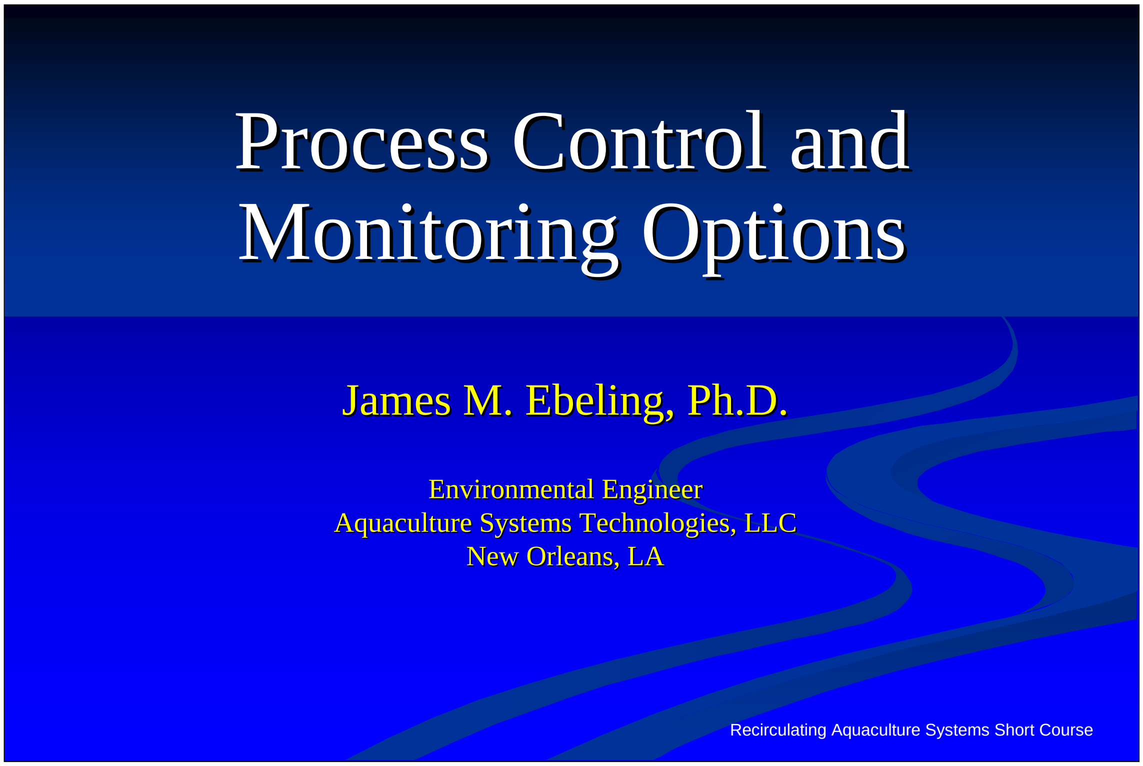



**Introduction**

Intensive recirculation systems have the potential for a significant increase in production per volume of water, but at the increased risk of catastrophic loss due to equipment or management failures. In addition, the managers of these intensive production facilities need accurate, real-time information on systems status and performance, in order to maximize their production potential. At production densities approaching and even exceeding a pound of fish per gallon of water (120 kg/m3), failure of a circulation pump or aeration system can result in severe stress to the fish or even significant losses within minutes. Expensive and sophisticated monitoring and control systems and components from other industries, such as the wastewater and petroleum industries, have been successfully modified for use in aquaculture. However, only a small fraction of their processing power is usually employed, due to aquaculture's relatively simple monitoring and control demands, i.e., digital inputs/outputs. Today, with the rapid decrease in costs for computers, software, and off-the-shelf monitoring hardware, systems of this type are within the reach of even small producers and are mandatory for large-scale production facilities.

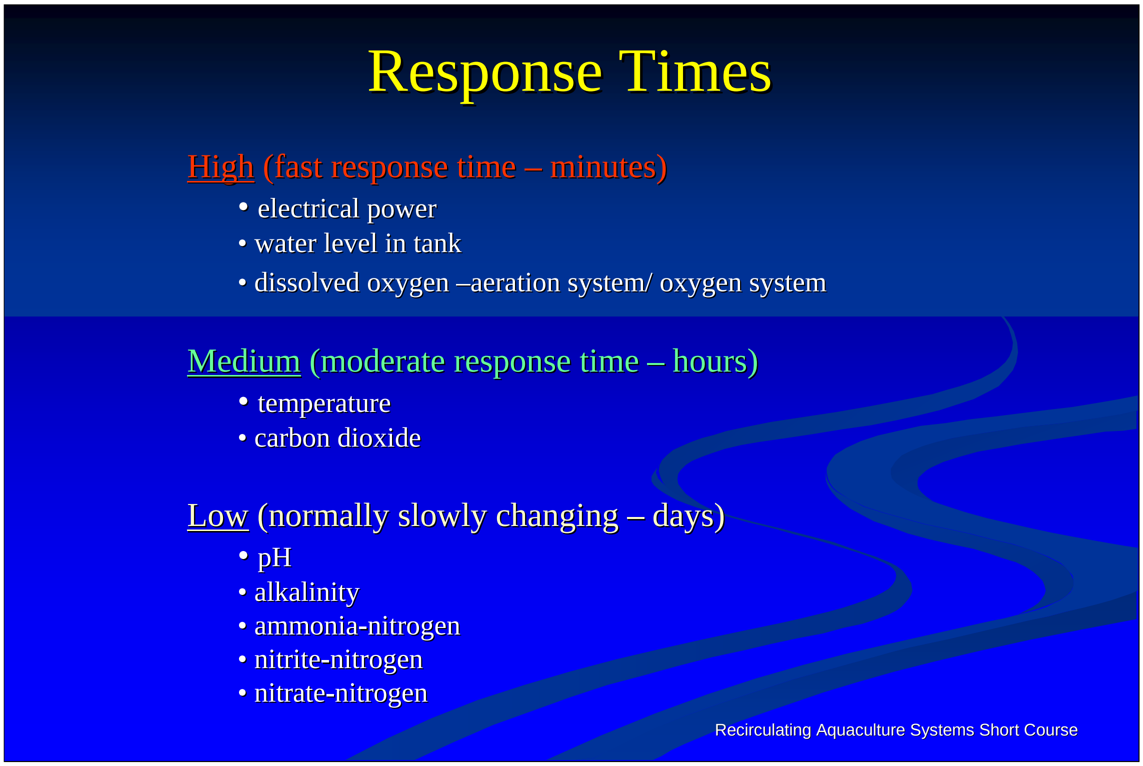

Before going any further, it should be emphasized that the most sophisticated (and normally, the most under appreciated and paid), monitoring and alarm system is an attentive human operator. Experienced staff can detect whether something is amiss the moment he or she steps into a facility, often just from the change in background noise. In the real world though, most facilities are not staffed 24 hours a day. Moreover, the watery environment of aquaculture is totally different from what most "air-breathing" operators are accustomed too, requiring the need for automated monitoring of critical water quality parameters and system components.


Murphy's Law states simply states that: if anything can go wrong, it will (authors note: "and usually at 4:00 am on a Sunday morning"). Determining what can go wrong and generating a list of worst-case scenarios is a never-ending quest. From the authors' personal experiences, no matter how hard you try or how long your list is, there will always be a surprise in the near or far future and usually at the most inconvenient moment. Table 1 presents a short list of potential emergencies. It makes a good place to start, and then let your imaginations go wild, and assume that anything is possible, no matter how impossible it may seem!

Keep in mind though, that it is also important during this initial design process not to go overboard in terms of technological complexity or in the sheer number of monitoring points and alarms. Sophisticated alarm systems are of little use, if the part-time help disarms them due to their unreliability and frequent false alarms. Has such a thing happened? Yes!

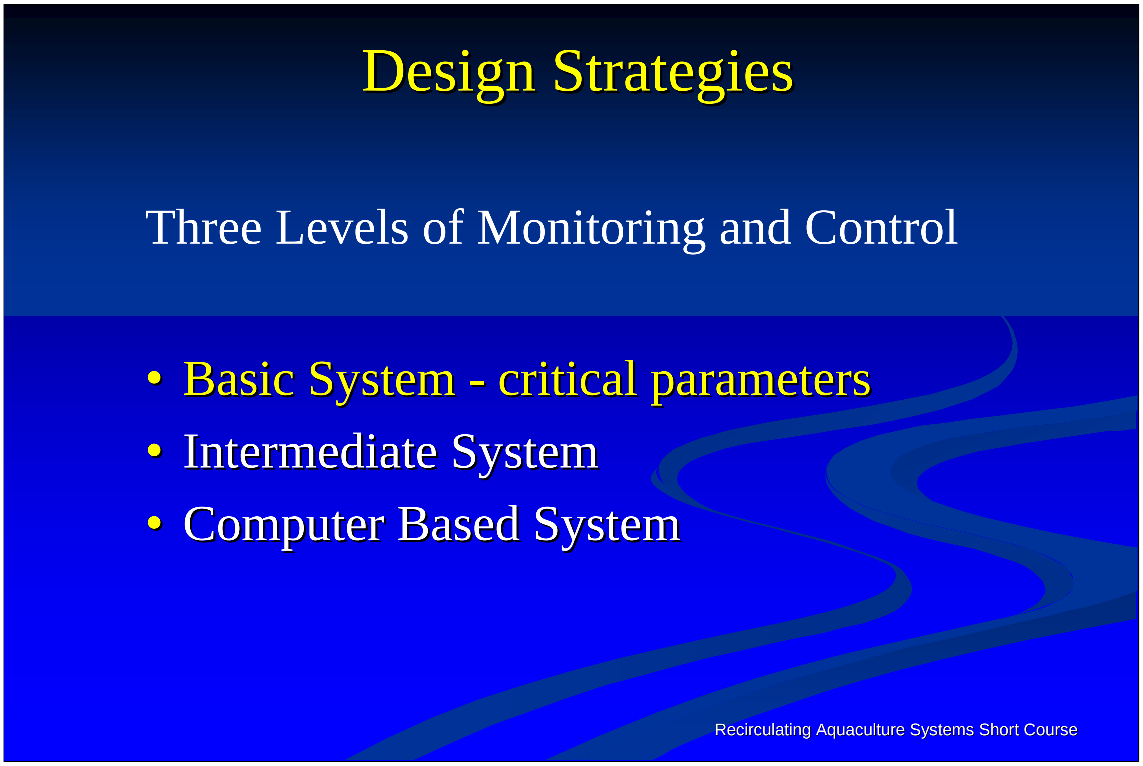
# What Processes Do I Have In Place to Respond to Emergencies

- Ready Phone List
  - **Plumbers**
  - **Electricians**
  - **Staff**
  - **Fire/Emergency**
- Trained Staff
  - **Logical Troubleshooting Procedures**
  - **Triage**
  - **Call for addition HELP!**
  - **Safety**
- System Designed to Fail Reliably

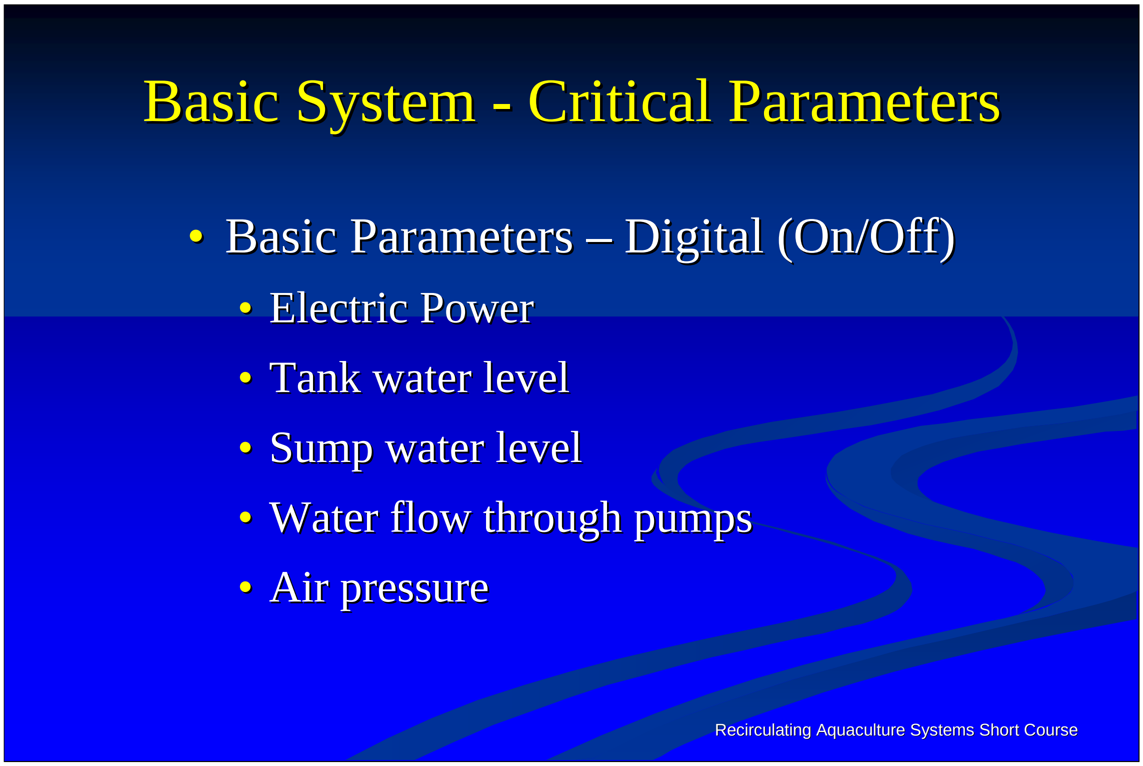



When compiling a list of potential problem areas and water quality parameters, keep in mind the relative importance and the required response time each will require. Life support priorities in aquaculture start with water, followed immediately by adequate levels of dissolved oxygen.

Then come the other water quality parameters, correct temperature, pH, and alkalinity, and finally, acceptable concentrations of ammonia-nitrogen, nitrite, nitrate, and carbon dioxide. At high stocking densities (greater than 1/3 lb/gal, 40 kg/m3), dissolved oxygen requires the most rapid response time. If either water flow or aeration is cut for any number of reasons, low oxygen and the resulting stress can lead to disease problems and/or mortality within minutes. Thus in the design of intensive systems, a simple audible alarm in the office may not be adequate, or even a pager if the manager lives 20 minutes away. Therefore, in addition to the monitoring, some form of backup aeration must be provided for and automatically engaged to insure survival of the fish. Except for dissolved oxygen, most of the other water quality parameters change relatively slowly and can take hours or days to reach levels of concern. This allows more time to discover and analyze the problem and take the necessary steps to correct them.




At low stocking densities (less than 0.33 lb/gal, 40 kg/m3), basic parameters to be monitored include system electrical power, tank water level (high and low), aeration system pressure, and water flow through the filters and tank. All of these parameters can be monitored by simple digital sensors, i.e., either on or off. Analog sensors, such as dissolved oxygen levels and pH monitors, are more expensive to buy, install, and operate. Continuous dissolved oxygen monitoring is crucial at high stocking densities or whenever oxygen is used. For all these critical parameters, it is equally important *where* you monitor parameters, as *what* you monitor. Common sense should be the guide in this aspect of monitoring. For example, it is of little value to monitor the flow from a pump into a tank, if the tank drain line is left open, and all the water is flowing out as fast as it is flowing in. What is important to the fish is the tank water level. Similarly, there is no advantage in monitoring the power to a pump, if the discharge valve is shut or the motor thermal-overload switch has turned the pump off. The critical parameter to monitor is whether there is flow from the pump. Finally measuring air pressure next to the aerator is of little help, if there is a major leak at the far end of the distribution system, resulting in low air pressure for the last tanks on the line. The aeration pressure needs to be monitored at the farthest point in the system or at several different points.

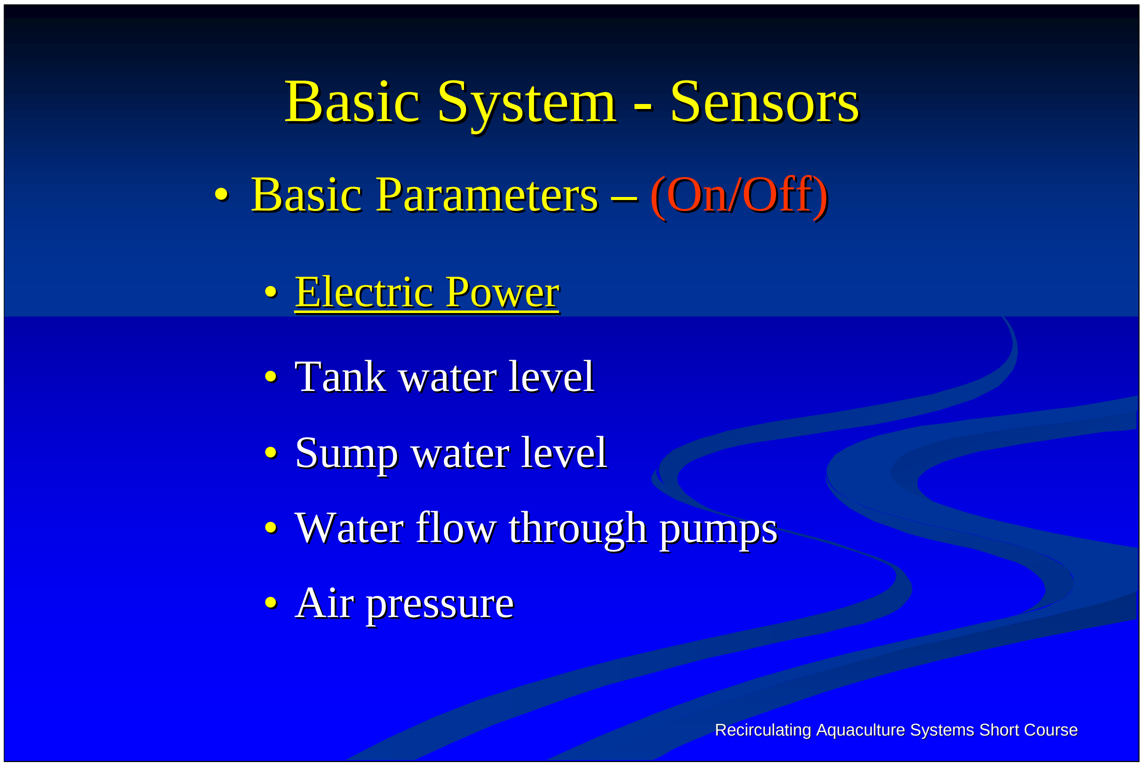



**Monitoring Sensors and Equipment Options**

Over the past few years, the cost of computer hardware and software has dramatically decreased, while the processing power and computer programming sophistication has greatly increased, (Lee, 1995, 1998). Sensor technology has become more reliable and sophisticated with such innovations as embedded microchips in the sensors that provide signal processing and linearization. A large number of sensors and monitoring systems components have been adopted from the wastewater treatment and chemical and petroleum industry. In many cases, the sophistication and corresponding expense of these types of monitoring and control equipment is not necessarily required in aquaculture facilities. Nevertheless, until specifically designed equipment becomes available for aquaculture and for high valued products, the added costs of this equipment may be justified. Keep in mind, that for any monitoring system, its overall reliability is determined by the most unreliable part, i.e., the weakest link.

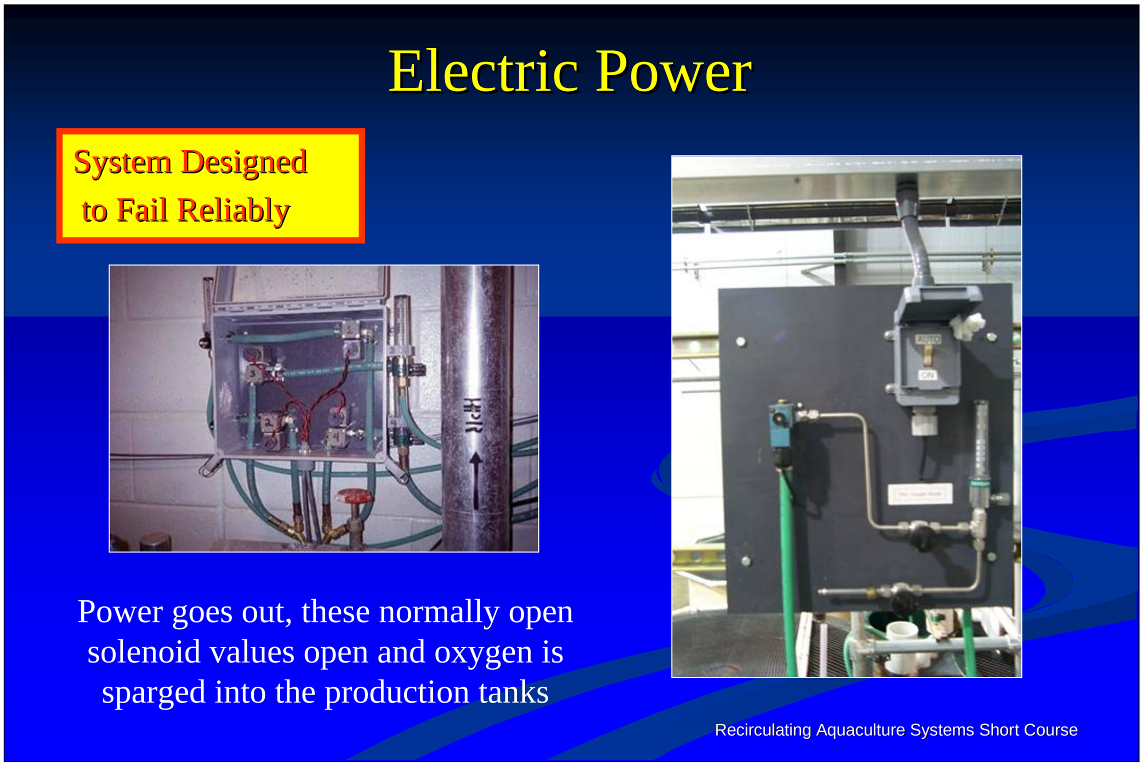
The following description of sensors represents the simplest and most cost-effective solutions to monitoring each individual parameter. These suggestions are not the only solutions available, however. For each of these parameters, there is a multitude of potential solutions, some of which are more expensive, more accurate, more reliable, more precise, with better interface capabilities, or simply more readily available. There is no simple right or wrong answer, and this is where the system engineering and design requirements come to play.

Sensors in aquaculture can be roughly divided into two major types: digital (on/off signals) such as water level, aeration pressure and water flow switches and analog (continuous output) such as dissolved oxygen, temperature, pH, conductivity, and ammonia-nitrogen probes. In addition, most analog probes require some additional hardware or controllers to convert the probe output to a usable signal, provide a digital display, and allow for calibration and zeroing. Thus the higher cost for these types of measurements, compared to simple switch closures. What follows is a short review of important monitoring parameters.

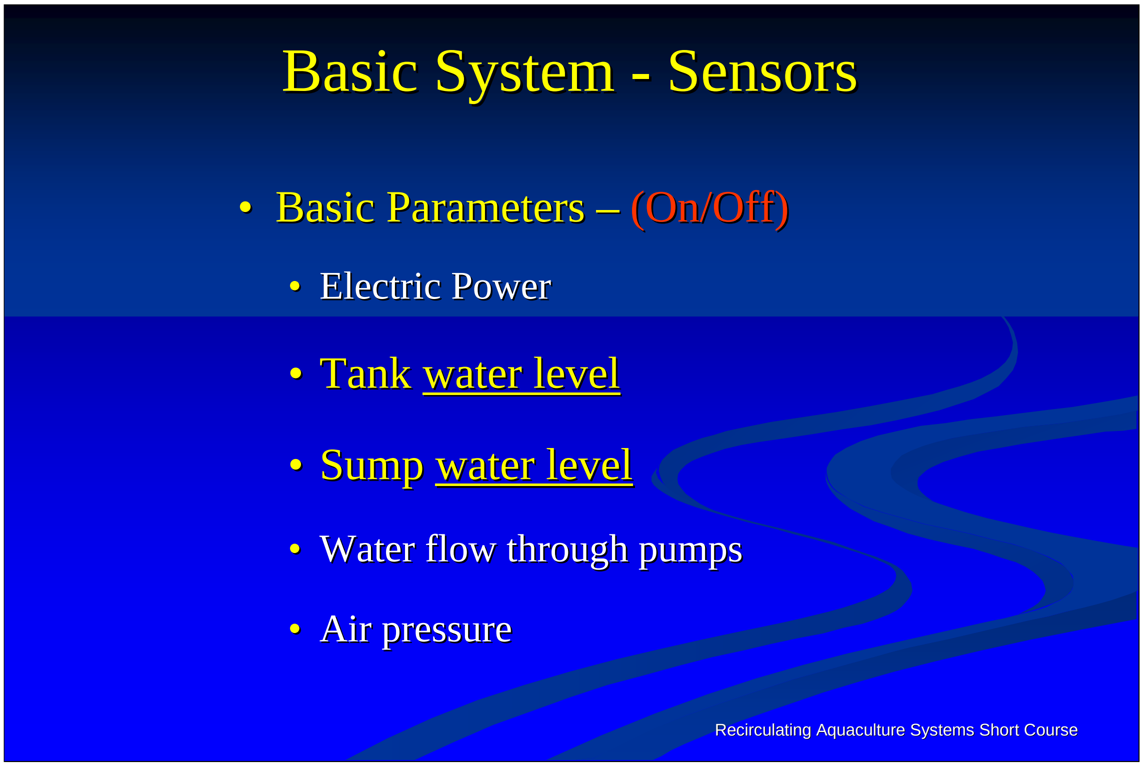



***Electric Power***

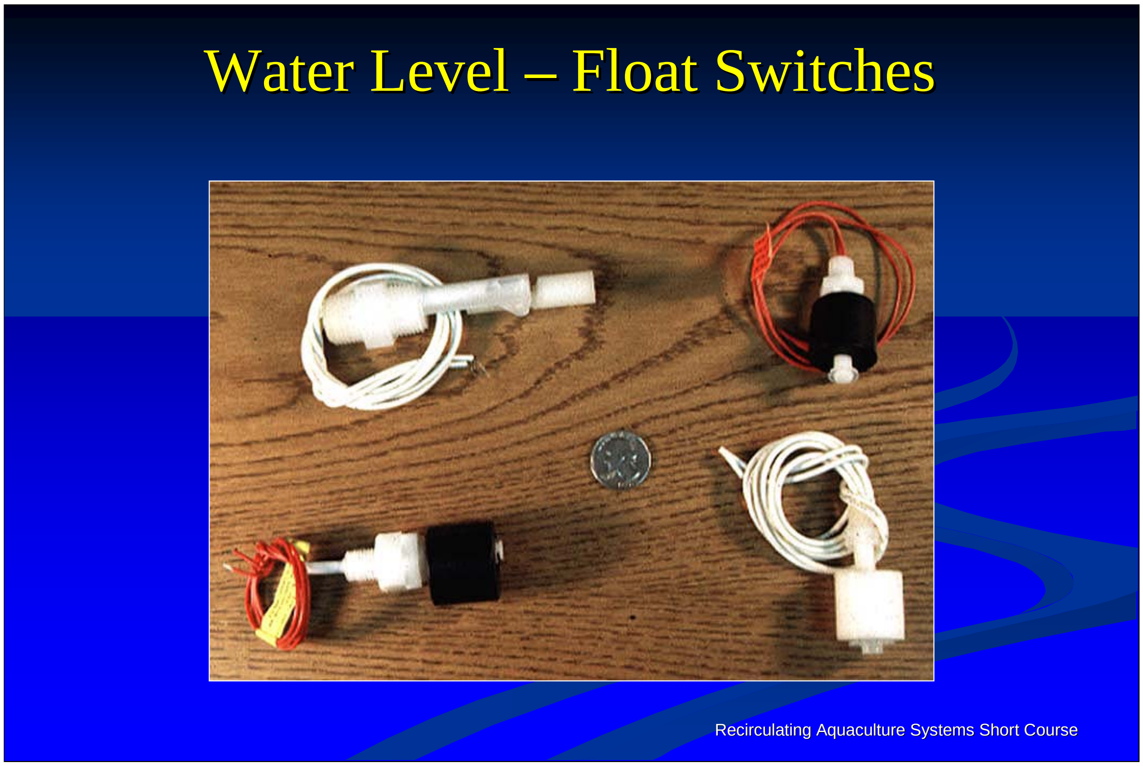
Power failure is probably the most common emergency and the one most easily monitored. Monitoring power is especially important when systems such as filters or supply pumps are located some distance from the main building. Three-phase power can be especially confusing, because if only one phase is down, it is possible to lose power to some systems, but not all. Murphy's Law assures that the monitoring system will not be on the one phase that goes down. In addition, when power is lost on only one phase, severe damage can occur to three-phase motors and pumps, if not properly protected. One often overlooked result of power outage is the loss of lights, which means that either numerous flashlights need to be maintained in good working order or back-up emergency lighting provided. When the power does go out, back-up generators suddenly become worth their weight in gold, as long as they have been properly maintained, regularly tested, have sufficient fuel and come on line when needed.




When the power goes out, these normally open solenoid values open and oxygen is sparged into the production tanks through a series of air stones. During normal operation, the solenoids are closed. Failure of power causes a safe mode.

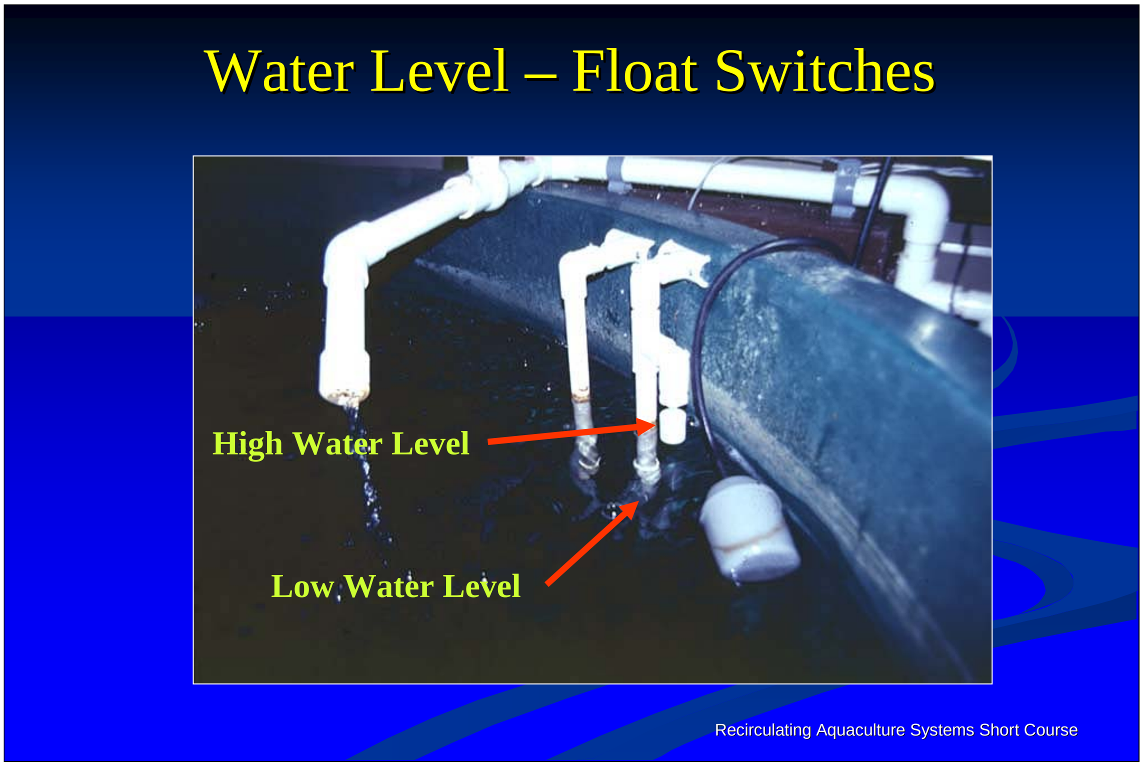



Water level is probably the easiest and most inexpensive parameter to measure, and should be monitored for both high and low levels in each production tank. High/low water level sensors will detect plugged drain lines, fallen standpipes or drain lines accidentally left open. Other locations to monitor include the intake side of pumps in wells or sumps. These should provide for automatic shutdown of the pumps to prevent their damage in the case of low water levels. Supply reservoirs or head tanks need to be monitored for both high and low levels. High levels can indicate unusual change in normal water demands, due to clogged pipes or valves accidentally turned off. Low levels can be caused by pump or water supply failure. If immersion heaters are used, low level monitoring should be designed to turn them off, to prevent overheating and burning out of the heaters and melting pipes. Alarm levels should be set so that normal operating transient do not activate an alarm. This can be accomplished either by setting the levels optimistically or by allowing some time delay before an alarm is activated after a sensor is triggered. Level sensors should be protected, so that active fish do not accidentally trigger them or even chew on them.

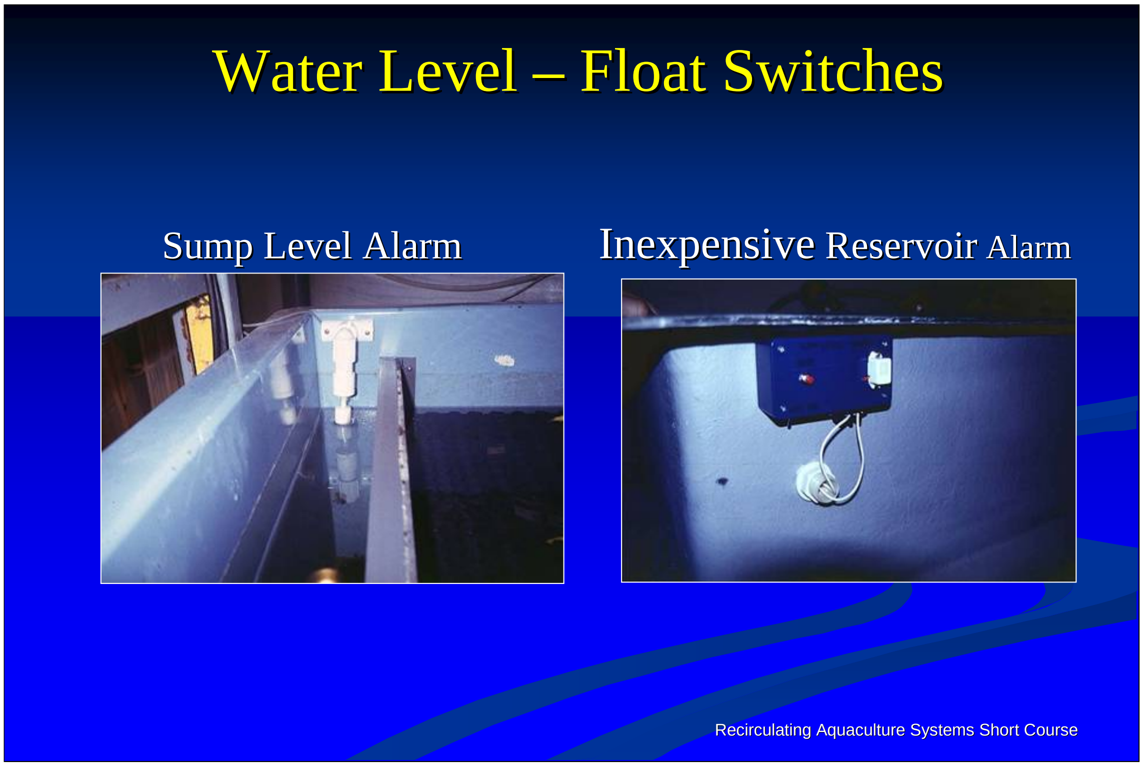



***Water Level – Float Switches***

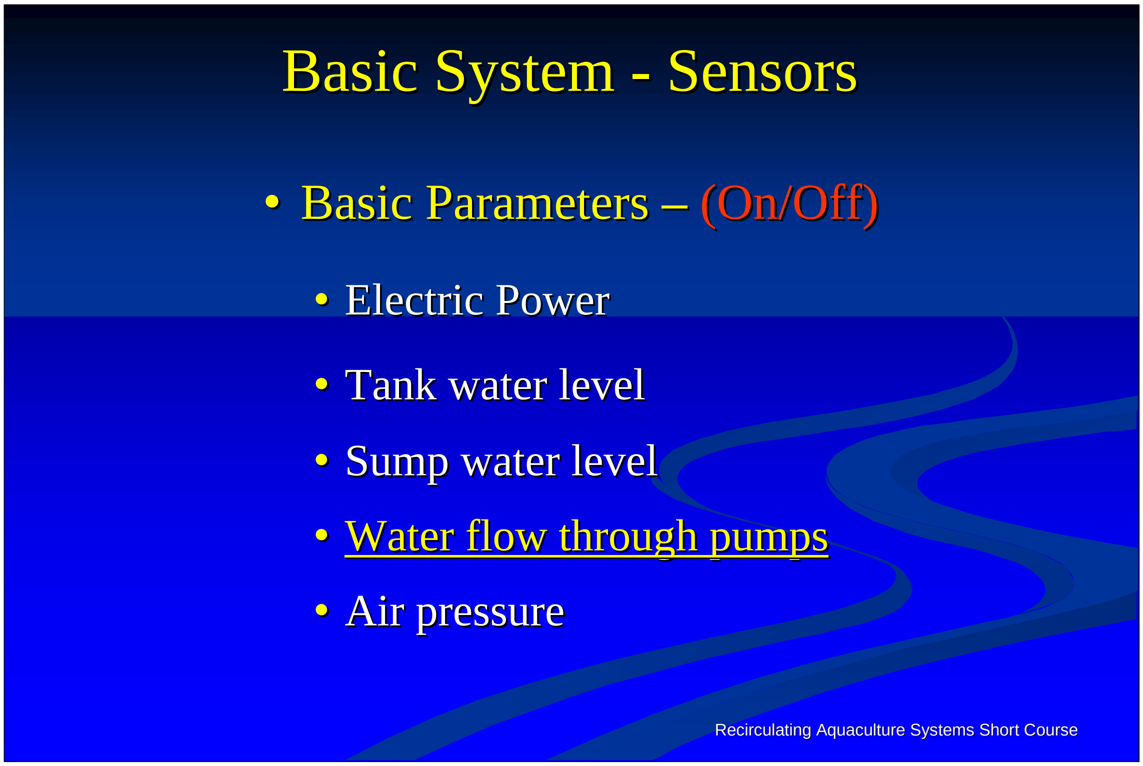
Water level is probably the easiest and most inexpensive parameter to measure. The basic float switch is designed to monitor a single, discrete, preset liquid level, Fig. 1. Simple float switches are constructed with a float containing a small magnet, which moves with the water level and actuates a hermetically sealed reed switch within the stem or body of the float switch. The rugged construction of this design provides for long and trouble free service with minimum maintenance requirements. Several different designs are available for mounting either vertically or horizontally in the tank or sump. Two float switches can be wired in series to monitor both high and low levels in a tank. Although most float switches are designed to handle 110 VAC at small currents, they should be powered by low voltages, i.e., 24 VAC or DC, to minimize danger to personnel and fish. Float switches are simple, foolproof, and relatively inexpensive. Examples of two float switches that have been successfully used by the author are Aquatic Eco-Systems Liquid Level Switch ST-3M and Grainger Liquid Level Switch 2A554.




As strange as it may seem, it is just as important to monitor for high as well as low water level. Plugged drain lines or excessive inflow can cause a tank to overflow. This has happened several times to the authors and the high level alarm is easy to install by wiring it in series with the low level. Thus if either senor is opened, an alarm is sounded.

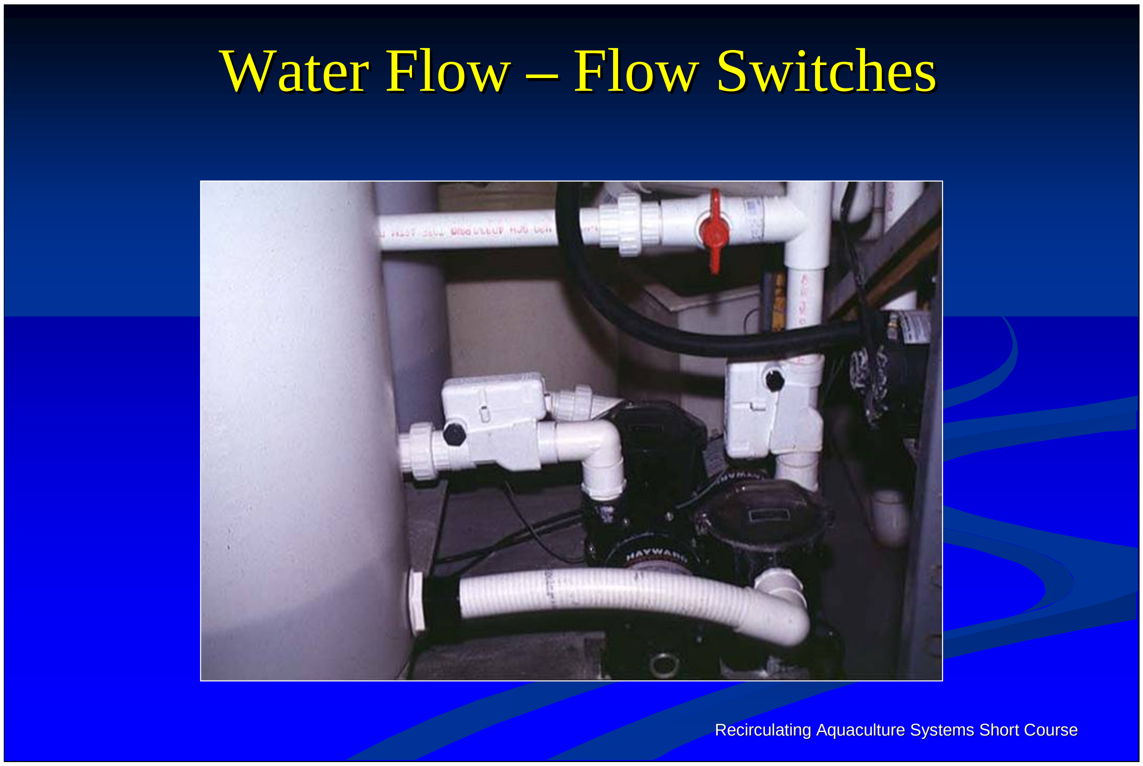



Other options for monitoring water level include optical liquid-sensing sensors that use an internal infrared circuit and the light refracting properties of water. Non-contacting ultrasonic level sensors measure the time required for the ultrasonic pulse to travel to the water surface and return. Conductivity level switches operate by detecting a small electric current between a single electrode probe and a grounded metal tank or between two electrodes. Finally, pressure-sensing systems use a pressure transducer to measure the pressure required to bubble air through an immersed pipe in the water column. Each of these has their application in specific design situations



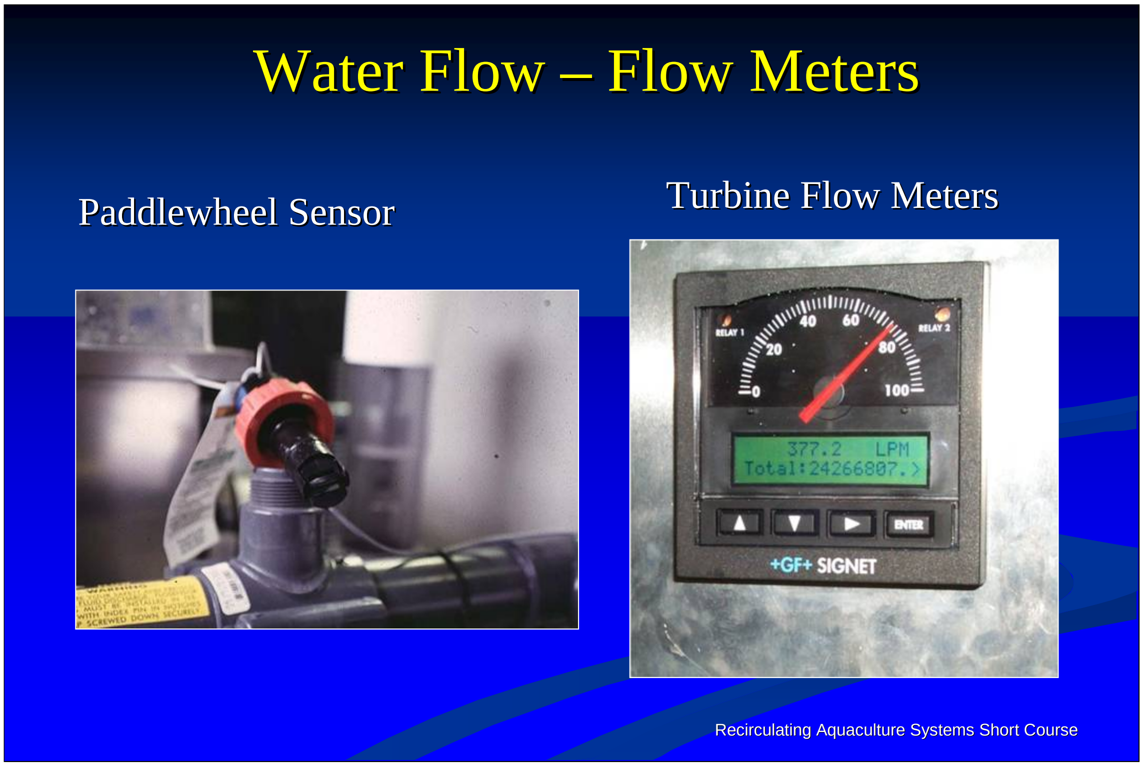

***Water Flow***

In some cases, the actual measurement of flow rate is important, such as when needed for the proper operation of chemical injection systems, for dechlorination, or for monitoring system performance. Normally however, simply monitoring whether water is actually flowing (flow/no-flow) with a digital sensor is adequate. One example of systems that these sensors protect is in-line heaters that require continuous water flow to prevent overheating and meltdown. Another example is submerged biological filters, where anaerobic condition due to pump failure can damage the nitrifying bacteria.

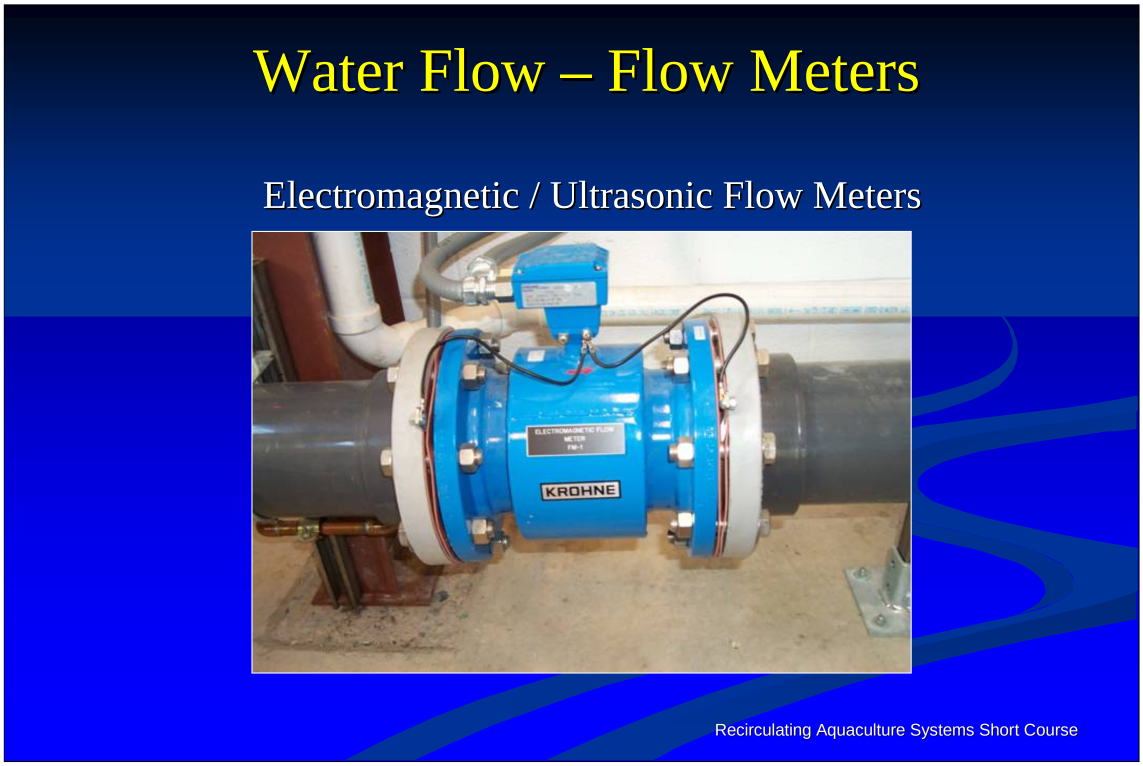



***Water Flow - Drag discs, PADDLE, and vane flow switches***

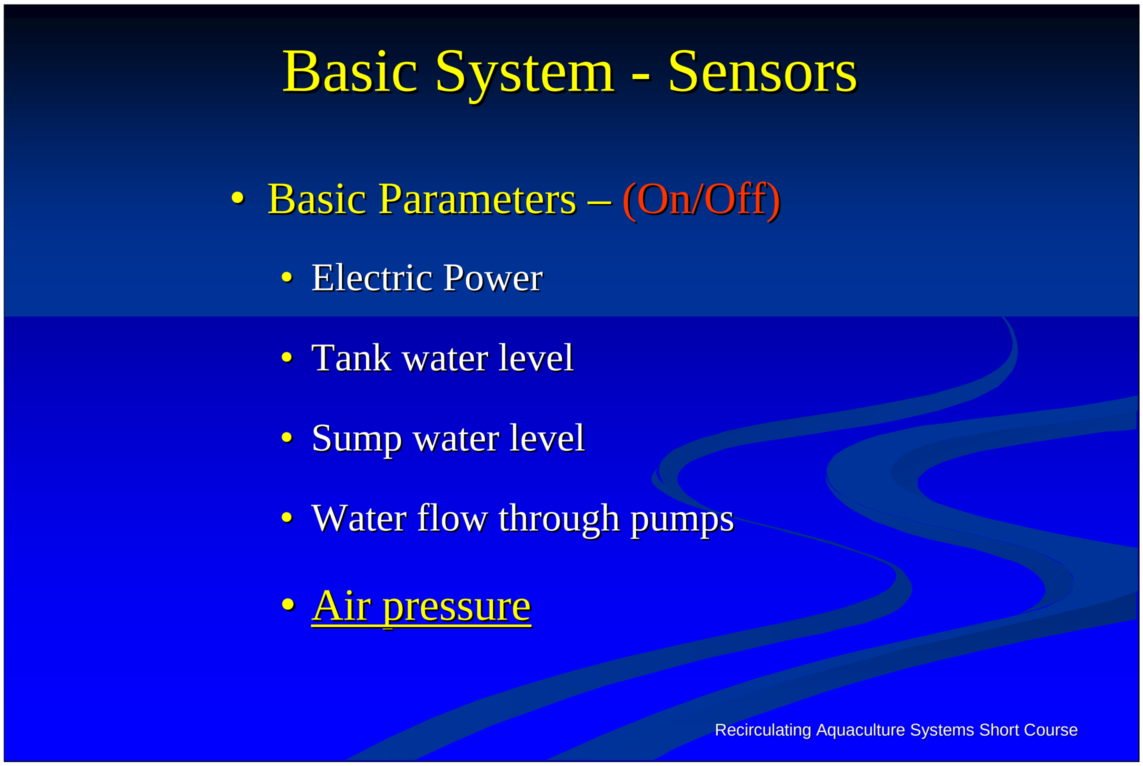
Drag discs, paddle and vane flow switches are all designed to monitor flow/no-flow or low flow conditions. Each operates on the drag force of the moving water against a small disk, paddle, or vane in its path, which in turn controls a small micro-switch. They are available in a wide range of flow rates and pipe sizes. Normally drag discs and paddles are installed using a Tee fitting and vane types are installed in-line, Fig. 3. An example of a flow switch that has been commonly used is Aquatic Eco-Systems Flow Switch, ST-9.




Other options for monitoring flow are rotameters. As the water flows through the rotameter, it raises a float in a tapered tube, increasing the area for passage of the fluid. The greater the flow, the higher the float raises in the tube, which is directly proportional to the flow rate. The float reaches a stable position, when the upward force exerted by the flowing water is equal to the downward force exerted by the weight of the float. These flow meters can be used to monitor flow by mounting a proximity switch externally, which is switched at a predetermined flow rate by a small magnet in the float. A second more expensive option is to use a turbine or paddlewheel flow meter. The flowing water turns a small turbine blade or paddlewheel, which generates an electrical pulse. This pulse is sent to the appropriate hardware, where the flow rate or the total flow can be displayed, and alarm conditions set and low/high flow alarm relays activated.



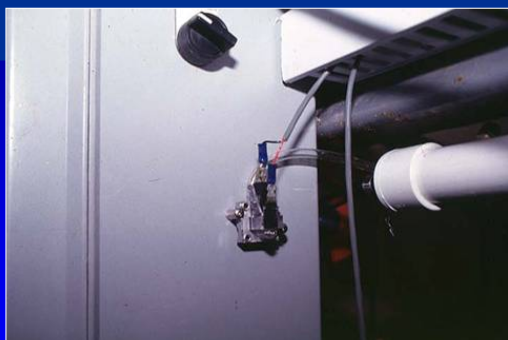

Although much more expensive, there are a variety of other methods to monitor flow rate using ultrasonic and Doppler measurements.




***Aeration System Pressure***

The aeration system is one of the most critical systems in any intensive recirculating aquaculture system. Response time to a detected failure is very short, and both monitoring and backup systems are important. Low pressure in the system may mean a ruptured airline, open or jammed pressure relief valve, disconnected diffusers, or blower failure. Although not monitored as often, excessive high pressure could indicate blocked supply lines, valves turned off or clogged diffusers

## Air Pressure – Pressure Switches



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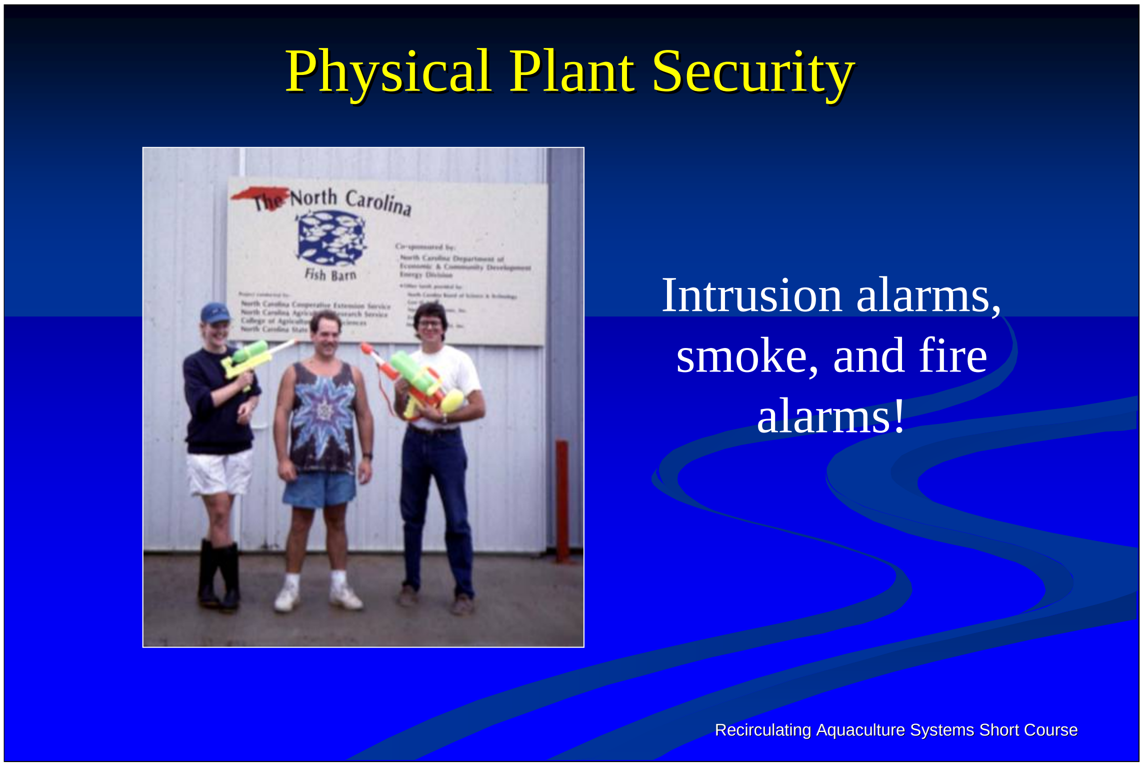
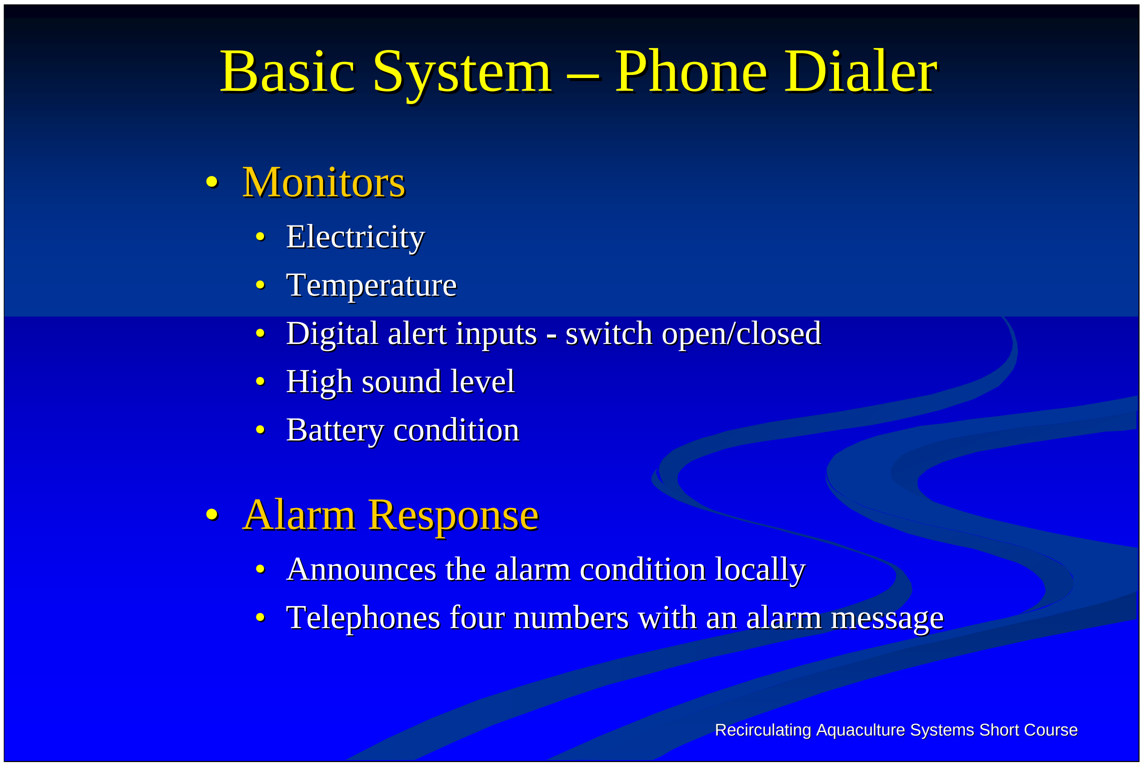
***Aeration Pressure***

Pressure is defined as a force per unit area, which is to be used to produce a deflection, distortion, or some other physical change in a sensor. A pressure control switch uses this deflection to trip an electrical switch at a preset pressure setting. Low and high pressure switches are available in a wide variety of configurations and price scales, from numerous manufacturers. One examples of a pressure switch that have been commonly used is Aquatic Eco-Systems Pressure Switch.




***Physical Plant Security***

Intrusion alarms, smoke, and high temperature sensors (fire) are readily available and commonly used to protect against fire, theft, and vandalism. Often existing alarm systems can be connected to the proposed monitoring system




**Automatic Phone Dialers**

The final step in the development of the monitoring/control systems is to bring each of the potentially catastrophic alarms to the attention of the manager and staff, especially when they are home sleeping (Ebeling, 1994, 1995). A very inexpensive, simple, and versatile monitoring system can be constructed around readily available automatic telephone dialers/alarm systems. These units are readily available for a wide range of inputs, sophistication, and costs. One such unit, the Sensaphone (Phonetics, Inc., Aston, PA, http://www.sensaphone.com/) has been used in numerous research and production facilities with excellent results.

The Sensaphone unit automatically monitors the following conditions:

AC electric power – power failure

four digital alert inputs or 3 digital and 1 temperature

temperature – reports actual temperature and checks for high or low limits

high sound level – fire/smoke alarm, intruder alarms, unauthorized parties

battery status – condition of its battery back-up

All monitoring is continuous and when an alarm condition occurs, the unit announces the alarm status locally for 30 seconds. If no response is received, it then sequentially dials up to four user-programmed telephone numbers (including pagers) with an alarm message. It will state in English the existing problem, disconnect, and wait for an acknowledging telephone call or coded response. It will continue dialing-out, up to sixteen attempts, until its message is properly acknowledged. In addition, it is also possible to call in, listen to a status report on the monitored conditions, and hear the background sounds through a built in microphone. For most small systems, this would provide all the necessary digital inputs for monitoring tank water level (high/low), aeration systems pressure, water flow, and sump water level or if desired, system water temperature


***The Basic System***

The *basic monitoring system* was designed for low-density (less than 40 kg/m3 or 0.33 lb/gal) recirculating systems, with aeration only and moderate feed rates, such as broodstock holding tanks, isolation/quarantine tanks, or educational systems. Basic system parameters (level, pressure, flow) are monitored by digital sensors, i.e., either on or off. Analog sensors, such as temperature and dissolved oxygen levels, are more difficult and expensive to utilize and are important only at much higher stocking densities or where pure oxygen aeration is required. Basic parameters to be monitored at this production level include electricity, tank water level (high and low), aeration system, and water flow. The actual number of subsystems monitored, depends on the specifics of the system design and the operating conditions. In most cases, only a few monitoring points should be necessary. Parameters monitored and sensors used include:

**System electrical power**: monitored directly using the Sensaphone or indirectly due to loss of other subsystems (pump flow, aeration, etc).

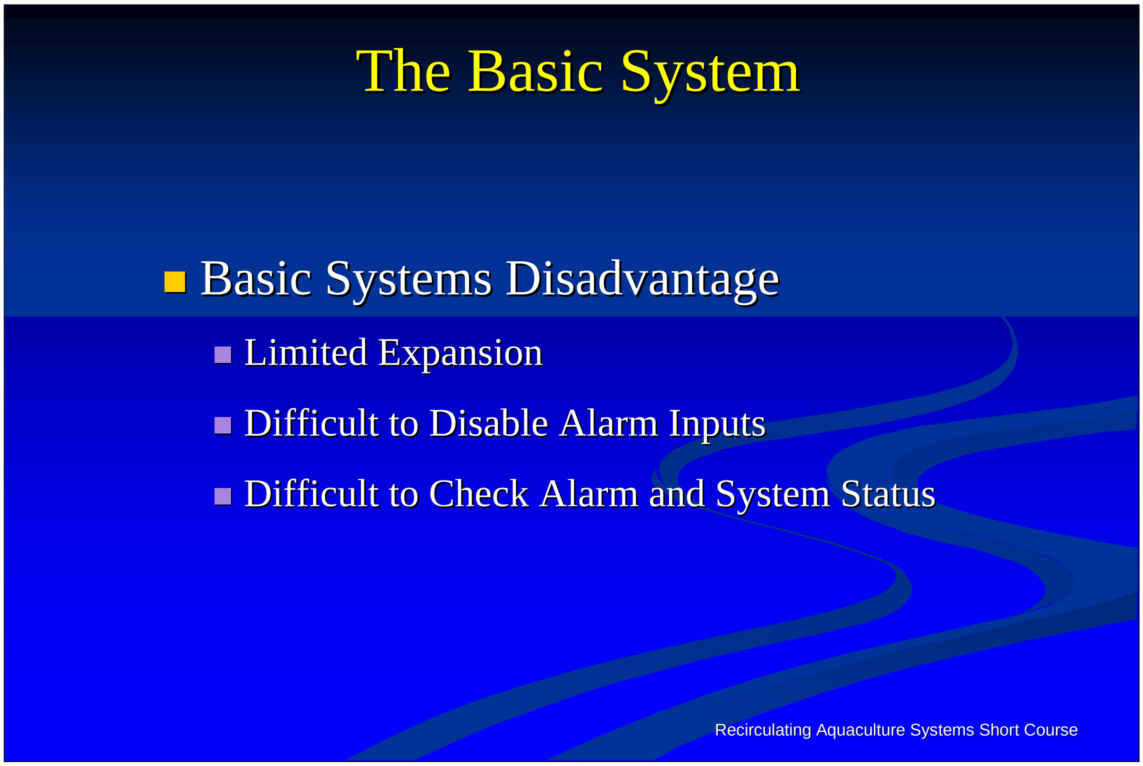
**Tank water level (high/low):** Aquatic Eco-Systems, Liquid Level Switch ST-3M, or Grainger Liquid Level Switch 2A554, wired in series.

**Aeration system pressure**: Aquatic Eco-Systems, Pressure Switch B601.

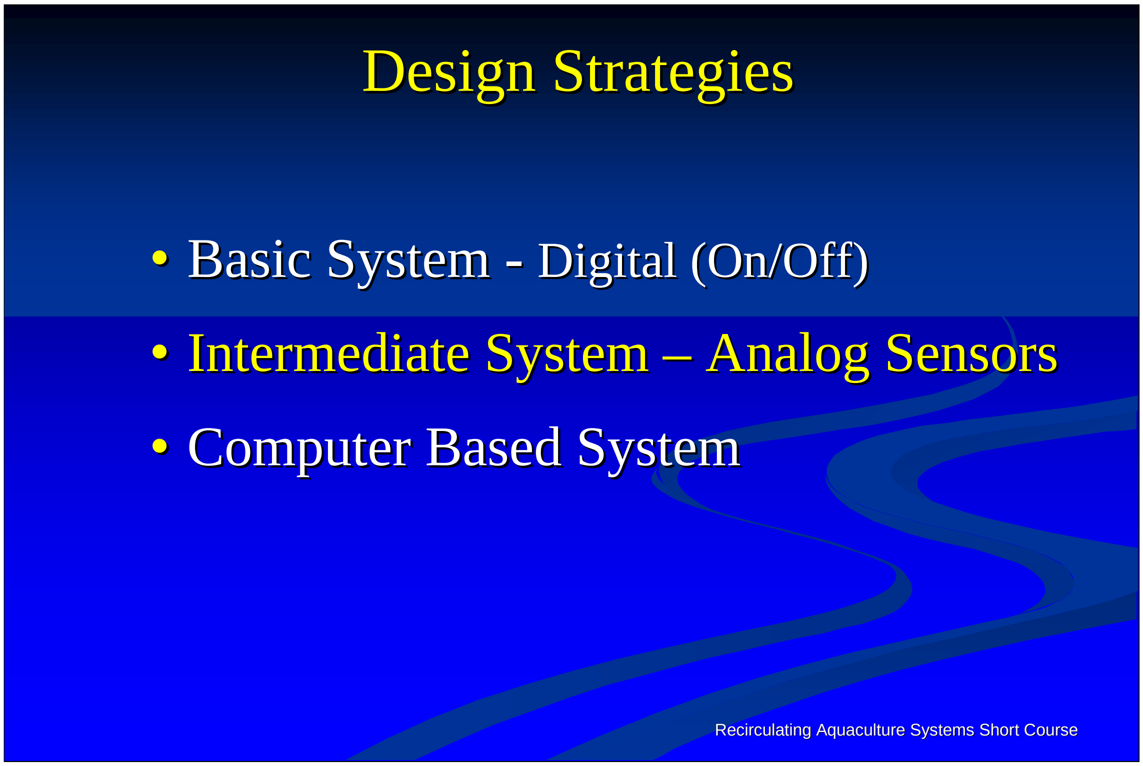
**Flow-sensing switch***:* Aquatic Eco-Systems, Flow Switch ST-9.

**Telephone dialer***:* Sensaphone Telephone Alarm System.

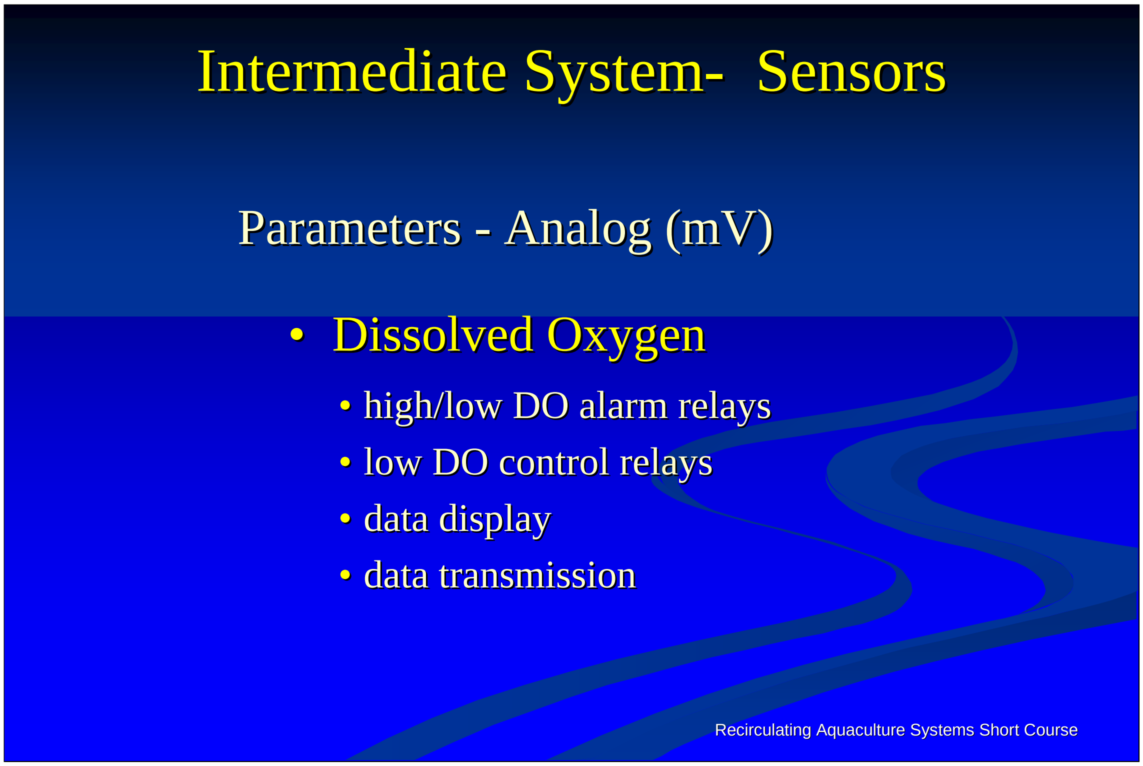
Each of the sensors is wired directly into a Sensaphone input, with the two float switches wired in series to monitor both high and low water level. The fourth input on the Sensaphone could be used to monitor either temperature of the water or an additional alarm. With this system design, a single tank or perhaps several could easily be monitored for the basic system parameters: water level, flow, aeration, and electricity.




The basic system has the disadvantage of not being easily expended as addition monitoring points are added. During routine cleaning and harvesting operations is it not possible to disable the alarms, resulting in numerous false calls. And finally, it is difficult to check whether the system is on or not and if individual alarms are active.

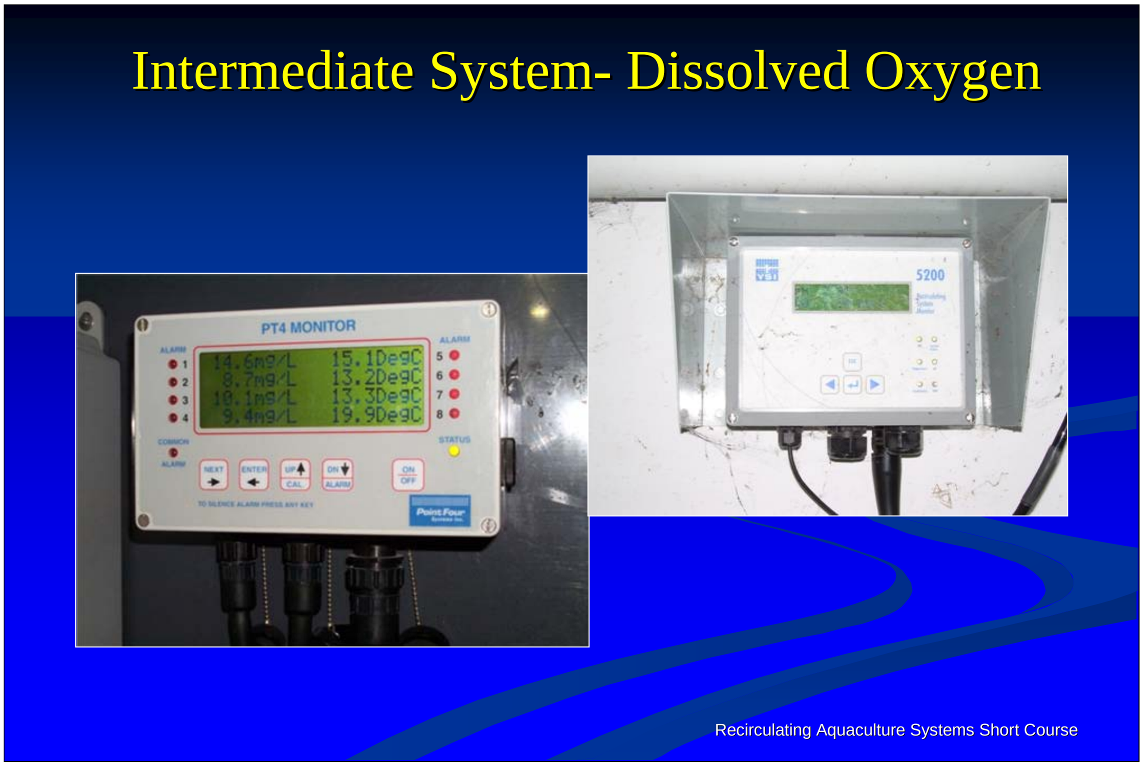



Sensors in aquaculture can be roughly divided into two major types: digital (on/off signals) such as water level, aeration pressure and water flow switches and analog (continuous output) such as dissolved oxygen, temperature, pH, conductivity, and ammonia-nitrogen probes. In addition, most analog probes require some additional hardware or controllers to convert the probe output to a usable signal, provide a digital display, and allow for calibration and zeroing. Thus the higher cost for these types of measurements, compared to simple switch closures. Typical analog sensors include dissolved oxygen, temperature, and pH.



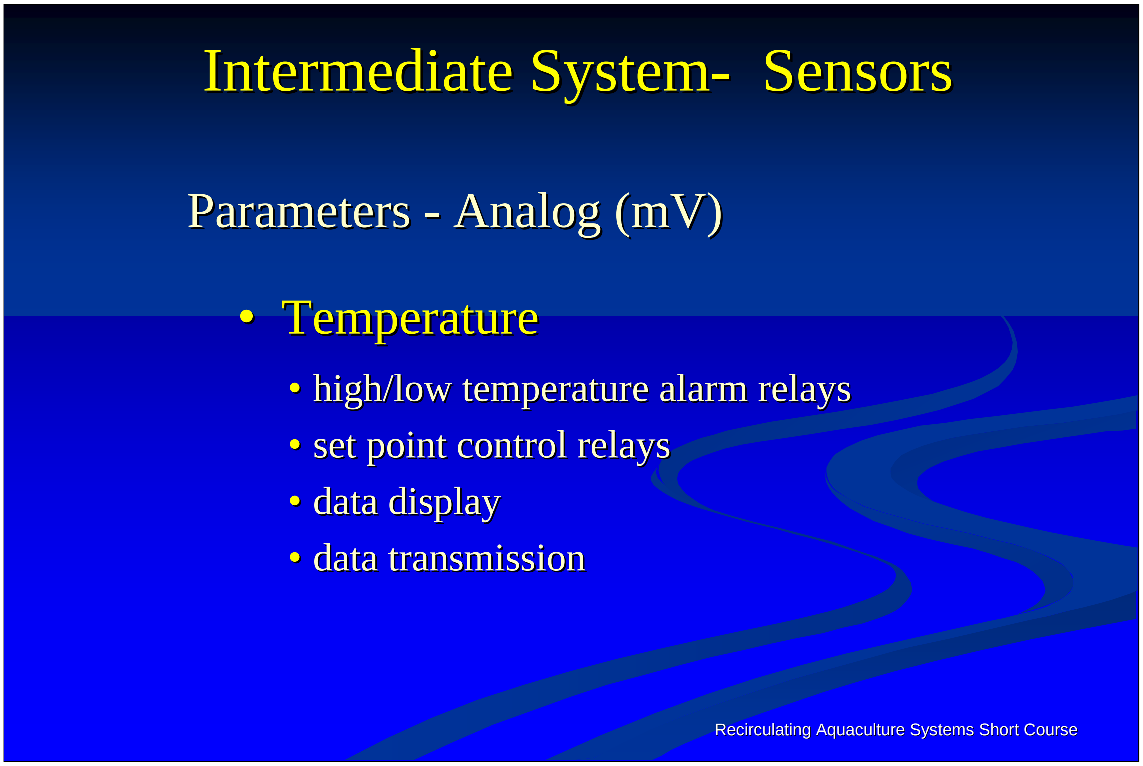

***Dissolved Oxygen***

Dissolved oxygen (DO) is one of the most expensive and difficult parameter to monitor continuously, (Ebeling, 1998). Thus, the decision whether or not DO should be continuously monitored is dependent on the overall economics of the system, stocking density, and degree of risk a manager is willing to accept. Normally, the actual value of DO (mg/L) is not needed, just whether it is above or below a given set point. However, to provide a simple digital signal, both an expensive probe and a sophisticated hardware interface are required. The availability and costs of both oxygen probes and interface hardware has dramatically decreased in the last few years, but remains too high for many aquaculture operations.



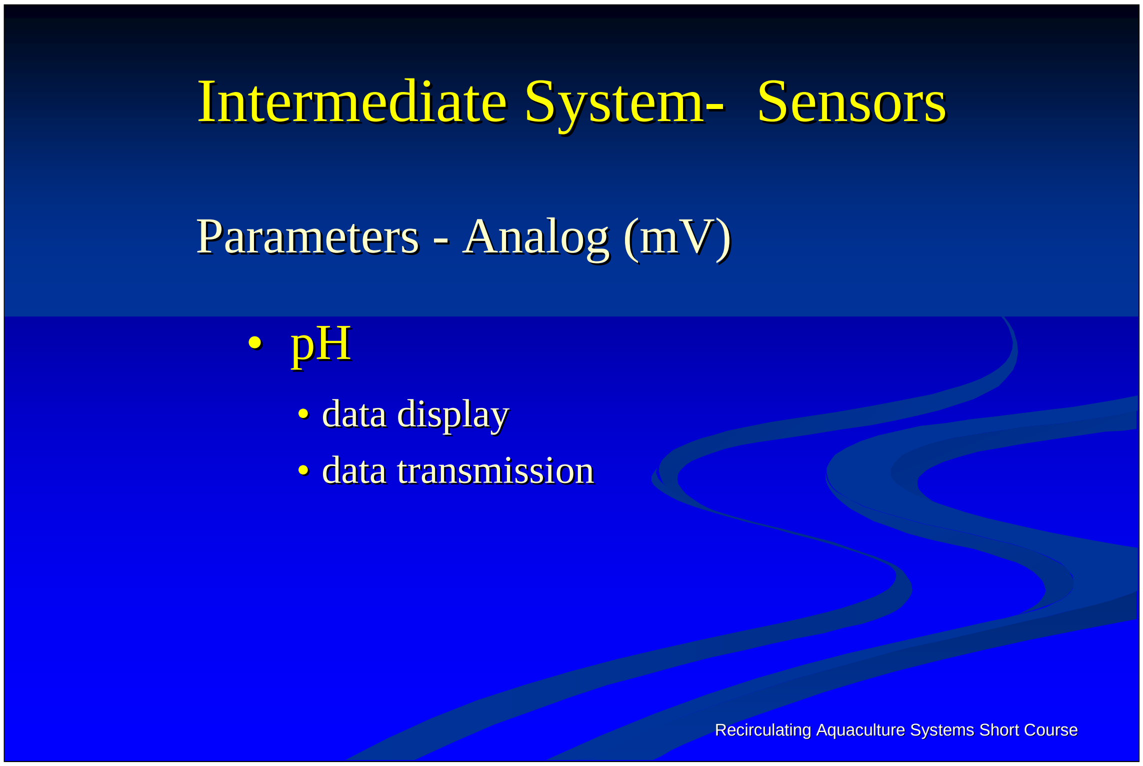

***Dissolved Oxygen***

Over the past few years, a number of dissolved oxygen probes and analyzers designed specifically for the aquaculture industry have become available. Most of these are microprocessor-based instruments capable of measuring levels of dissolved oxygen up to 100 PPM, important for monitoring oxygen injection systems. Standard recorder outputs (0–5 VDC) are built-in and many include 4–20 mA current loop outputs. Several models also provide serial outputs (RS-232, or RS-485) for direct interfacing with microcomputers and local area networks (LAN's). These also include high/low set point control relays for automatically controlling external devices such as aerators, pumps, valves, or other alarm monitoring equipment. Although the initial investment in this equipment can be high, the cost must be weighed against the potential loss and poor growth due to low dissolved oxygen levels. Dissolved oxygen meters designed specifically for aquaculture are available from Point Four Systems, Inc., YSI, Inc. and Royce Instrument Corp




***Temperature***

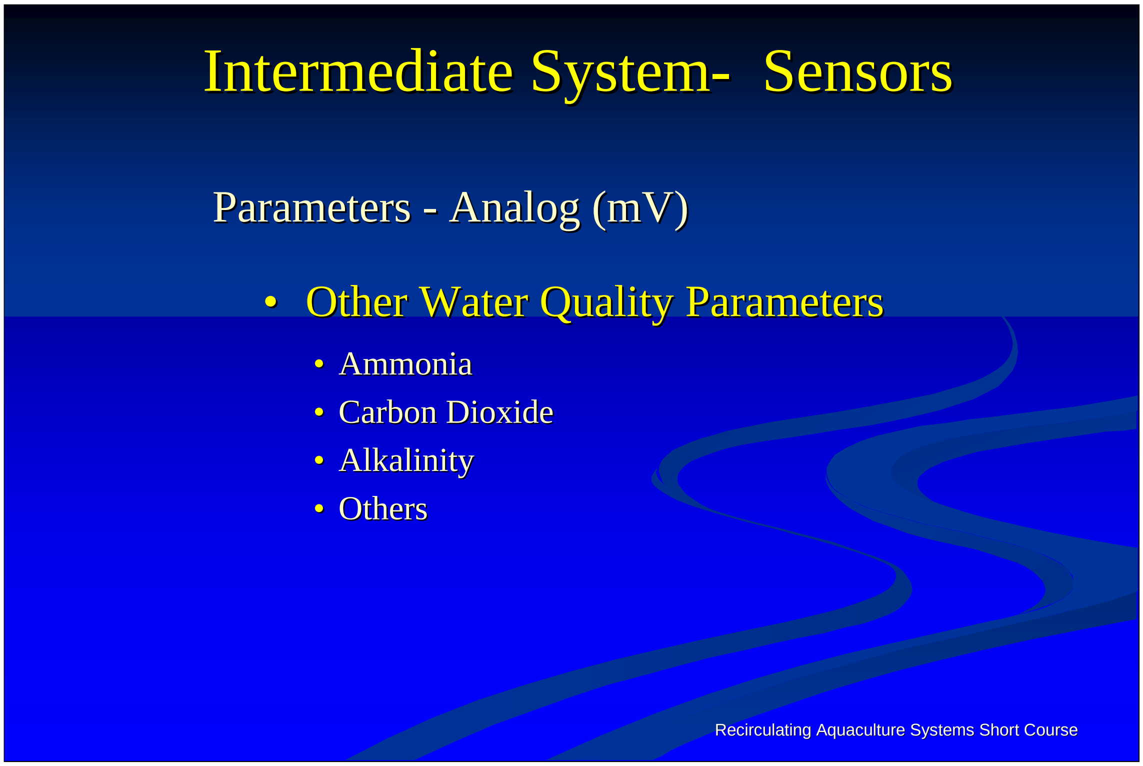
The continuous and precise monitoring of temperature in production tanks is important to optimize production, reduce stress, and minimize risk of disease. Systems should be monitored for both excessively high and low temperatures; keeping in mind the two extremes are not equal. While low temperatures may reduce growth, excessively high temperatures may yield a huge tank of fish soup and a new career path. Since most temperature controllers are cyclic in nature (either on or off), temperature alarm limits should not be set too close together, to prevent unnecessary alarms due to short term transients.


Intermediate System- Sensors
Parameters - Analog (mV)
• pH
• data display
• data transmission
Recirculating Aquaculture Systems Short Course

# Intermediate System- pH

Control Dosing for pH Control

Controls Degassing of $CO_2$




***Other Water Quality Parameters***

Other water quality parameters, pH, ammonia-nitrogen, nitrite, nitrate, alkalinity, and carbon dioxide change relatively slowly in comparison to dissolved oxygen. Although relatively expensive individual probes and automated systems are available to monitor these parameters, the most cost-effective method is daily or weekly manually monitoring with inexpensive off-the-shelf test kits.

# Intermediate System- Laboratory

A water quality lab doesn't have to be large,

but it should be dedicated only to that task.

# Intermediate System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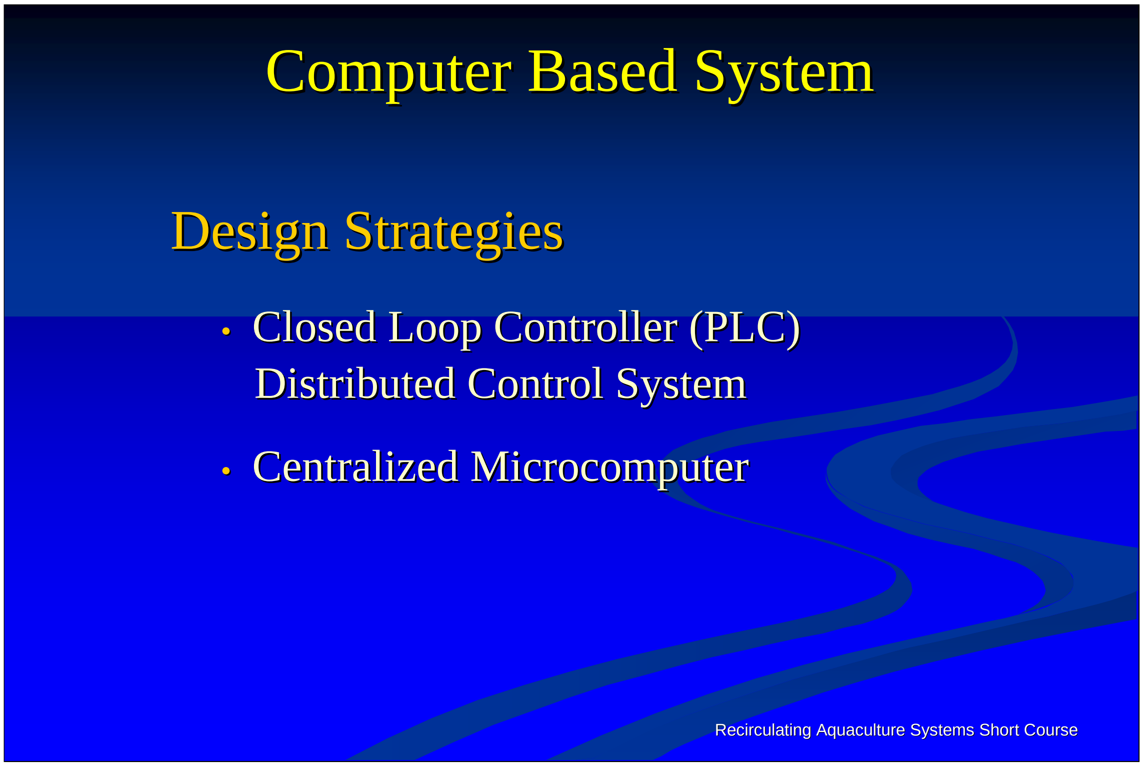
With the addition of DPDT relays, low voltage sensors can be used for safety. In addition, status of sensors is readily visible as well as location of any alarm condition.

Panel monitors two systems for level in tank and settling basin, air pressure and water flow. Audible alarm alerts staff to problems. The Sensaphone can be activated with a “false” alarm for checking the dial out procedure.

# Design Strategies

- Basic System - Digital (On/Off)
- Intermediate System – Analog Sensors
- Computer Based System




**Computer Based Systems**

Once it becomes necessary to monitor analog inputs, such as dissolved oxygen, pH, temperature or other output analog signals for control purposes, some form of computer-based system must be employed, (Tsukuda et al. 1998). With this added capability though, comes the cost of additional requirements for calibration of the probes and sensors and maintenance of the overall system. Until recently, the utilization of computer control and monitoring systems in aquaculture has been limited, with only a few custom-designed systems for research or large commercial operations. The vast majority of small producers has had neither the expertise nor the resources to custom-design and installs systems. However, in the past years, there has been a revolution in low-cost, high performance microcomputers and intuitive and relatively low cost process control software. With the rapid development of microcomputer technology, numerous ‘user-friendly’ software and hardware systems are becoming available for control and monitoring of industrial processes. These software packages use object-oriented programming that allows even inexperienced programmers to create customized programs. In addition, standardized data acquisition components and systems, software drivers and communication software are available for several different computer platforms and over a wide range of costs.

Supervisory control and data acquisition (SCADA) is the term used in industrial automation that refers to automated data collection usually by remote units and its display on a centrally located personal computer. The human machine interface (HMI) is the interface by which an operator interacts with the remote devices, i.e., pH, DO, temperature measurements. The HMI allow an operator to adjust set points, configure remote units, respond, and acknowledge alarms. In addition, system performance data can be recorded for future analysis and solutions to recurring and one-time problems. A data acquisition system has a variety of input/output (I/O) ports that provide connection between the sensors and the computer. Four of the most commonly used are: digital input (DI), digital output (DO), analog input (AI), and analog output (AO). Determining the type of I/O required by sensor is the first step to matching the sensor and the required I/O.


The first design strategy can also be expanded to a distributed process control system, where each of the stand-alone monitor/control units relays data to a central supervisory microcomputer. Examples of the stand-alone closed loop controllers are dissolved oxygen analyzers (YSI, Royce, Balanced *Aqua*Systems, and Point Four Systems, Inc.) and temperature controllers. Each of these closed-loop controllers is normally equipped with both control relays and high/low alarm relays. In general, these units have limited data display capabilities and normally do not store data, but are equipped to transmit the data to a central, supervisory microcomputer. With stand-alone systems, individual sensors are easy to service and calibrate, since each has its own hardware and display unit. In addition, monitoring and control is performed at the lowest system level, which provides a high degree of overall system stability and robustness. If a failure occurs in the supervisory microcomputer, the stand-alone units will continue to monitor and control critical processes. If a failure occurs in the stand-alone system, the supervisory microcomputer can by comparing to previous measurement or measurements from other sensors to detect the abnormal conditions and alert the operator.

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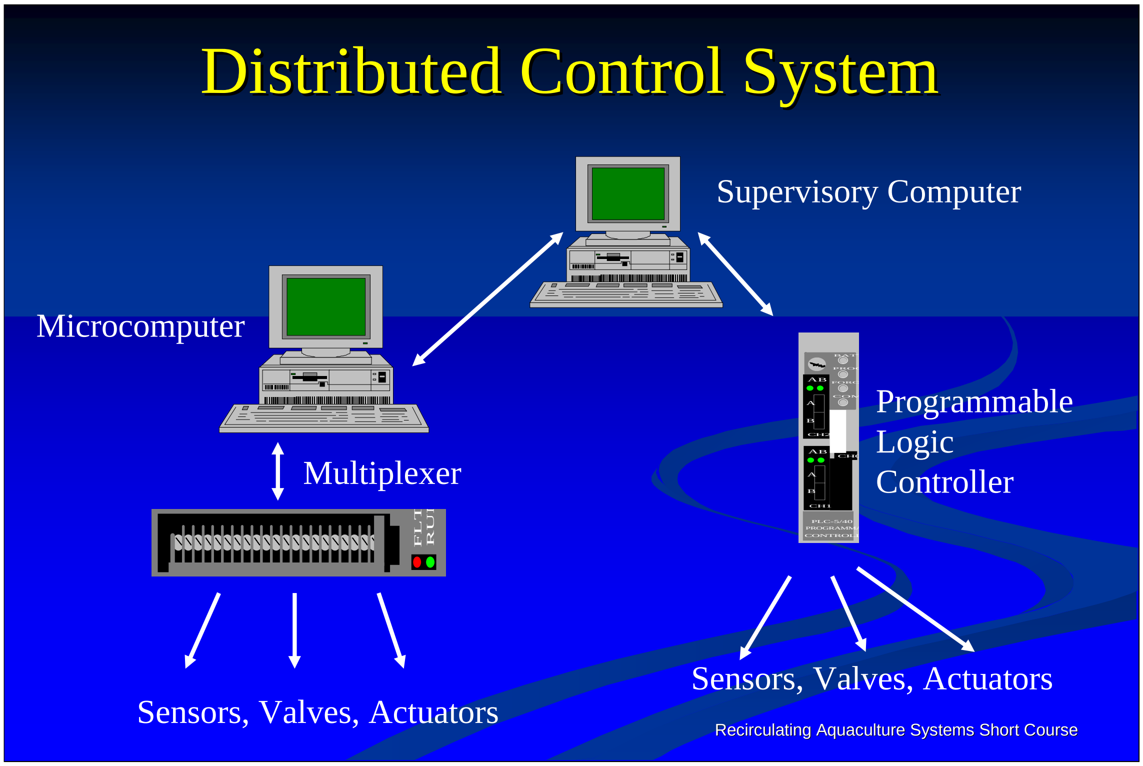
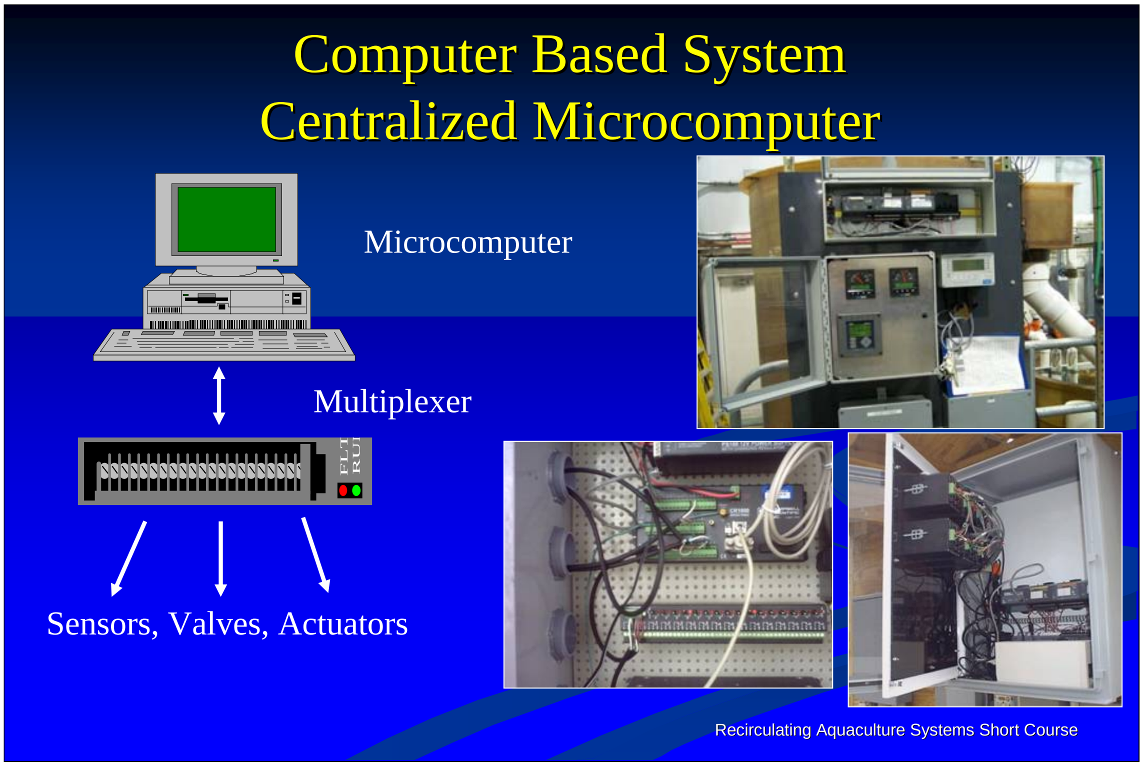
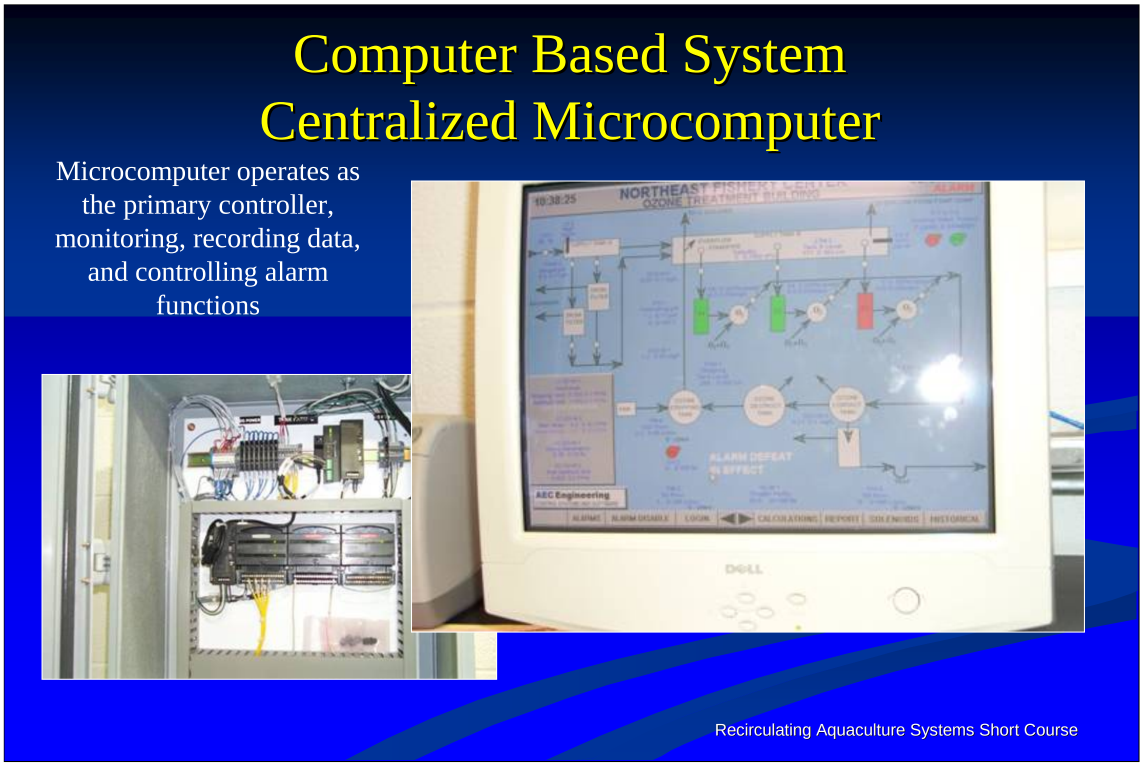
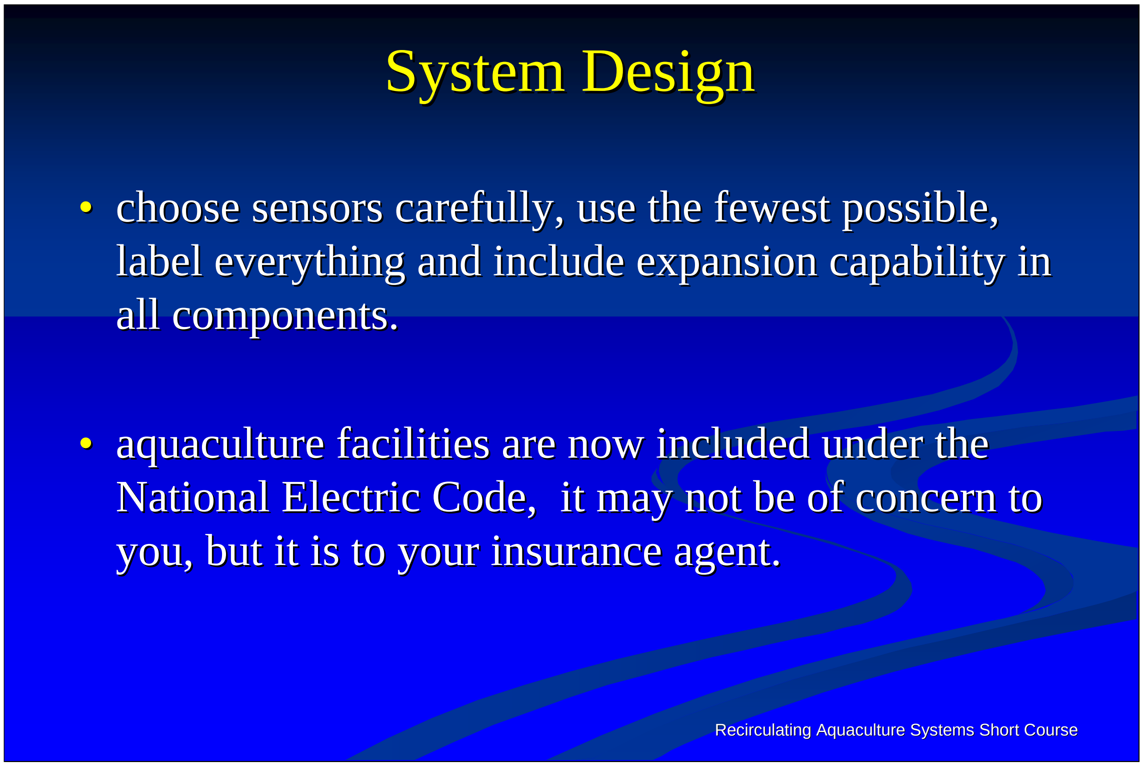

Distributed Control System
Supervisory Computer
Microcomputer
Programmable
Logic
Controller
Multiplexer
Sensors, Valves, Actuators
Sensors, Valves, Actuators
Recirculating Aquaculture Systems Short Course




The second design strategy utilizes commercially available data acquisition boards that are either located in existing expansion slots in the computer or communicated to it via a serial interface link. There is a wide selection of data acquisition boards available over a wide range of cost, performance and sophistication, including analog to digital (A/D) cards for monitoring voltages or currents from sensors, digital to analog (D/A) cards for outputting analog control voltages, and input/output cards (I/O) for monitoring and outputting digital control signals. They are easy to use, “just-plug-in”, and come with a set of standard drivers and application software programs. Many types of sensors can be connected directly to these boards and most meters usually have some form of recorder output (0–5 V or 4–20 mA).



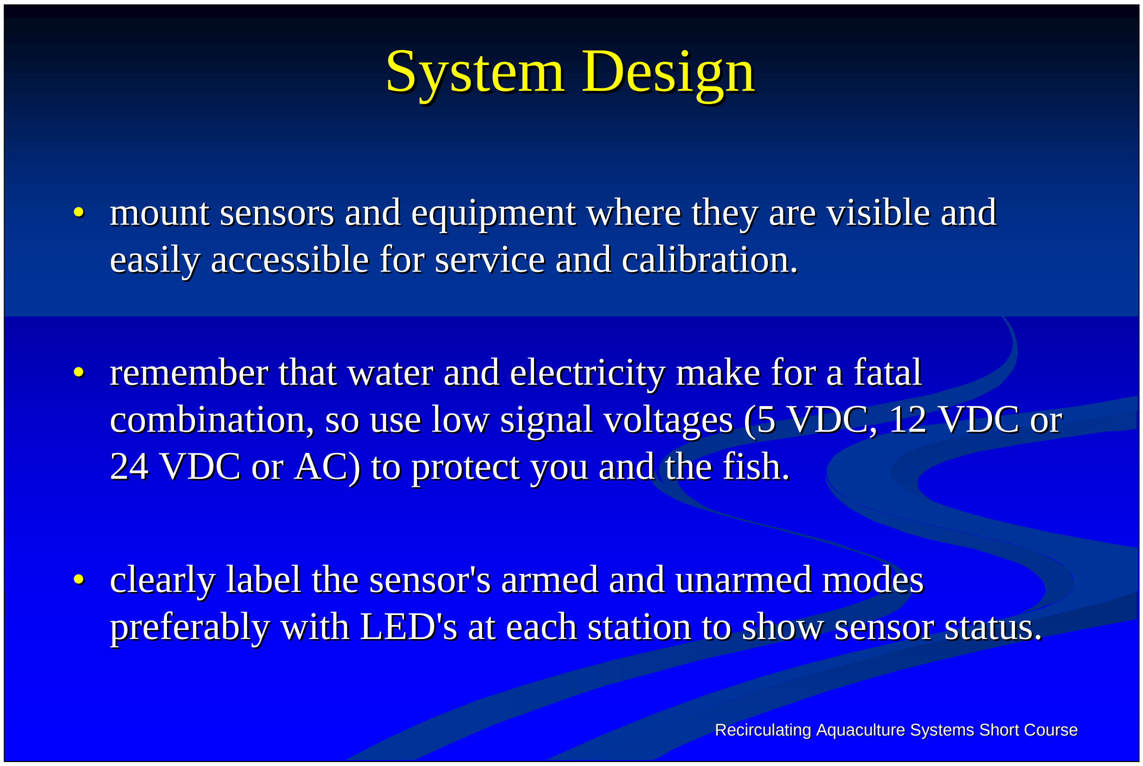

In contrast to the distributed system, the microcomputer operates as the primary controller, monitoring, recording data, and controlling alarm functions. These systems are not as inherently reliable as the distributed systems, but overall systems cost is less, since they are based on fewer and less expensive components.




System Design:

Choose sensors carefully, use the fewest possible, label everything, and include expansion capability in all components.

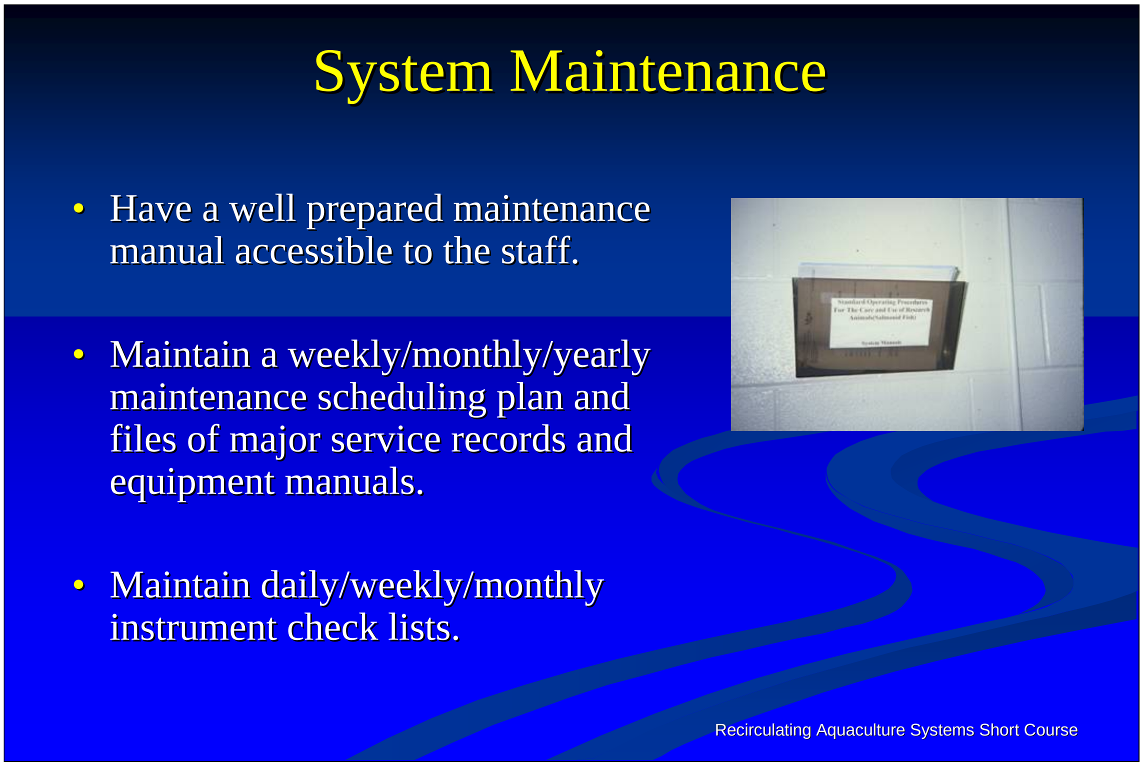
Aquaculture facilities are now included under the National Electric Code; it may not be of concern to you, but it is to your insurance agent.




Mount sensors and equipment where they are visible and easily accessible for service and calibration.

Remember that water and electricity make for a fatal combination, so use low signal voltages (5 VDC, 12 VDC or 24 VDC or AC) to protect you and the fish.

Clearly label the sensor's armed and unarmed modes preferably with LED's at each station to show sensor status.




System Maintenance:

Have a well prepared maintenance manual accessible to the staff.

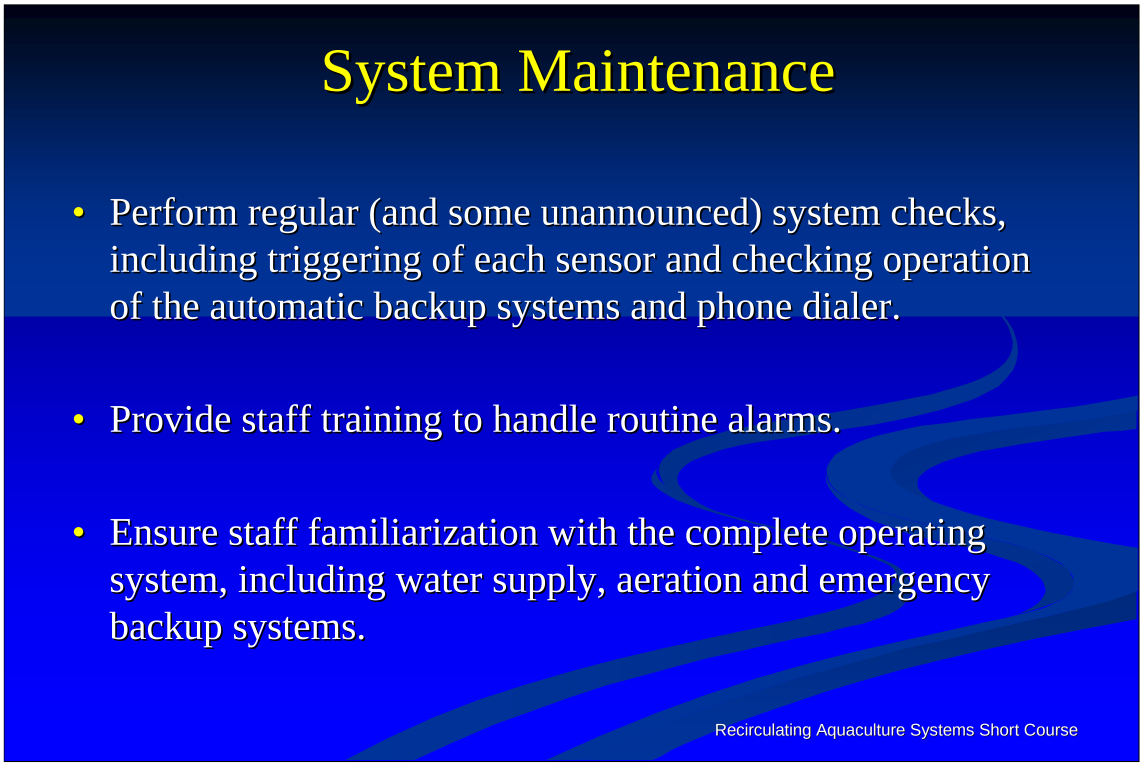
Maintain a weekly/monthly/yearly maintenance scheduling plan and files of major service records and equipment manuals.

Maintain daily/weekly/monthly instrument check lists.

Perform regular (and some unannounced) system checks, including triggering of each sensor and checking operation of the automatic backup systems and phone dialer.

Provide staff training to handle routine alarms.

Ensure staff familiarization with the complete operating system, including water supply, aeration and emergency backup systems.

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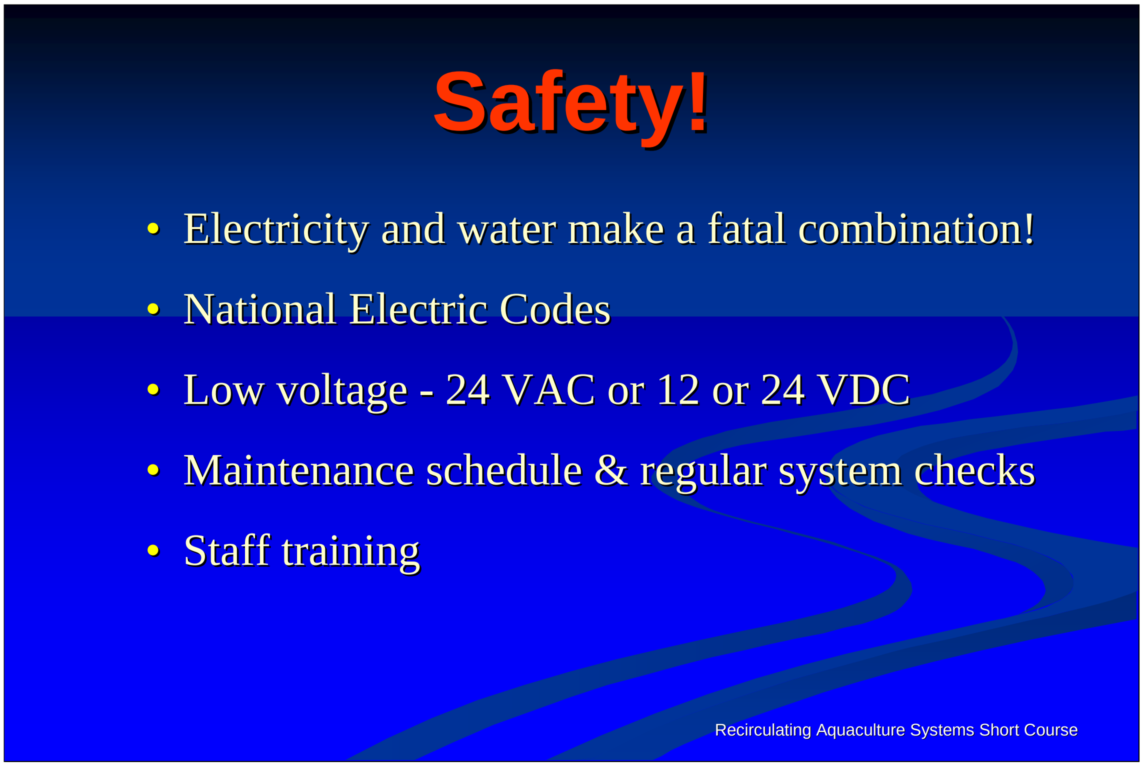


**Construction Hints**

Probably the most important rule during design and construction is to *keep it simple silly*, known as the "KISS" principle. The other rule is always assume that someone else will have to repair it, thus complete design notes, wiring diagrams, and labels are important. If you change a configuration of a monitoring system, update the documentation, and date the update. In addition, system components should be readily available from local or reliable sources. A "one-of-its-kind" is just that, and will soon become extinct. While designing and constructing, plan for expansion and leave room for additional systems or more "bells & whistles".

Monitoring and Control equipment should be mounted and operated in a clean, dry, and safe environment. Provide adequate space around and in front of the equipment for easy access and future expansion. Do not place equipment were it will be subject to shock and vibration, dirt, dust or moisture. As much as possible, all materials used for system housing and hardware should be PVC, fiberglass or stainless steel to minimize corrosion. Water-resistant PVC junction boxes and fiberglass electrical cabinets, NEMA-4 enclosure, are corrosion resistant and easy to drill holes into and are ideal housing to protect the electrical components, Fig. 9. Include several vent holes to minimize heat build up in the cabinets. Do not install the system near motor starters, contactors, or relays that switch inductive loads, i.e., motors! These devices generate large electromagnetic fields that can cause communications and system errors. If unavoidable, install the system in separate, grounded, steel enclosure to the shield from electrical interferences.

**Figure 9.** Fiberglass Electrical Cabinet to Protect Sensaphone and Relays.

All external sensors should be low voltage, i.e., 24 VAC or 24 VDC, ON/OFF, to minimize danger to operators and fish. Crimp style quick disconnect tab connectors on switches allow for easy construction and later modification. Solder joints should be covered with shrink-wrap tubing whenever possible. When buying individual components, look for extra options that may be useful in the future, such as extra alarm relays, voltage or current outputs and computer interfacing capabilities.

One simple trick to minimize the effects of aquaculture's harsh environment is to pressurize the control system housing using the aeration air supply. In this manner, relatively dry air is forced into the housing, preventing the high humidity and salt air from getting in. Alternatively, the step-down transformer in many of the systems provides a source of heat, thus preventing condensation from occurring.

# Questions?