A System for the Segregation of Aqueous Particulate-Laden Streams

by

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1.0 Introduction

A system is under development which can automatically draw a sample from a solids-containing aqueous stream, rapidly filter and analyze the sample using a number of possible technologies, and act on the results of that analysis. The action time for this process can be on the order of one to three seconds, although this is dependent on the time required before the stream sampled must be acted upon. For example, if it takes the sampled stream three seconds from when it is first sampled to reach the diverting valve, the system must respond within that time. Note that this time can be extended with an optional reservoir prior to the diverting valve, as shown in Figure 1.

The key to the effectiveness of this system is the fact that two key components, the filter system and the analyzer, are modular by design. If the particles in the stream to be sampled are large, or have a unique chemical characteristic, such as hydrophobicity, then the filters can be changed accordingly. Likewise, if the system is required to discern between two streams which are alike in all ways but pH, or conductivity, or color, all that is required is to change the analyzer subunit, which the rest of the system remains the same. Using this modularity, it is possible to efficiently and inexpensively tailor the system to the needs of a specific site.

2.0 Design Elements

For the purpose of obtaining an estimate of the cost of the system, a "base case" configuration will be used, assuming that the analysis is based on ADMI color density, a common optical property used in the textile industry to determine the degree of color in a wet textile finishing waste stream. The base case design also assumes that the liquid to be handled is corrosive, and possibly at a high temperature. It should be noted that if this is not the case, the total system cost may be substantially less.

2.1 Flow Sensor

The system detects the presence of the fluid to be sampled by means of a paddlewheel-type flow sensor. Since this is a Boolean yes/no condition, the output of this sensor feeds into the digital I/O of the microprocessor. When wastewater is detected, the microprocessor activates the pump power supply. The flow sensor is marked "1" in Figure 1.

2.2 Filters

In the majority of the possible analysis subunits, it is necessary to filter out any particulates to obtain reliable analysis data. The system has a combination of two filtration units, fine and coarse, to perform this function.

2.2.1 Coarse Filtration

The system has an inlet two inches in diameter. When the sample enters the system, it passes through a horizontal plate filter, consisting of a number of coarse filter screens of successively smaller mesh size. For the base system design, the plate filter consists of five filter screens, with the first screen being 0.5 inch mesh and the last being 0.25 inch mesh. When the backflush subunit is activated, the coarse filter screens are rinsed by the high-pressure house water applied across the screens as shown in Figure 2.

2.2.2 Fine Filtration

An in-line cartridge filter is used to screen out fine particles before the sample is analyzed. The fine filter uses a pure polypropylene housing and sump as well as a spun-polypropylene, progressive-density filter cartridge with a nominal pore size of 25 μm.

2.3 Backflush Subunit

The system shown in Figure 1 contains an automatic backflush subunit. This is activated when the pressure drop across the fine filter as determined by pressure sensors "2" and "3" exceeds a preset 5 to 20 psi or when pressure sensor "4" detects a vacuum pressure of -5 psi or less. When activated, a three-way valve closes the inlet to the optical subunit and allows the house water, typically at 40-80 psi, to flush backward through the filter, through a bypass around the pump and the coarse plate filter, and out to the process liquid pipe. Simultaneously, the pressurized house water washes across the coarse filter screens as shown in Figure 2. The backflushing can only occur when no liquid is present in the process liquid pipe, and should last no longer than ten seconds.

The pressure sensors contain a 300 series stainless steel diaphragm and all wetted parts are of stainless steel. The pressure range is from 0 to 100 psig. The backflush valves are a solenoid-type three-way valve with a 316 stainless steel body and internal parts with a Viton seal.

2.4 Tubing

The system inlet is two inches in diameter; once the liquid entering the system has been coarsely filtered, the tubing is reduced to 1/2-inch diameter stainless steel tubing for all sample transport. Eight feet of tubing is used between the system inlet and the analyzer unit, with an additional five feet of tubing running from the analyzer unit to the system outlet.

2.5 Sample Pump

The sample pump is a positive-displacement gear pump with a flow rate of ten gallons per minute. This will permit a turnover of two sample volumes (defined as the volume between the system inlet and the analyzer unit) per second. All wetted parts of the pump are of stainless steel.

A gear pump was chosen for this design because it is relatively insensitive to the fine particles still present after the sample has been coarsely filtered. Other pump types may be more advantageous for a given application.

2.6 Dilution Subunit

Certain types of streams which are to be sampled may contain solutes which are too concentrated to be measured accurately. Good examples of this measurement of ADMI color density. To prevent this, a dilution stream fed by the house water may be added to the system as shown in Figure 1. The ratio of dilution is dependent on a given application. The dilution ratio is preset in the programming of the microprocessor and carried out through a three-way, solenoid-type valve controlled by the analog-to-digital converter.

2.7 Analyzer

The analyzer is similar to that built for Vandy Price by Riley Chan[6,7]. The light source subunit consists of a high-voltage power supply connected to a 50 Watt tungsten halide lamp. Between these two elements is a controller to insure constant intensity from the lamp as the filament deteriorates. The light passes through a quartz tube containing the sample and through three interference color filters (marked "A", "B", and "C" in Figure 3) corresponding to wavelengths of 438, 540, and 590 nm. The filtered light is measured by three diodes (marked "D", "E", and "F" in Figure 2) which measure the light intensity. The light intensity is converted to voltage using the circuitry shown in Figure 4, and the signal is transmitted to the analog-to-digital converter in the microprocessor. Note that this information can either be manipulated to determine the ADMI color density of the sample, or the different signals can be compared and an estimate of the color of the sample can be obtained.

2.8 Microprocessor

The microprocessor consists of an 8052 processor, an EPROM containing the necessary programming, an analog-to-digital converter, a digital-to-analog converter, and a digital I/O interface. The latter is used for Boolean inputs and outputs, while more complex inputs and outputs are handled by the A/D and D/A converters. The microprocessor activates the pump power supply when liquid is detected in the process stream pipe, activates the backflush subunit based on the preprogrammed pressure parameters, controls the ratio of dilution, if any, and records the output of the analyzer and activates the diverting valve.

2.9 Backflow Prevention

The possibility exists that unfiltered solution could enter the outlet of the system and thereby foul the analyzer unit. To prevent this, a swing-type check valve has been placed near the exit of the system to prevent any backflow into the system.

2.10 Wastewater Valves

Finally, the wastewater is diverted according to the microprocessor programming using a solenoid-type, three-way valve similar to those used in the backwash subunit, only of a larger capacity.

3.0 System Costs

The material costs for the system are described below (RC denotes estimates provided by Riley Chan):

Unit	Cost	Source
Flow Sensor	$195.00	Omega FP-5100
Filter Housing	$54.00	Cole-Parmer H-01508-27
Filter Cartridge	$4.50	Cole-Parmer H-01509-35
Pressure Sensors (3)	$150.00	Omega PX120-100GV
Backflush Valves (4)	$70.00	Cole-Parmer H-08601-50
Sample Pump	$250.00	(estimated)
Analyzer:		
Interference Filters (3)	$100.00	RC
Diode Circuitry	$50.00	RC
Lamp and Controller	$200.00	RC
Microprocessor	$400.00	RC
High-Voltage Power Supply	$200.00	RC
Low-Voltage Power Supply	$150.00	RC
Check Valve	$150.00	(estimated)
Wastewater Valve	$150.00	(estimated)

Based on the above figures, the total material cost is approximately $3,000. The installed cost for the system is $7,500, using an approximation of a 150% markup to account for installing and tailoring the system to the requirements unique to a site.

4.0 A Case Study: Wet Textile Finishing Wastewater

Water usage in wet textile finishing processes can exceed 1,000,000 gallons per week[1]. Some of this water is re-used within the process, but the majority is discharged for processing at the local, publically-owned treatment works (POTW). This discharged water is usually the combined effluent of the individual finishing systems, and contains various colorants and suspended solids which must be treated and filtered prior to being discharged into the environment.

It may be economical and more efficient to segregate the waste streams and to thus isolate the streams which require specialized treatment. In this manner, for example, the clear-to-yellowish bleach waste stream may be prevented from mixing with the dye waste stream, the latter of which may require decolorizing pretreatment prior to discharge to the POTW. In this report, such a system for the automatic segregation of wet textile finishing waste streams is proposed, and some possible applications are considered.

4.1 The Wet Textile Finishing Process

In the wet textile finishing process, the waste streams generated are many and varied. Eighty percent[2] of the total aqueous waste comes from three processes: bleaching, mercerizing, and dyeing.

Bleaching uses a number of oxidizing agents , the most commonly used in the United States being hydroperoxide species (hydrogen peroxide or related peroxy compounds)[3]. The waste stream from this process is characterized by a high total solids, a high chemical oxygen demand (COD), residual oxidizing agents, color ranging from clear to yellowish and turbid, and an alkaline pH on the order of 8-11.

Mercerizing uses a strongly caustic agent such as sodium hydroxide or liquid ammonia. The waste stream has a low amount of total solids, a low biological oxygen demand (BOD), a clear-to-yellowish color, and a strongly alkaline pH ranging from 9-12, although the alkalinity can be decreased by 60-70% through the recovery of sodium hydroxide[4].

Many possible combinations of dyeing processes and dyes exist, but it is possible to make some generalizations about the process. Dye wastes usually have high ionic salt content, high BOD values, and are strongly colored.

4.2 Segregation of Wastewaters

At the present time, many textile finishing plants route all of their effluent to a common trench, which is then discharged directly to the local POTW for treatment. The drawback of this method is that the contaminant in one stream is now mixed with those of other streams, and, for example, it is now necessary to treat the entire volume of effluent for decolorization instead of just the 10-20% of the effluent comprised of dye waste. It is plain that segregating the wastes for pretreatment prior to discharge to the POTW can more efficient and less costly than the present method.

It is possible to assign the responsibility of this segregation to an operator; however, this assumes that the operator is not occupied with other duties, and can route the wastewater appropriately at the time of discharge from the process. Automation of the segregation avoids the loss of man-hours in this duty, as well as prevents any system down-time and possible spillage due to the operator not routing the effluent at the correct time.

4.3 Waste Stream Analysis

Analysis of the effluent on the basis of optical characteristics is an economical method of separating streams which may be similar in other physical properties such as pH or conductivity. The optical analysis can be done cheaply using transmittance measurements, and has the additional benefit of minimizing contact of sensitive equipment with the possibly corrosive wastewater.

If the transmittance analysis is done using three diodes at wavelengths of 438, 540, and 590 nm, then the analysis can be done in two ways. First, the ADMI color density can be determined to differentiate between the colored dye waste and the clear-to-yellowish bleach waste[5]. Second, by comparing the transmittance of light at the three different wavelengths against each other it is possible to gain an estimate of the color of the waste. The latter mode of operation could be used to discern between, say, red dye waste and green dye waste and shunt the green dye waste, which may contain copper or heavy metals, to a separate area for special treatment. Another possible application for this system is the testing of color density of dyebath effluent to determine if it is suitable for recycling back into the dyebath.

5.0 Other Applications

One of the benefits of this system design is that its use is not limited to textile wastewaters. With very few modifications, the entire system can be used in applications to segregate various aqueous streams automatically. The key to this flexibility is the analyzer subunit. Depending on the system, analyzers utilizing pH or conductivity measurements, or even spectroscopic methods such as UV/visible spectroscopy can be used, requiring only replacing the analyzer subunit and reprogramming the microprocessor.

In addition, the segregation system can be applied elsewhere in the textile finishing process to determine suitability of wastewater for recycling back into the process. In this manner, pH or conductivity measurements could be used to gauge the potential mercerizing wastewater for reuse, and color density measurements could be used in a similar manner for the dyeing process.

Another application is in the oxidative pretreatment of dye wastes. In this process, the dye waste is treated on-site prior to discharge to the POTW with an oxidative agent such as Fenton's reagent. During this treatment process, the segregation unit can be used to draw a sample from the treated waste and analyze for color density as part of a feedback control loop. If the color density is low enough, the treated waste may be discharged; if not, further treatment is required. In this manner, it is possible to entirely automate the decolorization process. Such an application of this system has been discussed by Price[6,7].

Pretreatment of dye waste to remove color is not always effective, though. In a textile finishing plant, many different types of dyes may be used. For example, disperse dyes are commonly used for synthetic fabrics, and reactive dyes on cellulosic fabrics. This poses a problem for the color-removal pretreatment process, since although oxidative pretreatment is excellent for neutralizing color from reactive dyes, it is much relatively ineffective on disperse dyes. Since the reactive dye process uses an appreciable amount of salts to prevent hydrolysis, while such salts are not necessary for disperse dyes. Therefore, it is possible to discern between the separate dye wastes on the basis of conductivity, and the proposed system is ideal for the separation of the waste streams, the reactive to the pretreatment system and the disperse dye wastes straight to the POTW. Note that in cases where conductivity measurements alone are not sufficient to differentiate between the two streams, it is possible to add a measurement of color density in series with the conductivity unit.

Finally, the above proposed system is designed for a small plant, in which discrete plugs of effluent are assured. In a larger finishing operation, it is possible that multiple systems could be installed in the fashion shown in Figure 5 to segregate the effluents of various processes before they reach the central discharge trench.

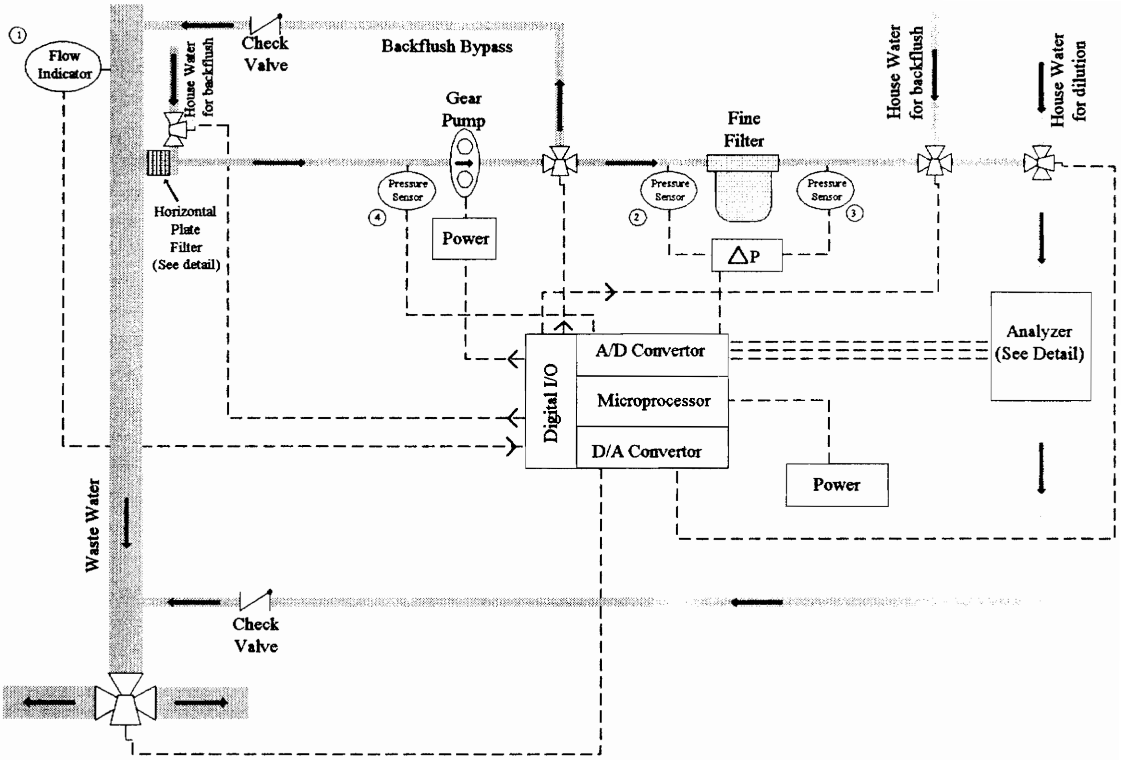

Figure 1: Overall System Schematic

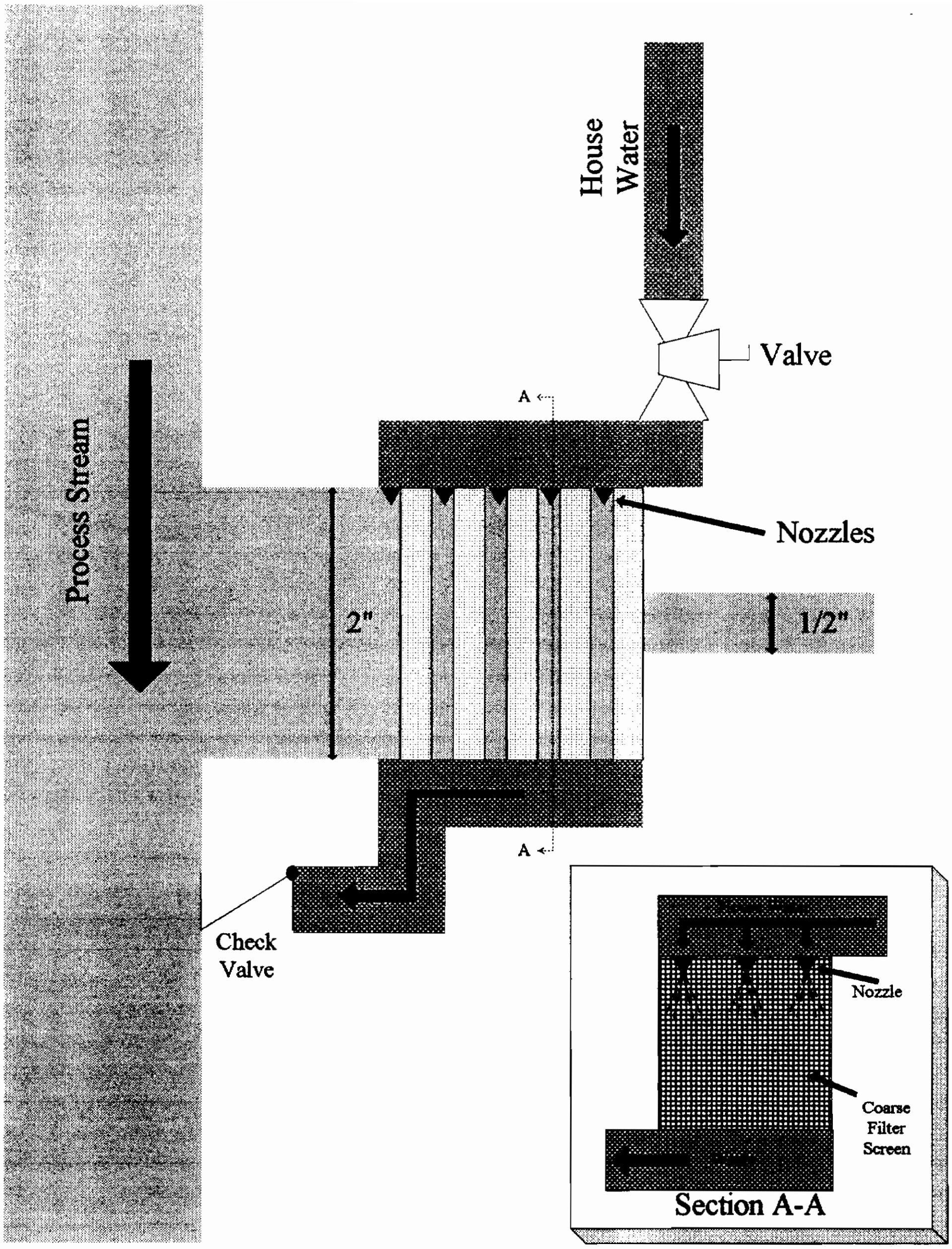

Figure 2: Detail of Coarse Filtration Unit

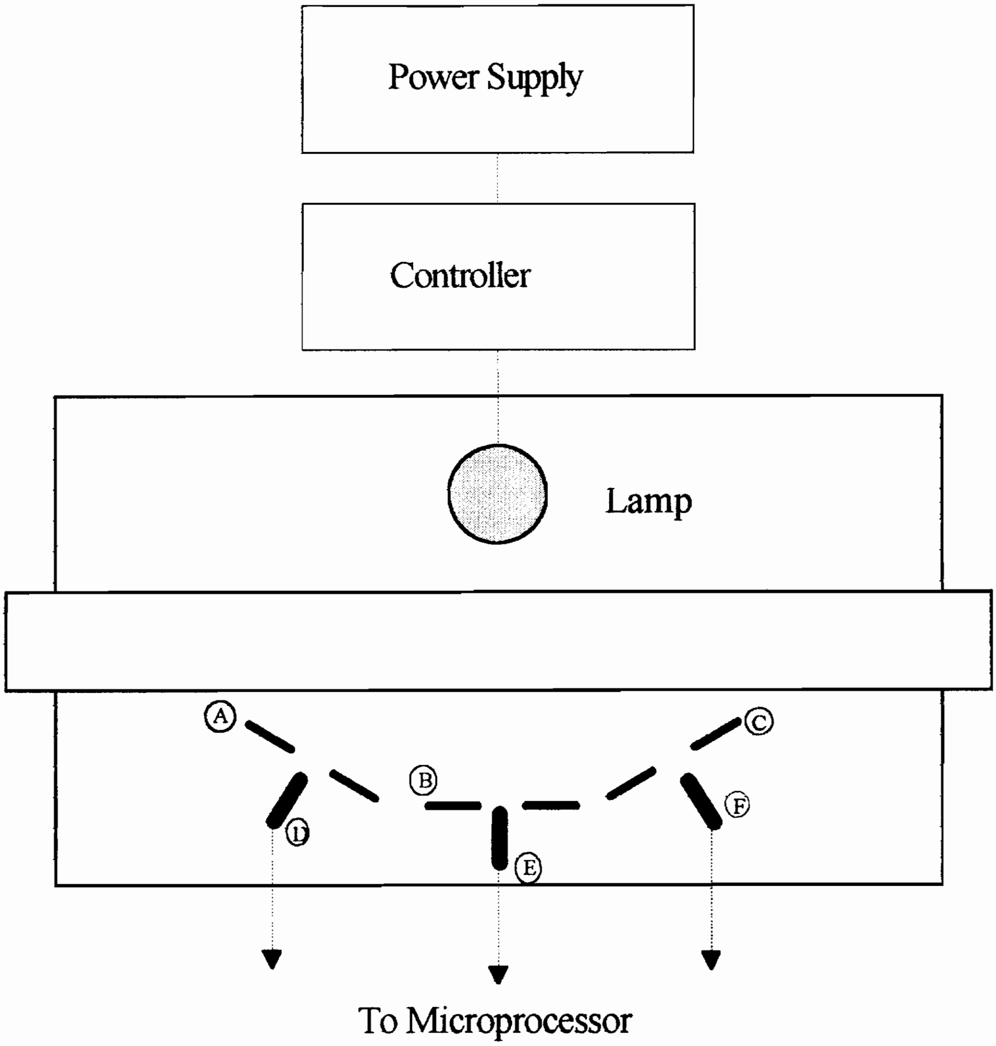

Figure 3: Detail of Color Density Analyzer

A,B,C = 438, 540, and 590 nm filter, respectively
D,E,F = diodes

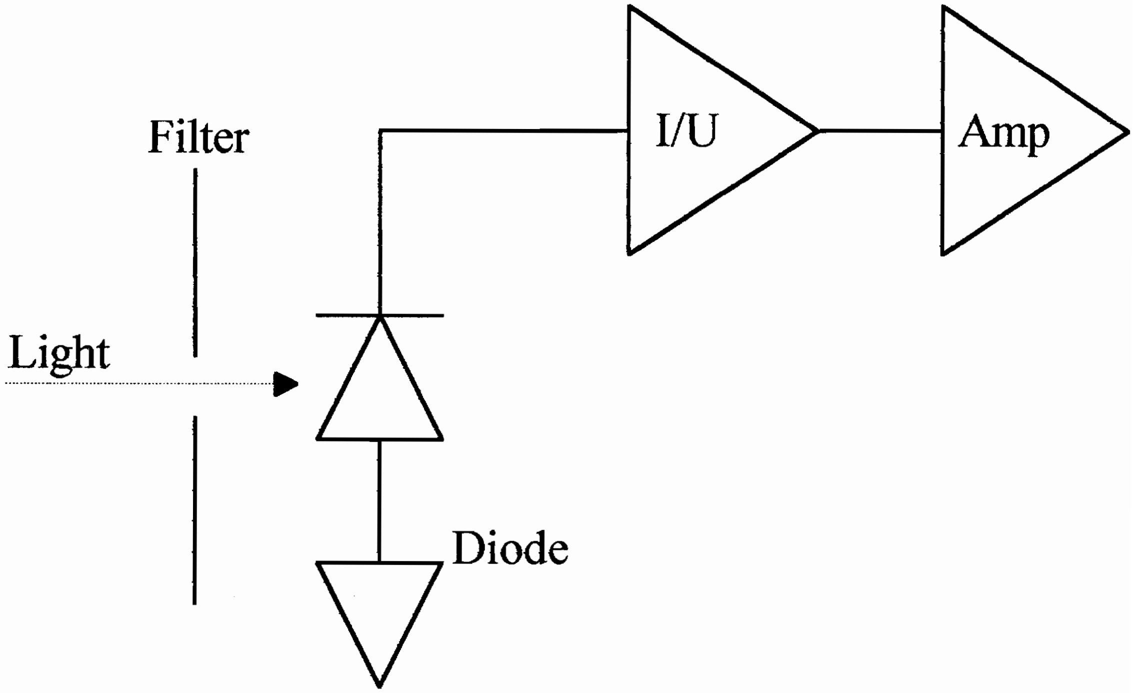

Figure 4: Detail of Electronics of Color Density Analyzer

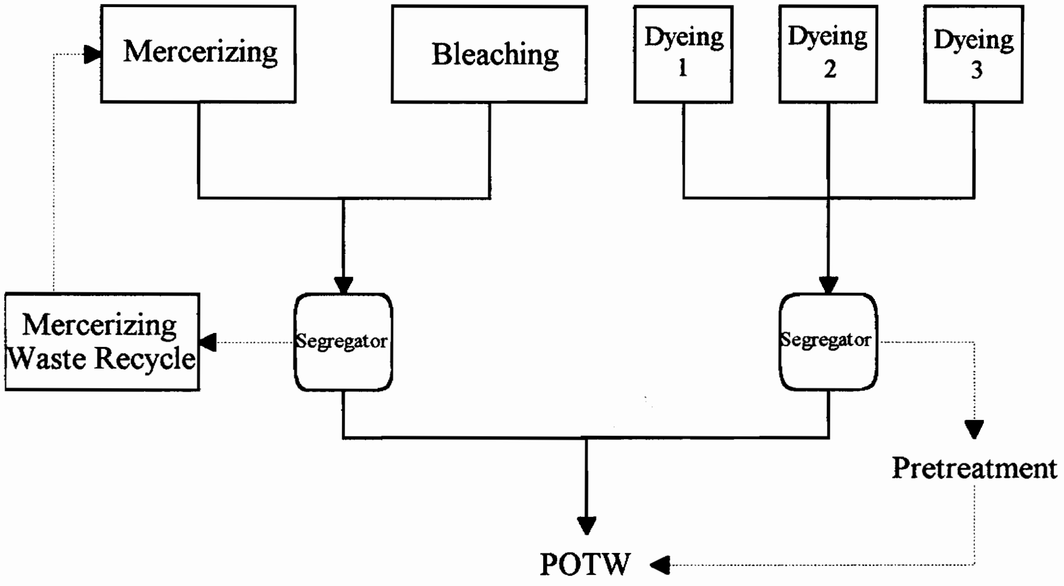

Figure 5: Proposed system using multiple segregators

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