Engineering Data Sheet

Product: CAKE™ (Capture And Kill Effect) Process Ballast Water Treatment System

Application Description

Untreated ballast water has become an international problem of massive significance because of the associated translocation of invasive marine organisms. These countless differing organisms have caused widespread ecosystem damage throughout the world costing billions of dollars annually to invaded habitats. Consequently, an international research and regulation effort has progressively evolved since 1980 for the purpose of identifying strategies for controlling species introductions via ballast water. At present, the only control practice is mid-ocean ballast exchange that consists of reballasting or ballast dilution. This particular control method is considered a quite modest starting point for much more effective ballast water treatment technologies yet to be developed.

Treatment Procedures

- Onboard port treatment
- Onboard in-transit treatment
- Shore based treatment
- Port based treatment
- Mobile treatment
- Treatment during ballasting
- Treatment during de-ballasting

Treatment Options

- Mechanical filtration and cyclonic separation
- Physical such as ozone, ultraviolet light (UV), heat, ultrasound, and electric/magnetic
- Chemical such as chlorine, hydrogen peroxide, copper/silver ions, chlorine dioxide, halogens, tank coatings, radiation, and biocide addition
- Combinations of the above

Since all ocean-going vessels must limit their stay in port, ballast water must be managed in a most timely and cost-effective manner. This is a very challenging task since proposed ballast water management is moving away from ballast exchange and towards ballast water treatment with a discharge requirement of a **sterile effluent containing zero live marine organisms**. Until the development of the CAKE™ capture and kill effect process, *not a single ballast water technology provider has yet accomplished, or attempted to achieve, either a sterile discharge or a near 100% organism kill.*

Ballast Water Variables

- Fresh Water
- Salt Water
- Heavy solids loading
- Light solids loading
- Clear water
- Colored water
- Many organisms
- Few organisms
- Temperature from 1-35ºC
- Salinity from 500-45,000 mg/L TDS
- Dissolved Oxygen from 0.5-13.4 mg/L
- Dissolved iron from 0-85 µg/L

To be process effective, a ballast water treatment system should accommodate each and all of the above variables without adverse impact on either treatment cost or effluent quality.

Developing Treatment Technologies

Velox Technology, Inc. is developing a two-stage shipboard in-transit ballast water treatment system consisting of cyclonic separation followed by UV light radiation. The ballast water is treated at the full rate of ballasting. The cyclonic separator clarified water is then sterilized through UV light radiation and subsequently discharged to the ballast tank(s). The reject stream from the cyclonic separator is returned overboard. Marine organism kill is marginal.

OptiMarin AS/Hyde Marine, Inc. is developing a three-stage onboard ballast water treatment system consisting of cyclonic separation followed by filtration and lastly by UV light radiation. On large flow applications the filtration step is omitted. The reject stream from the cyclonic separator is returned overboard. Marine organism kill is marginal.

Ontario Hydro Technologies has just recently completed pilot testing of a 1,500 USGPM (340 m^3/h) two-stage automatic backwash filtration system as part of *The Great Lakes Ballast Technology Demonstration Project.* The demonstration testing program was accomplished onboard the M/V Algonorth using 25, 50, and 100-micron filter screens. Although filtration appears promising from a treatment standpoint, about 10% of the ballast water is necessarily used to backwash the filters. The filter backwash water is returned overboard which therefore limits the use of this technology.

CAKE™ Process design and application engineers carefully reviewed and subsequently eliminated consideration of the following technologies in developing a final process design:

Ultraviolet light

1. Not effective for all organisms
2. Not effective for colored ballast water
3. Exhibit tendency toward scaling
4. Tubes use mercury as its fuel source
5. Tubes lose half of their biocidal effectiveness in six months and require yearly replacement

Cyclonic separators

1. Are highly ineffective at removing organisms that have specific gravities very close to that of their liquid environment. For effective cyclonic separation, there must exist a meaningful specific gravity differential of at least 0.15, and preferably more.
2. Are highly inefficient at removing small particles, i.e., less than 100 microns in size and therefore
3. Do not belong in ballast water treatment since they are incapable of significant or effective removals of marine organisms.

pH Control as far too expensive, even if effective.

Overboard discharge of all ballast water treatment side streams.

1. To be marine habitat friendly, an effective ballast water treatment system ought to capture and kill invasive marine species rather than permit their automatic release back to the environment.
2. Fresh water lakes and oceans should not be viewed or used as disposal sites.

In-transit heating of ballast water as ineffective.

The use of chlorine, bromine, iodine, hydrogen peroxide, chlorine dioxide, and copper based **biocides**

1. Because other clearly harmful by-products are produced,
2. And are far too expensive, even if effective.

Magnetic, ultrasound, and electronic treatment technologies as generally ineffective since none either kills or captures marine organisms.

Treatment during ballasting or de-ballasting because

1. These treatment systems are necessarily large, expensive, and used only during these operations.
2. Much smaller and more economical systems may be utilized around the clock to achieve the same results.

CAKE™ Process design requirements included the capability to treat both fresh and salt water, heavy and light solids loadings, clear and colored waters, all possible marine organism concentrations, a liquid temperature range of from 1-35°C (34-95°F), salinities from 500-45,000 mg/L TDS, dissolved oxygen from 0.5-13.4 mg/L, and dissolved iron from 0-85 µg/L. Three-stage treatment consists of two stages of sequential bag filtration followed by third stage ozone disinfection. Onboard treatment systems will treat ballast water only during transit. Mobile/port based systems will accommodate routine ship de-ballasting and treated ballast water re-supply by using barges as moveable storage containers. The **CAKE™** treatment system will normally be located on the de-ballasting receiver barge.

First stage bag filtration removes essentially all particles down to 50-microns in size. Second stage bag filtration removes essentially all particles to 1-micron in size. The 2-stage bag filtration system therefore effectively captures all marine organisms except bacteria, viruses, and toxins. The bag filter captured organisms are subsequently killed by steam autoclaving at +300°F (~150°C) for 1 hour. The bag filtered ballast water is completely disinfected by intense Ozone contact for about 1 minute. When treating ocean ballast water, Ozone reacts with bromides in seawater to form hypobromous acid, and to a lesser extent with amines to form bromamines, both of which provide residual disinfection. When treating fresh water ballasts, ozone itself provides the residual.

A filter aid addition system is provided to enhance the filterability of difficult-to-filter ballast waters. The idea is to fill up the bags before they plug up. Adding filter aid in the body feed mode greatly enhances system filterability. Filter aid is not expected to be used on a routine basis, only in case of rare necessity. Duplex bag filters are provided to achieve continuous ballast water treatment during steam autoclaving and bag change-out operations.

Steam, boiler water make-up, and ozone generation are integral and essential components of the treatment process. Ship electricity will be used for onboard units whereas diesel powered generators will provide necessary power for barge-based units. A process flow schematic is shown on engineering drawing S-2250. Onboard and barge based treatment units are shown on engineering drawings S-2251 and S-2252, respectively.

Sequence Of Operations

Ballast water is sequentially pumped through two bag filters in series flow, an eductor, a pulse blender static mixer, and lastly a flow meter before discharge. The bag filters are hydraulically oversized by a factor of 10 in order to achieve a very conservative filtration rate. The slower the rate the greater the ability of the bag to fill up before it plugs up.

- A differential pressure gauge is located in front of each duplex bag filtration system. When the differential pressure reaches 35 psig, the flow is automatically diverted through a 3-way valve to the out-of-service filter.
- After a programmed delay, a bag filter drain valve opens to permit air-pressurized expulsion of captive filter water to the inlet side of the feed pump. After a programmable time delay, the compressed air inlet valve is shut off automatically.
- Steam is then automatically initiated to the filter. The filter is equipped with a pressure release valve set at 100 psig. At this pressure, saturated steam exists at a temperature of 316°F (158°C). Excess steam slowly bleeds to the environment through the pressure relief valve. Steam supply is automatically terminated after a programmable delay of one hour
- The bag filter is then allowed to cool for about one hour. The filter can then be opened to remove the filter bags filled with dead marine organisms. The bags may be lifted out and disposed of as ordinary solid wastes.
- After new bags have been installed and the filter closed, water is manually introduced from the discharge side of the 1-micron bag filter for the purpose of flooding the filter. Captive filter vessel air is discharged through a combination air/vacuum release valve. When all air is fully exhausted, the bag filter is again ready for service at its next duty cycle.
- The vast majority of marine organisms are removed through bag filtration. Residual organisms may consist of bacteria, viruses, and toxins. The bag filtration effluent flows into an eductor where it is intensely mixed with aspirated ozone in its vena contracta or throat section. The eductor also beneficially acts as a flow-throttling device that maintains a quite constant rate of flow through the bag filters. Constant flow translates into a lesser tendency on the part of the bag to plug.
- Significant Ozone/ballast water mixing continues to occur in the following pulse blender static mixer for a period of some 60 seconds. The half-life of Ozone in seawater is about 5 seconds due to its reaction with ever-present bromides. In fresh waters, the half-life of Ozone is about 20 times greater. It is therefore important to always achieve maximum mixing between Ozone and marine organisms over a minimum time period. It is also important to reduce the concentration of organisms other than bacteria, viruses, and toxins to reduce competing Ozone demands. In so doing, maximum marine organism kill can be achieved.
- The relatively high dosage of Ozone is to accomplish virus kill as bacteria and toxins are far less resistant to Ozone destruction.
- A composite sampler is provided for the purpose of testing the efficacy of treatment.
- The flow meter indicates the instantaneous rate of flow as well as the totalized flow. During routine operations the flow totalizer can be monitored to approximately determine the next bag filter service requirement. Between bag filter servicing, the ballast water treatment system is fully automatic requiring but minimum attention.

Operational Requirements

- Onboard treatment units: 4-6 hours/day for each 500 USGPM treatment unit.
- Barge based units: 2 full time operators/8-hr shift for each 4,000 USGPM treatment capacity.

Onboard Treatment Requirements

May require more than one treatment unit depending on ballast water capacity and transit time requirements. If more than one unit is necessary, it may be located remotely to accommodate ballast water piping requirements.

Barge Requirements

Entirely site specific. Larger ports like the Port of Seattle, Washington will require a barge ship consisting of two or more ballast water receiver and companion treated ballast water storage barges. Barge size and monthly ballast water treatment requirements will determine the components of the barge ship as well as total treatment capacity. Smaller port requirements will be less.

Modular Component Construction permits the increase or decrease of total capacity by adding or removing individual treatment units. This design feature enables mobile port-based units to easily and rapidly change their total capacity in response to changing ballast water treatment requirements. Additionally, since a single design will likely satisfy all ballast water treatment requirements worldwide, individual units may be deployed indiscriminately on an international basis without sacrificing treatment efficacy. This is therefore an ideal situation for a single service company to offer mobile/port based ballast water treatment on a global basis. Each port could then continue to concentrate on its primary responsibility of accommodating and managing international trade in a traditional manner rather than taking on a new role of ballast water treatment.

Ballast Water Treatment

Using The **CAKE™**

Capture and Kill Effect Process

Existing Technologies

- Use High Flow Cyclonic Separation Followed by Ultraviolet Light Disinfection
- Use High Flow Automatic Backwashing Screens Followed By Ultraviolet Light Disinfection

These Technologies Are Highly Inefficient Because…

Cyclonic Separators

Are Designed To Remove

- Large Particles
- Heavy Particles

However…

- Marine Organisms Are Small
- Marine Organisms Are Light

And…

- The Few Marine Organisms Separated Are Discharged Overboard And
- The Remaining Organism Population Cannot Be Effectively Disinfected By Ultraviolet Light

Automatic Backwashing Screens

- Do A Far Better Job Than Cyclonic Separators In Removing Marine Organisms

But…

- Discharge Marine Organisms Overboard, And
- The Remaining Organism Population Cannot Be Effectively Disinfected By Ultraviolet Light

UltraViolet Light

- Is Highly Ineffective Technology On Colored Ballast Water
- Is Generally Ineffective Technology On Other Ballast Waters
- UV Light Tubes Lose About 50% Of Their Initial Biocidal Effectiveness In 6 Months
- UV Light Tubes Must Be Replaced Annually As Their Mercury Fuel Becomes Fully Depleted
- UV Light Tubes Are Expensive
- UV Light Tubes Carry Mercury Disposal Considerations

Existing Technologies

- Are designed for on-board use only
- Require the use of the ship's existing de-ballasting pumps
- Require the modification of the ship's existing de-ballasting pumps
- Apply ballast water treatment only during de-ballasting operations
- Are High-Flow Treatment Devices

The CAKE™ Process Features

- Around-The-Clock Low-Flow Rate Treatment In
- The Capture And Killing Of Marine Organisms

Utilizing …

- Steam Autoclaving and
- Biocidal Ozone

The CAKE™ Process Effectively Treats

- Salt And Fresh Waters
- Heavy And Light Organism Loadings
- Clear And Colored Ballasts
- All Organism Concentrations
- Temperatures From 1-35°C (34-95 °F)
- Salinities From 500-45,000 mg/L TDS
- Dissolved Oxygen From 0.5-13.4 mg/L
- Dissolved Iron From 0-85µg/L

The CAKE™ Process

- Does Not Require the Modification of the Ship's Existing De-ballasting Pumps
- Does Not Require the Use of the Ship's Existing De-ballasting Pumps
- Can Be Used On-board As Well As A Mobile Port-Based Treatment System

The CAKE™ Process Consists Of

- 50-Micron Bag Filtration Followed By
- 1-Micron Bag Filtration Followed By
- Biocidal Ozone Addition

The Bag Filter Captured Marine Organisms Are Subsequently Killed By Steam Autoclaving At +300°F (~150 °C) For 1 Hour

Marine Organisms Escaping Filtration Are Subsequently Killed By Ozone Biocide Treatment

Difficult-To-Filter Ballast Waters

- Are Made Quite Filterable By Applying A Very Conservative Filtration Rate
- Can Be Conditioned To Be More Filterable By Adding Filter Aid As a Body Feed

Site Generated Ozone

- Is Made From Site Generated Oxygen Using Pressure Swing Adsorption Technology
- Is Introduced To The Ballast Water In An Eductor Where Intense Mixing Occurs
- Is Thereafter Additionally Mixed With Ballast Water In A Downstream Static Mixer Where Significant Mixing Occurs
- Site Generated Ozone Eliminates The Necessity For Its Transportation To The Use Site

Bag Filters

- Are Provided in Duplex Sets to Permit Continuous Treatment While Steam Autoclaving And Subsequent Bag Filter Maintenance Is Accomplished

The CAKE^{TM} Process Is User Friendly

- Fully Automatic Operation Except For Filter Bag Removal And Replacement
- Little Operator Skill Required

Operational Requirements

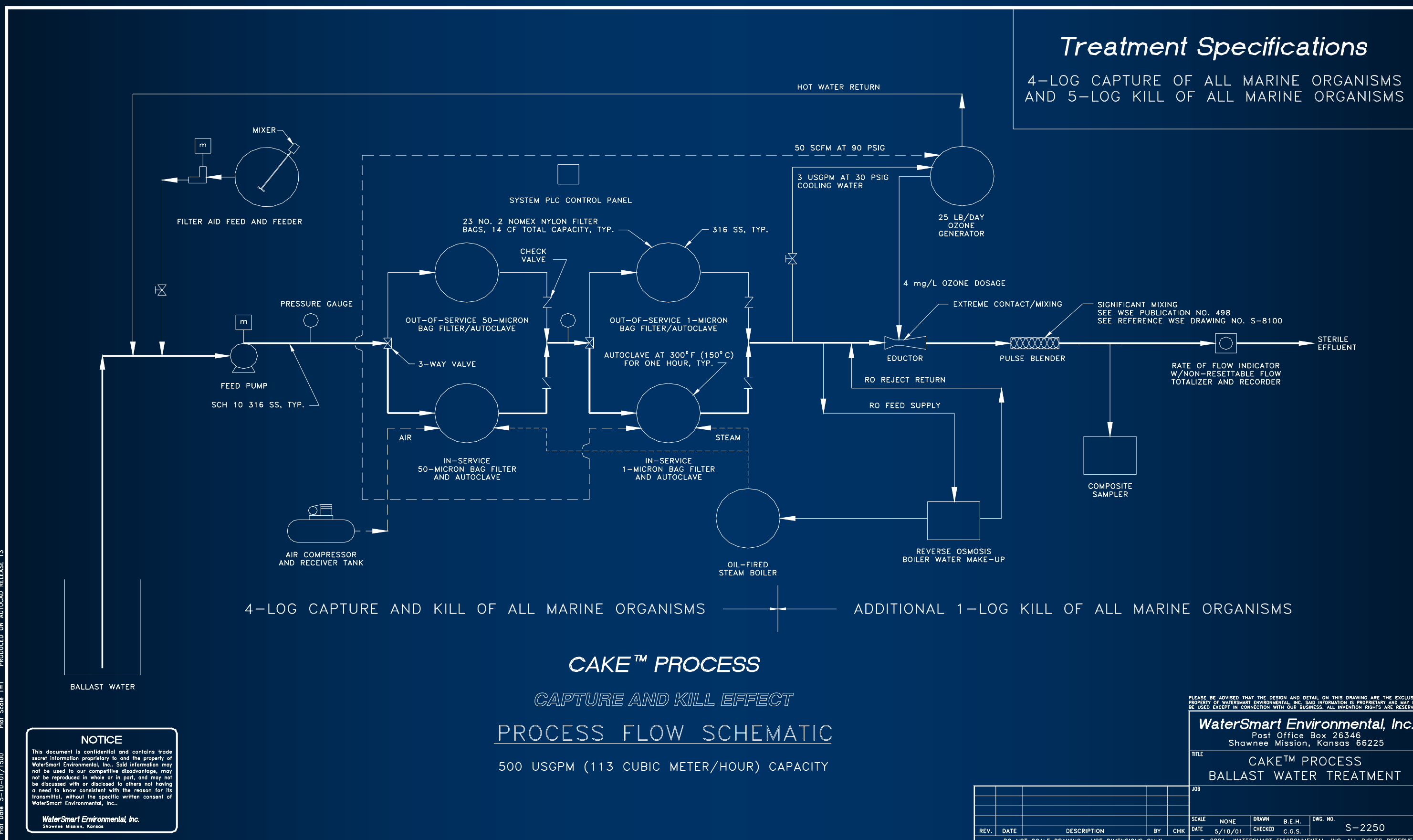
- Onboard Treatment:

  4-6 Hours/Day For Each 500 USGPM Unit
- Barge/Mobile Based Treatment:

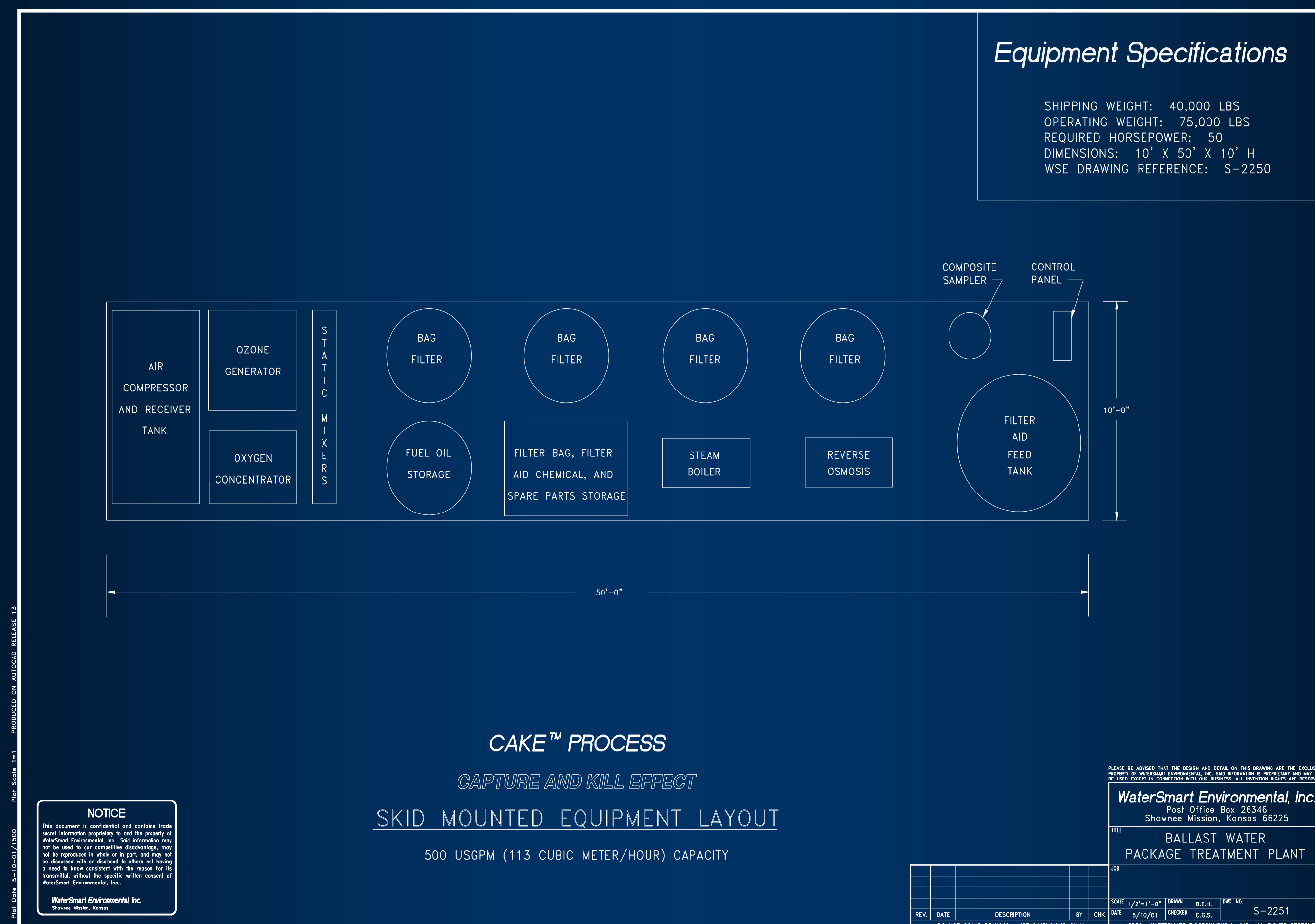
  2 Full-Time Operators/8-Hour Shift For Each

  4,000 USGPM Treatment Capacity

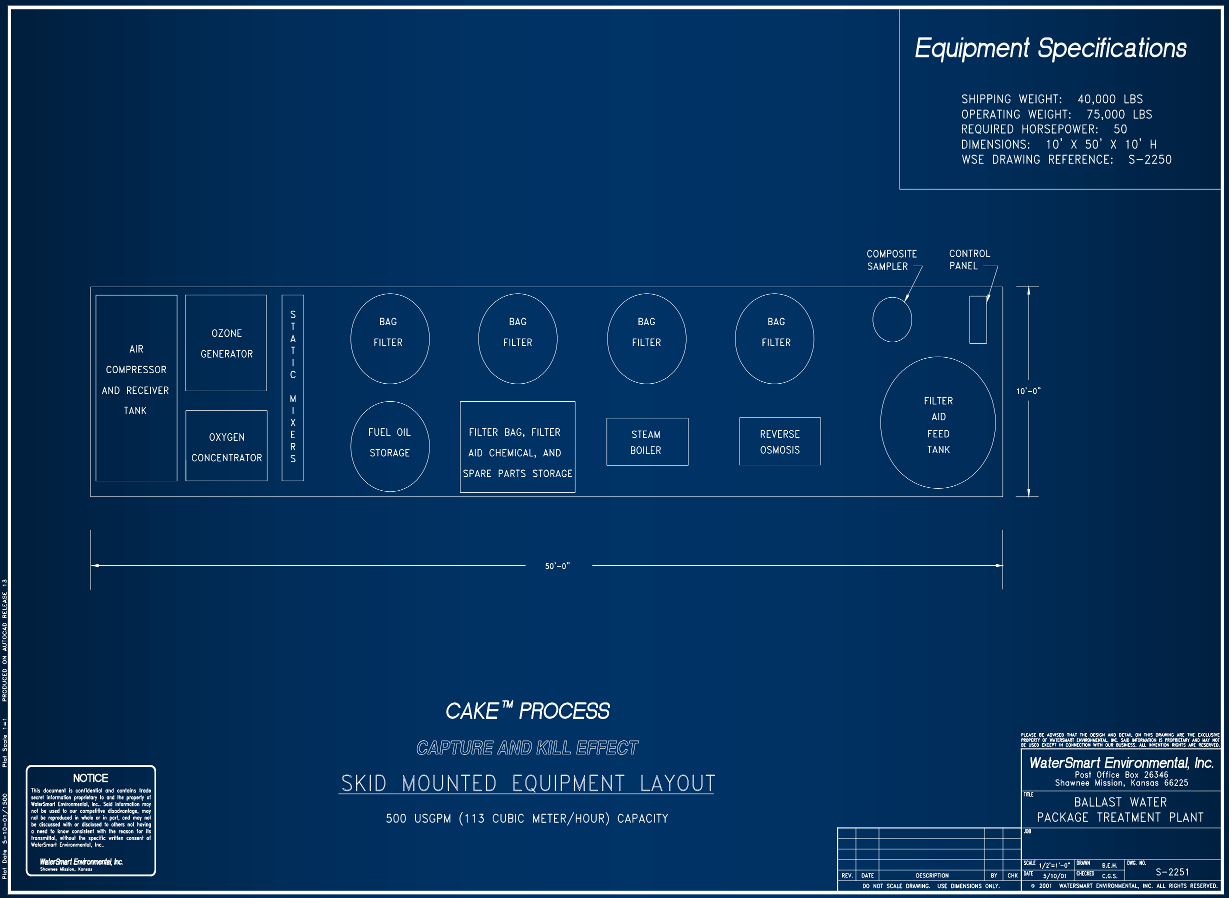
The CAKE™ Process



Onboard In-Transit 500 USGPM Unit



Mobile Barge Based 4,000 USGPM Unit



CAKE™ Process Proprietary and Confidential

Strictly Controlled Disclosure To Architech/Engineer Consultants, Governmental Agencies, And End Users

Additional Information

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