain a trusted partner of industry by supplying optimum Customer Centric Solutions based on Leading Edge Technology (http://www.yokogawa.com/tpc/productFinder/tpc-productfinder-en.htm).

8.9.1 Ph Sensor and Instrument

PH8EFP pH Sensor

Figure 8.10 PH8EFP pH Sensor

Picture taken from (Yokogawa)

Yokogawa's pH and ORP meters are highly reliable. They feature advanced functions and are useful for a wide variety of applications including production process water quality management and medium-sized wastewater treatment, or as general pH and ORP control systems. Based on Yokogawa's track record and years of experience, a comprehensive range of products has been produced to provide solutions best suited to individual applications. This includes the Ryton pH/ORP Electrodes PH8EFPas shown in figure 8.10. Appendix G provides a Specification Sheet for the PH8EFP Sensor.

Features

With a body made of Ryton, a strong engineering plastic which is comparable to Teflon in terms of corrosion resistance and heat resistance, a wide range of applications are possible

A single type of electrode can support all applications regardless of whether a holder or cleaner is used.

The integrated-electrode design simplifies calibration with standard solutions and maintenance.

The glass electrode of a pH meter, the platinum or gold electrode, and the junction of an ORP meter can each be easily replaced (http://www.yokogawa.com/tpc/productFinder/tpc-productfinder-en.htm).

PH402G pH/ORP Meter

PH402 4-Wire Type pH Meter

Figure 8.11 PH402G pH Meter

Picture taken from (Yokogawa)

Flexibility, reliability and low maintenance are among the benefits offered by the EXA PH402 pH converter as shown if figure 8.11. Designed to meet the exacting requirements of measuring pH in the modern industrial environment, it contains many features to ensure the best precision whatever the application. This 4-wire unit is housed in a robust IP65 field mountable case. Two mA outputs, four relays, digital communication and a clear LCD make the PH402 a truly comprehensive package.

The PH402 features PI control on both the auxiliary mA outputs and the pulse proportional relay outputs, thus avoiding the need for a separate controller.
The famous EXA sensor diagnostics are enhanced in the PH402, including improved impedance testing, stability and response checks, and a personal computer logbook feature to record events like calibration data and diagnostic messages, show trends and help predict sensor failure. The sensor washing cycle also provides an on-line response test, giving an immediate indication of sensor deterioration. Microprocessor-aided calibration uses internal buffer tables and stability checking to ensure maximum accuracy with minimum effort. Process temperature compensation enhances accuracy in applications where the influence of temperature is seen in process changes (http://www.yokogawa.com/tpc/productFinder/tpc-productfinder-en.htm). Figure 8.11 shows a picture of the PH402G Meter while appendix H provides a Specification Sheet for the meter.

8.9.2 Pressure Sensors

EJA510A, EJA530A Absolute and Gauge Pressure Transmitters

The absolute and gauge pressure transmitter model EJA510A and EJA530A as displayed in figure 8.12 can be used to measure liquid, gas, or steam pressure. Both output a 4 to 20mA DC signal corresponding to the measured pressure.

Figure 8.12 EJA Series Gauge Pressure Transmitter

Picture taken from (Yokogawa)

Excellent performance and stability - The EJA series uses a silicon resonant sensor formed from monocrystal silicon, a perfect material which has no hysteresis in pressure or temperature changes. The sensor minimizes overpressure, temperature change, and static pressure effects, and thus offers unmatched long-term stability. Compact and light-weight design - Half the weight of conventional models thanks to miniaturization of the casing with the amplifier ASIC, pressure cell structure, and flange. The ASIC uses the minimum number of parts and improves the reliability of the amplifier.

Fieldbus communication capability - Fieldbus is a digital two-way communication system. It is a revolutionary technology for configuring instrumentation control systems and a promising successor to the standard 4 to 20 mA analogue communication used in most field instruments today. The Fieldbus model of the EJA series adopts FOUNDATION fieldbus™ Low Voltage Mode, a specification standardized by the Fieldbus Foundation™, which ensures interoperability between Yokogawa and other manufacturers (http://www.yokogawa.com/tpc/productFinder/tpc-productfinder-en.htm).

8.9.3 Differential Pressure Sensors

EJA110A Differential Pressure Transmitter

The high-performance EJA110A differential pressure transmitter as displayed in figure 8.13 can be used to measure liquid, gas, or steam flow as well as liquid level, density and pressure. The high performance differential pressure transmitter model EJA110A can be used to measure liquid, gas, or steam flow as well as liquid level, density and pressure. It outputs a 4 to 20 mA DC signal corresponding to the measured differential pressure. Figure 8.13 shows a picture of the EJA110A differential pressure transmitter while a Specification Sheet for the transmitter is at appendix I.

Figure 8.13 EJA110 Differential Pressure Transmitter

Picture taken from (Yokogawa)

Excellent performance and stability. The EJA series uses a silicon resonant sensor formed from monocrystal silicon, a perfect material which has no hysteresis in pressure or temperature changes. The sensor minimizes overpressure, temperature change, and static pressure effects, and thus offers unmatched long-term stability. Compact and light-weight design - Half the weight of conventional models thanks to miniaturization of the casing with the amplifier ASIC, pressure cell structure, and flange. The ASIC uses the minimum number of parts and improves the reliability of the amplifier. Fieldbus communication capability - Fieldbus is a digital two-way communication system. It is a revolutionary technology for configuring instrumentation control systems and a promising successor to the standard 4 to 20 mA analogue communication used in most field instruments today. The Fieldbus model of the EJA series adopts FOUNDATION fieldbus™ Low Voltage Mode, a specification standardized by the Fieldbus Foundation™, which ensures interoperability between Yokogawa and other manufacturers (http://www.yokogawa.com/tpc/productFinder/tpc-productfinder-en.htm).

8.9.4 Flow Meters

ADMAG AXF series

The AXF magnetic flowmeter is a sophisticated product with outstanding reliability and ease of operation, developed on the basis of decades of field proven experience. Figure 8.14 shows a selection of AXF flowmeters. The AXF magnetic flowmeter is significantly easier to maintain thanks to the combination of replaceable electrodes and a diagnostic function that detects the adhesion level on the electrodes. The AXF also employs a dual frequency excitation method (available for sizes up to 400 mm / 16 in.) that eliminates fluid noise. A newly enhanced dual frequency excitation method is also available as an option for more difficult applications to ensure greater stability and quicker response. Based on FOUNDATION fieldbus™ specifications, AXF Fieldbus models offer more flexible instrumentation through a higher level communication capability and propose the cost reduction by multi-drop wirings with less cables.

Figure 8.14 Various AXF Series Flowmeters

Picture taken from (Yokogawa)

Fluid Adhesion Level Diagnosis - The amount of insulating material on the electrode is constantly monitored to determine when maintenance should be performed. An optional replaceable electrode is easy to remove and clean.

Flexible Electrical Connection Direction - The converter or the terminal box can be rotated in either direction to match the position of the electrical connections at the installation site.

Clear and Versatile Indications - The large, backlit full dot matrix LCD can display a variety of messages up to three lines in length. When an alarm condition occurs, a full description of the appropriate countermeasure is displayed.

Easy Setup - The most frequently used parameters are arranged in a group at the top of the display. Infrared switches enable the setting of parameters without opening the cover.

Operation Immediately after Installation - The AXF is shipped with the main parameters completely set and can go into operation as soon as installation and wiring are completed (http://www.yokogawa.com/tpc/productFinder/tpc-productfinder-en.htm).

8.10 CHEMICAL DOSING SYSTEMS

The chemical dosing systems that have been selected for use on the FDSU are sourced from Seko. Seko is an International Group, developing, manufacturing and delivering its products in more than 50 countries, through its 11 subsidiaries and an extended network of distributors, agents and authorized dealers. Seko was selected because they operate in the Global market and are familiar with national conditions and regulations, taking care of the specificity of each market and following its different and singular demands. Dosing systems for water treatment include solenoid metering pumps, motor driven mechanical pumps, measure and control instruments and a wide range of accessories. The design of metering units with tanks, stirrers, metering pumps and their accessories, together with systems for the automatic polyelectrolite preparation complete the range of products based increasingly on an approach oriented on Customers needs.

Figure 8.15 Seko Pumps and Meters

Picture taken from (Seko)

Electronic Dosing Systems

The high frequency of the dosing pulses and the great chemical compatibility of the components make these pumps extremely precise and versatile products. Thanks to their microprocessor-based electronics, they adapt easily to any dosing requirement.

Motor Driven Pumps

The new range of our motor driven pumps features a high level of reliability and accuracy. Tough and plain, they guarantee excellent quality in time.

Measure and Control Instruments

The instruments supplied by SEKO make our company the ideal partner for water treatment and for monitoring chemical and physical parameters in industrial processes. The instruments are completed by sensors and accessories enabling them to be installed in any application (http://www.seko.com/divisions_uk.php?id_div=wt).

8.11 Hoses

The hoses that will be utilised on the FDSU will be lay flat hoses supplied by Crusader Hose Pty Ltd, in Melbourne. The selected hose is the Cavalier hose and is displayed in figure8.16. This cavalier hose has an exterior polyurethane coating. This polyurethane coating is usually red in colour and it helps prevent the hose being stained by oil and dirt as well as enhancing abrasion resistance. Other coating colours are available subject to minimum order quantities. This lightweight super strength hose is recommended for industrial and commercial fire protection as well as for general usage on mines and farms (http://www.crusaderhose.com.au/fire.html).

Figure 8.16 Crusader Lay Flat Hoses

Picture taken from (Crusader)

8.12 Containers

As previously discussed in section 4.8 the FDSU will have to be housed in an appropriate container/containers for functionality and transportation. The containers that have been selected to house and accommodate the FDSU as well as the shower and change facility is selected containers by Royal Wolf. Royal Wolf offers a wide range of new and used containers suitable for transportation by road, rail or sea. All Royal Wolf road, rail and shipping containers are designed for strength, to hold maximum payloads, to resist wear and tear, and to reflect the lowest possible operating costs for their customers. Royal Wolf currently supply and provide Defence with a variety of ISO containers. They also have the capability to adapt and modify their containers to suite particular needs as is displayed below in figure 8.17 where Royal wolf have modified a container to provide a laundry facility.

Figure 8.17 Royal Wolf Container

Picture taken from (Royal Wolf)

Royal Wolf can provide Defence with the capability that they require. They are able to cater for remote locations that have special needs, and the modular-ability of containers means that your community can be tailored to meet your requirements. From eight-man units to large-scale catering facilities and portable offices, Royal Wolf can create the perfect village for its clients.

The strength of Royal Wolf's units is reflected in their long lifespan. When combined with the ease with which units can be transported from site to site, the value of the long-term investment is obvious (http://www.royalwolf.com.au/frame_new_mining_and_defence.htm#ablution).

Chapter 9

Consequential Effects

9.1 Outline of Effects

The Field Deployable Shower Unit (FDSU) is designed based on a simplistic approach which minimizes the complexity of the system but promotes and advocates the need for a system that is easy for an operator, technician or maintainer to work on and change or replace consumable components, parts or equipments. Therefore there will be continual ongoing costs involved with the system and its operation. These costs will include fuel, consumables, spare parts, manning costs as in the cost of operators to operate the equipment as well as initial costs to have the operators trained to a competent standard of operation of the equipment, the cost of technical expertise to maintain the system as well as the cost of having the technicians trained on the equipments utilized within the FDSU. The maintenance could have a flow on effect to the spare parts and consumables if the FDSU is not maintained and serviced at the regular prescribed hours of operation or the required service interval. That is due to poor maintenance; filters or membranes may degrade at a more rapid rate and consequently need replacing on a more regular basis (that is if both operator and maintainer are negligent in their duties, replacement costs will escalate). There will be transport costs whether the FDSU is moved by road, rail, sea or air. There may be occasions when physical repairs need to be carried out as a consequence of damage that may have been sustained in transit. This should be minimized due to the ruggedised design of the FDSU.

9.2 Environmental Effects

The environmental effects are much more severe for the FDSU than what they are for the reverse osmosis water purification unit. If the water purification unit is being operated it will be operated within close proximity to its water source of a river, ocean or lake. This allows the water purification unit to simply pump the more concentrated rejected water back into the free flowing river or ocean or back into the vast lake. The FDSU whether it is operated directly from a water purification unit, stored water whether potable or not, dam water, river water, bore water or recycled water from the FDSU itself will have reject water that will vary in its concentration of salts, minerals, body fats etc. It would be unethical to release this concentrated reject water onto the surrounding ground and surface area. The correct and ethical solution is to recycle the water up to an operable concentrate level and then store the waste in dedicated waste water onion tanks for disposal in accordance with the environmental and waste disposal regulations of the state, territory or country that the FDSU is being operated in. As a consequence of this waste there will be a further incurred cost on the disposal of the rejected water.

9.3 Safety Effects

The consequential effects of safety fall in to two categories. This includes the physical well being of operators and the health, safety and well being of operators, maintainers and the general populace that is being supported by the FDSU.

Category one encompasses the physical safety factors for operators and maintainers in that they will have to be safety conscious during the set up of the system due to the potential heaviness of valves, piping, hoses water tanks, handling of chemicals possibly in heavy containers, pumps, generators, fuels and oils in large quantities.

Category two covers the health, safety and well being of operators, maintainers and the personnel supported by the FDSU in that caution needs to be taken with the extraction of diesel and exhaust fumes from the direct vicinity of the FDSU to prevent the excessive inhalation of any type of fumes. Personnel when refuelling need to be cautious to prevent spillage within the direct area of the FDSU or on an individual. That is processes must be in place to minimize the possibility of any spillage. If spillage occurs whether on an individual or on the ground within the direct area processes must be in place to deal with the spillage and to treat the individual. If the supply water is drawn from a dam, the reject water is not to be returned to the dam due to the higher concentration levels of salts and minerals after it has been passed through the FDSU. The reject water from the FDSU should not be rejected to the environment under any circumstances unless it meets the relevant local environmental standards.

As with any project or design requirement there is the potential of risk and safety issues where it is possible that someone may get physically injured or damage to equipment may result. As a consequence the following tabled point of concern have been assessed and addressed accordingly with a relevant course of action to minimise the likelihood of injury to any persons or damage to any equipment occurring.

Chapter 10

Conclusion

10.1 Achievement of Design Concept

After the consolidated research and investigation of technical manuals, engineering notes, data bases, researching on line and communicating with industry experts and professionals a design concept for the Field Deployable Shower Unit was achieved. The design concept was achieved in the following areas:

1. Through the design of the input system, the feedwater is filtered and conditioned by the removal of sedimentation and larger particulate greater than 400 microns to a suitable standard which is then passed on to the next stage of the FDSU which is the Micro-filtration System.

2. The Micro-filtration System with its three modules is capable of filtering sufficient water to meet the required water needs to provide a shower facility for a ten hour day of operation

3. The Reverse Osmosis System through its design utilising the Disc Tube Membrane and housing eight modules will provide the required throughput of permeated water to a potable standard which will be delivered to the shower head for use.

4. The post Reverse Osmosis system will conduct a final water analysis and ensure that the water is delivered to the FDSU shower heads in a potable standard that meets the QSTAG-245 standard.

The FDSU having been based on current technologies and industry standards and has reached a conceptual design standard that would be able to be taken to a prototype stage. For this to occur the Department of Defence would have to approve that the FDSU meets their operational needs and requirements, as well as a full cost analysis being conducted. The cost analysis should prove to be favourable as commonality between the parts and components used on the FDSU and other equipment used by the Department of Defence has been maximised.

10.2 Further Work

10.2.1 Waste Water Treatment

Initially in the design concept all of the waste water that was generated was going to be disposed of as a whole. Depending on the amount of rejected concentrate this could accumulate to an extremely large volume of waste water. This is an area that will have further work conducted on it to minimise the amount of concentrated waste that is disposed off. There is a need to minimise the amount of waste water as much as possible because of environmental factors dictating the removal of the waste. If the waste concentrate can be minimised it will be easier to dispose of, as there will be smaller quantities of it. The means of addressing this waste problem will be by designing and introducing to the FDSU the inclusion of a Reverse Osmosis Disc Tube

Leachate system that will be operated at the end of the ten hour day's operation. The drain water that has been held in an onion tank from the days showering will be processed through the leachate system during the down time of the FDSU. The permeate that is extracted from the Leachate system can be used as a non potable supply for use on roads etc. The concentrate that is left over is pumped to an onion tank that is marked 'waste' and is disposed of in accordance with the environmental rules and regulation that are in place in the area of operations at the time.

10.2.2 Water Heating

The FDSU was not initially designed with the option of heated water. The final thought of modification to implement heating of the water came about because of the extremes of temperature that the FDSU could be operating in whether it is in Australia or overseas. Depending on the time of year and the area of operations a cold shower may not be to everybody's satisfaction, therefore a heating system will be required. A water heating system will be introduced to allow the heating of the water to a comfortable temperature for showering under. This will involve the inclusion of heat exchangers or heaters in the design.

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Appendix A

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG 4111/4112 RESEARCH PROJECT PROJECT SPECIFICATION

FOR: **Eugene Tinning**

TOPIC: Field Deployable Shower Unit

SUPERVISOR: Dr. David Ross

SPONSORSHIP: Faculty of Engineering and Surveying, USQ

PROJECT AIM: This aim of this project is to research and design a safer, more reliable, robuster and more versatile Field Deployable Shower Unit than is currently available in the market place for the use of the Department of Defence, humanitarian agencies and other Emergency Services during deployment to the field and whilst on disaster and humanitarian relief throughout the world.

PROGRAM: Issue A, 23rd March 2006

1. Research information relating to field deployable shower units with an emphasis on utilising reverse osmosis techniques and filtration.

2. Set design parameters for deployable field shower unit utilising reverse osmosis and filtration methods in order to produce a safe and efficient product.

3. Design a deployable field shower unit to meet the design parameters.

4. Evaluate the design for performance and make design modifications where necessary in order to improve performance and efficiency.

As time permits:

5. Design and implement a system using both trace minerals and an Ozonator system to kill bacteria and algae.

AGREED:

______________________ (Student) ______________________ (Supervisor)

____ / ____ /________ ____ / ____ / ________

Appendix B

Appendix C

Input Design Component Description

Sensors

S1- Sensor #1 Total Dissolved Solids (TDS) Sensor
Measures the TDS level of the feedwater
Read out in mg/L

S2 – Sensor #2 Turbidity Sensor
Measures the turbidity of the feedwater

S3 – Sensor #3 Water pH Sensor
Measures the pH level of the feedwater
Read out – 0 to11

S4 – Sensor #4 Chlorine Level Sensor
Measures the total chlorine level in the feedwater
Read out in ppm

S5 – Sensor #5 High/Low Level Sensor
Measures the level of feedwater stored in pre-filtration tank PFT1

S6 – Sensor #6 Water pH Sensor
Measures the pH level of the feedwater
Read out – 0 to11

S7 – Sensor #7 Chlorine Level Sensor
Measures the total chlorine level in the feedwater passing through to the Micro-filtration System
Read out in ppm

Valves

V1 – Valve #1 Pneumatically Controlled Actuator Valve
Controls the flow of the feedwater between the backflushable filter and the pre-filtration tank. If the water is of a suitable standard the valve flow is to PFT1. If the water quality is too poor V1 re-directs the feedwater to the drain tank.

V2 – Valve #2 Pneumatically Controlled Actuator Valve
Controls the flow of the feedwater between the pre-filtration tank and the Micro-filtration System. If the water is of a suitable standard the valve flow is to the Micro-

filtration System. If the water quality is too poor V2 re-directs the feedwater to the drain tank.

V3 – Valve #3 Pneumatically Controlled Actuator Valve
Controls the flow of the feedwater between the back flushable filter and the drain tank.

Filters

Sv1 – Strainer #Sv1 is an 800 micron Strainer
It is a raw water strainer that prevents debris, sediment and other larger particulate from passing through to the pump P1.

BFF1 – Back Flushable Filter #BFF1is a 400 micron filter
It provides another stage of filtering out debris. It has the back flushable capability to clean it and prevent it from clogging up.

Pumps

P1 – Pump #1 is the Raw Water Pump
It pumps the feedwater from a selected water supply

DP1 – Pump #DP1 Chlorine Dosing Pump
It pumps a sensed level of chlorine to the feedwater for disinfection.
Flow rate adjustable

DP2 – Pump #DP2 Sodium Hydroxide Dosing Pump
It pumps a sensed level of sodium hydroxide to the feedwater to adjust the feedwater pH level
Flow rate adjustable

Appendix D

Micro-filter System Component Description

Sensors

S10- Sensor #10 Temperature Sensor
Measures the temperature of the feedwater being pumped by P2 to the Micro-filter modules
Read out in degrees Celsius

S11 – Sensor #11 Pressure Sensor
Measures the pressure of the feedwater entering the Micro-filter modules
Read out in Bar

S12 – Sensor #12 Chlorine Level Sensor
Measures the total chlorine level in the feedwater entering the Micro-filter modules
Read out in ppm

S13 – Sensor #13 Water pH Sensor
Measures the pH level of the feedwater entering the Micro-filter modules
Read out – 0 to11

S14 – Sensor #14 Pressure Sensor
Measures the pressure of the feedwater exiting the concentrate output of the Micro-filter modules
Read out in Bar

S15 – Sensor #15 Flow Sensor
Measures the flow of the feedwater between the Micro-filtration modules MFB1 and feed tank FT10 and Micro-filter modules MFB1

S16 – Sensor #16 Chlorine Level Sensor
Measures the total chlorine level in the feedwater exiting the permeate output of the Micro-filter modules
Read out in ppm

S17 – Sensor #17 High/Low Level Sensor
Measures the level of feedwater stored in Micro-filtration feed tank FT10

S18 – Sensor #18 Chlorine Level Sensor
Measures the total chlorine level in the feedwater exiting the output of the Micro-filter feed tank FT10
Read out in ppm
Valves

V10 – Valve #10 Pneumatically Controlled Actuator Valve
Controls the flow of the feedwater between P2 and Micro-filtration modules. If the water is of a suitable standard the valve flow is to MFB1. If the water quality is too poor V10 re-directs the feedwater to the drain tank

V11 – Valve #11 Pneumatically Controlled Actuator Valve
Controls the flow of the feedwater between Micro-filtration modules MFB1 and the Micro-filtration feed tank FT10

V12 – Valve #12 Pneumatically Controlled Actuator Valve
Controls the flow of the feedwater between the Micro-filtration feed tank FT10 and the Micro-filtration modules MFB1

V13 – Valve #13 Pneumatically Controlled Actuator Valve
Controls the flow of the feedwater between the Micro-filtration feed tank FT10 and the Reverse Osmosis System. . If the water is of a suitable standard the valve flow is to the Reverse Osmosis System. If the water quality is too poor V13 re-directs the feedwater to the drain tank.

V14 – Valve #14 Check Valve
Controls the feedwater exiting from the Micro-filtration modules and prevents the concentrate passing back up to the Micro-filtration modules

Filters

MFB1 – Filter #MFB is a bank of 3 Pall Microza Micro-filter Modules
It is a finer filter for treating the water prior to the Reverse Osmosis System.

BFF1 – Back Flushable Filter #BFF1is a 400 micron filter
It provides another stage of filtering out debris. It has the back flushable capability to clean it and prevent it from clogging up.

Pumps

P2 – Pump #2 is the Micro-filtration Pump
It pumps the feedwater from the input through to the Micro-filtration modules at a raised pressure of 1.5 Bar

P3 – Pump #3 is the Back Wash Pump
An electric pump that pumps the feedwater from FT10 back to the Micro-filtration modules during the back wash sequence of the Micro-filter modules

DP11 – Pump #DP11 Sodium Bisulphate Dosing Pump
It pumps a sensed level of sodium bisulphate to the feedwater in FT10 to neutralise the chlorine in the water
Flow rate adjustable

AC1 – Compressor #AC1
It provides the compressed air to the Micro-filter modules during the back wash process

Appendix E

Reverse Osmosis System Component Description

Sensors

S21 – Sensor #21 Chlorine Level Sensor
Measures the total chlorine level in the feedwater entering the Reverse Osmosis System from HP1
Read out in ppm

S22 – Sensor #22 Flow Sensor
Measures the flow of the feedwater between HP1 and Reverse Osmosis modules RO1

S23 – Sensor #23 Pressure Sensor
Measures the pressure of the feedwater entering the Reverse Osmosis modules
Read out in Bar

S24 – Sensor #24 Water pH Sensor
Measures the pH level of the feedwater entering the Reverse Osmosis modules
Read out – 0 to11

S25 – Sensor #25 Water pH Sensor
Measures the pH level of the feedwater entering the Reverse Osmosis modules
Read out – 0 to11

S26- Sensor #26 Total Dissolved Solids (TDS) Sensor
Measures the TDS level of the feedwater
Read out in mg/L

S27 – Sensor #27 Water Salinity Sensor
Measures the salinity level of the feedwater exiting the Reverse Osmosis modules

S28 – Sensor #28 Water Conductivity Sensor
Measures the conductivity level of the feedwater exiting the Reverse Osmosis modules

S29 – Sensor #29 Turbidity Sensor
Measures the turbidity of the feedwater

S30 – Sensor #30 Pressure Sensor
Measures the pressure of the feedwater exiting the permeate output of the Reverse Osmosis modules RO1
Read out in Bar

S31 – Sensor #31 Flow Sensor
Measures the flow of the feedwater exiting the permeate output f the Reverse Osmosis modules RO1

S32 – Sensor #32 Pressure Sensor
Measures the pressure of the feedwater exiting the concentrate output of the Reverse Osmosis modules RO1
Read out in Bar

S33 – Sensor #331 Flow Sensor
Measures the flow of the feedwater exiting the concentrate output of the Reverse Osmosis modules RO1

Valves

V20 – Valve #20 Check Valve
Controls the feedwater exiting from the Micro-filtration modules and prevents the concentrate passing back up to the Micro-filtration modules

V21 – Valve #21 Check Valve
Controls the feedwater exiting from the high pressure pump HP1 passing through to the Reverse Osmosis modules RO1. There is 8 valves, one for each Disc Tube module

V22 – Valve #22 Shut Off Valve
Controls flow of water, normally open, closed if maintenance is being conducted on a module. There is 8 valves, one for each Disc Tube module

V23 – Valve #23 Check Valve
Controls the feedwater exiting from the Reverse Osmosis modules RO1. There is 8 valves, one for each Disc Tube module. .Wont allow water to flow back into RO1.

V24 – Valve #24 Shut Off Valve
Controls flow of water, normally open, closed if maintenance is being conducted on a module. There is 8 valves, one for each Disc Tube module. Controls the water exiting from the permeate output of RO1

V25 – Valve #25 Pneumatically Controlled Actuator Valve
Controls the flow of the feedwater between HP1 and Reverse Osmosis modules. Normally open for flow through to RO1, changes to re-direct the feedwater through to V20 and V31 to the drain tank if the feedwater is unsuitable or for safety reasons

V26 – Valve #26 Pressure Relief Valve
Releases feedwater to drain tank through V31 if feedwater pressure is too high for the Reverse Osmosis modules.

V27 – Valve #27 Pressure Reduction Valve
Reduces the pressure of the feedwater from the HP1 if required

V28 – Valve #28 Pressure Relief Valve
Releases feedwater to drain tank through V29. On the concentrate output of the Reverse Osmosis modules.

V29 – Valve #29 Pressure Reduction Valve
Reduces the pressure of the feedwater from the V28 or MCV1

V30 – Valve #30 Check Valve
Controls the feedwater exiting from the concentrate output of the Reverse Osmosis modules RO1. There is 8 valves, one for each Disc Tube module. V30 Won't allow water to flow back into RO1.

V31– Valve #31 Pressure Reduction Valve
Reduces the pressure of the feedwater from the HP1 through V20 if required

SCV1 – Valve #SCV1 Solenoid Controlled Valve
Controls the flow of the permeate output between passing through to the shower system if the water is of a potable standard or re-direct the water to the drain tank if the water is not of a potable standard

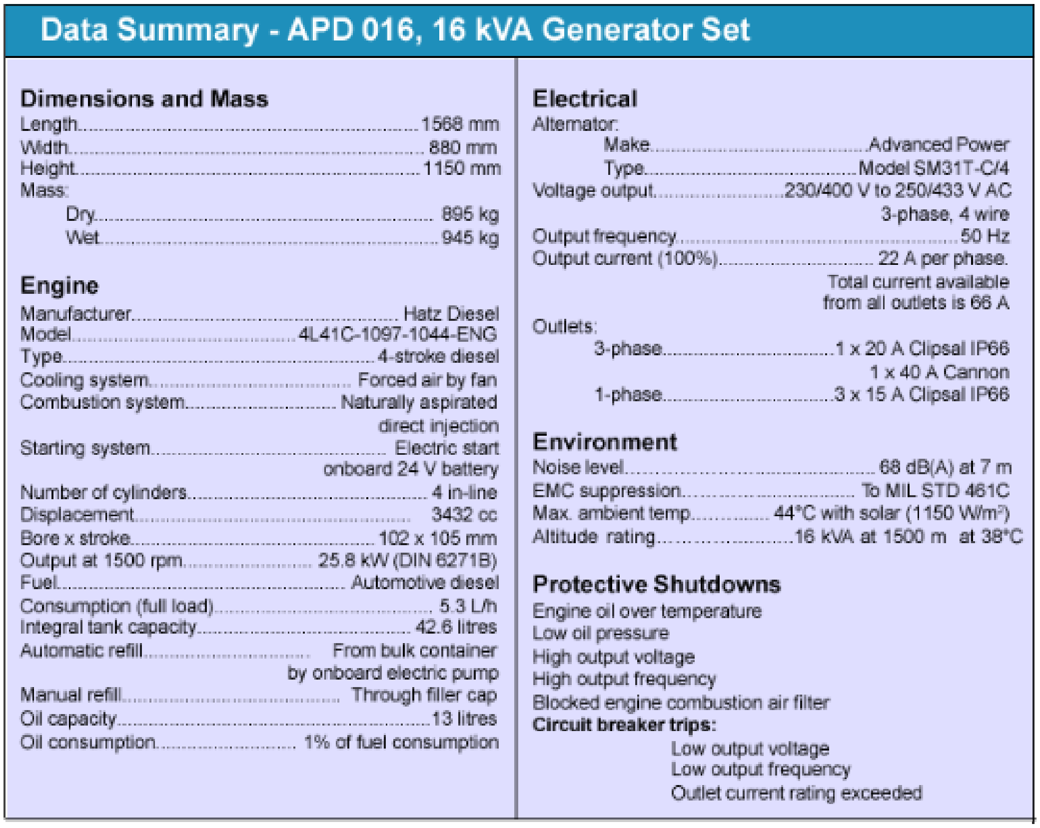
MCV1 – Valve #MCV1 Motor Controlled Valve
Controls the flow of the feedwater. It won't allow the permeate to flow until after the pressure within the Disc Tube modules rises above the osmotic pressure within the Disc Tube module system

Pumps

HP1 – Pump #HP1 High Pressure Pump
It pumps the feedwater from the Micro-filtration modules at a raised pressure of 45 Bar through to the Reverse Osmosis modules RO1

Appendix F

Data Summary for APD016, 16kVA Generator



Data Summary - APD 016, 16 kVA Generator Set

Dimensions and Mass

Length	1568 mm
Width	880 mm
Height	1150 mm
Mass:	
Dry	895 kg
Wet	945 kg

Engine

Manufacturer	Hatz Diesel
Model	4L41C-1097-1044-ENG
Type	4-stroke diesel
Cooling system	Forced air by fan
Combustion system	Naturally aspirated direct injection
Starting system	Electric start onboard 24 V battery
Number of cylinders	4 in-line
Displacement	3432 cc
Bore x stroke	102 x 105 mm
Output at 1500 rpm	25.8 kW (DIN 6271B)
Fuel	Automotive diesel
Consumption (full load)	5.3 L/h
Integral tank capacity	42.6 litres
Automatic refill	From bulk container by onboard electric pump
Manual refill	Through filler cap
Oil capacity	13 litres
Oil consumption	1% of fuel consumption

Electrical

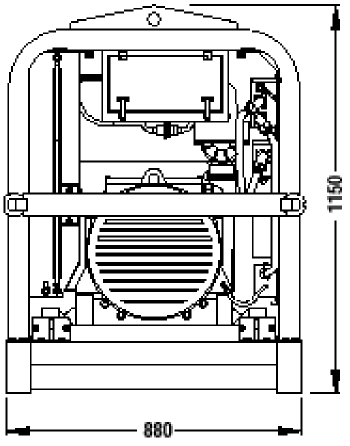
Alternator:	
Make	Advanced Power
Type	Model SM31T-C/4
Voltage output	230/400 V to 250/433 V AC 3-phase, 4 wire
Output frequency	50 Hz
Output current (100%)	22 A per phase. Total current available from all outlets is 66 A
Outlets:	
3-phase	1 x 20 A Clipsal IP66 1 x 40 A Cannon
1-phase	3 x 15 A Clipsal IP66

Environment

Noise level	68 dB(A) at 7 m
EMC suppression	To MIL STD 461C
Max. ambient temp	44°C with solar (1150 W/m^2)
Altitude rating	16 kVA at 1500 m at 38°C

Protective Shutdowns

Engine oil over temperature
Low oil pressure
High output voltage
High output frequency
Blocked engine combustion air filter
Circuit breaker trips:
Low output voltage
Low output frequency
Outlet current rating exceeded



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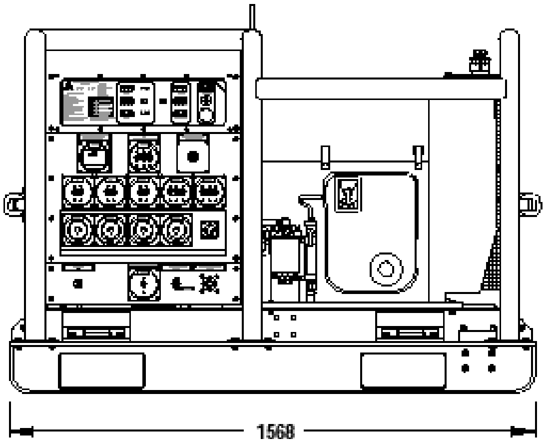

FRONT VIEW

Appendix G

Specification Sheet for PH8EFP pH/ORP Sensor

PH8EFP pH/ORP Sensor

Specifications

KCl Filling Type Electrode PH8EFP

Measuring range	pH 0 to 14
Measuring temperature	-5 to 105 degree C (-5 to 80 degree C when using Guidepipe holder)
Measuring pressure	Atmospheric pressure to 10kPa (General purpose or big volume tank 500ml) (See our GS when using holder)
	Atmospheric pressure to 500kPa (Medium pressure) (See our GS when using holder)
Temperature compensation sensor	Pt1000
Wetted part materials	Body; Ryton (PPS resin), glass, titanium or Hastelloy C, ceramics, fluorocarbon rubber or Daielperfrow rubber Cable; Chlorinated polyethylene rubber (Cable sheath) KCl tube; Heat-resistant soft PVC (General purpose or big volume tank 500ml), Polyethylene (Medium pressure)
Weight	Electrode; Approx. 0.4kg Tank; Approx. 0.3kg (General purpose), Approx. 1kg (Medium pressure)

Appendix H

Specification Sheet for PH402G pH/ORP Meter

pH/ORP Meter PH402G

PH402
4-Wire Type pH Meter

Specifications

Measuring principle	Glass electrode method
Measuring range	0 to 14 pH
Contact input	Dry contact for manual start for automatic cleaning
Ambient temperature	-10 ☐ to 55 degree C
Storage temperature	-30 ☐ to 70 degree C
Ambient humidity	10 to 90% RH
Construction	Watertight complying with JIS C0920 equivalent to NEMA4 waterproof construction
Material	Case;Aluminum alloy casting Cover and window;Polycarbonate
Finish	Baked polyurethane resin coating
Power supply voltage	88 to 132 V AC,50/60 Hz,176 to 264 V AC,50/60 Hz
Power consumption	Approx.8.5 VA
Weight	Body:Approx.2.5kg

Appendix I

Specification Sheet for EJA110A Differential Pressure Transmitter

EJA110A Differential Pressure Transmitter

The high-performance EJA110A differential pressure transmitter can be used to measure liquid, gas, or steam flow as well as liquid level, density and pressure.

Specifications

		EJA110A Differential Pressure Transmitter			
		L Capsule	M Capsule	H Capsule	V Capsule
Range		-10 to 10 kPa (-40 to 40 inH$_2$O)	-100 to 100 kPa (-400 to 400 inH$_2$O)	-500 to 500 kPa (-2000 to 2000 inH$_2$O)	-0.5 to 14 MPa (-70 to 2000 psi)
Span		0.5 to 10 kPa (2 to 40 inH$_2$O)	1 to 100 kPa (4 to 400 inH$_2$O)	5 to 500 kPa (20 to 2000 inH$_2$O)	0.14 to 14 MPa (20 to 2000 psi)
Accuracy		±0.075%	±0.075%	±0.075%	±0.075%
Degrees of protection		IP67, NEMA 4X, and JIS C0920 immersion proof			
Certificates		FM, CENELEC ATEX, CSA, IECEx			
Output		4 to 20 mA DC or FOUNDATION fieldbus™, 2-wire system with digital communication			
Supply voltage		BRAIN and HART:10.5 to 42 V DC (10.5 to 30 V DC for Intrinsically safe type) Fieldbus:9 to 32 V DC (9 to 24 V DC for Entity and 9 to 17.5 V DC for FISCO)			
Ambient temperature		-40 to 85 deg C (-40 to 185 deg F) (general use type) -30 to 80 deg C (-22 to 176 deg F) (with integral indicator)			
Process temperature		-40 to 120 deg C (-40 to 248 deg F) (general use type)			
Maximum working pressure		16MPa(2300psi) 3.5MPa(500psi) for L capsule with special materials			
Mounting		2-inch pipe mounting			
Wetted parts material	Capsule	SUS316L(Diaphragm material is Hastelloy C-276), Hastelloy C-276, Tantalum, Monel			
	Cover flange	SUS316, Hastelloy C-276, Monel			
Housing		Cast aluminum alloy or SUS316 equivalent stainless steel (optional)			