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Project Summary

Process Spill Monitoring, Control and Recovery in the Pulp and Paper Industry

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In order to develop strategies to control intermittent spills associated with the production of chemical wood pulp, examinations of process effluents from kraft pulp mills and investigations of existing loss control systems were conducted. Dynamic computer modelling, using data from process effluent monitoring, was employed to illustrate the utility of this technique to arrive at various loss control strategies for particular process configurations. Examples were presented, using the monitoring data, of the economic benefit possible from recovery of chemicals and organic solids. A loss control strategy for pulping, pulp washing, and chemical recovery areas was implemented in the existing spill control system of a large kraft pulp mill. Control was successfully effected utilizing a digital computer. In addition to managing process losses, the direct digital control system allowed gathering, processing and managing data obtained from the sensors monitoring the system.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

This report outlines the examination and characterization of process effluents and explains a loss control system for a large kraft pulp mill which utilizes a digital computer.

Effluent Characterization

Samples were analyzed from process and liquor storage areas and sewers in 20 pulp mills - representing various locations, ages, process types, and wood species. Because compositions varied widely, predictive correlation equations could not be derived. The absolute values of the parameters varied relatively little within each class of fluid, however, so reasonably consistent ratios could be established to describe different parameter pairs. Table 1 gives representative ratios for weak black liquor (WBL) samples from the mills tested. As an example, the data for 26 different liquor samples showed that biochemical oxygen demand (BOD) was approximately 23% of the total dissolved solids (TS) content, with a standard deviation of 4%.

Selection of variables for monitoring was also influenced by the linearity of the measured response with concentration. Figure 1 shows how total organic carbon (TOC) changes in proportion to weak black liquor concentration and Figure 2 indicates how conductivity varies with weak wash concentration. The data were obtained by adding con-

Table 1. *Characteristic Parameter Ratios for Weak Black Liquor Samples.*

Ratio	Average	Standard Deviation	No. of Samples
BOD/TS	0.23	0.04	26
TOC/TS	0.39	0.03	28
BOD/TOC	0.59	0.08	22
Na/Conductivity	0.71	0.34	24
PCU/Conductivity	4.84	1.92	34
TS/Conductivity	2.90	0.84	30

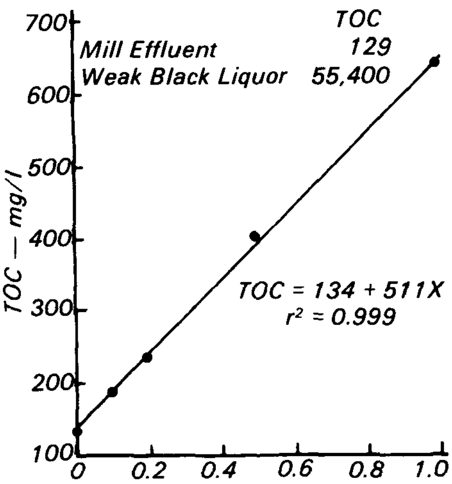

Figure 1. *Linearity of TOC response weak black liquor added to mill effluent.*

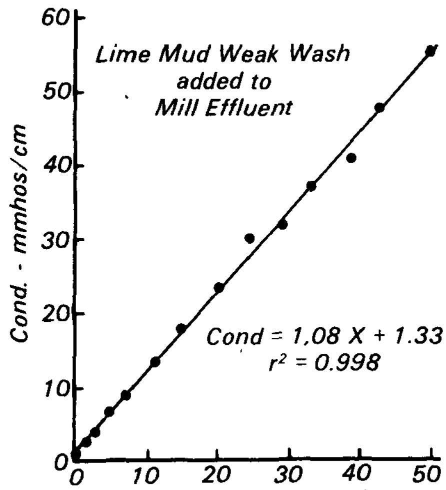

Figure 2. *Linearity of conductivity response lime mud weak wash added to mill effluent.*

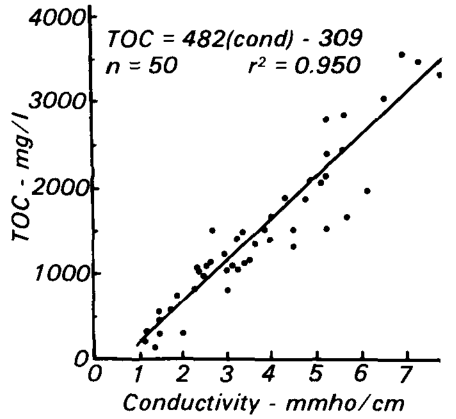

Figure 3. *Linearity of conductivit[y] related to TOC.*

centrated samples incrementally to normal mill effluent.

These findings suggest that pH and other specific ions, TOC, color, and conductivity might be appropriate as indicators of effluent conditions. pH was eliminated as lacking the required sensitivity. Specific ions, TOC, and color measurements were considered too expensive for large monitoring networks, in part owing to requirements for sophisticated sample systems. Conductivity was found to be a suitable linear predictor of parameters such as sodium and TOC; this variable can also serve as a direct indicator of spills because its value increases with dissolved inorganic solids concentration. Moreover, conductivity instrumentation is widely used, relatively simple, reliable, and reasonably inexpensive.

Control Equations

Developing the control equations for the spill recovery system required that conductivity be related to mass flows of solids, sodium, and organic carbon from the various processes. This was accomplished using data from process sewers in pulping, pulp washing, liquor recovery, and causticizing areas at two mills. Samples were drawn using automated equipment at 1 to 12 times per hour depending on process conditions. Analyses were made in a laboratory for accuracy.

Linear equations of the form $y = mx + b$ were sought, relating conductivity (x) to other parameters (y). Many samples were analyzed and data points like those in Figure 3 were used with regression techniques to evaluate slope (m) and intercept (b). Table 2 shows values obtained at the monitoring stations in one of the mills sampled.

System Design

The loss control system gathers and analyzes sensor data to detect and log problems, responds to appropriate situ[-]ations by queuing remote devices an[d] notifying the operator, and provide[s] reports and summaries of occurrence[s]. These functions are implemented usin[g] a system based on a central compute[r] with a keyboard printer for operat[or] action and a process input/output (I/O) interface. Sensors include conductivit[y,] flow, and level probes; actuators includ[e] pumps, valves, and samplers. In th[e] system specified, the interface may b[e] 6000 feet from the central processin[g] unit and the remote devices can b[e] 1500 feet from the interface.

Operation

The system was installed in the larg[e] kraft pulp mill in Figure 4 and include[s] the monitored stations listed in Table [.] Sumps receive overflows from variou[s] storage tanks as well as leaks fro[m] transfer pumps and heaters. Each sum[p] has a conductivity probe, a flow meter, [a] sampler, and a self-priming pump.

Effluent normally flows from th[e] batch digesters, brown stock washer[s,] evaporators, and recovery furnaces [to] mill sewers, where flow and conducti[v]ity are measured, and then to biologic[al] treatment. Spills are picked up by th[e] sump pumps and transferred to [a] 200,000-gallon tank. The fluid m[ay] then be bled to the sewer or pump[ed] back to the 20,000-gallon overflow ta[nk] and into the vats on the first stages [of] the washers.

Ranges of parameters and values [of] ratios obtained from the prelimina[ry] analyses were used to determi[ne] conductivity setpoint. Mass flow se[t]points for Na, TOC, and TS are calc[u]lated using flow measurements in t[he] equations relating these parameters

Table 2. *Parameters Derived for Use in the Linearized Control Equation (y = mx + b)*

Station	Variable	No. of Observations	Slope (m) μmho/cm	Intercept (b)	Observed Conductivity Range μmhos/cm	Observed Variable Range mg/l	Multiple Correlation Coefficient
1	Na	97	0.249	- 95	702 - 11730	134 - 2730	0.951
	TOC	50	0.482	-309	1140 - 8110	144 - 4090	0.950
	TS	59	1.655	-884	900 - 18800	440 - 34520	0.943
2	Na	96	0.308	- 87	165 - 9560	18 - 3046	0.995
	TOC	68	0.599	-101	165 - 9560	66 - 5730	0.985
	TS	33	1.743	-550	730 - 7160	1860 - 19790	0.977
3	Na	95	0.261	- 81	1166 - 15300	142 - 4772	0.974
	TOC	55	0.462	-363	67 - 11700	94 - 5415	0.979
	TS	40	0.565	+863	460 - 5800	530 - 6230	0.458
4	Na	60	0.258	- 39	238 - 3351	43 - 822	0.988
	TOC	40	0.492	+ 91	338 - 9630	249 - 4950	0.985
	TS	42	2.120	-845	350 - 8200	720 - 21400	0.928

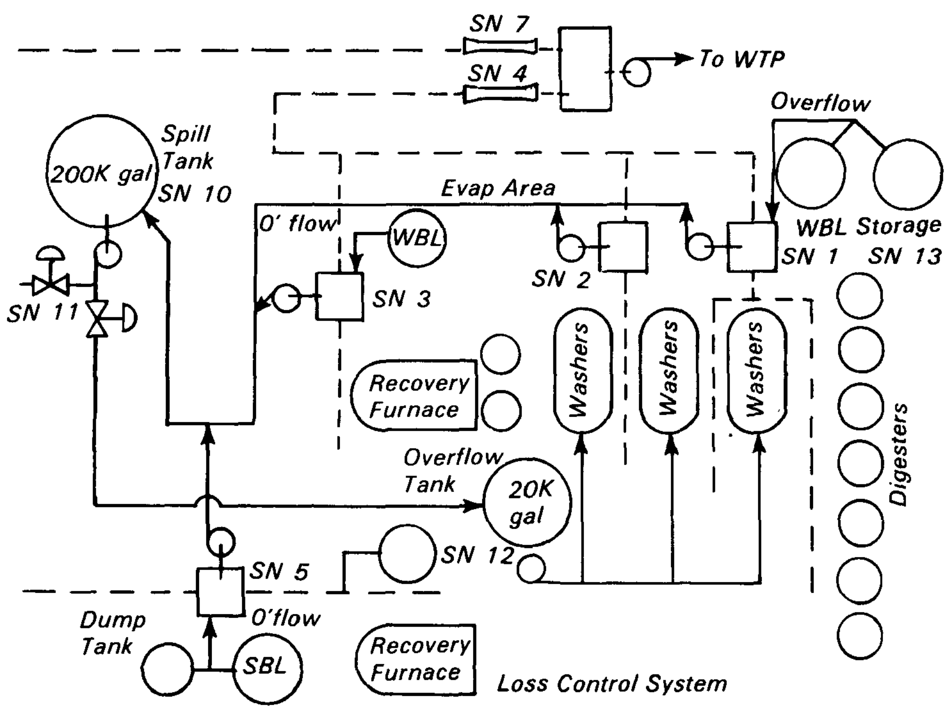

Figure 4. Schematic of Brown Co., loss control strategy system.

conductivity. These mass targets rather than conductivity are used to initiate action, so that control is exercised on the basis of material being lost, the capacity of the waste treatment plant, compatability of new spills with the present contents of the tank, and minimum total solids to be economically recovered. As an example, high conductivity may occur while only a small amount of material is passing through the system, neither of which requires a control response. Likewise, conductivity may be low when flow is high, and it may be desirable to exercise control for recovery or to prevent overloading the treatment plant.

In one instance, a conductivity setpoint of 2 mmho/cm at 200 gpm corresponded to 484 lb/day Na, 786 lb/day TOC, and 2700 lb/day TS. If the setpoints for these constituents were established for reasons of economy or environmental protection at 900 lb/day Na, 4000 lb/day TOC, and 2900 lb/day TS, material would not be pumped to the spill tank unless flow or conductivity increased.

Table 3. Variables Measured at the Monitoring Stations for the Loss Control System.

Station	*Device 1*	*Device 2*	*Device 3*	*Device 4*
Digester Sump	*Conductivity*	*Flow*	*Pump*	*Sampler*
Brown Stock Washer Sump	*Conductivity*	*Flow*	*Pump*	*Sampler*
No. 8 Recovery Sump	*Conductivity*	*Flow*	*Pump*	*Sampler*
Main Kraft Sewer	*Conductivity*	*Flow*	---	*Sampler*
No. 11 Recovery Sump	*Conductivity*	*Flow*	*Pump*	*Sampler*
Causticizing Sewer	*Conductivity*	---	---	*Sampler*
Total Caustic Sewer	*Conductivity*	*Flow*	---	*Sampler*
Spill Tank	*Conductivity*	*Level*	*Pump*	*Sampler*
Spill Tank Valves	*Valve to Recovery*	*Valve to Sewer*	---	---
Overflow Tank	---	*Level*	---	---
Weak Black Liquor Tanks	---	*Level*	---	---

Control Strategies

The sump pumps and the spill tank valves may be operated manually, under analog control using conductivity setpoints, or in a direct digital mode with targets stored in computer memory. Digital control offers operators the most immediate and comprehensive information and also offers advantages such as rapid and easy setpoint changes. In addition, the computer provides the best base of data for management information.

The real-time executive for the computer system has the logic shown in Figure 5. The program restarts when the computer is powered, and may be initialized at any time for data averaging. The sensors are read in a burst every 10 to 15 seconds so all readings are obtained in the same relative time frame. Each reading is converted to appropriate units, and running averages are created and stored. Values are checked to verify whether the sensor is out of service or if action is already being taken at the particular station. If not, the readings are compared to parameters such as low and high limits, allowable rate of change, a confidence period to determine if a condition has been out of tolerance too long, and the number of times the system must detect a condition out of tolerance during the confidence interval. If readings are no within the setpoints, control is transferred to a real-time applications module like that in Figure 6, comprising routines for each station and senso which activate pumps or valves and notify the operator of situations and actions taken.

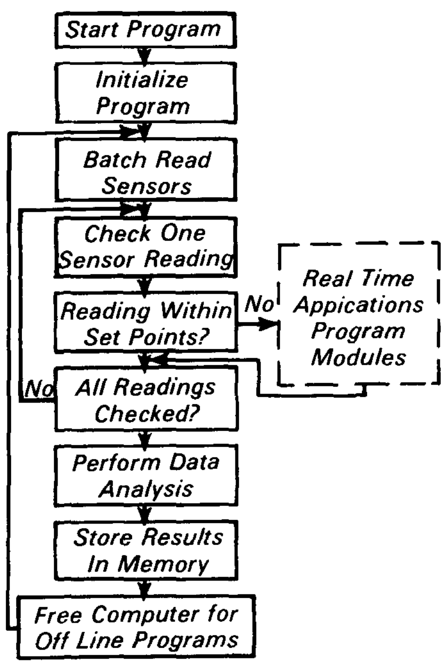

Figure 5. *Real time executive program module.*

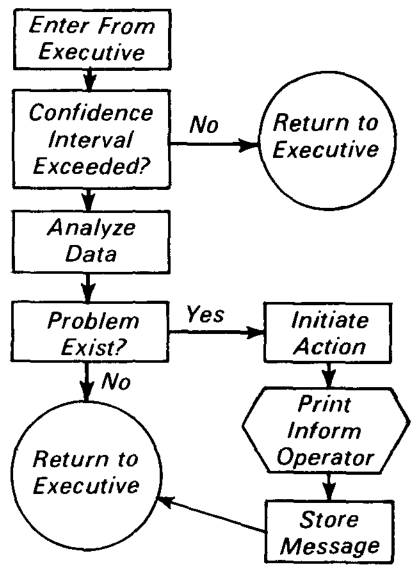

Figure 6. *On line applicatio module general structure*

The executive and application modules run in the foreground mode. The executive completes a cycle in les than 5 ms if no action is required, and i about 500 ms if control is transferred t the applications modules for ever station. Since the sensors are rea every 10 s, time is available to run othe programs in the background. Fo example, the operator ma communicate with the system throug the printer to monitor selected sensor change tolerance parameters o setpoints, open or close valves, tur pumps on or off, activate samplers, o mark sensors or control devices in o out of service for maintenance.

Performance

The loss control strategy has bee monitoring, intercepting and recoverin process spills and losses in the pulpin pulp washing and chemical recove areas of a large kraft pulp mill for ov two years. During that time all materi that has been sent to the spill tank has been returned to the chemical recovery system, which has resulted in the spill tank being generally less than 20% full. Because of this, the spill tank also served as extra weak black liquor storage, but only during times of high liquor inventory, as during mill shutdowns or when evaporators were out of service. During a representative 18-day period the system intercepted and returned nearly 900,000 gallons containing more than 12 tons of sodium, 15 tons of BOD and 67 tons of dissolved solids.

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***D. L. Wilson** is the EPA Project Officer (see below).*

The complete report, entitled "Process Spill Monitoring, Control and Recovery in the Pulp and Paper Industry," (Order No. PB 81-131 971; Cost: $17.00, subject to change) will be available only from:

National Technical Information Service
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