TRASAR® TECHNOLOGY – A REVIEW AND COMPARISON

Cooling Water Feed Control Automation

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Special Acknowledgements

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Forward

The Association of Water Technologies (AWT) is an international trade association founded to serve the interests of regional water treatment companies and to advance the technologies of safe, sound and responsible water treatment practice. AWT is a non-profit organization providing education and training, public awareness, networking, research, industry standards and resource support. Association activities serve to benefit members, as well as advance the arts and sciences of the water treatment industry.

This paper will provide a review of the Nalco Company's Trasar® and will position the Trasar feed control automation concept in respect to what is currently being used in the industry (outside of Nalco). This topic should be of interest to the AWT membership since the original Nalco patent is due to expire in 2005. Consequently, the AWT membership will be in a position to consider the use of this technology in comparison to the methods currently used to monitor chemical treatment addition.

Further, this paper will report and summarize a new development to Nalco's automated feed control technology. The Nalco Company has dedicated significant resources and commitment in developing a next generation Trasar® technology in hopes that it will differentiate them in the market. This next generation in Trasar technology is being marketed under the trade name of "3-D Technology".

Some of the questions this document will review are:

- What is the basic Trasar feed control technology?
- What are the claims of Nalco's next generation technology?
- Why or when should fluorescent-based feed control technology be considered?
- How does fluorescent-based control feed compare to the conventional methods currently used?
- What issues should be considered if fluorescent-based feed control technology is used?

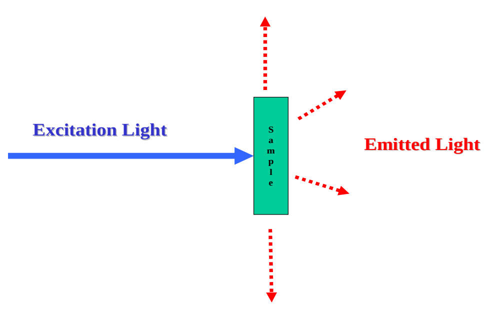
Basic Trasar® Concept

Introduction to Fluorescence

There are certain types of molecules that absorb light at one frequency, and then emit light at a different frequency. This is called fluorescence (see figure 1). By comparing the intensity of the incoming light (incident or excitation light) to the intensity of the emitted light, the concentration of the fluorescent molecule can be determined very accurately. Because the emitted light is of a different frequency than the incident light, the emitted light can be measured without serious interference from scattered light. This characteristic of fluorescence enables these types of molecules to be accurately measured at very low concentrations.

For many years, scientists have been adding fluorescent chemicals to water. Fluorescent chemicals have been used to study flow, mixing, volume, and other properties of lakes, streams, pipelines, etc. The green glow of automobile radiator fluid is from a fluorescent molecule used to indicate the presence of a protective additive.

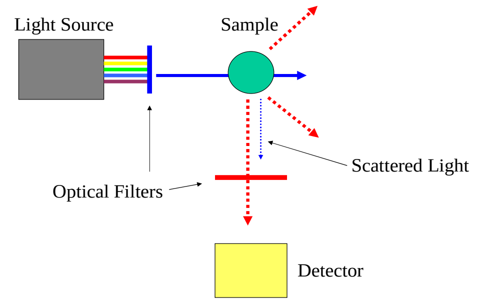
Figure 1 – Description of Fluorescence



Fluorescent-based Tracing

There are several challenges to applying fluorescence-based monitoring to water treatment. The molecule must be reasonably inert under the system's operating condition.

Figure 2 – Illustration of a Fluorometer



The fluorescence of the tracer component must be distinct from other molecules in the water that may fluoresce. The fluorescent molecule should not change after exposure to oxidizers, acids, bases, sunlight, or microorganisms. It must remain in the water, not be removed by corrosion by-products or by precipitation. Its fluorescence should not change if the pH, conductivity, hardness, or temperature of the water changes. When tracing a product, the fluorescent molecule must be precisely added to the blended product and accurately measured at low concentration.

Nalco's Trasar®

Nalco has been using Trasar technology for approximately 15 years. Nalco has addressed many of the issues (some noted above) impacting the reliability of fluorescent-based feed monitoring and feed automation. Trasar uses a chemically "inert" molecule that is highly fluorescent. This compound is blended at a carefully controlled concentration in select Nalco products. When the product is dosed into a water system, a fluorometer is used to measure the fluorescence of the recirculating water (see figure 2). One supplier of fluorometers is Turner Designs, Inc. of Sunnyvale, CA. The fluorescence measurement is used to determine treatment dosage and assess need for altering the chemical dosage. Automation can be achieved when a fluorometer is used in-line, continuously or continually sampling and measuring fluorescence. The Trasar controller sends a signal to the product feed pump, keeping it in the on or off position, to maintain control of fluorescent component concentration (indirectly maintaining product dosage, see figure 3). When properly performed, fluorescence technology can eliminate the problem of incorrect product feed. The primary patent for Trasar technology will expire in November of 2005.

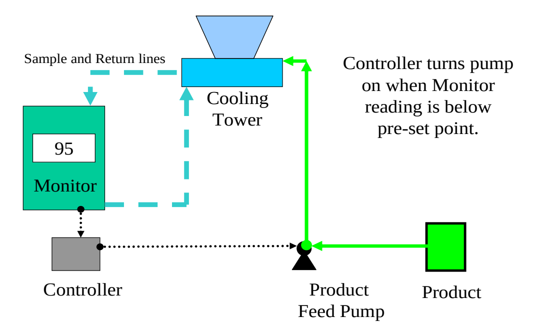
Advantages - Trasar® technology has been effectively adapted to automation:

1. The fluorescence test does not require handling of test reagents.
2. Feed dosage is verified by direct measurement of fluorescence, not based on assumptions of system volume or cycles.
3. Fluorometer measurement is a relatively simple and rapid test and results can be observed immediately. Using an in-line fluorometer generates several measurements every minute providing accurate feed control.
4. Fluorescence can be detected accurately at very low concentration. Thus, the amount of fluorescent component in the product formula can be quite low and overall cost-effective.
5. Fluorescent molecules used are inert and environmentally safe when used at the typically low concentration needed for feed automation.

Disadvantages - Trasar® technology has been effectively adapted to automation:

1. Various impurities in the water may fluoresce at similar frequencies to the tracer. Others may absorb or scatter some of the light. This will distort product feed control accuracy.
2. Fouling of the flow cell will reduce the amount of light reaching the detector.
3. Fluorescence will vary with temperature and so temperature compensation is needed.
4. To ensure reliability with the measurements, routine calibration and maintenance are required.
5. Applications of two or a multi-drum program are limited since only one product can contain the fluorescent tracer.
6. The tracer is only an indirect measurement of treatment actives. Consequently, the treatment actives can be misrepresented since the tracer is not consumed and does not typically become part of any deposit. Therefore, chemical analysis for the active constituents (phosphate, polymer, etc.) may still be required.

Figure 3 – Illustration of a Trasar Set-up



Trasar® Economics

A relative comparison of the economics is covered later in this paper. The areas of cost that one must consider for Trasar-type technology are:

Cost of fluorescent tracer(s):
1) Raw material cost
2) Manufacturing cost

The fluorescent molecule can be expensive, although the high raw material cost is offset somewhat due to small percentage required in the product formulation. The difficulty is in quality control, since the amount of tracer must be very accurate and precise. Variations in the raw material activity or variations in batch size must be measured and corrected for. This can be a labor-intensive production process.

Cost of equipment:

1) Cost of controller(s)
2) Cost of chemical pump
3) Cost of installation

A key consideration for the AWT membership will be the cost and availability of sensors and controllers to implement fluorescent-based control. The original Trasar® units cost several thousand dollars. Only large volume customers could justify the cost of the equipment. This is an area that will need to be fleshed before the true economics of fluorescent-based feed control can be understood.

Nalco has introduced a new fluorometer based on light emitting diode technology. These units are reported to be reliable and low cost (reportedly they are leased at $100 - $300/month). In addition to low cost for individual units, the new units can be "stacked" to measure several fluorescent compounds at the same time. As a practical matter, only about three different spectral signatures can be combined in the same water system without interfering with each other. Reportedly, Nalco has also been developing a fourth channel to monitor background for correcting the other three measurements.

<u>Recent Trasar® Innovations</u>

New fluorescence-based monitoring capability - performance-based treatment automation:

1. Tagged Polymer

One of the problems with the original Trasar® monitoring technique is the lack of information about the active constituents in the system. Since the fluorescent molecule is inert, it is not affected by corrosion, scale, or microbial activity. Nalco focused significant resources on addressing this problem. They have developed a dispersant polymer that contains a fluorescent "tag". The tagged polymer is claimed to have equal effectiveness as a dispersant compared to the standard, untagged polymer.

The tagged polymer's fluorescence can be measured at the same time as the background Trasar molecule in the formulated product. The difference between the background Trasar molecule and the tagged polymer indicates consumption. Consumption of tagged polymer can be directly related to scale formation in the system. It is reportedly more sensitive than DATS™ units (<u>D</u>eposit <u>A</u>ccumulation <u>T</u>esting <u>S</u>ystem provided by Bridger Scientific Inc.) or chemical analyses. The question is, "What do you do with this information?"

In principle, one can use this measurement of consumption to operate the system very close to its limits, thus saving water and chemical. Nalco claims Trasar negates the need to depend on scale and corrosion indices that are typically used to develop treatment operating guidelines such as system cycles and pH . Also, it is claimed that it is not necessary to fully understand how much of a particular treatment is required under the possible myriad of operating conditions. Cycles can be increased automatically until scale begins to form, and then the cycles can be reduced to the point where scale formation is prevented, eliminating scale deposition problems.

Another option is to feed product to maintain a certain level of polymer actives rather than a certain level of product dosage. If a scale begins to develop, precipitating the polymer, the controller will increase the product feed producing an increase in polymer concentration. This is a simpler control approach, but abandons the "automatic optimization" concept. It is not clear what happens when the Tag:Trasar molecule ratio changes - there should at least be some type of alarm.

2. Biosensar®

Resazurin chemistry is currently used in some food processing (especially dairy) to monitor microbial contamination. Resazurin is blue in color, but bacteria can metabolize it to a red compound.

The red to blue ratio or the rate of change from blue to red indicates the level of microbial activity in the system. Reportedly, Nalco has adapted this concept to Trasar®, and is calling it Biosensar®. The major advantage of Biosensar is that this dye travels throughout the system, and interacts with biofilms that cannot be measured by dipslides, ATP, or plate counts. Resazurin is not specific to any particular species of bacteria, but it is very sensitive to oxidizing biocides. Nalco's published data show their molecule is unstable above 0.1-0.2 ppm total halogen.

While the exact molecule Nalco uses may or may not be resazurin, Nalco uses fluorescence, and not absorbance to measure the blue and red forms. The concept is to adjust biocide feed according to performance or the ratio of blue-to-red color. Nalco claims they can feed biocide only when needed, and only as much as needed, thus optimizing biocide usage and performance. Because the Biosensar reacts with oxidizers, there <u>must not</u> be a significant halogen residual in the cooling water system for the Biosensar to function properly. If there is a requirement to maintain a certain halogen residual, that requirement will not be met.

<u>Trasar® Application Issues:</u>

<u>Limitations, Implementation, Reliability, Testing, and Manufacturing:</u>

Reportedly, Nalco wanted to introduce this technology a few years ago. What has caused the delay? There are many practical problems to overcome. It is believed that one issue is that the Tag:Trasar ratio is too sensitive. Data must be tracked for hours to detect any trend. This means response time will be much slower than promised.

In real world operating systems, there are many fluctuations that can affect the readings. Water level, temperature, and contamination, coupled with slow system dynamics, can defeat many of the proposed gains from this technology.

Also, when delivering a new lot of product, the Tag:Trasar ratio may not be the same, impacting the computer response to properly adjust the feed rate.

Customers do not want to watch their towers scale up. It is the responsibility of the vendor to prevent the tower from scaling. However, it often happens that the cooling system will "crash" and scale up faster than can be prevented by the controller. It is of little comfort to say, "Here at 7:36 PM is where the scale started to precipitate."

Biosensar is even more complicated. Reportedly, one problem is that oxidizers react with the red and blue molecules, and can form a blue-green molecule. The dye is extremely expensive and cannot be wasted. Further, you <u>cannot</u> maintain a significant oxidizer residual when using Biosensar. Maintaining an oxidizer residual defeats the use of the Biosensar.

The coordination of all the data is very complex, and logically the responses will also be complex. Should more product be fed, blow down the system, or lower the pH? The question is - will the controller's control logic be capable of responding properly?

<u>Automation Alternatives</u>

This section will address automation feed control alternatives to Trasar®. The water treatment community, outside the confines of Nalco, utilizes alternative automation technologies to Trasar®. An obvious reason is due to Nalco's patents, which are protecting the use of fluorescent-based automation. However, this discussion will offer some comparison and reasons why non-Trasar® methods will likely remain a prevalent alternative choice even after Nalco's initial patent expires in 2005.

The more common alternatives to Trasar® for chemical feed automation (of cooling systems) will include:

1) Chemical proportioning pace to a flow along with and without cycles control (using conductivity measurement)
2) Chemical proportioning based on system volume along with a timer to control the frequency and duration of feed.

It is important to assess the degree of automation that is required for an effective cooling treatment. This is a very practical question when considering that a recent AWT survey (on feed automation) showed economics (equipment and installation cost) to be the primary barrier to implementing automation. In reality, it can be said that no system is fully automated – in other words there will always be some form of human intervention required for even the most sophisticated automation scheme.

Consequently, the goal of automation needs to be defined for each customer and facility. Universally, most customers want to accomplish the following:

- Improve safety – reduce chemical handling & exposure
- Increase productivity – reduce cost required to operate and maintain
- Improve reliability – obtain better performance

Full service contracts have become a popular business arrangement in the water treatment industry allowing the customer to achieve the above goals (at least in perception) by shifting the burden of compliance to the water treatment professional. In this case, the implementation of automation is a greater benefit to the water treatment professional than it is to the customer. Consequently, the water treatment professional may need to be responsible for some or the entire economic burden to achieve the goals shown above. Hence, the economics of feed automation will be scrutinized by both the end-user and the water treatment professional.

Another key consideration in choosing a feed automation scheme is reliability and required preventative maintenance. This is especially true when the water treatment professional has committed to a "full service" type business arrangement.

What is Meant by Automation?

Automation is the replacement of a routine and presumably undesirable task that would otherwise be done by human intervention. For example, three primary aspects of chemical feed automation may include:

1. Chemical handling: batch feed chemical (via a mix tank) versus feeding chemical neat from the shipping container or from a bulk storage tank.
2. Physical introduction of chemical into the system: manual introduction of chemical versus the feed of chemical using a chemical injection system (such as a chemical feed pump).
3. Modifying feedrate and/or frequency: manual adjustment of either versus automated adjustment using on/off sequence or variable speed motors.

What Control Schemes Exist for Chemical Feed Automation?

Feed forward and feed back control describes the theory of control. Feed forward automation involves making adjustments based on things that will affect a target control parameter.

Feed back automation involves adjustments based on things that have already affected the control parameter. For example, adjustments based on flow are considered feed forward control. Adjustments based on a monitored parameter (such as ORP or fluorescent concentration) are considered feedback control. If both control methods are combined (i.e., feed forward and feed back control) then the loop is said to be closed – this is typically an ideal control method, but it is usually more complicated and can be more expensive as well.

A practical example of feed forward control is to feed cooling inhibitor proportional to makeup water flow. The feed back control could be achieved by testing of molybdate (assuming the inhibitor formula contains molybdate) and then by making adjustments to the chemical feed pump based on measured molybdate residual versus the target molybdate residual. In this case, the testing for molybdate enables verification of feed as well. Verification can be done in other ways, such as monitoring the usage or depletion rate of the chemical.

Practically, there are four common control schemes used to control the feed of cooling treatments.

Makeup Paced Control – Chemical feed based on proportioning chemical feed paced (on/off) to makeup flow (a mass balance approach based on makeup flow). As noted, this is a form of feed forward control. In a non-evaporative system (closed loop), this is all that will be required to achieve reasonable control. In an evaporative system (cooling tower loop), control of tower cycles is typically performed using conductivity measurement. The recent (feed automation) survey of the AWT membership indicated that this feed control method was quite common.

The economics are reasonable, especially if the customer has already installed a makeup flow meter with contacting head.

Key advantages include: 1) water flow and conductivity probe components (for measurement and control) are generally considered reliable and easy to maintain, and 2) chemical feed control is maintained even with operating load variations.

Key limitations include: 1) unwanted chemical usage if the tower makeup float is stuck open, 2) poor feed control if the tower cycles vary (i.e., variation in makeup conductivity) and 3) poor feed control under low operating load condition resulting in little to no evaporation/blowdown and consequently little to no demand for makeup flow.

This can be common in HVAC systems during the early-Spring and late-Fall seasons. It is also common in air washers (found in Textile Facilities) during high humidity, high temperature weather.

Bleed & Feed Control – This review pertains to today's bleed and feed control method, which is greatly enhanced compared to older methods due to the advancements in controller capabilities. Chemical feed is based on a timed sequence in proportion to blowdown frequency and duration (this also is considered a feed forward control loop). Each time the blowdown solenoid activates the controller will feed chemical. Typically, the duration of chemical feed is in proportion to the duration of the blowdown sequence. In essence, the goal is to replenish the chemicals that are lost due to blowdown – a mass balance approach based on blowdown flow. This control scheme is typically used only in evaporative cooling systems (systems where blowdown frequency is routine and controlled).

The economics of this set-up is even better than the Makeup Paced Control, especially if a makeup flow meter with contacting head is not already installed.

Key advantages include: 1) simplicity - does not require installation of a makeup flow meter, 2) chemical feed control is maintained even with operating load variations, and 3) no concern for wasted chemical feed should the makeup float valve become stuck in the open position.

Key limitations include: 1) poor feed control if blowdown is uncontrolled, and 2) insufficient feed under low operating load with little to no evaporation/blowdown as noted above. This feed control method is dependent upon controlled blowdown occurring.

Time-Based Control – Chemical feed is triggered and controlled by a timer. The time-based approach is commonly used during slug feeding of chemicals (such as microbiocides) and feed is based on the system's volume. Another version of this theme is to feed inhibitor based on percent of time on/off sequence – commonly used during the low/non-evaporative conditions associated above with HVAC and textile facilities. These are both feed forward control loops.

The economics of this control scheme is similar to or has lower cost relative to a bleed and feed approach, and is typically simpler.

The key advantages include: 1) very simple way to dose chemicals, and 2) provides a viable feed control approach for systems with little to no operating load.

Key limitations include: 1) inability to automatically adjust to changing operating conditions (i.e., varying heat loads), and 2) inability to automatically compensate for variable cycles.

Parameter Target Control – Chemical feed is based on maintaining a particular target for a specific parameter (using some in-line measurement device).

This feed automation method is typically a feedback loop. Trasar® is an example of this type of feed control scheme. Other examples include ORP control and reverse conductivity control (in closed loops, conductivity can be used as a set point to activate and control chemical feed).

These control set-ups tend to be higher cost.

Key advantages include: 1) the control loop is specific to the control of the chemical, 2) the control scheme can work well with varying operating conditions and 3) the control scheme will function well where water losses are uncontrolled or generally where mass balance chemical can not be used effectively.

Key limitations include: 1) often times the control equipment is more sensitive and more maintenance intensive, 2) these control set-ups are parameter specific – potentially locking a customer into an automation approach which is proprietary and less versatile.

Table 1 – Control Scheme Application Summary

Control Scheme	System Application	Treatment Application
Makeup Paced Control (MPC)	Evaporative or Non-evaporative Cooling	Inhibitor, Continuous biocide, pH (need cycles control w/ Evap., Cl^-)
Bleed & Feed Control (B&FC)	Evaporative Cooling	Inhibitor
Time Based Control (TBC)	Evaporative or Non-evaporative Cooling	Inhibitor - % of Time (needs cycles control w/Evap., Cl^-) Biocide - % of Time or intermittent slug dosing
Parameter Target Control (PTC)	Evaporative or Non-Evaporative Cooling	Inhibitor – fluorescence, reverse conductivity (performs even without cycles control) Oxidizing biocides – ORP, Cl_2 pH, Blowdown and Cycles (based on conductivity)

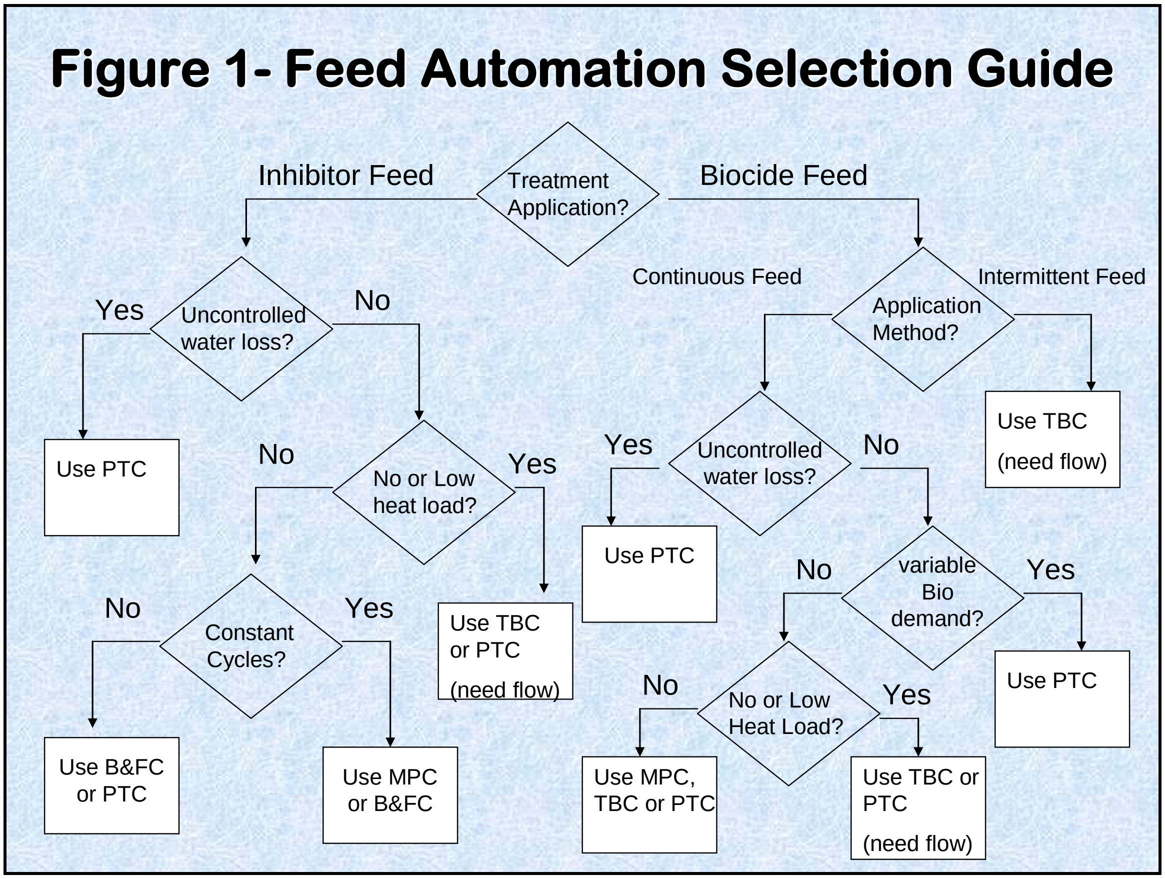
Table 2 – Control Scheme Advantages & Limitations Summary

Control Scheme	Advantages	Limitations
Makeup Paced Control (MPC)	1) Flow meter and conductivity probe (used for evaporative cooling systems) are reliable and easy to maintain 2) Adjusts chemical under variable load conditions	1) Unwanted chemical usage if tower float gets stuck open 2) Poor feed control if cycles vary 3) Insufficient chemical feed during nil or no load conditions
Bleed & Feed Control (B&FC)	1) Does not require makeup flow meter 2) Adjusts chemical under variable load conditions 3) Will not overfeed if makeup float gets stuck	1) Poor feed control if blowdown loss is uncontrolled 2) Insufficient chemical feed during nil or no load conditions
Time Based Control (TBC)	1) Most simple method of automation – a timer. 2) Provides chemical feed control under no load condition	1) Poor feed control under variable load conditions 2) Poor feed control if cycles vary
Parameter Target Control (PTC)	1) Direct control of a variable/key parameter 2) Provides chemical feed control under variable load conditions 3) Provide chemical feed control with uncontrolled water losses	1) Control components can be more difficult to maintain 2) Tends to be more proprietary and less versatile

Table 3 – Control Scheme Economics Summary

Control Scheme	Relative Economics	Relative Reliability
Makeup Paced Control (MPC)	+ Relatively low cost if flow meter with contacting head already exists. - Cost of contacting head flow meter can be moderate to high, depending on meter design. - May need to add conductivity measurement of makeup if makeup quality is variable - Excessive chemical usage if makeup float get stuck open	+ Good – Flow meter, conductivity probe, controller are easy to maintain and generally reliable
Bleed & Feed Control (B&FC)	+ Lower cost option versus Makeup Paced - Control if flow meter is not already in place.	+ Very Good – conductivity probe and controller are easy to maintain and generally reliable
Time Based Control (TBC)	+ Lowest expense to set-up - Less versatile control set-up	Very Good – timer based control is simple with little maintenance required
Parameter Target Control (PTC)	+ Typically most expensive to set-up +Typically most maintenance intensive	+ Fair to Good – parameter specific probe with controller

Selecting the best-feed automation control method(s) requires some understanding of the system design and operating conditions. And although this paper is not meant to address the comparison or selection of supplier specific control equipment, it is important to note that this factor is a key one in the selection process. Figure 1 offers some guidance in selecting a feed automation control method.



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This is not intended to be a complete list of all fluorescence related papers and patents.

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