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Rock crusher including improved feeder control.

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A method and apparatus for controlling the operation of a rock crusher and feeder such that the rate of supply by the feeder to the crusher hopper is kept within carefully controlled parameters and such that the power level at which the crusher operates is maintained within a narrow range at the optimum operating range of the rock crusher. A microprocessor having a first PID control loop receives an input signal from a transducer sensing the power draw by the crusher motor and a second PID control loop receives a signal from an analog level sensor measuring the level of rock in the hopper. The first PID compares the sensed power draw with a selected maximum power draw and produces an output signal proportional to the difference between the sensed power draw and the selected power draw. The second PID compares the sensed level in the hopper to a selected or desired level in the hopper and produces a signal proportional to this measured difference. The signal from the first PID and the signal from the second PID are transmitted to an arbitration routine for comparing the signals. The first or second signal calling for the lower feeder speed will be transmitted to the feeder variable speed drive.

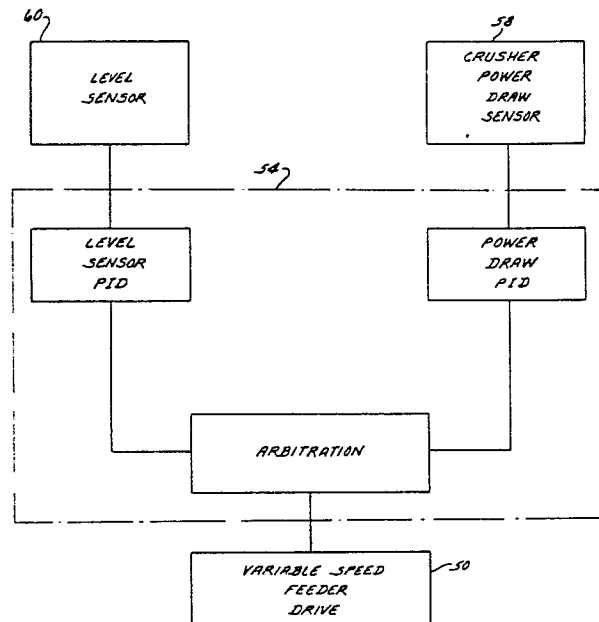


FIG. 2

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Rock crusher including improved feeder control

The invention is directed to rock crushers and more particularly to a method and apparatus for controlling the operation of a rock crusher to maximize the efficiency of the rock crusher.

A conventional cone crusher for use in crushing rock is comprised of a large housing having a central cavity and including a stationary upper cone and a gyrating lower cone housed in the central cavity. A drive arrangement is provided for causing gyration of the lower cone in the central cavity. In conventional arrangements an electric motor is provided for driving the cone. The cone crusher also includes a hopper above the cone adapted to contain rock to be fed to the central cavity for crushing between the stationary and gyrating cones.

Conventional cone crushers also commonly employ a conveyor belt feeder or a vibrating feeder for supplying rock to the hopper, such feeders including a variable speed drive arrangement for varying the rate at which rock is supplied to the hopper.

Prior art rock crushers have also included control apparatus for controlling the rate at which rock is supplied to the hopper. In one prior art rock crusher manufactured by the assignee of the present invention, the control means includes means for increasing the feed rate of the rock to the rock crusher to a point where the rock crusher is operating at a capacity maximizing the productivity of the machine. Control features are also provided to prevent the feed rate from becoming so great that the hopper is too full. In such prior art rock crushers, a transducer is connected to the cone crusher motor to measure the power draw of the cone crusher during its operation. An analog level sensor or a level contact probe is also suspended above the hopper and produces a signal responsive to the level of the rock in the hopper. The power draw transducer is connected to a microprocessor including a proportional integral derivative (PID) control loop. The PID control loop compares the measured power draw to a selected power draw at which the rock crusher operates at its maximum safe power level. If the measure power draw is less than the selected power draw, the PID sends a signal to the variable speed feeder drive to cause an increased feeder speed. If the measured power draw is at the selected power draw level, the PID will send a control signal, to the variable speed feeder to cause it to maintain its speed. If the measured power draw is greater than the selected power draw, the PID sends a signal to the variable speed feeder drive to cause a decrease in feeder

speeds. In the event the feeder speed is such that the level of rock in the hopper exceeds a predetermined level, the analog level sensor will send a signal to the feeder decreasing the feeder speed.

In operation of such a prior art cone crusher, when the crusher is operating in a condition that is limited by the level of feed in the hopper, and while the horsepower draw is below the selected value, the PID will send a signal to the feeder causing the feeder speed to increase the rate of supply of rock to the hopper. As the supply of rock increases, the horsepower draw will increase and the level of rock in the hopper will increase. As the level of rock in the hopper reaches the upper limit, the analog level sensor or level probe will cause the feeder speed to be reduced. As the rate of supply of rock is reduced, the sensed power draw by the crusher motor will be reduced, and the PID will then again increase the feeder speed. The PID will continue to increase the feeder speed until the level of rock is once again above the acceptable level in the hopper, and the analog level device or level probe will decrease the feeder speed.

This arrangement results in operation of the rock crusher at a level approaching the desired power draw level, but causes a continued cyclical fluctuation in the rate of supply of rocks to the hopper as the feeder speed is increased by the PID and is then decreased by the analog level sensor or level probe. The average production rate is less than maximum due to the cyclical fluctuations.

The present invention provides an improved rock crusher and an improved method and apparatus for controlling the operation of a rock crusher and rock feed conveyor such that the rate of supply by the feeder to the crusher hopper is kept within carefully controlled parameters and such that the power level at which the crusher operates is maintained within a narrow range at the optimum operating range of the rock crusher.

The apparatus embodying the invention comprises a control means such as a microprocessor having a first PID control loop receiving an input signal from a watt transducer sensing the power draw by the crusher motor and having a second PID control loop receiving a signal from an analog level sensor measuring the level of rock in the hopper. The first PID compares the sensed power draw with a selected power draw and produces an output signal proportional to the error or difference between the sensed power draw and the selected power draw. The second PID compares the sensed level in the hopper to a selected or desired level in

the hopper and produces a signal proportional to this measured difference. The signal from the first PID and the signal from the second PID are transmitted to an arbitration routine of the control means and the signals will be compared. If the feeder is operating at a speed wherein the sensed power draw is below the selected power draw, and if the sensed level in the hopper is below the selected level of rock in the hopper, both the first PID and the second PID will send signals to the arbitration routine calling for an increase in the feeder speed. The first or second signal calling for the lower feeder speed will be transmitted to the feeder.

As the feeder speed is increased, the power draw and material level will increase. The power draw and the level of the material in the hopper will continue to be sensed and the PIDs will continue to produce first and second output signals which are transmitted to the arbitration routine. When either the power draw or material level reach their selected or desired value, the feeder speed will be maintained at the speed producing the preferred power draw or material level.

The power draw by the crusher motor is affected by the size of the rocks being supplied to the crusher as well as by the hardness of the rocks. The rocks supplied to the crusher will not be homogeneous in size and hardness, and as a result, the power draw by the motor will vary during operation of the crusher. During operation of the crusher, the control signal to the feeder may be generated alternately by the power draw PID and the material level PID depending on which PID calls for the lower feeder speed. As the power draw of the motor varies in response to different materials being fed to the crusher, the feeder speed may be controlled by one PID output and then by the other PID.

This control arrangement provides for accurate control of the feeder such that the rock crusher will operate at a power draw and material level closely approximating a desired or maximum productivity power draw and material level, and the power draw and material level will be held relatively constant with the variations in the power draw or material level being caused by variation in character of the rock being supplied to the rock crusher.

In other embodiments of the invention, the microprocessor can include additional PID control loops adapted to receive signals from other crusher parameter sensing devices and control the feeder speed in response to these additional inputs as well as power level and material level.

Various other features and advantages of the invention will be apparent by reference to the following description of a preferred embodiment, from the drawings and from the claims.

A more thorough understanding of the present invention will be gained by reading the following description of the preferred embodiments with reference to the accompanying drawings in which:

Fig. 1 is a schematic view of a rock crusher, a rock feeder conveyor, and a control apparatus embodying the present invention.

Fig. 2 is a schematic view of the operation of the control apparatus illustrated in Fig. 1.

Before describing a preferred embodiment of the invention in detail, it is to be understood that the invention is not limited to the details of construction and to the arrangement of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein is for the purpose of description and should not be regarded as limiting.

Illustrated in Fig. 1 is a rock crusher 10 of the type used to crush rock to reduce ore for processing or to form aggregate or gravel. The rock crusher 10 includes a base or frame 12 supporting a generally cylindrical bowl 14 having a central conical cavity 16. A blow lifter 17 is housed in the central conical cavity 16 and is fixedly supported by the bowl 14. A lower cone or mantle is housed in the cavity 16 and is driven in such a manner that there is gyration of the lower cone or mantle 18 with respect to the inner surface of the bowl liner 17. The construction of the bowl 14, the mantle 18 and the cone drive mechanism are conventional, and are not illustrated in detail. While various apparatus could be provided for driving the mantle 18, in the illustrated arrangement a central generally vertical rotatable main shaft 20 supports the mantle 18 within the central chamber 16 of the bowl 14, and an electric motor 22 is drivingly connected to the mantle 18 by a pulley 24, a drive shaft 26, gears 28 and 30 and an eccentric 31 to cause gyration of the mantle 18 about the axis of the bowl liner 17.

The rock crusher 10 also includes a generally cylindrical hopper 34 mounted above the cylindrical bowl 14 and adapted to support a quantity of rocks to be fed into the crusher.

In operation of the rock crusher 10, rocks in the hopper 34 will fall through the opening 36 in the upper portion of the crusher and will be received between the mantle 18 and the bowl liner 17. As the mantle 18 is caused to gyrate eccentrically, the cone 18 will crush the rocks against the cone liner 17, and the crushed rock will fall through the gap 38 between a bottom portion of the cone 18 and the cone liner 17 and will fall onto a conveyor 40 whereby the material can be conveyed to a storage area.

Means are also provided for supplying rocks to the hopper 34. While various means could be provided, in the illustrated arrangement, the means for supplying rocks to the hopper comprises a conventional belt conveyor or feeder 42 adapted to have one end 44 positioned beneath a large supply hopper 46 and an opposite end 48 positioned above the rock crusher hopper 34. In other constructions the feeder 42 could also comprise a variable speed vibrating pan positioned directly below a large supply hopper. The belt conveyor 42 includes a variable speed drive including a variable speed motor 50 drivingly connected to a belt 43. Rocks in the hopper 46 are deposited on the belt of the feeder 42 and carried by the belt to the opposite end 48 of the feeder where they are dropped into the hopper 34.

Means are also provided for controlling operation of the variable speed motor 50 to control the rate at which rocks are fed to the rock crusher hopper 34. The means for controlling the variable speed motor 50 includes a controller 54 operably connected to the variable speed motor 50 and functional to produce an electrical signal controlling the operation of the variable speed motor 50. While in one preferred form of the invention the controller 54 comprises a conventional microprocessor, in other arrangements the microprocessor could be replaced by a programmable controller or a computer.

The means for controlling the operation of the variable speed motor 50 also includes a means for sensing the power drawn by the motor 22 of the rock crusher 10 and a means for sensing the level of rocks or other material in the crusher hopper 34. While various means could be provided for sensing the power drawn by the motor 22, in the illustrated arrangement a conventional watt transducer 58 is connected to the crusher motor 22 and measures the power output or horsepower output of the motor. A signal from the watt transducer 58 is transmitted to the microprocessor controller 54. This signal can be in the form of a percentage of the horsepower output of the motor 22 when operating at its maximum output.

While various means could be provided for sensing the level of material in the hopper 34, in the illustrated arrangement an analog level sensor 60 is mounted above the hopper 34. The analog level sensor 60 is conventional and produces an electrical signal indicating the level of rock in the hopper 34, and this electrical signal is transmitted to the microprocessor 54. The signal from the analog level sensor 60 can be in the form of a percentage of the total capacity of the hopper.

While the microprocessor controller 54 could have other constructions, in one form of the invention the microprocessor controller 54 can comprise a Model 8031 microprocessor manufactured by Intel Corporation, Sunnyvale, California.

The microprocessor 54 includes two proportional integral derivative (PID) control loops (Fig. 2). The watt transducer 58 is operably connected to the microprocessor 54 such that the watt transducer 58 supplies a first input signal indicating the power draw to one of the two PIDs, and the output from the analog level material level sensor 60 is also transmitted to the microprocessor 54 so as to supply a second electrical input signal to a second one of the PIDs.

Proportional integral derivative control loops are conventional and produce an output signal based on the following equation:

Output - bias + (gain) * ((error + integral term) -- (derivative term)).

The microprocessor 54 is programmed such that in this application the "bias" term in the PIDs will be a selected startup speed of the variable speed feeder 42. This startup speed can be input into the PIDs as a percentage of the maximum operating speed of the conveyor. The start-up speed will be a feeder speed selected by the crusher operator close to the speed of the conveyor or feeder 42 where the crusher 10 will operate at maximum productivity but which is known by the operator to be below the safe operating limits of the crusher and below the speed at which the feeder 42 will supply an excess of material to the hopper 34. The operator can select this start-up speed based on his experience in operating the cone crusher and feed conveyor. The feeder start-up speed can be, for example, 60% of the maximum operating speed of the feeder, and will normally supply rocks to the crusher at a rate where the crusher will operate at 75% to 90% of its maximum productivity. The feeder start-up speed is set relatively low so that the crusher will initially

operate under a relatively light load. The PIDs will then cause an increase in the speed of the feeder until the crusher is operating at its most productive level.

The "error" term of the PID receiving a signal from the motor power draw transducer 58 comprises the selected power draw at which the crusher operates at its maximum productivity minus the power draw at which the cone crusher is actually operating as measured by the power draw transducer. When programming the power draw PID, the microprocessor 54 will be programmed to include the horsepower at which the crusher will perform at its maximum productivity. During operation of the crusher, the power draw transducer 58 will produce a signal identifying the actual power draw by the crusher motor 22, and these two power factors will be compared to produce the "error" term used in the power draw PID control loop.

The material level PID is programmed to include a selected maximum hopper material level. During operation of the crusher, the analog level sensor 60 will produce a signal identifying the actual level of material in the hopper 34. The selected hopper level is compared to the actual hopper level, as sensed by the analog level sensor 60 to produce the "error" terms for the material level PID control loop.

In each PID control loop the "integral term" is a summation of the "errors" measured during successive operations of the PID loop divided by a selected integral time parameter.

Another factor which is input into the microprocessor 54 is the empty crusher power draw. The empty crusher power draw is the power draw of the crusher 10 when the crusher is running empty plus a factor of approximately 10% to 20%. The controller 54 requires the input of the empty crusher power draw because, if the power draw falls below the empty crusher power draw, the PID control loop signal to the feeder will be interrupted and the PID will be reset and send a signal to the feeder 42 causing the feeder to operate at the feeder start-up speed. It is important, if the crusher power draw falls below the empty crusher power draw, that the feeder speed be reset to the startup speed. There may be a blockage or other interruption of rock to the feeder such that the rock will not be fed to the crusher 10. As the rate of material delivered to the hopper decreases, the crusher power draw would decrease, and the power draw PID would attempt to increase the crusher power draw by increasing the speed of the feeder. Without the reset feature, the power draw PID would try to continue to increase the feeder speed even though rocks are not

being delivered to the feeder. By providing an empty crusher power draw input, the feeder speed will be set back to the startup speed such that, when the obstruction or interruption of rocks to the feeder 42 is cleared, stones can be supplied by the feeder to the rock crusher at the start-up speed, and the PIDs can once again increase the feeder speed to the desired operating level.

The microprocessor 54 is also provided with a start-up time factor. This is a time period during which the microprocessor will hold the feeder speed at the feeder start-up speed. The microprocessor is programmed such that the time period will start running when the power draw by the cone crusher exceeds the empty crusher power draw. A suitable start-up time may be, for example, approximately 15 seconds. During start-up of the crusher, the PIDs will produce output signals to maintain the feeder speed at the start-up speed during this time period. This permits the crusher power draw and the material level signals fed to the PIDs to stabilize at the feeder start-up speed and prevents the PIDs from overreacting to wide fluctuations caused by large "error" figures generated during the initial operation of the PID control loop. Large "errors" are generated during start-up because of the substantial difference between the set points and the measured values supplied to the PIDs by the power draw transducer 58 and the analog level sensor 60.

In operation, when the crusher 10 is running at its empty power draw, the operator will then start the feeder or conveyor 42, and the feeder will operate at its preset feeder start-up speed. As the rock is delivered to the crusher 10, a load will be placed on the crusher motor 22, and the crusher power draw will begin to rise above the empty power draw thereby causing the start-up timer to function. The feeder speed is maintained at the feeder start-up speed during the 15 second start-up time. If, at any time, the power draw sensed by the transducer 58 falls below the empty power draw level, the feeder speed will be set back to the feeder start-up speed, and the start-up timer will be reset again to begin counting off the start-up time. During this start-up time, the signals from the transducer 58 and the analog level sensor 60 are continually sent to the PIDs. If the power draw signal or material level signal supplied to the PIDs exceeds either of the power draw or material level set points, the timer is canceled, and the PIDs will begin immediate control of the feeder speed without allowing the timer to run out.

After the start-up time is completed, or the timer is canceled, output signals from the power draw and material level PIDs will control the feeder operating speed. In the case of the PID receiving a signal from the transducer identifying the crusher power draw, the output signal of the PID is equal to:

Start-up speed + (gain) ((power draw set point - actual power draw signal) + (integral term))

For purposes of example, if the start-up speed is 75% of the maximum feeder speed and the power draw set point is 80% of the maximum of the crusher power draw, if the gain is selected to be 0.5, and if at a particular point in time the actual power draw signal is 70% of the maximum power draw, the error at that particular point in time is 10%. The output signal will be calculated as follows:

$$\text{output} = 75 + 0.5(10 + 1)$$

and the output signal emitted by the power draw PID will direct the feeder drive motor 50 to increase the feeder speed to 80% of maximum feeder speed. (For convenience, decimals are truncated.) The crusher power draw transducer will continue to transmit a power draw signal to the first PID control loop, and the first PID control loop will continue to transmit an output signal.

The second PID control loop will similarly receive an input signal from the analog level sensor and will produce an output signal:

$$\text{output} = \text{start-up speed} + (\text{gain}) (\text{material}$$

$$\text{level set point} - \text{actual material level}$$

$$\text{sensed}) + (\text{integral term}))$$

Means are also provided for receiving the output signals from the two PID control loops and for transmitting a selected one of the signals from the control loops to the variable speed motor of the feed conveyor. In the illustrated construction the microprocessor 54 is also programmed to include an arbitration routine for selecting an output signal from the first PID and second PID. The output signal from the power draw PID and the output signal from the material level PID are sent to the arbitration routine, and the PID output signal calling for the lower feeder speed will be transmitted to the variable speed motor 50 of the feed conveyor

or feeder 42. In one form of the invention the arbitration routine can comprise a conventional comparison statement for selecting one of two signals.

The arbitration routine is also programmed such that the PID producing the higher feeder speed signal is then caused to add the error sensed at that time into the integral term. If the sensed value is below the set point such that the addition of the error to the integral term in the PID equation would cause an increase in the feeder speed output signal, the error is not added to the integral term, and the integral term and output signal remain unchanged. If the sensed value is above the set point, the error is added to the integral term, and the PID will produce a new lower output signal. The output signals from the two PIDs are again compared, and the output signal calling for the lower feeder speed will be transmitted to the variable speed feeder drive.

The result of the arbitration of the outputs of each of the PID control loops is that the power draw set point and the maximum material level set point can be set at their maximum safe limit without regard to the other. The cone crusher will operate at a level of operation approximating the lowest of these operating limits.

Various features of the invention are set forth in the following claims.

Claims

1. A method for controlling the operation of a rock crusher and a rock feeder supplying rocks to the rock crusher, the rock crusher including a crushing chamber, a hopper for receiving rocks from a rock feeder and for depositing the rocks in the crushing chamber, means for crushing rocks in the crushing chamber, a motor for driving the means for crushing rocks, a power draw sensing means for measuring the power drawn by the motor driving the means for crushing rocks, a level sensing means for measuring the level of rocks in the hopper, means for driving the feeder at variable speeds, and a control means for controlling the speed of the feeder, the method for controlling the operation of the rocks crusher comprising the steps of:

generating a first signal proportional to the difference between the power draw sensed by the power draw sensing means and a selected power draw,

generating a second signal proportional to the difference between the level of rocks in the hopper

sensed by the means for measuring the level of rocks in the hopper and a selected level of rocks in the hopper,

comparing said first signal and said second signal, and

transmitting a selected one of said first signal and said second signal to said control means for controlling the speed of the feeder, said selected one of said signals being that signal which produces the lower feeder speed.

2. A method as set forth in claim 1 and wherein the selected power draw is the power draw by the motor where the rock crusher is operating at its maximum productivity.

3. A method as set forth in claim 1 and wherein the step of generating a first signal includes the steps of measuring the power draw by the motor, and transmitting a signal indicative of the power draw by the motor to a first proportional integral derivative control loop of a controller wherein the power draw signal is compared to the selected power draw.

4. A method as set forth in claim 3 and wherein the step of generating the second signal includes the step of measuring the level of rocks in the hopper, transmitting the signal indicative of the level of rocks in the hopper to a second proportional integral derivative control loop of a controller wherein the sensed level of rocks in the hopper is compared to the selected level of rocks in the hopper.

5. A method for controlling the operation of a rock crusher and a rock feeder supplying rocks to the rock crusher, the rock crusher including a crushing chamber, a hopper for receiving rocks from a conveyor and for depositing the rocks in the crushing chamber, means for causing rocks in the crushing chamber to be crushed, a motor for driving the means for causing rocks to be crushed, a power draw sensing means for measuring the level of rocks in the hopper, a control means having a first proportional integral derivative control loop for producing a first output signal and a second proportional integral derivative control loop for producing a second output signal, and means for driving the rock feeder at variable speeds, the method for controlling the operation of the rock crusher comprising the steps of:

sensing the power draw of the motor for driving the means for crushing rocks and producing a first

input signal proportional to the power draw by the motor for driving the means for crushing rocks,

transmitting the first input signal to the first proportional integral derivative control loop,

sensing the material level in the hopper and producing a second input signal proportional to the level of material in the hopper,

transmitting the second input signal to the second proportional integral derivative control loop,

comparing the first output signal from the first proportional integral derivative control loop and the second output signal from the second proportional integral derivative control loop, and

transmitting a selected one of said first and second output signals to the means for driving the conveyor to control the speed at which the feeder is drive, the selected one of the first and second output signals being the one of the first and second output signals producing the lower feeder speed.

6. A method for controlling the operation of a rock crusher and a rock feeder means for supplying rock to rock crusher, the rock crusher including a housing having a crushing chamber, a hopper positioned above the crushing chamber and for receiving rock from the rock feeder means and for depositing rocks in the crushing chamber, a cone housed in the crushing chamber, a motor for causing crushing movement of the cone, a power draw sensing means for measuring the power draw by the motor for causing crushing movement of the cone, a material level measuring means for measuring the level of material in the hopper, and means for driving the feeder means, the means for driving the feeder means including means for controlling the speed at which the feeder means is driven, the method for controlling the operation of the rock crusher comprising the steps:

sensing the power draw by the motor for causing crushing movement of the cone,

producing a first input signal indicative of the power draw by the motor for causing crushing movement of the cone,

transmitting the first input signal to a first proportional integral derivative control loop of a microprocessor wherein the first input signal is converted to a first output signal,

sensing the level of material in the hopper,

producing a second input signal indicative of the level of material in the hopper,

transmitting the second input signal to a second proportional integral derivative control loop of a microprocessor wherein the second input signal is converted to a second output signal,

comparing the first and second output signals, and

transmitting a selected one of the first and second output signals to the means for driving the feeder means to control the speed at which the feeder means is driven, the selected one of the first and second output signals being transmitted being that output signal which produces the lower rate of speed of the feeder means.

7. Apparatus for controlling the operation of a rock crusher and a rock feeder supplying rocks to the rock crusher, the rock crusher including a crushing chamber, a hopper for receiving rocks from a rock feeder and for depositing the rocks in the crushing chamber, means for causing rocks in the crushing chamber to be crushed, a motor for driving the means for causing rocks to be crushed, a power draw sensing means for measuring the power draw by the motor, a level sensing means for measuring the level of rocks in the hopper, means for driving the feeder at variable speeds, and a control means for controlling the speed of the feeder, the apparatus comprising:

means for generating a first signal proportional to the difference between the power draw sensed by the power draw sensing means and a selected power draw,

means for generating a second signal proportional to the difference between the level of rocks in the hopper sensed by the means for measuring the level of rocks in the hopper and a selected level of rocks in the hopper,

means for comparing said first signal and said second signal, and

means for transmitting a selected one of said first signal and said second signal to said control means for controlling the speed of the feeder, said selected one of said signals being that signal which produces the lower feeder speed, said means for transmitting including means for comparing said first signal and said second signal.

8. Apparatus as set forth in claim 7 and wherein said means for generating a first signal includes means for measuring the power draw by the motor, a controller including means for comparing the power draw by the motor to the selected power draw, and means for transmitting a signal identifying the power draw by the motor to said controller.

Apparatus as set forth in claim 8 and wherein said means for comparing the power draw by the motor to the selected power draw includes a first proportional integral control loop.

10. Apparatus as set forth in claim 8 and wherein said means for generating the second signal includes means for measuring the level of rocks in the hopper, means for comparing the sensed level of rocks in the hopper to a selected level of rocks in the hopper, and means for transmitting said signal indicative of the level of rocks in the hopper to said means for comparing the sensed level of rocks in the hopper to a selected level of rocks in the hopper.

11. Apparatus comprising:

a rock crusher including a body having a chamber, a crushing means housed in the chamber, means for causing movement of the crushing means in the chamber, the means for causing movement including a rock crusher motor, and a hopper positioned above the chamber and adapted to supply rocks to the chamber,

means for supplying rocks to the hopper, the means for supplying rocks including variable speed drive means for controlling the speed at which rocks are supplied to the hopper,

means for sensing the power draw of the rock crusher motor, the means for sensing the power draw including means for producing a first input signal indicating the power draw of the rock crusher motor,

means for sensing the level of rocks in the hopper, the means for sensing the level of rocks including means for producing a second input signal indicating the level of rocks in the hopper,

means for receiving said first input signal and for producing a first output signal, said means for receiving said first input signal including a first proportional integral derivative control loop, and means for receiving said second input signal and for producing a second output signal, said means

for receiving said second signal including a second proportional integral derivative control loop, and

means for transmitting a selected one of said first output signal and said second output signal to the variable speed drive means for controlling the speed at which rocks are supplied to the hopper, said selected signal transmitted to the variable speed drive means being the signal that causes lower speed supply of rocks to the hopper.

12. Apparatus for controlling the operation of a rock crusher assembly including a rock crusher having a body, the body including a chamber, a cone housed in the chamber and supported for movement in the chamber such that movement of the cone in the chamber crushes rock between the cone and the body, means for causing movement of the cone in said chamber, the means for causing movement of the cone including a rock crusher motor, and a hopper positioned above the chamber and adapted to supply rocks to the chamber, and means for supplying rocks to the hopper, the means for supplying rocks including variable speed drive means for controlling the speed at which rocks are supplied to the hopper, the apparatus for controlling the operation of a rock crusher assembly comprising:

means for sensing the power draw of the rock crusher motor, the means for sensing the power draw including means for producing a first input signal indicating the power draw of the rock crusher motor,

means for sensing the level of rocks in the hopper, the means for sensing the level of rocks including means for producing a second input signal indicating the level of rocks in the hopper,

means for receiving said first input signal and for producing a first output signal, said means for receiving said first input signal including a first proportional integral derivative control loop, and means for receiving said second input signal and for producing a second output signal, said means for receiving said second signal including a second proportional integral derivative control loop, and

means for transmitting a selected one of said first output signal and said second output signal to the variable speed drive means to control the speed at which rocks are supplied to the hopper, said selected signal transmitted to the variable speed drive means being the signal that causes the lower speed supply of rocks to the hopper.

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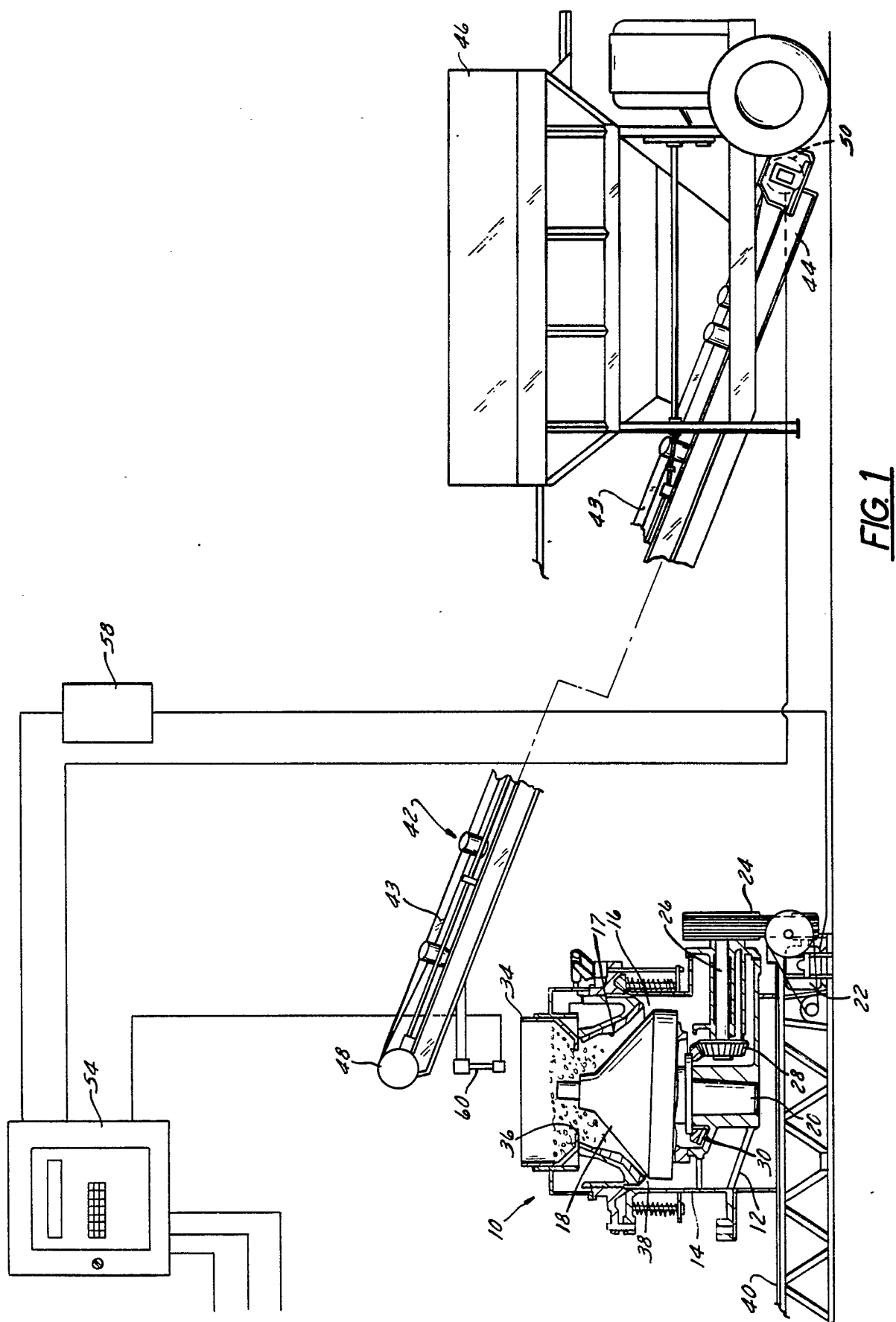
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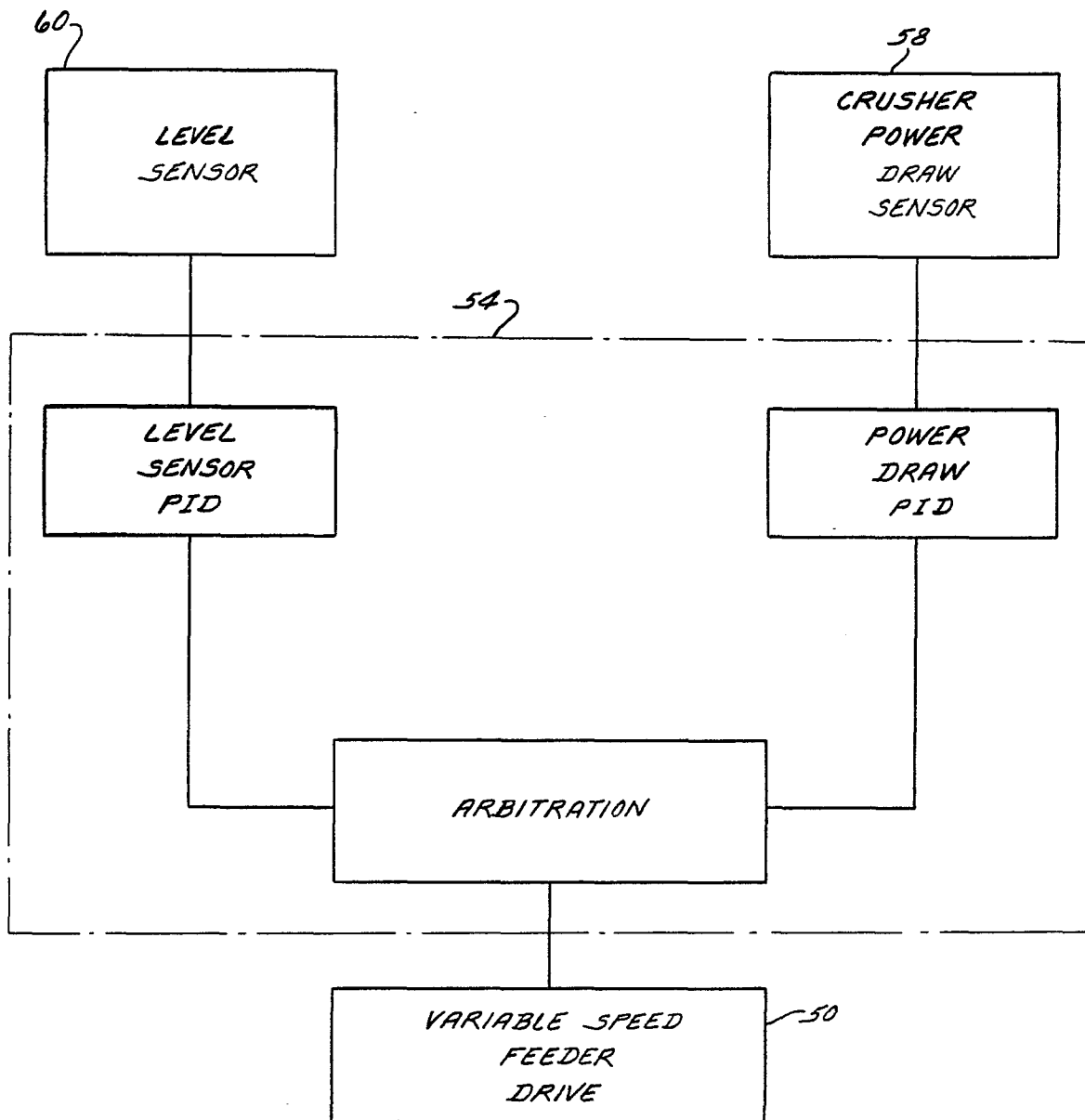


FIG. 2