CONTROL SYSTEMS FOR CANADIAN COAL PREPARATION PLANTS

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ABSTRACT

The operation of a modern coal preparation plant, particularly in western Canada, is a very complex task. Most western Canadian operations are processing two or more, sometimes up to ten, different seams through the same plant. This requires a sophisticated multi-circuit plant that needs close operational control. Add the soft nature and large amounts of natural fines of western Canadian coal and you have a formidable cleaning task. To assist in the operation, programmable controllers and sophisticated control concepts are being more widely used. Two of the newest coal preparation plants in Canada have been designed by Raymond Kaiser Engineers Inc. and its Canadian subsidiary, Phillips Barratt Kaiser Engineering, Ltd. The use of programmable controllers and control systems will be illustrated by showing their application in a "typical" western Canadian coal plant. This example will cover flowsheet design, control concept systems application, and possible future uses.

Introduction

A plant feed that averages 30% minus 0.6 mm and has a Hardgrove grindability index in excess of 80 (average of 90) may seem unusual to the eastern United States coal operator; this is normal for a western Canadian coal operation.

For example, one Canadian coal operation has a run-of-mine size distribution with 70% minus 38 mm. After the rotary breaker, the plant feed is only 1% plus 38 mm. Table 1 shows some typical size distributions for run-of-mine, plant feed and plant product in western Canada. These are plotted in Figure 1. The fine size distributions and soft nature of the coal has been attributed to the geological conditions that existed after the deposition and through the coal forming process.

Average run-of-mine coal quality will vary anywhere from 16 to 40% ash. Cleaning produces a 7 to 10% ash product with a yield of 60 to 80%. Near gravity material will be 5 to 20% at a cleaning gravity of 1.5 to 1.8.

Coal Preparation Process

Most western Canadian coal is surface mined. The coal preparation facility begins at a truck dump station. Some coal, however, is from underground hydraulic mines. The hydraulic raw coal is dewatered at the mine and trucked to the preparation plant. The raw coal is crushed to minus

Table 1

SIZE DISTRIBUTION

WESTERN CANADIAN COAL

Size	Plant 1		Plant 2		Plant 3		Plant 4	
	%wt.	Cum. %wt.	%wt.	Cum. %wt.	%wt.	Cum. %wt.	%wt.	Cum. $wt.
+38mm	6.5	6.5	T		4.0	4.0	T	
38mm x 64mm	22.3	28.8	1.5	1.5	22.0	26.0	16.0	16.0
6.4mm x .6mm	37.8	66.6	49.5	51.0	39.0	65.0	54.0	70.0
.6mm x .15mm	20.4	87.0	30.0	81.0	16.0	81.0	17.0	87.0
.15mm x 0	13.0	100.0	19.0	100.0	19.0	100.0	13.0	100.0
TOTAL	100.0		100.0		100.0		100.0	
Average Hardgrove Grindability	80.0		95.0		105.0		85.0	

FORM 8

FIGURE 1

Graphical Form For Representing Distribution of Size of Broken Coal

Client Typical Size Distribution

Job Number ______

Mine/Plant/Seam ______

Type of Sample ______

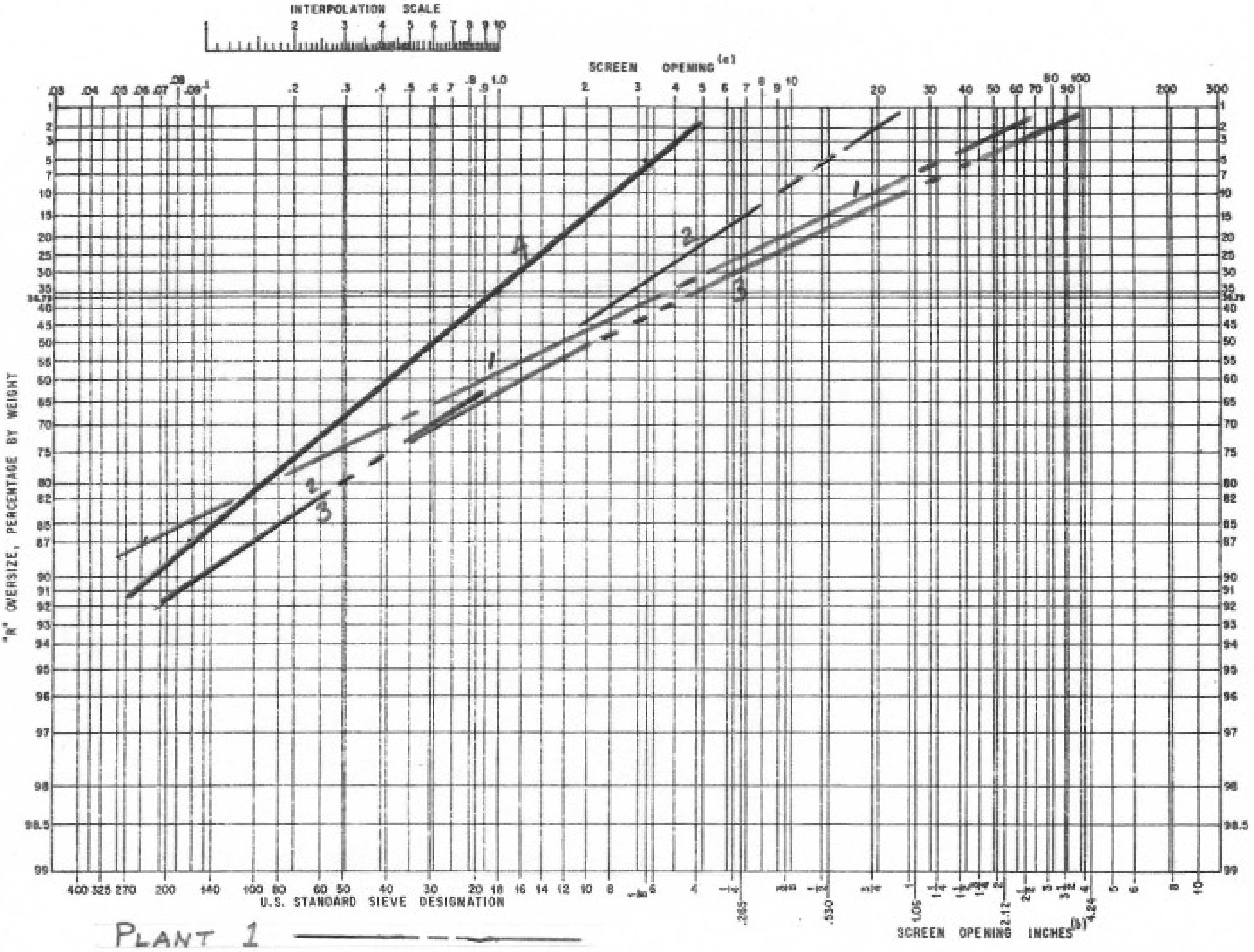
Purpose ______

Remarks ______

Date ______

Average Particle Size (Intersection of Size Distribution Line With 63.21% Passing Line) $\bar{x}$

Slope of Size Distribution Line (Tangent of Angle) n



PLANT 1 ——— — — ———

PLANT 2 ——— — — ———

PLANT 3 ——— - - - ———

PLANT 4 ————————

(a) Any scale, if in millimeters, coincides with lower scale
(b) Square hole if used as continuation of fine series.

$$R = 100\,e^{-(x/\bar{x})^n}$$

R = % Larger than size x
$\bar{x}$ = Size constant
n = Distribution constant

38 mm in a rotary breaker. The breaker product is conveyed to storage or to a preparation plant. A typical preparation plant is described below and shown on Figure 2.

Plant Feed and Distribution

The minus 38 mm raw coal from the plant feed conveyor is slurried and distributed to desliming sieve bends and vibrating screens which make a 0.6 mm separation. The 38 mm by 0.6 mm raw coal becomes heavy media cyclone circuit feed and the minus 0.6 mm raw coal is cleaned in a water-only cyclone/froth flotation circuit.

Heavy Media Cyclone Cleaning

The desliming screen oversize (plus 0.6 mm) flows to the heavy media cyclone sump to be slurried with media, (a mixture of fine magnetite and water). The coal-media slurry is pumped to heavy media cyclones where the coarse raw coal is separated into clean coal and refuse products.

Media is recovered for re-use by combinations of sieve bends and vibrating drain and rinse screens. The drained media returns to the heavy media sump via a bleed control box. Media adhering to the coal or refuse products are rinsed from the coal on the vibrating screens and, together with undersized coal, refuse and dilute media, report to a magnetic separation circuit, commonly called the dilute media circuit.

The oversize product from the clean coal drain and rinse screens is dewatered in horizontal mechanical centrifuges. Coarse refuse is conveyed to a refuse bin for disposal.

Dilute Media

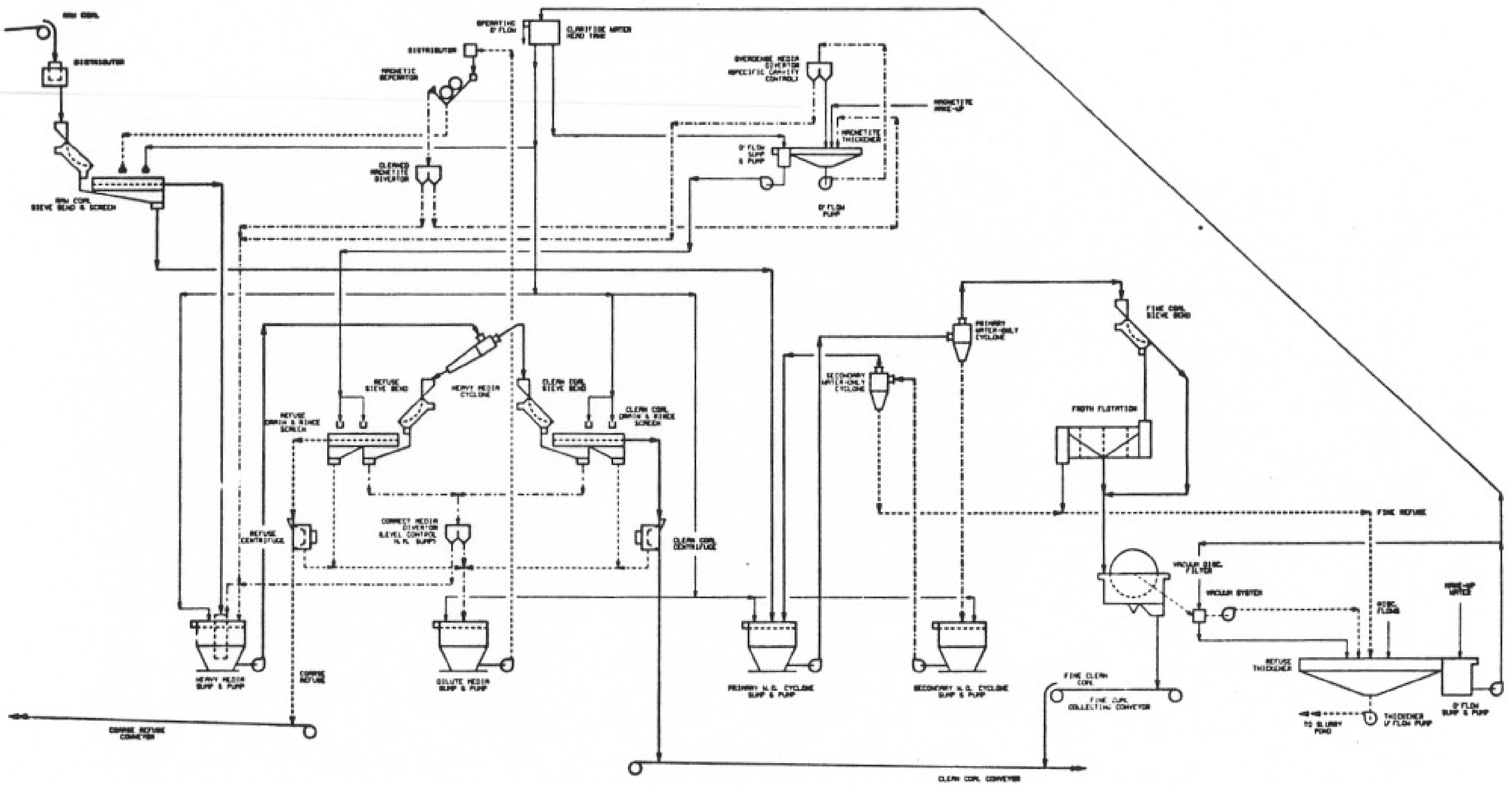
The dilute media from the drain portions of the vibrating screens reports to a sump and is pumped to magnetic separators where the magnetics are separated out, concentrated, and returned to the heavy media sump or to temporary storage. The nonmagnetics and water slurry from the magnetic separators return to the fine coal circuit. Fresh or makeup magnetite is brought into the system directly or from storage in a magnetite thickener. Normal media losses typical for western Canadian preparation plants have been reported in the 1 to 1-1/2 kg/tonne range.

Water-Only Cyclone Cleaning

The deslime sieve bend and vibrating screen undersize (minus 0.6 mm) is collected and pumped to primary water-only cyclones. The overflow from the primary water-only cyclones is fed to vibrated sieve bends or other classifiers separating at 0.25 mm. The minus 0.6 by plus 0.25 product from the sieve bends passes directly to the disk filters. The sieve bend underflow (minus 0.25 mm) flows by gravity to a froth flotation circuit. The underflow from the primary water-only cyclones flows to a secondary water-only cyclone feed sump where it is pulped with water and pumped to secondary water-only cyclones. The secondary water-only cyclone overflow returns to the primary cyclone feed sump for recleaning.

FIGURE 2

TYPICAL COAL PREPARATION PLANT
FLOWSHEET



The secondary water-only cyclone underflow is either dewatered on a sludge screen or sent directly to a refuse thickener or pond.

Flotation and Fine Coal Cleaning

Flotation cells process the undersize of the vibrated sieve bends (minus 0.25 mm). The float product and the vibrated sieve bend oversize are dewatered by vacuum disc filters. Filter cake combines with the clean coal from the coarse circuit for conveying out of the preparation plant.

Refuse Thickener

A refuse thickener is usually provided to remove the fine solids and recover water for reuse throughout the preparation plant. The major sources of slurry to the refuse thickener are the tailings from the flotation cells and the filtrate from the vacuum filter. The thickener overflow, or clarified water, is pumped to the plant head tank and the thickener underflow is pumped to a settling or refuse pond.

Control Systems for the Plant

Control systems for the Canadian coal preparation plants are mainly logic control with some process control.

The logic control or motor control system includes an equipment interlocking system that allows the plant to operate in a safe manner. The logic control system currently being installed uses a programmable controller, eliminating most hardwire interlocking. The programmable controller consists of a software-supported microprocessor designed for automatic with manual override, process data acquisition, alarming, logging, and control functions. The systems currently being installed are the minimum required for the basic application but include provisions for future expansion. The typical system features the following:

- Process control functions are either group start or operated individually in a manual mode.

- The system is capable of minor expansions to accommodate future growth without extensive redesign. Hardware, system software, and application software are field configurable by the owner.

- The system is capable of performing data storage, retrieval, correlation, and logging.

- Systems operator interface is either through a computer input terminal or through a standard-type operator control panel. The system treats the standard control panel as another terminal for the computer system. The computer terminal is the keyboard and cathode ray tube (CRT) type. The keyboard is used for input and the CRT for displaying data.

- o Input/output multiplexers are located throughout the plant with central terminal ports to minimize field wiring.
- o The system is commonly designed as a control system for outlying functional areas such as a rotary breaker, thermal dryer, or clean coal loadout.

System Functions

The system can be used to control the rotary breaker, thermal dryer, and clean coal storage from a central control room in or near the main cleaning area of the preparation plant if they are close to the main plant. The main system components are normally located in the plant control room. Remote satellite terminals are located at the breaker station and the dryer control room for local control purposes. Those components, located in the main control room, are interconnected by prefabricated cable. The system normally interfaces with all plant process instrumentation for alarming and logging functions. The actual process control by use of feedback through the microprocessor is normally not included, but the possibility of future use has been considered. Control pushbutton stations are provided at the equipment for local operation such as maintenance jogging.

Normal input/outputs are digital and analog signals from the process and motor control instrumentation. Provision is made for manual entry of data for modifying set point controls directly from the plant operator control station. These data are tabulated and stored for future use as required. Analog and digital type variables are automatically scanned and tested for validity, converted to engineering units, and tested to determine if any alarm levels have been exceeded.

The automatic alarm messages on the CRT and/or recorder show the time, date, and point identification. Input variable value messages such as "high" and "low" are also shown. The alarm status and summary appears on a logging printer for long-term recordkeeping.

The operator is able to change the alarm limits from the plant operator control station as system requirements change. Process and production data can also be logged on the printer for analytical control and accounting purposes.

The system has the capability of controlling all plant motors for starting, stopping, interlocking, and speed adjusting sequencing. The primary objective of the system is to provide for both continuity of motor operation and correct motor sequencing and interlocking. The system has the capability of both set point control and direct digital control for very specific loops as defined by the operator.

Process Control

The process control for a Canadian preparation plant includes heavy media gravity control for the coarse system (38 mm by .6 mm) and sump level control for the fine coal circuit (minus 0.6 mm). In addition, the fine coal circuit requires control of reagents for flocculation and flotation. These latter are primarily rate control systems.

The following paragraphs will describe typical circuit controls for these systems.

Control Objectives

The primary objectives of the heavy medium gravity control system are:

- Ease of adjustment and accuracy of maintaining the separating gravity. The system allows for wide ranges of separating gravity to accommodate the wide variation in raw coal characteristics.

- Control of sump levels for proper operation and adequate warning to prevent damage to circuit equipment, e.g., pumps running dry.

Meeting of these objectives requires incorporation of the following features in the control system.

- Medium specific gravity measurement and control of overdense medium addition.

- Steady feed pressure to the heavy medium cyclone.

- Low sump level measurement and water addition control.

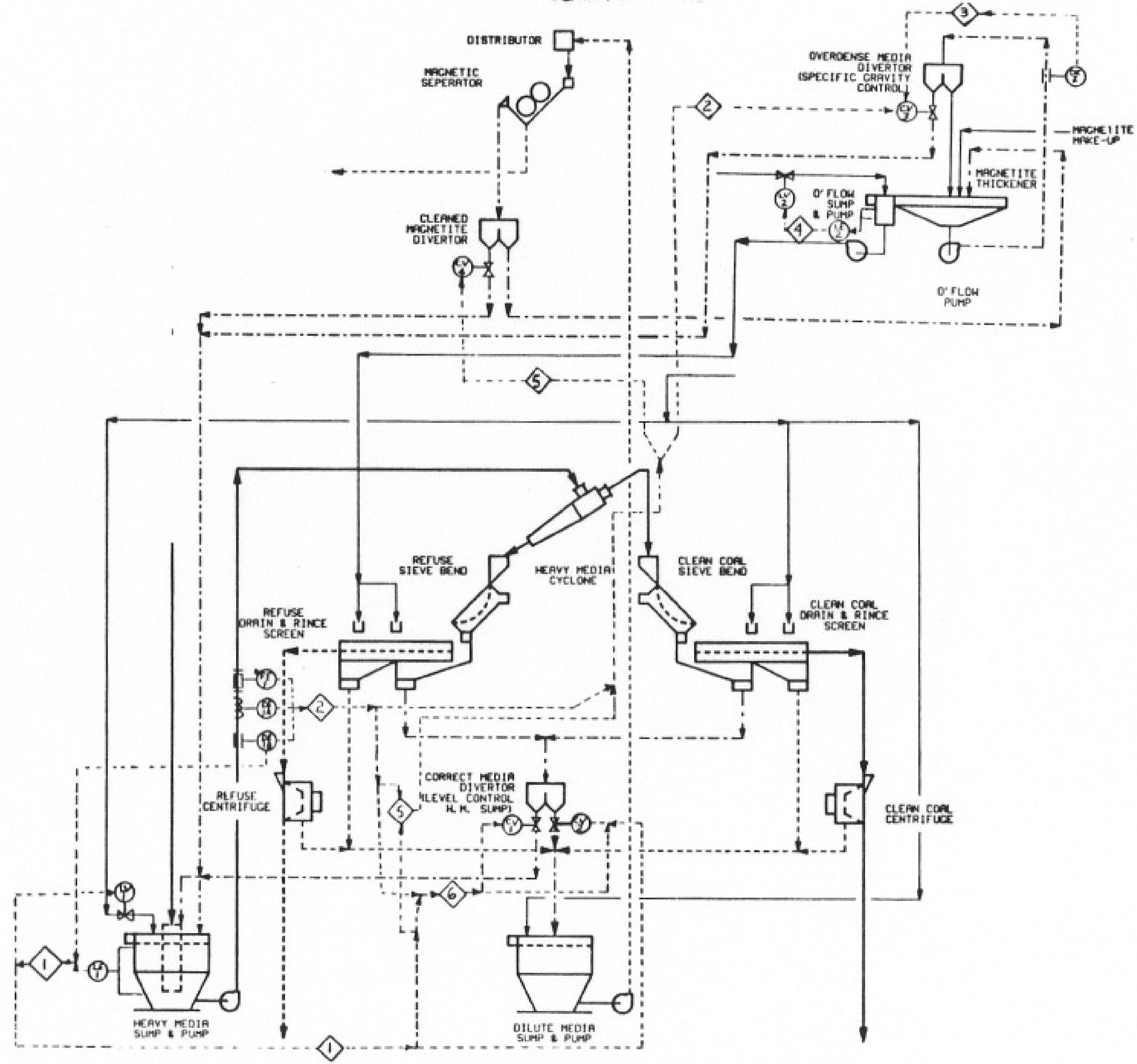
- High sump level measurement and bleed splitter box control.

Heavy Medium Cyclone Circuit

See Figure 3 Process Control Schematic SK-HMC; the following numbered control loops are indicated by diamonds (◇) with the appropriate number inside of them on the schematic.

1. Heavy Media Sump Level Control - Sump level is established by measuring the differential pressure using a level tube (LE-1) or other differential pressure instrument. To obtain a 'true' sump level, this reading is corrected by integration with the specific gravity of the slurry as measured by the nuclear density gauge on the pump discharge (DE-1B). Heavy media sump level control will control the sump level between two plant operator defined set points: low level at maximum flow, and high level at zero flow. At low level, water will be added by valve LV-1 at a rate directly proportional to the 'true' sump level. At high level, the water valve (LV-1) is closed, but this action alone may not be sufficient to prevent sump overflow. If the level remains high or increases and the media specific gravity is below the set point, the bleed control box valve (CV-2) will be closed. If the media specific gravity is above the set point, overdense medium will be diverted at the splitter box (CV-3).

FIGURE 3
PROCESS CONTROL SCHEMATIC



2. Heavy Media Specific Gravity Control - Heavy media specific gravity is measured by combining the slurry density (nuclear density gauge DE-1B), magnetite mass flow (Ramsey coil DE-1B), and the slurry flow rate (flow meter FE-1) to calculate coal, magnetite, water mass flows, and the media (magnetite in water) specific gravity. Heavy media specific gravity control compares the measured media specific gravity to the set point specific gravity to determine gravity error. If the media gravity is less, overdense media from the overdense splitter box will be added by means of opening and closing the valve (CV-3). If the media specific gravity is high, heavy media sump level control, overdense splitter box position control, and coal bleed valve control are used to remove media from the system. Overdense splitter box position control is used if system gravity is low, and coal bleed valve control is used if the time average gravity is high or the gravity error is very high and the emergency sump level is not high.

3. Overdense Media Recirculation System Gravity Control - The density gauge (DE-2) measures overdense media gravity for heavy media specific gravity control. To maintain set point if gravity is low, VC-3 will close. Based on the settling rate of the magnetite, it is not expected that gravity will get too high.

4. Magnetite Thickener Level Control - Magnetite thicken levels are measured by a level (LE-2). The magnetite thickener level control maintains the sump level by opening valve LV-2 at low level in the magnetite thickener overflow sump and closing the valve at high level.

5. Overdense Media Control - The cleaned magnetite diverter and overdense media diverter position controls receive information from three sources to determine if the control valves CV-3 and CV-4 should be at a closed or open position. The open position allows the cleaned magnetite and a portion of the overdense media to flow to the heavy media sumps while the closed position directs all of the cleaned magnetite and overdense media back to the magnetite thickener. The hierarchy of control is:

a. Heavy Media Sump Level - If the heavy media sump is at high-high level and the system density is above set point, the heavy media sump level control causes the control valves (CV-3 and CV-4) to shift from open to closed position.

b. High Gravity Control

(1) If the time averaged gravity input from the heavy media specific gravity control is consistently high, but within the set points, this will cause the control valves to go to the closed position. This position will be maintained until a low gravity signal is received.

(2) If a high gravity signal from the heavy media specific gravity control exceeds the normal operating specific gravity range set points then the control valves are placed in the closed position.

c. Low Gravity Control - If the heavy media sump level control gives a low gravity signal, the control valves will go to the open position.

6. Coal Bleed Valve Control - Coal bleed valve control receives control signals from the heavy media sump level control. If gravity and level are high, CV-1 closes and CV-2 opens to allow some media and fine coal to be bled from the circuit, preventing a fine coal buildup. If gravity is low and level high, CV-1 opens and CV-2 closes. If gravity is high and level low, both valves are open and CV-3 is open.

Sump - Level Control

See Figure 4 Process Control Schematic SK-WOC; control loop seven (7) is shown by a diamond with a numeral seven inside it.

7. Sump Level Control (Dilute Media, Primary and Secondary Water-Only Cyclone)

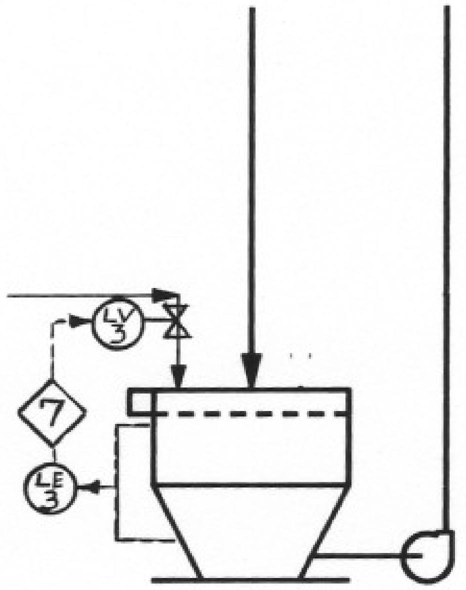
Level indicator LE-3 measures the sump level for level control which controls the water level in the sump proportionally by adjusting water valve LV-3 (similar to heavy media sump level control without calculating 'true' sump level).

Current and Future Trends

As the cost of labor in western Canada escalates and the profit margin on the coal operations decreases, greater use of automation can be anticipated. This will require increased use of programmable controllers for direct process control and motor control logic, allowing for fast changes and ease of startup under varying conditions. It is our belief that the use of computers and microprocessors for process control will increase in western Canada and throughout the world.

Conclusion

Western Canadian coal is very complex and requires a sophisticated cleaning system. To cope with varying coal qualities from different seams and the fine nature of the coal, the most advanced coal cleaning circuitry is warranted. Process and motor control philosophy that can be implemented by use of programmable controllers should, in the future, see greater and greater use, not only in western Canada, but throughout the coal industry.



SUMP & PUMP
SK-WOC

FIGURE 4