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BLUESCOPE STEEL

**STEELWORKS COGENERATION PLANT PROJECT**

**ENGINEERING DOCUMENT**

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**Title:** ILLAWARRA COGENERATION PLANT (ICP) PROJECT

MACROFOULING CONTROL

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# 1.0 INTRODUCTION

## 1.1 SUMMARY OF ICP PROJECT

The BlueScope Steel Limited Port Kembla Steelworks is a fully integrated iron and steel making plant located on a 742-hectare site within the Wollongong Local Government Area of New South Wales.

On 1 July 2005, Wollongong City Council, in Development Consent DA 767/01A, approved the construction and operation of a 225 MW cogeneration plant at Port Kembla Steelworks. The project was called the "Illawarra Cogeneration Plant" Project (ICP Project).

The ICP will harness by-product fuel from the Port Kembla Steelworks iron and steelmaking processes, as well as some natural gas, to generate steam and electricity. The by-product fuels are currently generated but are flared to the atmosphere.

BlueScope Steel Limited (BSL) is seeking to modify the existing Development Consent to construct and operate the ICP as follows:

- The use of 3 new boilers whilst retaining and utilising the existing No.25 Boiler to generate approximately 1,100 tonnes per hour of steam;
- relocation and re-sizing of the Basic Oxygen Steelmaking off-gas (LDG) gas holder and associated ductwork;
- use of a once-through salt water cooling system instead of a closed circuit fresh water cooling system with a cooling tower;
- relocation of the high voltage substation and electrical connections;
- consolidation of the ICP footprint; and
- relocation of construction laydown areas.

## 1.2 MACROFOULING

Fouling of cooling systems caused by large organisms, such as oysters, mussels, clams, and barnacles, is referred to as macrofouling. Typically, organisms are a problem only in large once-through cooling systems or low cycle cooling systems that draw cooling water directly from natural water sources (rivers, lakes, coastal seas). Water that has been processed by an influent clarification and disinfection system is usually free of the larvae of macrofouling organisms.

At the Port Kembla Steelworks, macrofouling is a problem which affects:

- the salt water inlet channel, which supplies water from the Port Kembla Inner Harbour to No 1 Power House and No 2 Blower Station;
- individual cooling circuits, such as steam turbine condensers and other once-through cooling circuits, which are supplied from the salt water inlet channel.

Significant infestation of macrofouling organisms leads to a reduction in the cross sectional area of the channel or pipework, resulting in a reduction in the flow capacity of the system.

The existing salt water inlet channel is severely fouled. Divers are currently used to manually remove mollusc infestations. Significant modifications to the channel need to be made to increase the capacity to that required for the new ICP turbo alternator's condenser operation. The scope of the proposed modifications is based on an estimated level of fouling in the channel. Cleaning of the channel to achieve, or better, that level of fouling is required to allow the increased salt water flows to be achieved. Any future significant reduction in the available cross sectional area would reduce the capacity of the channel, and potentially impact on iron and steel production and the ability of the ICP facility to consume available by-product fuel.

BSL considers that the use of divers may no longer be viable following the commissioning of the ICP plant, due to safety issues arising from the increased water velocity in the channel. An alternate cleaning method is therefore required.

Fouling of the new condenser's salt water cooling circuit would result in a lower coolant flow, with a consequent reduction in the power output of the turbo alternator, and an increase in flaring of by-product fuels during periods of high by-product fuel availability.

BSL is committed to identifying and implementing environmentally acceptable methods to effectively control macrofouling in the Steelworks salt water cooling system.

## 2.0 CONTROL METHODS FOR MACROFOULING

The most appropriate control strategy for any particular power plant subject to cooling water system macrofouling is dependant on a variety of factors which are specific to facility location, design and operation. Subsequently, there is no single solution which will be optimal for all power plants, and in general a power plant will require a combination of macrofouling control methods for successful and efficient operation.

Below is a brief review of the main control methods that have been applied in different power plants around the world.

### 2.1 MECHANICAL SCREENING

Mechanical controls, such as screens, strainers, and filters prevent the inlet cooling water from entraining macrofouling organisms, fish, and debris. They can play an important role in the success or failure of a macrofouling control program.

The key advantage associated with mechanical controls is that they have minimal impact on the environment, however they are limited in their effectiveness by the practical aspects of removing microscopic larvae from the large water flows required for power plant cooling.

BSL Port Kembla has three sets of salt water channel inlet screens:

- wide bar spacing at the inlet to the channel,

- inlet to the blower station offtake, and
- fine mesh bandscreens at the blower station end of the inlet channel,

and self cleaning strainers on the discharge side of the cooling water pumps for individual cooling circuits.

This screening system will remain in operation when the new power plant starts up, with extra screens and strainers to be installed as part of the new power plant cooling water system.

Eraring Energy's Eraring Power Station (Lake Macquarie, NSW) employs large strainers at the condenser cooling water inlets and smaller debris inlet filters for their steam-driven boiler feed pumps. These strainers are maintained in a clean condition via regular back flushing.

## 2.2 PHYSICAL

Physical controls involve the cleaning of fouled cooling water systems. Manual cleaning of cooling systems (scraping and vacuuming) is the oldest known macrofouling mitigation measure used in power plants, and is highly labour intensive and expensive (cleaning of equipment and pipework must take place offline), and smaller diameter pipelines are often inaccessible.

Manual cleaning of large channels is possible on-line, with divers working to remove fouling, if water velocities are low enough to ensure safe working conditions.

The most well known in-service physical cleaning method is the Taprogge system, which involves a continuous or regular application of abrasive sponge balls which pass through the condenser cooling circuit and remove macrofouling organisms from the condenser tubes. The key advantage of the Taprogge system is that it is environmentally benign in successful normal operation.

The abrasive sponge ball systems are known to cause increased erosion / corrosion of the condenser tube cooling surfaces. Jenner et. al. noted that there is often a need for supplemental biocide application to control fouling of service water systems and other areas of the cooling water system (particularly smaller diameter piping eg instrument piping) that the balls cannot access. In some cases it is necessary to employ chemical solutions in parallel with ball cleaning systems to achieve effective control of bio-film within condensers. Taprogge systems also occupy a large on-site footprint, require high levels of maintenance, and are known to create environmental issues when balls are not captured and are discharged into waterways.

BSL Port Kembla first installed Taprogge ball cleaning systems on 2, 4, and 21 Turbo Alternators. Operational problems included ball losses, problems with control electronics, blockages of cooling tubes and back flushing systems, and the salt water environment caused increased repair and maintenance demand on valve actuators, strainers, catch plates, pumps, seals, and gearboxes. The effectiveness of the systems was reduced to the point where they fell into disuse. A Taprogge system was also installed on 24 Turbo Blower at construction, but was not fully commissioned due to a variety of problems including:

- frequent loss of the balls from the cooling circuit to Allan's Creek (due to jamming of the inlet tubes by the wadding effect of debris such as ribbon weed and detached marine growth etc.),
- balls becoming trapped in eddies in the condenser water boxes or circulating system, and

- fouling of the condenser tail pipe catching screens which affected the cooling water flow and resulted in binding of the rotating catcher screens.

Eraring Power Station has a Taprogge ball cleaning system installed on its once-through cooling water system, however it is not primarily used for macrofouling control. Eraring doses their condensers with $FeCl_2$ to coat and protect the Cu-Ni tubes from salt water corrosion. The ball cleaning system operates for two hours per day to ensure that the coating is maintained as thin as possible to manage the compromise between corrosion protection and maximum condenser heat transfer. In operation, Eraring has found that ball cleaning systems are troublesome, requiring high levels of inspection, monitoring and troubleshooting. They have had issues with ball loss, jamming of balls, and trapping of balls in air pockets.

A power plant situated on the Venice Lagoon in Italy employs an in-service ball cleaning system combined with chemical treatment ($CO_2$). Cristiani (Centro Elettrotecnico Sperimentale Italiano (CESI) – Business Unit Environment, 2004) noted that this power plant initially operated the ball cleaning system alone, but was forced to set up the chemical treatment system as the condensers were suffering from growth of macrofouling organisms and efficiency was being compromised.

The Koeberg nuclear power plant in South Africa stopped operating it's salt water ball cleaning system over 15 years ago. The system was previously used only occasionally post-commissioning; operational problems included loss of balls and reduction in condenser performance due to fouling. The plant now uses continuous chlorine injection, and has had no further operational problems.

AES Hawaii uses a Taprogge ball cleaning system to minimising fouling of it's recirculating salt water system. Though they have operational issues with the reliability of the Taprogge systems and frequent loss of balls due to screen damage, the plant has not had any issues with plant fouling due to the nature of recirculating water (in recirculating salt water systems with cooling towers, salt and contaminant concentrations increase by a factor of 3-8 and chemical dosing is required to control legionella outbreaks, corrosion and macrofouling).

## 2.3 THERMAL

Thermal control methods have been used in once-through salt water cooling systems for many years. Increased water temperature results in relatively rapid mortality rates of macrofouling organisms. Published data is available describing the relationship between exposure time and rate of temperature rise for satisfactory mortality rates for representative organisms.

A common method to facilitate on-line thermal shock is reverse flow. The power plant must be constructed or modified to provide reverse flow, where heated discharge water (typically from a heat exchanger operating in parallel) is directed to the discharge of the unit to be treated, producing a rapid increase in the water temperature surrounding the target organisms. This method also provides backwash functionality, flushing debris out of cooling water tunnels. On-line thermal shock by reverse flow is only effective when there is sufficient temperature difference between the cooling water inlet and outlet.

Retrofitting an existing power plant for reverse flow thermal shock macrofouling control can be cumbersome and very expensive and power plants that are not capable of heating water to the required lethal temperatures must apply the technique in conjunction with chemical treatment. Further, reverse flow thermal shock systems require significant space due to the size of the additional pipework and valves. Depending on the system configuration, it also may not be possible to treat the entire pipe network.

Another option which has not been used extensively is direct injection of steam into cooling water intake legs, achieving a rapid rate of change in temperature. Significant quantities of steam would be required for this method, with practical design issues associated with the injections of such large quantities of steam directly into the cooling water system.

A third option involves the recirculation of the cooling water discharge from a heat exchanger system back to the system inlet. In this type of system, the cooling system temperature can be raised and held at a suitable level long enough to ensure fatality of target species. The temperature is maintained at the desired level by bleeding an appropriate proportion of the system discharge to drain, while allowing the mixing of the remaining elevated temperature discharge with normal cooling water supply. While the system temperature is held at the higher level, the discharge to drain will contain slightly less than the heat load present before the thermal treatment, but with a lower discharge volumetric rate, and a higher temperature.

Retrofitting recirculating systems to existing facilities can also be very difficult and expensive, due to the significant space required for additional large diameter pipework and valves. This type of system is best included in the original design of new facilities.

For steam turbine condenser cooling applications, all of these thermal treatment methods result in higher than normal turbine steam discharge pressures, and therefore lower turbine power output. Treatments would normally be carried out during low load operation, to reduce power losses, and to minimise the likelihood of environmental impacts of a lower volume / higher temperature discharge to drain during the treatment period. For example, if the treatment was carried out while the turbine was operating at 50% full load, the heat load in the discharge stream would be 50% of the maximum design heat load.

It should be noted that high water temperatures required for effective thermal shock often sends turbine back pressure over the manufacturer’s limit, and high water temperatures can also be lethal to non-target aquatic organisms. Care must be taken in the design and operation of such a system to ensure environmental and operational issues do not arise.

Retrofitting an existing power plant for reverse flow thermal shock macrofouling control can be cumbersome and very expensive and power plants that are not capable of heating water to the required lethal temperatures must apply the technique in conjunction with chemical treatment. Further, reverse flow thermal shock systems require significant space due to the size of the additional pipework and valves. Depending on the system configuration, it also may not be possible to treat the entire pipe network.

Reverse flow thermal shock is employed as the primary macrofouling control treatment at Eraring Power Station. Implementation of this treatment has been effective on the main turbine condensers. The condensers on the steam turbine powered feedwater pumps need to be operating at a reasonable load to ensure an adequate temperature difference between inlet and discharge. At times, high pressure water blasting of pipes is required during plant outages. The $FeCl_2$ used at

Eraring Power Station for corrosion control is also known to be slightly toxic to marine life and is expected to play a role in the reduction of macrofouling.

## 2.4 PAINTS AND COATINGS

Internal application of paints and coatings have been heavily investigated and trialled for a variety of marine uses. The two most effective types of internal pipe coatings have been found to be hard epoxy resins containing copper, and silicone rubber oil based paints.

The toxic copper in the hard epoxy resin is slowly released in order to control macrofouling in cooling water systems. However, the formation of corrosion-resistant films on the surface of the resin coating diminishes the effectiveness of the coating, and many applications require initial activation and semi-annual reactivation by light abrasive blasting. Overcoating is required every 2-5 years.

Silicone rubber oil based paints are non toxic and hence have a reduced potential for environmental impact when compared to heavy metal coatings. These paints are resistant to macrofouling for up to four years prior to reapplication. Reapplication requires complete dewatering and cleaning of the cooling water system before the paint is applied.

A key issue with internal paints and coatings is a reduction in the heat transfer coefficient and hence a loss of cooling water efficiency if coatings are retro-fitted, ie if the heat transfer resistance is not factored into the system design.

## 2.5 OXIDISING COMPOUNDS

Several oxidising compounds, including chlorine, chlorine dioxide, bromine and hydrogen peroxide, have been utilised for macrofouling control in industrial once-through salt water cooling systems. Though proven to be a highly effective method for minimisation of macrofouling, application of oxidising compounds is now considered to be unacceptable.

All oxidising compounds are readily detected by the mollusc's sensitive chemoreceptor system, so that the mollusc immediately withdraws its siphon and closes it's shell to avoid contact. Consequently, long exposure times are required to achieve effective treatment, and large amounts of chemical are required. Further, oxidising compounds are also lethal to non-target species such as plankton and fish at relatively similar concentrations. Once released into the cooling water system, the reactive nature of by-products formed (including organohalogenated compounds) is highly undesirable.

The large volumes of chemicals required to effectively treat macrofouling increases risks associated with transportation and personnel exposure; many oxidising compounds used for macrofouling control are toxic to humans. Oxidising compounds are also by nature aggressive to cooling water system components. This corrosion, as well as the large chemical volumes required, contributed to high costs associated with application of these chemicals.

Chlorine dioxide became the oxidising chemical of choice, as despite having similar toxicity to chlorine, it requires lower dosages and shorter exposure times. Chlorine dioxide does not form organohalogenated by-products, though it quickly reacts to form chlorite, which is also toxic to aquatic organisms.

Until the late 1980's, BSL Port Kembla dosed its cooling water systems with chlorine. This was effective, however issues arose with problematic injectors, and breakages of injection piping. The possibility of toxic leaks of gaseous chlorine and the need for large on-site inventory of bulk chlorine cylinders were considered to contribute to an unacceptably high risk installation. Direct chlorination was replaced by a chlorine dioxide generator. This was intended to eliminate the hazard of bulk storage of chlorine, however a serious incident occurred when a chemical delivery mistakenly transferred sodium hypochlorite into a hydrochloric acid tank and chlorine gas (which is highly toxic) was generated, affecting a number of employees and resulting in hospitalisations. The system also had serious operational issues; despite servicing by the vendor, pipes, valves and electrical components regularly failed. The chlorine dioxide generation system eventually became unusable without a major refit.

## 2.6 NON-OXIDISING COMPOUNDS

Non-oxidising compounds are far more specific to target organisms than oxidising compounds, and include quaternary and tertiary amines, ethanoamines, isothyazolones, and glutaraldehyde. The success of these compounds is due to the fact that molluscs do not sense them at lethal concentrations. Amine based compounds damage mollusc gill tissue, while others form a film over the organisms which effectively deprives them of oxygen and prevents fresh settlement.

These compounds are favoured over oxidising compounds as not only are they specific to target organisms, they do not react with naturally occurring organics to produce chlorinated and halogenated by-products. Non-oxidising compounds only require brief, low dose exposures which results in less chemicals being released into the environment, and reduced impact on entrained plankton. Lower dose rates also reduce the safety risks associated with large on-site inventories of a substance which is toxic to humans, and frequent transportation of dangerous goods.

The brief exposures also mean that the product concentrations being dosed can be monitored and verified during the entire application, and the small on-site dosing plant requires minimal inventory. The active compounds may be carried by fresh water, which reduces corrosion issues associated with salt water solutions.

Chemical treatment methods are not effective on marine plants entrained in the cooling water such as ribbon weed. Such foulants must be physically removed from the system.

BSL Port Kembla started using a non-oxidising molluscicide, Spectrus CT1301 (also known as ClamTrol I) in 1995, which proved to be very effective. BSL later changed to Spectrus CT1300 (ClamTrol II) which does not contain dodecylguanidine and is more environmentally friendly.

### 2.6.1 Spectrus CT1300 (Clamtrol II)

Spectrus CT1300 is a non-oxidising molluscicide containing 50% Quaternary Ammonium Hydrochloride (QUAT) in an aqueous solution with alcohol. When applied in relatively brief periodic applications, it is an effective control of macrofouling organisms, such as molluscs, in industrial once-through cooling systems. Non-target species such as fish and algae are not affected by the low concentrations required for effective antifouling control of once through cooling water pipes.

Spectrus CT1300 is adsorbed onto pipework, valves, debris, and macrofouling organisms. This adsorbed layer creates a film which inhibits oxygen transfer to molluscs, resulting in a high mollusc mortality rate in very short periods of time. This film also prevents settlement of macrofouling organisms on clean surfaces, without impacting on cooling tube heat transfer performance or causing corrosion issues.

The active ingredient (QUAT) in Spectrus CT1300 is short-lived in the environment. This is because QUATs are cationic, and readily adsorbed by natural anionic substrates and sediments. Once adsorbed, Spectrus CT1300 is biodegraded to simple compounds such as $CO_2$ and $H_2O$; it is therefore effectively detoxified and rendered harmless to aquatic organisms.

### 2.6.2 CSIRO Ecotoxicology Investigations

BSL engaged CSIRO Centre for Environmental Contaminants Research in 2004/2005 to undertake specific toxicity testing of Spectrus CT1300, and toxicity testing of effluent from #2 Blower Station (BS2) drain following dosing of Spectrus CT1300. The purpose of the investigations was to determine an ecologically appropriate concentration of Spectrus CT1300 for discharge into Allan's Creek, and make recommendations on any required changes in practice.

An assessment of the toxicity of Spectrus CT1300 to marine biota was conducted in November 2004. Spectrus CT1300 and sea water from the BSL salt water channel were provided by BSL for the ecotoxicity testing. Two separate BS2 effluent samples were collected following dosing of Spectrus CT1300; the first sample (with a Spectrus CT1300 concentration of 0.15-0.2mg/L) was collected in June 2004 and the second sample (with a Spectrus CT1300 concentration of 0.18mg/L) was collected in October 2005. These samples also underwent ecotoxicity testing by the CSIRO.

The following tests were conducted on the samples:

- Light inhibition in marine bacteria
- Growth inhibition in microalgae
- Fertilisation inhibition in Sea Urchin
- Scallop larval development
- Immobilisation of fish larvae

Results were reported as either:

- EC50 (concentration having 50% effect compared to controls, for example, the test sample concentration at which there is 50% inhibition of light output compared to controls), or
- IC50 (concentration inhibiting 50% of a parameter such as the growth rate compared to controls), and also included
- LOEC (lowest observable effect concentration; the concentration with a very weak observable effect) where available, and
- NOEC (no observable effect concentration; the highest concentration tested for which the effect is significantly not different from controls).

Detail on test methodology may be found in the CSIRO report "Assessment of the Toxicity of the Biocide ClamTrol II to Marine Biota" (November 2004).

### 2.6.3 Results of Ecotoxicity Tests

*Light inhibition in marine bacteria*

- EC50 (5min) = 2.3mg/L
- LOEC (5min) = 0.75mg/L
- NOEC (5min) = 0.37mg/L
- EC50 (15min) = 1.4mg/L
- LOEC (15min) = 0.30mg/L
- NOEC (15min) = 0.15mg/L

- BS2 2004 Sample ($C_{CT1300}$ = 0.15-0.2mg/L) showed no toxicity
- BS2 2005 Sample ($C_{CT1300}$ = 0.18mg/L) indicated no observable effect on 45% of specimens

*Growth inhibition in microalgae*

- IC50 (72hr) = 0.75mg/L
- NOEC (72hr) = 0.3mg/L

- BS2 2004 Sample ($C_{CT1300}$ = 0.15-0.2mg/L) showed no toxicity
- BS2 2005 Sample ($C_{CT1300}$ = 0.18mg/L) not tested as only the three most sensitive tests from previous studies were chosen to assess the toxicity of Spectrus CT1300

*Fertilisation inhibition in Sea Urchin*

- EC50 (1hr) = 0.023mg/L
- LOEC (1hr) = 0.01mg/L
- NOEC (1hr) = 0.003mg/L

- BS2 2004 Sample ($C_{CT1300}$ = 0.15-0.2mg/L) showed no toxicity
- BS2 2005 Sample ($C_{CT1300}$ = 0.18mg/L) indicated an NOEC of 12.5%; this was half as toxic as predicted; both the 2004 and 2005 results suggesting Spectrus CT1300 toxicity to sea urchins was ameliorated.

*Scallop larval development*

- EC50 (48hr) = 0.043mg/L
- NOEC (48hr) = 0.01mg/L

- BS2 2004 Sample ($C_{CT1300}$ = 0.15-0.2mg/L) indicated an NOEC of 50%;
- BS2 2005 Sample ($C_{CT1300}$ = 0.18mg/L) indicated an NOEC of 6.3%; this was twice as toxic as predicted – low levels of Zinc on the sample may have contributed to some additional toxicity, however 35% of the observed toxicity could not be attributed to known toxicants

*Immobilisation of fish larvae*

- EC50 (96hr) = 1.0-3.0mg/L (lack of partial response)
- NOEC (96hr) = 1.0mg/L

- BS2 2004 Sample ($C_{CT1300}$ = 0.15-0.2mg/L) showed no toxicity
- BS2 2005 Sample ($C_{CT1300}$ = 0.18mg/L) not tested as only the three most sensitive tests from previous studies were chosen to assess the toxicity of Spectrus CT1300

These tests demonstrated the sub-lethal effects of Spectrus CT1300 to a variety of aquatic organisms; as expected, invertebrates (as the target species) were most sensitive to Spectrus CT1300.

The CSIRO report states:
*"although fish fry and microalgal growth would be unlikely to be affected by Clamtrol II at these concentrations, it may be preferable to reduce dosing so that Clamtrol concentrations in the BS2 drain do not exceed 0.15 mg/L (bacterial NOEC). Further dilution in Allan's Creek and Port Kembla Inner Harbour should reduce Clamtrol concentrations even further so that impact on non-target invertebrate populations (if they exist in the vicinity) could be minimised".*

It is understood that the CSIRO report has used the marine bacteria 15 minute NOEC value (the lowest calculated NOEC concentration for non-target species) as the basis for their recommended discharge concentration.

The immediate dilution of the Clamtrol concentration when the ICP discharge enters Allan's Creek suggests that a 5 minute NOEC value would be more appropriate than a 15 minute value.

It should also be noted that the ecotoxicology test method involves testing at discrete concentrations, and does not attempt to determine the actual NOEC value. The actual NOEC value falls somewhere between the observed NOEC and LOEC values. This means that the use of any NOEC value is somewhat conservative.

It should also be noted that the CSIRO report stated:
*"Actual testing of BS2 drainwater (containing about 0.15 mg/L Clamtrol II) in May, 2004, confirmed that there were no inhibitory effects on fish, micoalgae, sea urchins or bacteria, suggesting that the potential toxicity of Clamtrol II is ameliorated by environmental factors."*

#### 2.6.4 APVMA Registration

Spectrus CT1300 is supplied by GE Water and Process Technologies under an APVMA (Australian Pesticides and Veterinary Medicines Authority) provisional permit (PER9324). This provisional permit is issued to allow time for the assessment of the application for full APVMA registration. The current provisional permit is due to expire in June 2008, and extension or renewal of this provisional permit is subject to satisfactory progress being made by GE Water and Process Technologies to fulfil application requirements. It is expected that this provisional permit will be extended in June 2008 as GE Water and Process Technologies has demonstrated compliance towards addressing APVMA requests.

GE Water and Process Technologies is confident that approval for APVMA registration will be finalised in December 2008. Specific concerns have been addressed with additional testing and discussion, and this additional testing and discussion has been screened by the APVMA without additional questions. The product is also used at other (non-BSL) power plant sites in Australia.

It should be noted that although Spectrus CT1300 is not currently registered with the APVMA, the active ingredient (commonly known as benzalkonium chloride) is registered as an approved active constituent; it appears on the APVMA list "Active constituents (ACs) excluded from the requirements of APVMA approval".

The product registration process has been progressed by GE Infrastructure (Water and Process Technologies) for the past five years. The prolonged application duration has been partly due to transient APVMA staff and organisational restructures, and the process has proven to be quite intensive and expensive. The timeline below demonstrates the application process thus far.

| | |
|---|---|
| April 2004 | Initial application submitted to APVMA comprising of 10 modules. |
| May 2005 | Initial application screened and accepted by APVMA. |
| Dec 2005 | APVMA requested further information on Efficacy and Environmental modules. The deficiencies identified were difficult to address and required additional testing.<br>APVMA provisional permit extended to March 2006. |
| June 2006 | APVMA provisional permit extended to June 2007. |
| Nov 2006 | Ecotox Services Australia engaged to conduct efficacy testing on shellfish, sensitive marine diatom, and green algae.<br>Case studies demonstrating efficient use of Spectrus CT1300 in Australia and overseas were developed. |
| June 2007 | APVMA provisional permit extended to June 2008.<br>Following compilation of additional data and a request on how the additional data should be submitted, APVMA advised that as new data protection laws came into force during 2005, the best option was to provide an entirely new application. |
| Sept 2007 | Toxikos Toxicology Consultants compiled revised modules which were successfully submitted to APVMA. |
| Feb 2008 | Application passed screening; APVMA sent out copies to the eight evaluators and advised that the time frame for approval is 8 months. |
| June 2008 | Extension of APVMA provisional permit required. |
| Dec 2008 | Expectation of full APVMA registration of Spectrus CT1300. |

### 2.6.5 Use of Spectrus CT1300 at Port Kembla Steelworks

Spectrus CT1300 was first implemented at No. 2 Blower Station in May 2004, replacing Spectrus CT1301. The new product contained higher levels of the QUAT to counteract the removal of the non-biodegradable component (which enhanced efficacy) in the superseded product. Spectrus CT1301 was periodically dosed at 6mg/L for 8hrs with a discharge limit of 0.4mg/L. When Spectrus CT1300 was introduced, the dosing concentration was reduced to 3mg/L, and the dosing duration was maintained at 8 hours. The discharge concentration was consistently measured at less than 0.25mg/L. This strategy was employed for several months.When 24 Turbo Blower condenser was next opened for routine maintenance, however, significant macrofouling was observed. The dosing strategy was adjusted to dose at 3mg/L for 12hrs. This resulted in satisfactory fouling control in that cooling circuit.

Following the work performed by the CSIRO in 2004/2005, BSL agreed to lower the No. 2 Blower Station Drain discharge limit to 0.25mg/L.

In the 13 years of employing Spectrus CT1301/1300 for control of macrofouling at No. 2 Blower Station Drain, there have not been any marine or biota incidents.

No. 1 Power House trialed a discharge limit of 0.15mg/L during 2007. To achieve this discharge limit, the dosing concentrations were reduced, and the duration increased as indicated below:

| | Dosing Conc (mg/L) | | Dosing Time (hr) | |
|---|---|---|---|---|
| | Pre-Trial | Trial | Pre-Trial | Trial |
| No. 2 Turbo Alternator | 2.5 | 2.0 | 12 | 24 |
| No. 4 Turbo Alternator | 2.0 | 1.0 | 12 | 24. |

The different dosing concentrations were a result of the different cooling flows through each of the condensers, and the corresponding variation in physical dilution of each discharge before entering the Main Drain.

An initial offline inspection of the No 4 Turbo Alternator condenser in December 2007 confirmed successful cleaning had been achieved to that date. Fouling has, however, been historically worse during the summer period. A further inspection following a summer period with the trial dosing regime is required before the lower discharge concentration is fully accepted.

The lower discharge concentration is achievable at No. 1 Power House due to its unique drain configuration. The cooling water circuits from No. 1 Power House flow into the Main Drain, which has a high residence time and contains a variety of natural anionic substrates and sediments, before being discharged to Allan's Creek (where the discharge limit is applied). This high residence time provides increased opportunity for Spectrus CT1300 to be adsorbed and deactivated. No. 2 Blower Station cooling water circuits flow straight into the No 2 Blower Station Drain which discharges directly into Allan's Creek; there is a relatively short residence time in this drain, and far less opportunity for adsorption and deactivation of the product. This phenomenon is reflected in the apparent "consumption" of Spectrus CT1300 at each location. Taking into account the dilution resulting from non-treated streams flowing to each drain, approximately 85% of the biocide is consumed during dosing of the No 1 Power House systems, compared to 55 - 75% biocide consumption when dosing one of the largest systems in the No 2 Blower Station. A review of the limited available data suggests that the consumption of Spectrus CT1300 may be lower during winter. It is possible that this variation is linked to the quantity of marine organisms available in the salt water stream to consume the biocide. It is considered appropriate to use a 50% consumption factor, and the calculated physical dilution factor when estimating the relationship between the dosing concentration and the discharge concentration.

The current BSL Port Kembla discharge limits for Spectrus CT1300 are 0.15mg/L at the Main Drain discharge point (for No. 1 Power House), and 0.25mg/L at the No. 2 Blower Station Drain discharge point in Allan's Creek.

Spectrus CT1300 has been proven in operation at BSL Port Kembla as an effective control for macrofouling over entire cooling water circuits, with low maintenance and high reliability (see Section 3.2.2 for further detail on reliability of the dosing system).

# 3.0 PROPOSED ICP MACROFOULING CONTROL METHODOLOGY

## 3.1 SALT WATER INLET CHANNEL

The inlet channel currently contains significant “reefs” of mollusc organisms. Previous attempts to remove large quantities of this material with a front end loader were aborted due to the discolouration of the salt water stream, caused by the crushing of shells and general disturbance.

Removal of most of the existing build-up is required prior to establishing an ongoing maintenance cleaning program.

It is proposed to initiate a Spectrus CT1300 dosing regime to:

- remove as many organisms as possible to minimise the work required to be carried out by the divers,
- ensure that the macrofouling does not re-occur.

The initial dosing would be controlled to achieve the following:

- no exceedance of agreed drain discharge concentration,
- controlled mortality of the molluscs present in the inlet channel so that the existing screening facilities are not blocked by the quantity of material produced.

Any new dosing regime would be only be implemented following consultation with, and agreement from, the DECC. The following discussion is indicative of the proposed dosing regime and it’s initial implementation.

It is recognised that dosing the entire inlet channel flow means that no dilution would be available to help manage the discharge concentration. Consumption of the biocide in the system is required to reduce the concentration to the discharge limit value. As indicated in Section 2.6.5, 50% consumption has been historically experienced on the large condenser circuits at No. 2 Blower Station. This suggests a concentration of 0.5 mg/L at the No. 2 Blower Station and of the inlet channel would not cause an exceedance of the proposed 0.25 mg/L discharge limit.

To ensure the existing band screens in the branch of the channel feeding No. 2 Blower Station are not subjected to excessive material, it may be appropriate to commence dosing of the inlet channel a short distance (say 100m) upstream of the screens. An initial dosing concentration of 0.5 mg/L would be used, with consumption over the remainder of the inlet channel, machine pipework and drains expected to cause the concentration to be lowered to acceptable levels. The concentration at the No. 2 Blower Station Drain would be monitored to assess the opportunity to slowly increase the dosing concentration in steps of 0.1 mg/L to a maximum of 1.0 mg/L over a period of approximately 4 hours, without exceeding 0.25 mg/L at the discharge point. The existing band screens and downstream filters would be closely monitored during that period and later, to assess the impact of the dosing regime, and the capacity of the screening / filtering equipment to remove the necessary material.

Following a full review of the initial dosing period, further dosing would be carried out, within the discharge concentration and screening / filtering equipment limits. When it is established that the dosed section upsteam of the band screens has been adequately cleaned, the dosing point would be moved further upstream, and the process re-started. The distance the dosing point was moved would be determined following a review of the impact of dosing on the performance on the band screens.

When the entire inlet channel had been cleaned, an appropriate maintenance dosing regime would then be determined and implemented. It is expected that such dosing would occur at 4-6 week intervals. This philosophy would not guarantee that the individual cooling circuits fed from the channel would remain clean, and additional treatment of these cooling circuits would also be required. Current treatment methods for non-ICP equipment may also require modification to account for the contribution from an inlet dosing regime. Such a modification would be likely to be a reduction in dosing time or frequency. Any chemical dosing of the inlet channel would not be carried out at the same time as any downstream dosing.

Divers would be used to remove any residual material which had not been dislodged by the biocide treatment for the full length of the inlet channel to the No. 2 Blower Station offtake, and the No. 2 Blower Station supply channel. It is believed that the maintenance dosing regime would then prevent unacceptable re-growth and resulting flow restriction. The need for divers to enter the inlet channel to remove organic fouling would be eliminated

The inlet channel dosing program is targeting mollusc-like organisms. The No Observable Effect Concentration (NOEC) value for fish larvae determined during the CSIRO ecotoxicology tests was 1.0 mg/L. It is expected that juvenile and adult fish would be even more tolerant to concentrations of Spectrus CT1300, and therefore the existing fish population is not expected to be affected. Future fish numbers may be reduced due to ongoing impacts on larvae during dosing periods, depending on the final dosing concentration required to achieve adequate anti-fouling.

Significant quantities of sand and silt material is transferred to the inlet channel by the lift pumps. “Sand traps” were designed into the system to catch this material at the lift pumps and at the No. 2 Blower Station offtake channel entrance, to stop it migrating further into the system. Cleaning of these sand traps is made difficult due to the presence of the mollusc infestations.

BlueScope intends to investigate methods to remove sand and silt from these locations without the need for divers. Removal of this material is not expected to produce unacceptable environmental impacts.

## 3.2 ICP MACROFOULING CONTROL

Fouling of the proposed ICP Turbo Alternator condenser is expected to occur due to a combination of growth of macrofouling organisms, and blockages caused by weed or other materials.

BSL proposes to control macrofouling in the ICP condenser cooling water system with a combination of different control methods.

### 3.2.1 Mechanical Screening / Filtering

The salt water supply to ICP from the inlet channel would pass through a series of screens and filters to remove large macrofouling organisms, fish, and debris. This first line of defence is currently utilised in the existing No. 2 Blower Station and No. 1 Powerhouse cooling water systems. Experience has proven, however, that the screens and filters cannot prevent microscopic larvae and ribbon weed from entering the cooling water system. Weed has been found to be a significant contributor to fouling at Port Kembla.

### 3.2.2 Physical Cleaning

The ICP Turbo Alternator would be designed with a split condenser to create two parallel water circuits which could be individually isolated. The condenser is a "shell and tube" type heat exchanger, where heat from the turbine exhaust steam is transferred to salt water passing through small diameter tubes, leading to the condensing of the steam.

The ICP salt water system is shown in the figures listed below:

Figure 1. Overall Salt Water System Schematic – shows ICP condenser arrangement and location relative to salt water inlet channel and No. 2 Blower Station salt water supply

Figure 2. Average Operation – salt water flows and temperatures are shown for the average salt water supply temperature and average power generation (corresponding to average by-product fuel availability

Figure 3. Maximum Power Generation - salt water flows and temperatures are shown for the average salt water supply temperature and maximum power generation (associated with maximum steam generation due to high by-product fuel availability or "peaking" with natural gas)

The maintenance schedule for the turbo alternator allows for a major outage every six years and a minor outage every two years. During any of these outages, it would be possible to access and clean the interior of all of the condenser salt water components. Between these full access opportunities, it is possible to isolate half of the condenser to allow cleaning. Such a cleaning operation significantly reduces the capacity of the turbo alternator, and therefore reduces power generation and by-product fuel consumption.

During this physical cleaning operation, any build-up on the walls of the accessible pipework, waterboxes (the end chambers of the condenser), or the condenser tube plates (entrances to small diameter heat exchange tubes), is manually removed. The interior of the tubes is cleaned by the injection of "darts" through the tubes.

It is expected that this type of physical cleaning will be necessary every six months to remove material that is not controlled by other cleaning methods.

To prevent settling and growth of sufficient macrofouling organisms to affect equipment performance between scheduled turbo alternator maintenance outages, BSL intend to adopt one or both of the proposed thermal treatment, or Spectrus CT1300 dosing methods, described in the following sections, subject to further detailed investigation. It is BSL's preference to adopt a thermal treatment method. The Spectrus CT1300 methodology described would only be used if for some reason the proposed thermal method was not possible or successful. Approval is therefore sought to apply either of the methods below.

### 3.2.3 Thermal Treatment of ICP Turbo Alternator Condenser Cooling Circuit

The preferred thermal treatment option for ICP involves the periodic recirculation of the salt water discharge from the turbo alternator condenser outlet back to the cooling water pump inlet basin as shown in Figure 4. By controlling the proportion of the discharge returned to the pump inlets, the temperature can be raised to, and maintained at, a suitable level long enough to ensure fatality of target species.

Figure 4 shows the proposed flows and temperature distribution, if the treatment was conducted when the turbo alternator was operating at approximately half its maximum load, with a 5°C temperature rise in the salt water cooling stream. 40°C is the maximum condenser discharge temperature acceptable to the turbine supplier. A literature review suggests that 35-40°C appears to be a high enough temperature to achieve adequate cleaning. The time required at the elevated temperature to ensure fatality of the target species is a function of the starting temperature, as molluscs are able to acclimatise to the prevailing salt water temperature. It is expected that the treatment time would be in the order of 4-8 hours. It is also expected that the required frequency would be similar to that required for a chemical treatment program, proven at Port Kembla to be every four to six weeks.

While the system temperature was raised then held at the higher level, the heat load discharged to drain would not increase, remaining at approximately 50% of the design maximum in the case shown, with a lower discharge volumetric flow rate, and a higher temperature.

Harbour temperature modelling was carried out for the worst case scenario, ie. if the inlet water temperature was 25°C, where 10,000m3/hr of 40°C water was discharged to the harbour during summer conditions (see Cardno Lawson Treloar "BlueScope Steel Limited Illawarra Cogeneration Plant (ICP) Proposed Salt Water Cooling Numerical Cooling Water Studies Addendum Report" April 2008). The modelling showed that the temperature at any of the specified outlet locations would not be higher than those calculated for the "Maximum Heat-Load Conditions – Summer" case, and would therefore be acceptable.

Treatments would normally be carried out during low turbo alternator load operation, corresponding with low by-product fuel availability, to reduce power generation losses, and to minimise the likelihood of environmental impacts of the higher temperature discharge to drain during the treatment period.

### 3.2.4 Spectrus CT1300 Treatment of ICP Turbo Alternator Condenser Cooling Circuit

As previously mentioned, Spectrus CT1300 has been proven in operation at BSL Port Kembla as an effective control for macrofouling. Trials have been conducted to examine opportunities to reduce the concentration of the biocide in the discharge streams, by reducing the concentration at the inlet of the equipment to be cleaned, and extending the duration of the dosing to produce the same impact on macrofouling organisms. These trials are necessarily time consuming, as the only opportunity to confirm the adequacy of a particular concentration versus time dosing regime is an internal inspection of the equipment, which is possible only during scheduled maintenance periods, which are usually 6 months apart. The minimum acceptable dosing concentration and duration have not yet been determined.

The lowest dosing concentration trialled to date is 1 mg/L, trialled on the No 4 Turbo Alternator at the No. 1 Power House with a 24 hour dosing period. As described in section 2.6.5 above, the dosing duration was extended for the lower dosing concentration to provide a greater likelihood of successful cleaning.

The following discussion assumes that a dosing concentration of 1mg/L is proven to provide a successful cleaning outcome.

As shown in Figure 5,the ICP Turbo Alternator would be designed with a split condenser to create two individual water circuits which would be dosed separately with Spectrus CT1300 to control macrofouling. The cooling circuit discharge pipework would be combined in a tundish prior to piping to a discharge device at Allan's Creek.

The flows from the two individual sides of the condenser cooling water system would each be approximately 13500kl/hr. An additional flow of approximately 3000kl/hr of "Secondary Salt Water" from the Recirculated Water Cooling system heat exchangers and strainer back-flushing systems would be added into the condenser discharge.

If Spectrus CT1300 was dosed to produce a concentration of 1 mg/L at the inlet to one side of the new condenser, assuming 50% consumption within the condenser and salt water pipework, combined with the physical dilution from the flow from the other half of the condenser and the peripheral heat exchangers, would result in a discharge concentration of approximately 0.225 mg/L.

This expected discharge concentration is lower than:

- 5 min NOEC value of 0.37 mg/L for marine bacteria,
- quoted NOEC value of 0.3 mg/L for microalgae, and
- current No 2 Blower Station Drain discharge limit

BSL are committed to continued trials aimed at further reducing the dosing concentration and extending dosing duration, while maintaining an adequate degree of macrofouling control. Without further systematic trials, it would not be possible to lower the dosing concentration below 1 mg/L without risking operational problems due to excessive macrofouling. Due to the potential seasonal variation in consumption of the biocide, a limit of 0.25 mg/L appears appropriate until a lower level is proven to be achievable.

Upon discharge into Allan's Creek at the proposed location downstream of No. 2 Blower Station Drain discharge (which would not be dosed at the same time), it is expected that concentrations of Spectrus CT1300 would be further quickly reduced via dilution, adsorption and deactivation, and impacts on aquatic life would be quickly minimised. The sub-lethal ecotoxicology data demonstrates that there are no observable effects on fish larvae imbalance at a concentration of 1mg/L. This concentration is four times greater than the recommended discharge limit, and it would be expected that far higher concentrations of Spectrus CT1300 would be required to have a toxic impact on juvenile and adult fish.

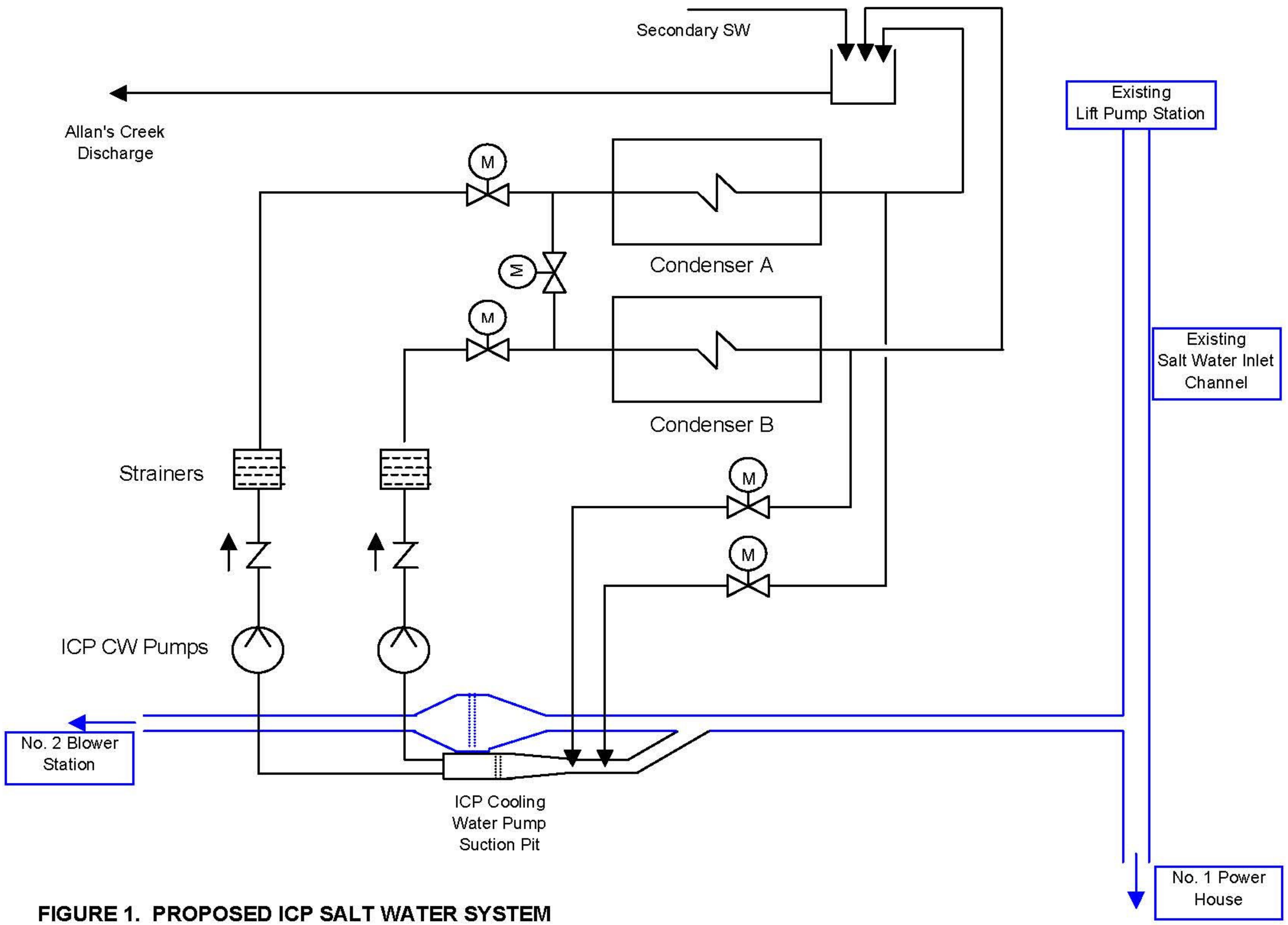


**FIGURE 1. PROPOSED ICP SALT WATER SYSTEM**

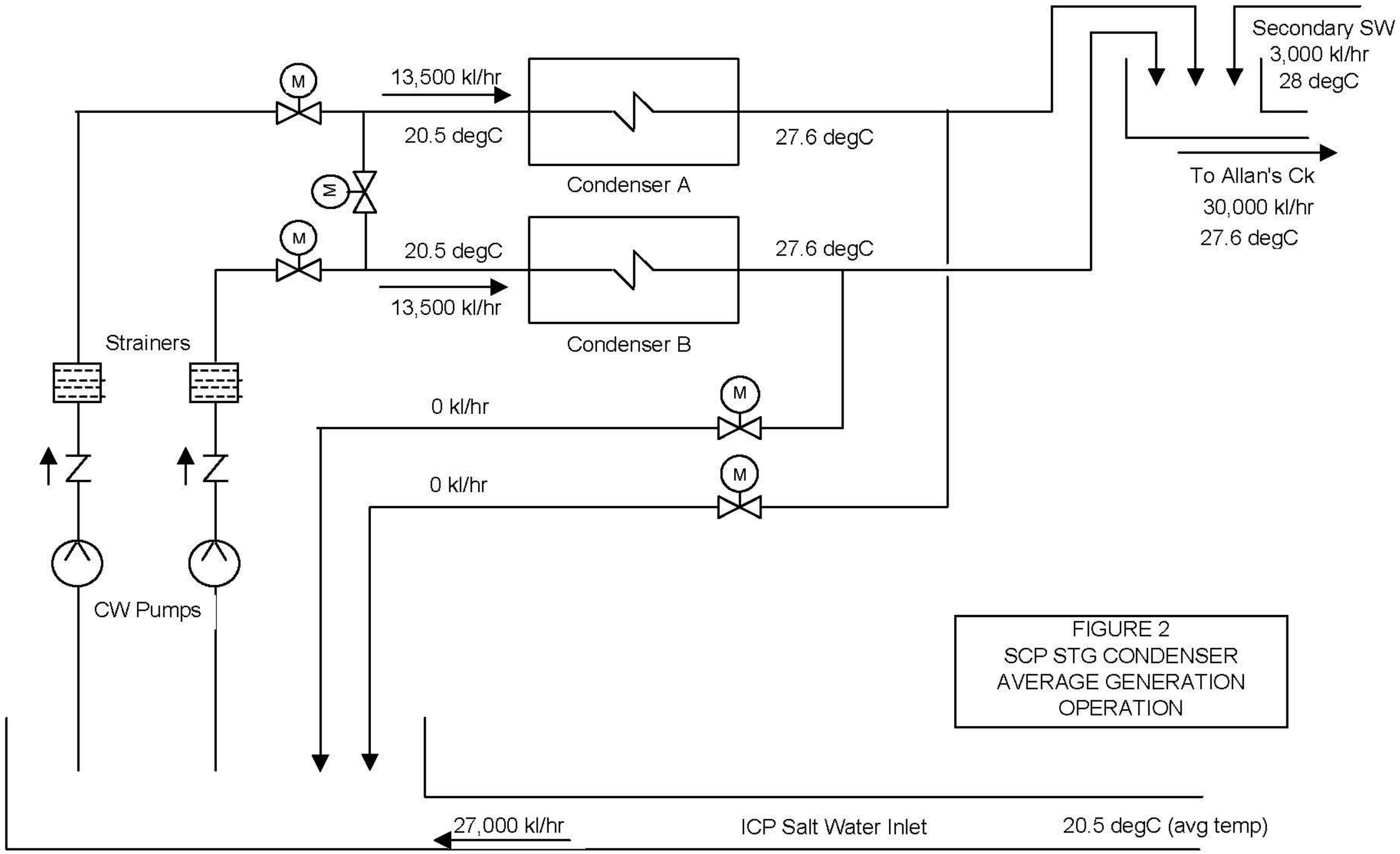


FIGURE 2
SCP STG CONDENSER
AVERAGE GENERATION
OPERATION

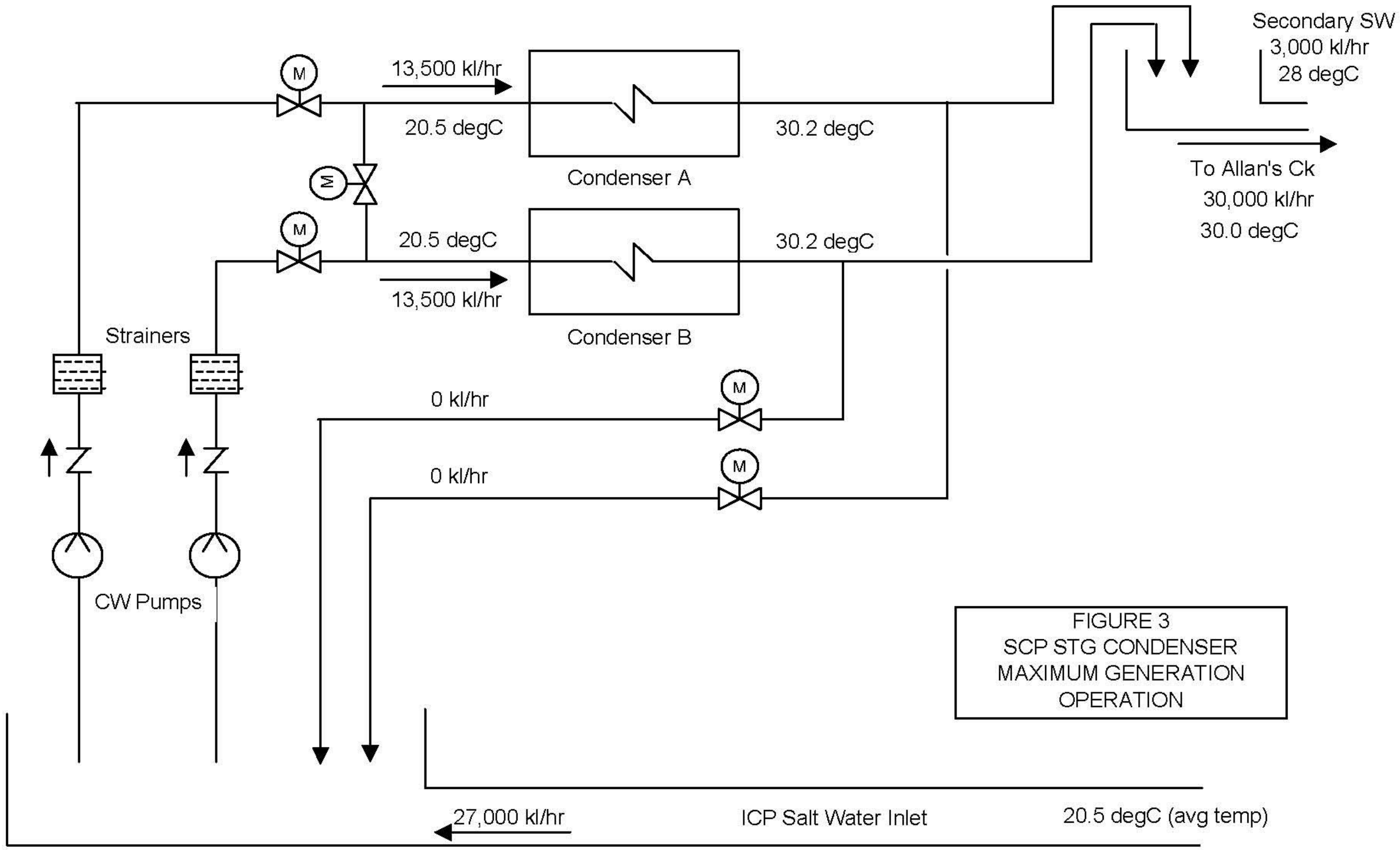


FIGURE 3
SCP STG CONDENSER
MAXIMUM GENERATION
OPERATION

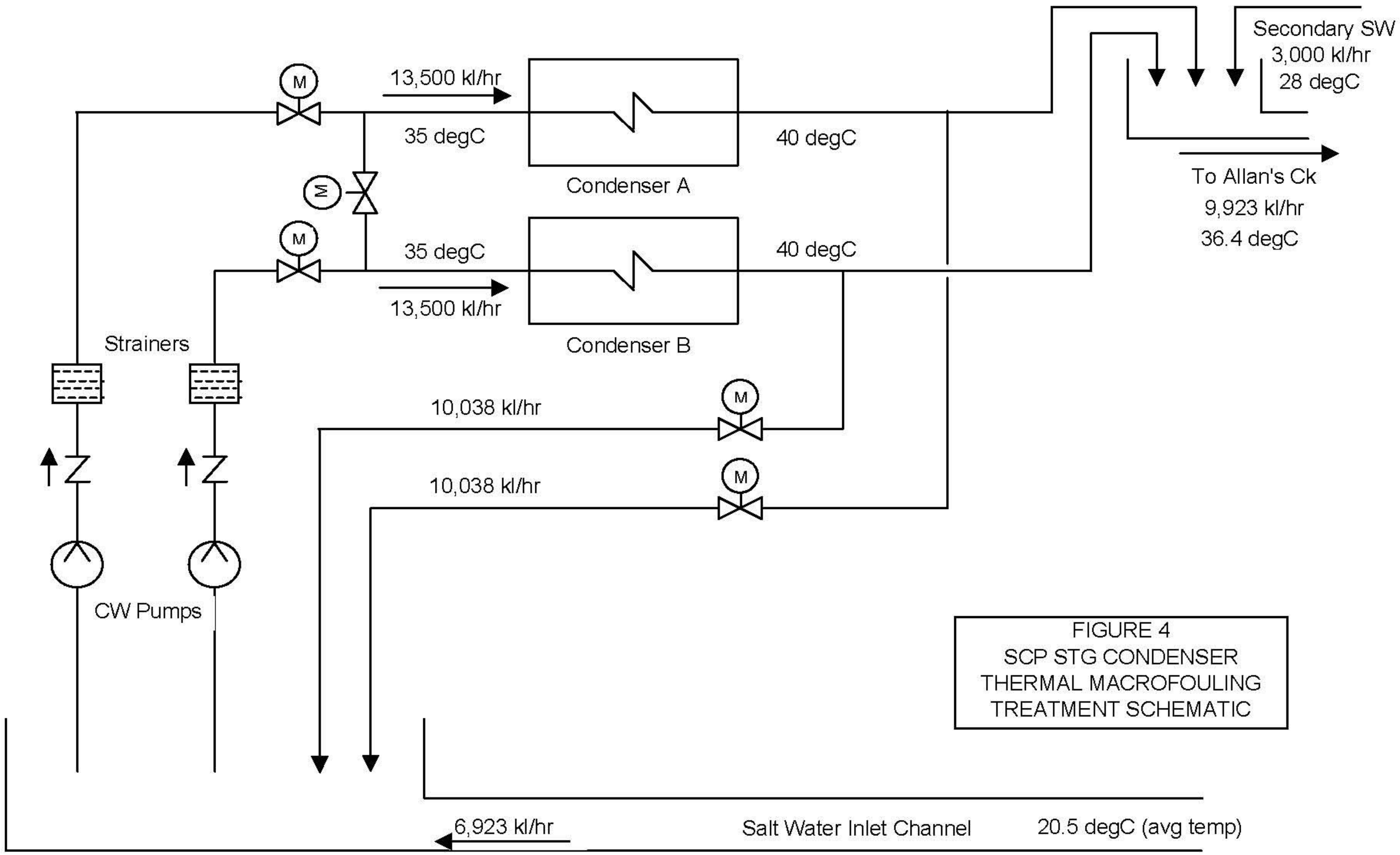


FIGURE 4
SCP STG CONDENSER
THERMAL MACROFOULING
TREATMENT SCHEMATIC

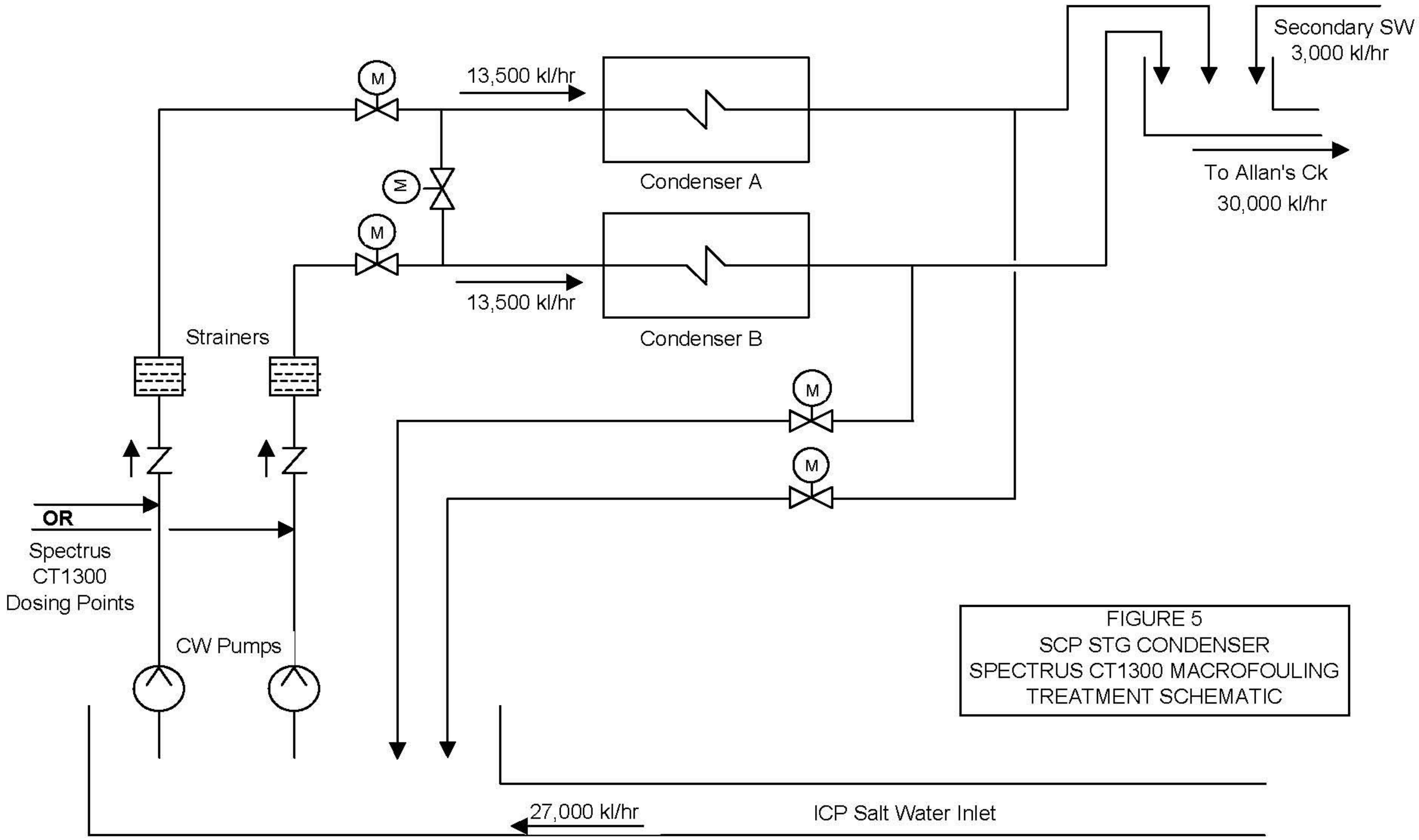


FIGURE 5
SCP STG CONDENSER
SPECTRUS CT1300 MACROFOULING
TREATMENT SCHEMATIC

#### 3.2.4.1 Proposed Dosing System

Dosing of Spectrus CT1300 would be conducted by GE Water and Process Technologies and administered by an automatic dosing system. This system would consist of a chemical storage feed tank, drawdown assembly with chemical dosing / metering pump, and a PaceSetter controller, and would minimise exposure and handling of Spectrus CT1300.

Based on BSL experience, the dosing system is expected to be highly reliable and would continuously measure the amount of chemical being fed against the calculated setpoint. Adjustments would be made to ensure feed accuracy is maintained at all times.

The drawdown assembly consists of a valve, control electronics, and a drawdown chamber to determine actual chemical delivery of the feed pump. Small deviations from the expected output would be corrected (in regular systems, deviations are often due to pump variations and changing head pressures) by adjusting the speed of the pump. Larger deviations from the expected output would trigger a pump trip and complete system shutdown. Any errors in drawdown limits, pump performance, or PLC results would also trigger a complete system shutdown.

The PaceSetter controller would manage the operation of the drawdown assembly and communicate directly to the central plant control system. It is known for its high reliability as it has four verified and separate chemical control loops (each unit is equivalent to four pre-programmed PLC's). The controller has capacity for local storage of data.

On-line monitoring of the quantities of Spectrus CT1300 dosed into the system would be provided by the PaceSetter Controller. System interlocks incorporating condenser cooling water pumps would be considered in further detailed design and risk studies. Emergency planning and response in the event of uncontrolled release of Spectrus CT1300 would also be considered in future risk studies.

The proposed dosing system would be a modernised version of the existing system, which has not failed (ie not overdosed biocide) since it's initial operation in 1995.

#### 3.2.4.2 Proposed Dosing Strategy

Spectrus CT1300 is currently dosed into each of the salt water cooling circuits at No. 1 Power House and No. 2 Blower Station at four-weekly intervals during summer and six-weekly intervals during winter. It is expected that a similar dosing interval would be initially adopted for the proposed ICP system. The duration of dosing would be based on the dose-time relationship required to achieve effective macrofouling control while maintaining discharge concentrations below licence limits. The current proposal is to implement a dosing strategy of 1.0mg/L for 24hrs with monitoring performed at -2, 1, 18, and 24hrs. Test data has shown that the discharge concentration during dosing is relatively static and therefore there is little value in conducting further sampling throughout the dosing period. GE Infrastructure (Water and Process Technologies) would be required to submit dosing reports similar to those they currently submit. These reports would detail the levels of Spectrus CT1300 measured at the licensed discharge point and would be sent to BSL Energy Services and Environment Departments shortly after dosing.

This proposed dosing concentration would be verified as part of the commissioning process; this is required for calibration of the dosing concentration with the background demand and the material chosen for construction of condenser cooling tubes (which may also impact on the performance of Spectrus CT1300). Positive verification of the dosing strategy would be via physical inspection during the first planned plant shutdown (half condenser inspection / clean expected to be 12 months from start-up).

During commissioning, dosing would commence at low concentration levels whilst monitoring the discharge in accordance with an operating procedure. This process would be repeated with a number of small step increments to raise the concentration levels in conjunction with discharge testing so that data may be obtained to finalise the on-line dosing rate and define the dosing control parameters. This closely monitored incremental process is designed to ensure concentrations of Spectrus CT1300 remain under discharge limits at all times. The GE Water and Process Technologies test procedure for biocide concentration is given as Attachment 1.

An operational procedure similar to the existing operational procedure for No. 1 Power House and No. 2 Blower Station would be developed to provide clear instruction for the operation of the dosing system within discharge limits. Experienced personnel from GE Water and Process Technologies would manage and operate the system in accordance with the operational procedure.

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**Attachment 1 – GE Water Spectrus CT1300 – Methyl Orange Method, Salt Water Test Procedure**

GE
Water & Process Technologies

**Analytical Procedure**

AP413

# Clam-Trol CT-2

## Mollusk Control Agent
## Methyl Orange Method
## Salt Water Testing
## (0.08 6.00 mg/L, as Clam- Trol CT-2)

### Summary of Method

In this procedure the dye in the CT-1 Buffer Reagent complexes with the active ingredients in Clam-Trol CT-2. This complex is extracted into 1, 2 - dichloroethane. The organic layer containing the complex is separated from the aqueous layer and dried with a drying reagent containing anhydrous sodium sulfate. The color intensity of the 1, 2 - dichloroethane layer is then measured in a spectrophotometer at 416 nm.

| Apparatus Required | Code |
|---|---|
| Beaker, glass, 50 mL (2 required) | ** |
| Cylinder, graduated, 25 mL | 2622 |
| Funnel Rack, separatory | 936 |
| Funnel, separatory, with a Teflon stopcock, 500 mL (2 required) | ** |
| Glass Rod | 114 |
| Optical Cell, (2 required) | ** |
| Safety Bulb, rubber | 1575 |
| Spectrophotometer | ** |

| General Apparatus* | Code |
|---|---|
| Cylinder, graduated, 100 mL | 121 |
| Cylinder, graduated, 250 mL | 917 |
| Flask, volumetric, 1 L, glass (4 required) | 935 |
| Pipet, glass, graduated, 1 mL | 140 |
| Pipet, glass, volumetric, 1 mL | 866 |
| Pipet, glass, volumetric, 3 mL | ** |
| Pipet, glass, volumetric, 5 mL | 124 |
| Pipet, glass, volumetric, 10 mL | 123 |
| Pipet, glass, volumetric, 15 mL | 861 |
| Pipet, glass, volumetric, 20 mL | 1278 |
| Pipet, glass, volumetric, 25 mL | 117 |
| Pipet, glass, volumetric, 30 mL | ** |

* The general apparatus required for the test is determined by the specific test procedure used.

** Apparatus not available through Lab Supply should be obtained through a local supplier.

| Chemicals Required | Code |
|---|---|
| 1, 2 - Dichloroethane (reagent grade or equivalent) | 1666 |
| CT-1 Buffer Reagent | 1591 |
| Methanol (reagent grade or equivalent) | 322 |
| Drying Reagent, with a plastic dipper | 1271 |

Find a contact near you by visiting www.gewater.com or e-mailing custhelp@ge.com.

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## Procedure

**Use a well-ventilated or hooded area to run the test. Always use a safety bulb when pipetting liquids.**

1, 2 - Dichloroethane (also known as Ethylene Dichloride) is a priority pollutant and a specifically-listed RCRA-regulated material subject to specific disposal restrictions and/or prohibitions. For this reason, all used 1, 2 - dichloroethane should be segregated from other waste streams.

Dispose of waste 1, 2 - dichloroethane in an approved manner (e.g., lab packing or incineration). A kit is available for disposal of used 1, 2 - dichloroethane. Contact Analytical Testing and Development in Trevose, PA for information (215-355-3300).

1. Refer to Table 1 for the appropriate range and volumes to use in this procedure. Transfer an aliquot of the water sample to a separatory funnel (the sample). Transfer the same volume of Clam-Trol CT-2 free system water to a second separatory funnel (the blank). Run the blank once for each set of samples tested (see Notes 1, 2, and 3).

**Table 1: Suggested Volumes for Various Levels of Clam- Trol CT-2**

| Range *a* Clam-Trol CT-2 (mL) | Volume CT-1 Buffer (mg/L) | Volume 1,2-Dichloroethane (mL) | Volume Sample (mL) | Optical Cell Size |
|---|---|---|---|---|
| 0.80 – 6.00 | 10 | 30 | 50 | 2.5 cm |
| 0.25 – 3.00 c | 20 | 20 | 200 | 1.0 cm b |
| 0.08 – 0.25 | 20 | 20 | 200 | 5.0 cm d |

a. The lower limit given in the range represents the minimum detectable limit for the test conditions listed.

b. The 1.0-cm cell (Code 1312) can be used with Betz spectrophotometers using a 1-cm cell adapter (Code 2776C).

c. To reduce waste solvent, you can also use 10 mL CT-1 Buffer Reagent, 10 mL 1,2 - dichloroethane, and 100 mL of sample for this range (1-cm cell).

d. Five centimeter cells are not available for use with the GE Water & Process Technologies DR 2000 photometers. Many laboratory spectrophotometers require an adapter to accommodate 5-cm cells. Check with the instrument manufacturer for details.

2. Add CT-1 Buffer Reagent to both the sample and the blank.
3. Using a pipets, add 1, 2 - dichloroethane to both separatory funnels.
4. Insert the stoppers in each of the separatory funnels. Invert and briefly open the stopcock to vent the funnels (see Notes 4 and 5). When venting the funnels, point the tip of the funnel away from yourself and others.
5. Shake the funnels moderately for 30 sec, vent the funnels, then allow them to stand for 10 min (but no longer than 15 min).
6. Collect the lower layer (1, 2 - dichloroethane) from each funnel in 50-mL beakers leaving about 1 - 2 mL in the funnel. This will prevent significant removal of water.
7. Using the plastic dipper, add 2 scoops of Drying Reagent to each beaker and stir with a glass rod for 15 sec (but no longer than 30 sec).
8. Wait approximately 1 - 2 min (but not more than 5 min). Then carefully decant the extract off of the drying reagent into an optical cell.

9. Set the spectrophotometer at 416 nm and zero with 1, 2 - dichloroethane. Measure and record the absorbance of the blank and the sample (see Note 6).
10. The sample absorbance minus the blank absorbance is used to determine the concentration of Clam-Trol CT-2 in the sample. From a prepared calibration curve, determine the Clam-Trol CT-2 concentration in the sample (see Calibration Curve Preparation).
11. Clean the cells after each measurement (see Notes 7 and 8).

## Calibration Curve Preparation

1. Prepare a 150 mg/L Clam-Trol CT-2 stock solution by accurately weighing 0.150 g of Clam-Trol CT-2 into a 1-L glass, volumetric flask containing about 500 mL of deionized water. Swirl to mix. Dilute to volume using deionized water. Mix thoroughly.
2. Pipet designated volumes of the stock solution into 1-L volumetric flasks. Dilute to volume using Clam-Trol CT-2 free system water. These are the standard solutions used in preparing a calibration curve. Use Table 2 to make appropriate dilutions of the stock solution for each specific application.
3. Follow the General Procedure using the specific solution volumes that have been determined for the application and prepare a calibration curve.
4. Determine the absorbance of a blank solution using Clam-Trol CT-2 free system water. This blank is subtracted from the sample absorbance or used to zero the spectrophotometer so that the calibration curve goes through the origin. The calibration curve should be linear over the indicated ranges.

**Table 2: Dilutions for Calibration Curve Preparation Based on a Final Solution Volume of 1 L**

| Concentration Clam-Trol CT-2 Desired (mg/L) | Clam-Trol CT-2 Stock Solution Added to Make 1 L (mL)* |
|---|---|
| 0.08 | 0.50 |
| 0.15 | 1.00 |
| 0.23 | 1.50 |
| 0.30 | 2.00 |
| 0.75 | 5.00 |
| 1.50 | 10.00 |
| 3.00 | 20.00 |
| 4.50 | 30.00 |
| 6.00 | 40.00 |

* Dilutions should be made using Clam-Trol CT-2 free system water.

## NOTES

1. For maximum accuracy the calibration curve should be checked by every operator using this test and should be verified a minimum of twice per month using a freshly prepared Clam-Trol CT-2 standard.
2. A blank measurement (the blank should be a sample of the system water prior to Clam-Trol CT-2 treatment) must be recorded for each set of samples (i.e., each sample point tested). The blank reading may vary slightly; however, the absolute difference between the sample and the blank remains relatively constant.
3. Chlorine causes a negative interference in the test. This can be eliminated by adding 0.1 N Sodium Thiosulfate (Code 235) to the water sample before running the test. The amount added is based on the concentration of chlorine in the system. For a 100-mL water sample containing 0.3 mg/L chlorine, add 10 drops of 0.1 N Sodium Thiosulfate to remove the interference.
4. A slight emulsion may form when using natural water samples. When this happens, vary step 5 of the procedure. Shake the funnel for 30 sec, vent it, then allow it to stand for 5 min. Gently invert the funnel once then allow the funnel to stand for 5min.
5. It is important to vent the separatory funnel both before and after shaking it. Otherwise, a pressure will build up in the funnel that can cause the stopper to be forced out of the top of the funnel.
6. Use caution when inserting or removing the sample cell in the photometer. The 1,2 - dichloroethane can damage the cell compartment.
7. It is imperative that the sample cells are kept clean during the running of the test. It is recommended that the cells are cleaned after each measurement using the following procedure:

   a. Rinse the cell three times with distilled (or deionized) water.

   b. Rinse the cell three times with methanol.

   c. Rinse the cell three times with 1, 2 - dichloroethane to remove methanol from the cell.
8. Separatory funnels must be cleaned following each test. Use the following cleaning procedure:

   a. Drain the aqueous layer out of the separatory funnel.

   b. Rinse the funnel with methanol (make sure no traces of yellow are left in the funnel).

   c. Rinse the funnel with deionized water. (Small amounts of water may remain in the funnel. This will have no effect on the test.)
9. Turbidity can interfere with this test procedure. Turbidity may:

- Create an emulsion in the 1, 2 – dichloroethane layer that does not separate after standing for 10 min when the funnel is shaken .
- Create a positive interference. ( A yellow color is extracted into the 1, 2 – dichloroethane layer. )

These problems can be removed by centrifuging the sample (10 min at 3500 rpm or 30 min at 2500 rpm) before performing step 1 of the procedure.

10. Do not change test conditions (i.e., use different volumes than those given in Table 1). Contact the Analytical Testing and Development Group in Trevose, PA for assistance if you experience any difficulties running this test.
11. When using this test to measure Clam-Trol CT-2 levels below 0.30 mg/L, you must pretreat the glassware before testing begins. Contact the Analytical Testing and Development Group in Trevose, PA for assistance.
12. This method is adapted from Wang, L. K., Langly, D. F., *Ind. Eng. Chem., Prod. Res. Dev.*, 1975, 14, 3, 210-212.