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(54) Control system and method for the manufacture of plaster board.

(57) To control the manufacture of plasterboard the supervisor enters required board parameters and production rate into a central processor. The processor senses the ratio of liquid raw materials to solid raw materials (AWAT) in a mixer and compares AWAT to a calculated setpoint value (SWAT). The set point value is adjusted in accordance with the difference between AWAT and SWAT.

The height of a slurry dam behind an extruder on the boardline is then sensed and compared with a set point value (SDAM). If the sensed value (ADAM) differs from the set point value (SDAM) the setting belt speed (ABEL) is adjusted. The adjusted belt speed is then compared to the desired production rate (SBEL) and the raw materials feed rates varied to compensate for the difference.

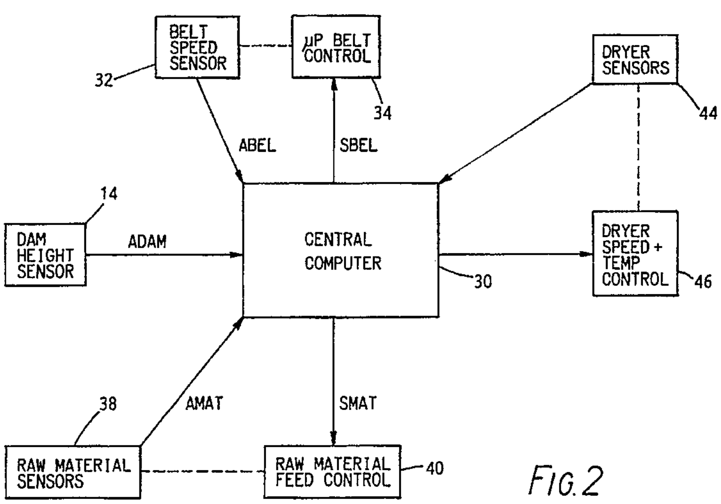

FIG.2

EP 0 422 833 A2

CONTROL SYSTEM AND METHOD FOR THE MANUFACTURE OF PLASTER BOARD

The invention relates to the manufacture of plaster board, and in particular to the control of the manufacturing process for optimisation of quality and resources.

In the plasterboard manufacturing process, raw components are fed to a mixer. The solid raw materials are calcium sulphate-hemihydrate and any additives required for the particular board being made. The liquid raw materials are process water, lignosulphonate solution, which is a water demand reducer, and a foaming solution. The foam is mixed in a foamer and includes water, air and a foaming agent.

From the mixer, the slurry of raw materials is released onto a sheet of facing paper and passed through an extruder. Before the extruder the edges of the paper are scored and folded upwards to provide side walls. A dam of slurry builds up in front of the extruder. Just before the extruder an upper layer of paper is laid down and adheres to the slurry and to the inwardly turned sides of the lower paper layer. After the extruder, the slurry, sandwiched between the paper layers, passes onto an endless belt.

The board is then allowed to set as it travels along the boardline. Setting takes place of over about 3 to 6 minutes after which the board is scored and cut into lengths for drying. Drying typically takes place in a multideck dryer over a period of about 1 hour. After drying the board may be divided into shorter lengths as desired.

In this process, it is essential to ensure that the formulation of the slurry, the delivery of the slurry onto the setting belt and the drying conditions for the formed board are correct to produce a high quality product.

Furthermore, changing over from production of one board type to another requires that the production line be stopped for periods of up to one hour while belt speeds are adjusted, slurry compositions altered and dryer times and temperatures changed. Each change in board type involves the line being shut down for up to an hour. As the line operates at speeds of around 50-60 metres per minute the loss in production is considerable.

A number of control processes for conveyor belt type production lines are known for example GB-A-2035617 discloses a control process for a dewatering press in which the level of sludge in a reservoir is monitored and compared with a set point sludge level. The delivery rate of the sludge is regulated to maintain the sludge level in the reservoir at the set point level. Although of interest to the general field of liquid material control the system disclosed in this document is not suitable for a plasterboard control line as it does not address the problems of controlling anything other than liquid materials. Plasterboard is a mixture of gaseous, liquid and solid components and requires a more sophisticated treatment. Moreover, in the plasterboard manufacturing process it is the board thickness which is of importance and regulating reservoir levels, although desirable, does not guarantee a constant board thickness.

Attention is also directed to GB-A-2025088, GB-A-1214084, GB-A-953635 and EP-A-4690, all of which disclose liquid material control processes.

The present invention aims to control the production of plasterboard to fulfil the requirements noted above and to overcome the abovementioned problems, and accordingly provides a method of controlling the manufacture of plasterboard in which a slurry of raw materials from a reservoir passes to a setting belt, the method comprising the steps of selecting a desired belt speed and board composition, sensing the height of a slurry dam on the boardline, comparing the sensed height with a setpoint height and adjusting a parameter affecting the dam height in accordance with the deviation between the sensed and setpoint heights.

Preferably the parameter affecting the dam height is the setting belt speed and the method further comprises comparing the setting belt speed with a setpoint belt speed and adjusting the feed rates of raw materials to the reservoir to compensate for the difference between the setting belt speed and the setting belt setpoint. The advantage of adjusting the belt speed is that the belt motor can react to instructions to change speed almost instantaneously whereas other parameters such as raw material feeds can take up to 30 seconds to react.

By a system of interactive control loops the method of the invention may optimise operating conditions for a given board formulation. Preferably the system is controlled by a central processor into which the supervisor enters the desired formulation and production rate. The processor then adjusts the variables in accordance with the method of the invention.

Preferably, the central processor can transmit to local parameter controllers details of a fresh set of set point values indicative of a change in desired board parameters. In the case of a change in board width the method further comprises stopping the board production, adjusting the width of board to be produced, restarting the board production at slow speed and resuming the set point conditions on sensing that board edges are being formed correctly.

The invention also provides apparatus for controlling the manufacture of plasterboard in a boardline comprising a slurry reservoir for raw materials, a setting belt arranged to receive the slurry passed from the reservoir and feeds for feeding individual materials into the reservoir, the apparatus comprising means for sensing the height of a slurry dam on the boardline, means for comparing the sensed height with a set point height, and means for adjusting a parameter affecting the dam height in accordance with the deviation between the sensed and setpoint heights.

Preferably the adjusting means comprises means for adjusting the setting belt speed, the apparatus further comprising means for comparing the setting belt speed with a set point belt speed, and means for adjusting the feed rates of raw material to the reservoir to compensate for the difference between the setting belt speed and the set point setting belt speed.

The invention also provides a method of controlling the manufacture of plasterboard in which a slurry of raw material is passed from a reservoir to a setting belt, the method comprising the steps of selecting a desired belt speed and board composition, sensing at least one parameter dependent on the composition of the slurry, comparing the sensed parameter value with a setpoint parameter value, and adjusting a setpoint value of a component of the slurry in accordance with the deviation between the sensed and setpoint parameter values to adjust the sensed parameter value to the setpoint parameter value.

In a further aspect of the invention there is provided apparatus for controlling the manufacture of plasterboard in a boardline comprising a slurry reservoir for raw materials, a setting belt arranged to receive the slurry from the reservoir and feeds for feeding individual materials into the reservoir, the apparatus comprising means for sensing at least one parameter dependent on the slurry composition, means for comparing the sensed parameter value with a setpoint parameter value, and means for adjusting a setpoint value of a component of the slurry in accordance with the deviation between the sensed and setpoint parameter values to adjust the sensed parameter value to the setpoint parameter value.

A preferred embodiment of the method and apparatus of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of a plaster board manufacturing line;

Figure 2 is a block diagram of the control apparatus; and

Figure 3 is a flow diagram of the control process of the invention.

In Figure 1 the raw components are introduced into a mixer 1 by feeds, two of which are shown at 3 and 5. Sensors (not shown) monitor the amount of each of the raw materials introduced into the mixer. The mixer has an exit 7 for egress of slurry onto lining paper 9 fed from a roller 11. Once the slurry has been laid down a dam of slurry builds up in front of an extruder 13. The extruder regulates the thickness of the plasterboard and may be raised and lowered as desired. Before the lower paper layer 9 reaches the extruder its edges are scored (at 10) and bent upwards to form the sides of the board. A capacitative sensor 14 measures the height of the slurry dam. A second, upper layer of lining paper 15 is applied from a roller 17 before the extruder and is glued on the upper inturned edges of the lower lining paper. After the extruder the board is conveyed on a setting belt 19 until the slurry sets, after which it is cut and fed into a dryer. The dryer may be a multilayer dryer in which, for example, twelve parallel lines of board are dried, the lines being separated to allow drying air to pass over each surface of each board in the drier.

Figure 2 shows the main elements of the control system embodying the invention. Overall control is from the control computer 30 which can dictate operating parameters to each local control unit.

The type of plasterboard produced by the process, and its quality, depends on three principal factors: the composition of the slurry; the dam height, that is the height of slurry behind the extruder; and the setting belt speed.

Each of these three factors has its own control loop or loops which the control computer oversees. The loops interact to ensure that the amount and proportions of raw materials fed to the mixer is correct for the type of board being produced and that there is sufficient slurry leaving the mixer for the production rate, which is dictated by the setting belt speed and the board type.

Thus in Figure 2 a speed sensor 32 is mounted on the setting belt drive motor and sends speed signals of actual belt speed ABEL to the computer. The central computer 30 can send set point belt speeds SBEL to a microprocessor control unit 34 for the setting belt motor.

Similarly a sensor 14 is mounted in the extruder 19 to sense actual dam height ADAM and these height signals are sent back to the central computer.

The amount of raw materials supplied by each of the feeds is also measured, shown at 38, and corresponding signals transmitted back to the central computer 30. In turn the computer can transmit set point raw materials levels to the local control units 40 of the raw material feeds. The set points may either be determined by the process supervisor in accordance with the board to be produced and the desired production rate or recalculated by the computer in accordance with the other sensed conditions as will be described.

Sensors 44 are also mounted in the dryer and the computer can dictate drying temperatures and feed through-speeds to the local dryer control 46.

The first control loop is the production rate. This rate is determined by the setting belt speed. The operator enters a desired, or set point, belt speed, SBEL from the control panel and also enters estimated raw material set points for the board to be produced at this belt speed. The material set points will be referred to as SMAT.

The belt drive is provided with a speed sensor that passes a signal ABEL to the computer indicating the actual belt speed. The belt speed controller can compare ABEL with SBEL and make necessary adjustments to the belt speed.

The second control loop is the water gauge. It is important that this is maintained at a constant level for the purposes of quality control, cost control and drying efficiency. The water input to the slurry comprises three separate sources; an aqueous foam, lignosulphonate water and process water which provides the balance. The target, or setpoint, water gauge SWAT is entered from the central control either manually or by calculation from one of the other control parameters.

The raw materials which are fed to the mixer 1 are measured by conventional means and controlled using local dedicated loop controllers. These local loop controllers are subject to the main system control in the system hierarchy; that is, the main control can override the local microprocessors or controller.

The calcium sulphate-hemihydrate is measured by a Schenck weigh belt feeder which incorporates its own microprocessor based controller.

Other solid raw materials, which may be added in dependence on the type of board to be produced, are measured using loss-in-weight feeders incorporating their own microprocessors.

The three liquid feeds are measured using mag-flow meters and controlled using dedicated microprocessor-based loop controllers to adjust pump speeds or valve positions.

The weigh belt feeders, loss-in-weight feeders and the flow meters act to sense the amounts of materials entering the mixer as mentioned in the description of figure 1. Of course, any other type of measuring devices may be used as is convenient.

Thus, the actual water gauge AWAT is dependent on the solid and liquid feed rates as follows

$$AWAT \simeq \frac{ALIQ}{ASOL}$$

Where ASOL is the actual solid feed rate and ALIQ is the actual liquid rate.

The main system controller controls the value of AWAT by comparing AWAT with SWAT and trimming the setpoint sent to the main water feed which has the effect of altering the proportion of liquid to solid in the raw materials.

In practice, each of the dedicated loops of the water gauge control operates continuously, whereas the set point comparison and revision by the main controller operates on a one second cycle.

The third control loop is the dam height. Whereas the production rate and the water gauge ensure that the feed rates of the various components of the slurry are constant and that the production targets are met, changes in temperature, entrainment factors, splices from one paper reel to the next and other variables require that the dam size varies. If the rate of egress of slurry from the mixer is too high, excess slurry will weep at the edges through the fold over of the lining paper, destroying the adhesion between the top and bottom liners. A feed rate that is too low results in the edges of the board being empty.

The dam height is a secondary control is conveyor speed SBEL provides the primary control. The dam height ADAM is a measure of the height of slurry behind the extruder. The dam height may be varied either by adjusting the belt speed for a given feed rate or by varying the feed rates.

The action of the dam height control loop is superimposed on the conveyor speed setpoint SBEL. The range of the output of the dam height controller may be varied but is typically between +/- 0.1 m/min and +/- 1.0 m/min. Thus as the dam height ADAM varies from its setpoint SDAM, a control signal CDAM is generated which is proportional to the deviation from the setpoint. Thus, $CDAM \propto ADAM-SDAM$.

The dam height ADAM is measured by a capacitance-type sensor which is incorporated into the main forming section and generates an output proportional to the dam height. This is a departure from conventional dam sensors which use on-off capacitance devices to indicate excessive dam heights.

Other control parameters may be introduced into the dam height control loop. For example, filters to eliminate the effects of minor variations, dead band, timer delays and conventional integral and derivative terms. The output of the dam height loop controller is mathematically treated by the central computer to provide the appropriate trimming value (typically +/- 0.75 m/min) which is then added to the belt speed set point originally entered by the plant supervisor to give an adjusted setpoint SBEL which is transmitted to the dedicated local belt speed controller. The overall effect of this loop is to maintain the dam size by trimming the belt speed.

Figure 3 shows a way of a flow chart how the various control loops interact to provide an overall control for the system.

After the central computer has determined, at 100, whether the plant is running, it compares, at 102, whether the measured water gauge AWAT equals the pre-entered setpoint SWAT. If AWAT = SWAT then the dam height is examined.

If AWAT ≠ SWAT then the value of AWAT is altered at 104 by varying the amount of water introduced into the slurry. This is done by the main computer which calculates a new main water set point SMAIN for the dedicated water controller based on the deviation between AWAT and SWAT. Once the new value of SMAIN has been transmitted to the local controller step 102 is repeated. The recalculation of SMAIN continues until AWAT = SWAT.

The control computer then compares the dam height to the setpoint dam height. Thus in step 106 the computer compares ADAM and SDAM. If the two values are equal the process moves on to step 110. If not, the belt speed setpoint SBEL is varied at step 106. The belt set point is adjusted as a function of the difference between the sensed dam height ADAM and the set point dam height SDAM.

The adjusted belt speed setpoint determined by the central computer is then transmitted to the local belt speed controller. Step 106 and, if necessary step 108, is repeated until the sensed dam height ADAM is equal to the setpoint dam height SDAM.

At the next step 110 the raw material feeds are trimmed to take account of changes in set points in the first two control loops. If no trim is required the control process is completed and the process holds for a predetermined delay of between 1 and 30 seconds.

It is possible that the effect of adjusting the belt speed setpoint SBEL to maintain the dam height SDAM is that SBEL deviates from the original speed selected by the operator to meet the required production rate. AT step 112 the system performs a continuous 'running average' calculation on the speed. At regular intervals, which might be between ten seconds and ten minutes and which typically is approximately three minutes, the system uses the deviation between the required speed and the running average to calculate adjustments to be made to the setpoints of selected raw materials. It is possible to use this deviation to provide adjustments for all of the raw materials or to apply adjustments to only selected items. The corrective control signals might be directly proportional to the deviation or might be subject to intermediate mathematical manipulation.

Thus, at step 114 the central computer calculates new raw material setpoints and transmits these to the dedicated control loops for the materials. Steps 112 and 114 are repeated until the average belt speed is correct and no setpoint changes are necessary. This step signals the end of the control process and the computer waits for the predetermined delay at 116 before returning to step 100.

The water gauge control loop is dedicated to ensuring that whenever adjustments are made to the feedrates of the gypsum plaster and/or to the water-containing additives, the overall proportion of gypsum plaster to water is preserved. Thus as the dam controller adjusts the belt speed and belt speed controller adjusts the raw material feedrates, so the water gauge controller adjusts the setpoint to the main water feeder.

In addition to the optimisation of running conditions for a selected set of board parameters the process has advantages in switching between different board formulations, board widths and board thickness, as the system supervisor may change the operating parameters at the central control and the control program described with reference to Figure 3 will adjust the setpoints as is necessary. In addition the computer calculates the revised formulation for each of the set points together with revised speeds through the temperatures in the drying oven.

After selecting appropriate operating conditions the supervisor may direct the computer either to proceed or to abort the changeover. If the 'proceed' instruction is given the computer activates a further program which selects the appropriate changeover routine from four main programs, 1, 2, 3 and 4. The routine is selected according to the board currently being produced and the type of board to be produced. The programs perform the following functions:

Program 1. Intended for changeover when the plant is already off-line or when the changeover will necessitate the plant being stopped e.g. for a width change.
The plant is restarted at a slow speed to enable the edges to be properly formed whilst generating the minimum amount of waste. Once the edges are properly formed, the computer oversees acceleration up to full speed.

Program 2. Intended for changeovers which do not involve a board type change e.g. changes in belt speed, board weights, water gauge etc.
There are two versions of this routine, one being used for small changes e.g. speed changes of less

than two metres per minute, the other for larger changes.
For small changes, the computer initiates a step change at the wet end and changes dryer conditions at appropriate times i.e. immediately if the change is in belt speed or after calculated delays if the change is in formulation.

Program 3. Intended for changeovers to a new board type which is run at a higher speed than the board currently being made e.g. forthinner board. Such changeovers would previously require the plantto be stopped for up to an hour whilst the dryer is emptied.
When changing board types the routine produces a buffer board of the new type for typically ten to fifteen minutes. Once it has started to make the buffer board, the computer begins to alter the formulation to the normal formulation for the new board but at the speed of the old board. Upon completion of this ramp, the new board is made at the old (slower) speed until it is safe to go to full productions speed. Throughout this time, dedicated sub-routines ensure that all of the board is properly dried by trimming dryer temperatures.
The use of this changeover routine does not result in any losses in dry board.

4. The final routine is intended for changeovers involving reduced production speeds e.g. for thicker board. It is similar to the previous routine and but operates in reverse. Again, the routine does not result in losses of dried board, and small amounts of waste material only are generated.

In existing board lines, each automatic changeover enables the machine to be run for 45 mins longer than would be the case with manually controlled systems. This represents an increase in weekly machine availability of 0.45% per changeover made.

Moreover, the effect of the control process to change production without serious loss is that 'just-in-time' manufacturing techniques may be adopted. Such techniques allow special types of board to be manufactured as and when they are required. Thus, such boards need not be kept in stock reducing warehousing requirements and reducing the amount of board lost due to damage whilst in stock.

Claims

1. A method of controlling the manufacture of plasterboard in which a slurry of raw materials from a reservoir passes to a setting belt, the method comprising the steps of selecting a desired belt speed (SBEL) and board composition (SMAT), sensing the height (ADAM) of a slurry dam on the boardline, comparing the sensed height (ADAM) with a setpoint height (SDAM) and adjusting a parameter affecting the dam height in accordance with the deviation between the sensed and setpoint heights.
2. A method according to claim 1, wherein the parameter affecting the dam height is the setting belt speed (ABEL) and the method further comprises comparing the setting belt speed with a setpoint belt speed (SBEL) and adjusting the feed rates of raw materials to the reservoir to compensate for the difference between the setting belt and the setting belt setpoint.
3. A method according to claim 1 or 2 wherein prior to sensing the dam height at least one parameter dependent of slurry composition is sensed, the sensed parameter value is compared with a setpoint parameter value and a setpoint value of a component of the slurry is adjusted in accordance with the deviation between the sensed and setpoint parameter values to adjust the sensed parameter value to the setpoint parameter value.
4. A method according to claim 1, 2 or 3 wherein the composition dependent parameter sensed is the ratio of water to solid raw materials in the slurry.
5. A method according to any of claims 1 or 4, wherein the composition dependent setpoint is adjusted by varying a setpoint controlling the amount of water admitted into the slurry.
6. A method according to any of claims 1 to 5, wherein the setpoint belt speed is indicative of the desired production rate.
7. A method according to any of claims 1 to 6 wherein the feed rates of raw materials are measured by sensors prior to the admittance of the respective materials into the reservoir.
8. A method according to any preceding claim wherein the height of slurry in the dam is further controlled by adjustment of the raw material feed rates.
9. A method according to any preceding claims, wherein the respective values sensed are transmitted to a central processor (30) and the adjusted setpoint values are calculated by the central processor and transmitted to respective local controllers.
10. A method according to claim 9 comprising the step of transmitting to respective local controllers a fresh set of setpoint values indicative of a change in desired board parameters.
11. A method according to claim 10, comprising stopping the board production, adjusting the width of board to be produced, restarting the board production at slow speed and resuming the setpoint conditions on sensing that board edges are being formed correctly.
12. A method according to claim 10, comprising effecting a step change in the set point values and adjusting formed board drying conditions.

13. A method according to claim 10, wherein the setpoints are changed for production of a thinner depth board, comprising producing a buffer board at the new board thickness, gradually adjusting the composition of the buffer board to the desired composition of the thinner board until the desired composition is reached, holding the production at the desired composition for a predetermined period, and increasing the belt speed to that required for the new board thickness.

14. A method according to claim 10, wherein the setpoints are changed for production of a thicker board, comprising producing a buffer board at the original board thickness, adjusting the composition of the buffer board to that of the thicker board, and decreasing the setpoint belt speed in accordance with the increased thickness board.

15. Apparatus for controlling the manufacture of plasterboard in a boardline comprising a slurry reservoir (1) for raw materials, a setting belt (19) arranged to receive the slurry passed from the reservoir and feeds (3,5) for feeding individual materials into the reservoir, the apparatus comprising means (14,38) for sensing the height (7) of a slurry dam on the boardline, means (30) for comparing the sensed height with a set point height, and means (34,40) for adjusting a parameter affecting the dam height (7) in accordance with the deviation between the sensed and setpoint heights.

16. Apparatus according to claim 15 wherein the adjusting means (34) comprises means for adjusting the setting belt speed, the apparatus further comprising means (30) for comparing the setting belt speed with a set point belt speed and means (40) for adjusting the feed rates of raw material to the reservoir to compensate for the difference between the setting belt speed and the set point setting belt speed.

17. Apparatus according to claim 15 or 16 comprising sensor means (38) for sensing at least one parameter dependent on the slurry composition, means (30) for comparing the sensed parameter value with a setpoint parameter value, and means (30) for adjusting a setpoint value of a component of the slurry in accordance with the deviation between the sensed and setpoint parameter values to adjust the sensed parameter value to the setpoint parameter value,

18. A plaster boardline comprising the control apparatus of claim 15, 16 or 17.

19. Plasterboard manufactured under the control of the process of any of claims 1 to 14.

20. A method of controlling the manufacture of plasterboard in which a slurry of raw material is passed from a reservoir to a setting belt, the method comprising the steps of selecting a desired belt speed and board composition, sensing at least one parameter dependent on the composition of the slurry, comparing the sensed parameter value with a setpoint parameter value, and adjusting a setpoint value of a component of the slurry in accordance with the deviation between the sensed and setpoint parameter values to adjust the sensed parameter value to the setpoint parameter value.

21. Apparatus for controlling the manufacture of plasterboard in a boardline comprising a slurry reservoir (1) for raw materials, a setting belt (19) arranged to receive the slurry passed from the reservoir and feeds (3,5) for feeding individual materials into the reservoir, the apparatus comprising means (14,38) for sensing at least one parameter dependent on the slurry composition, means (30) for comparing the sensed parameter value with a setpoint parameter value, and means for adjusting (34,40) a setpoint value of a component of the slurry in accordance with the deviation between the sensed and setpoint parameter values to adjust the sensed parameter value to the setpoint parameter value.

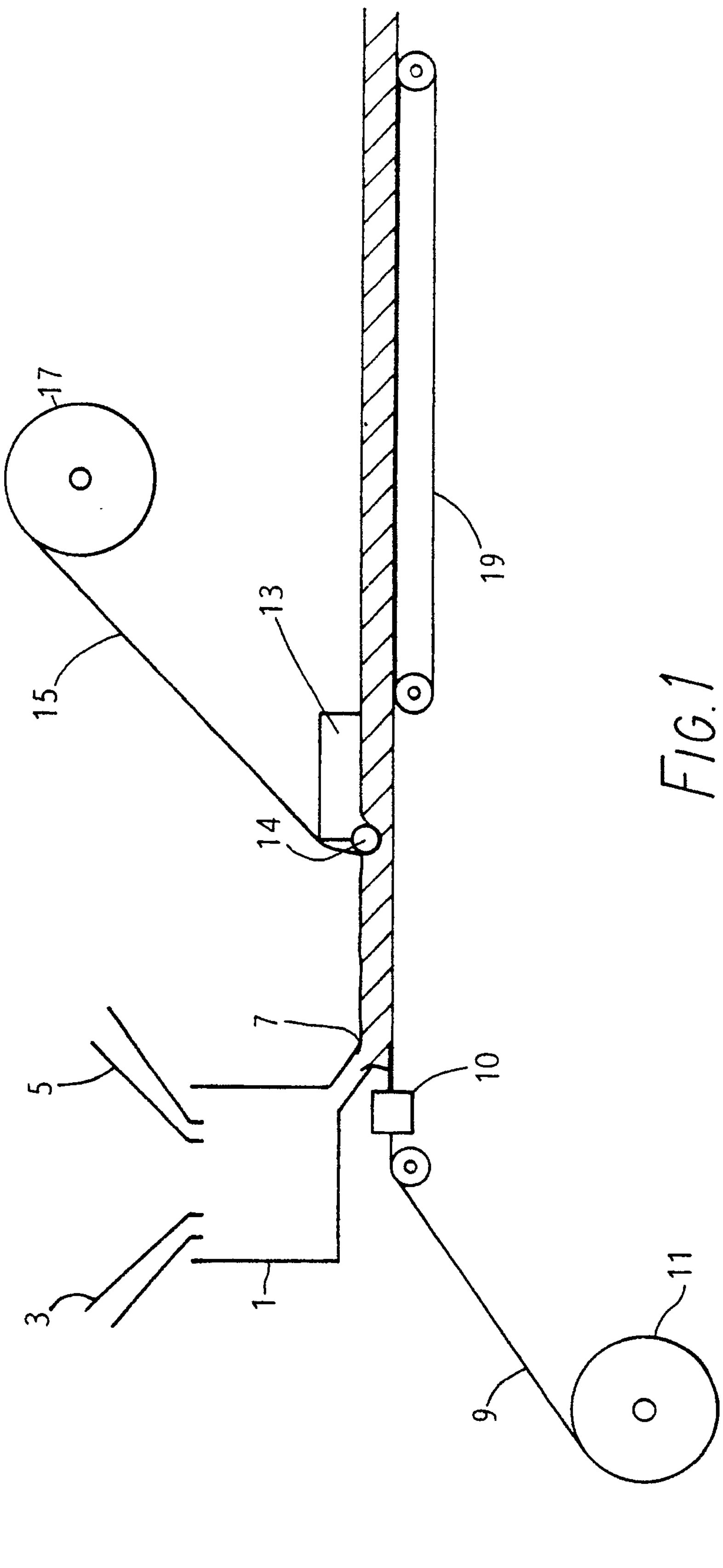

FIG.1

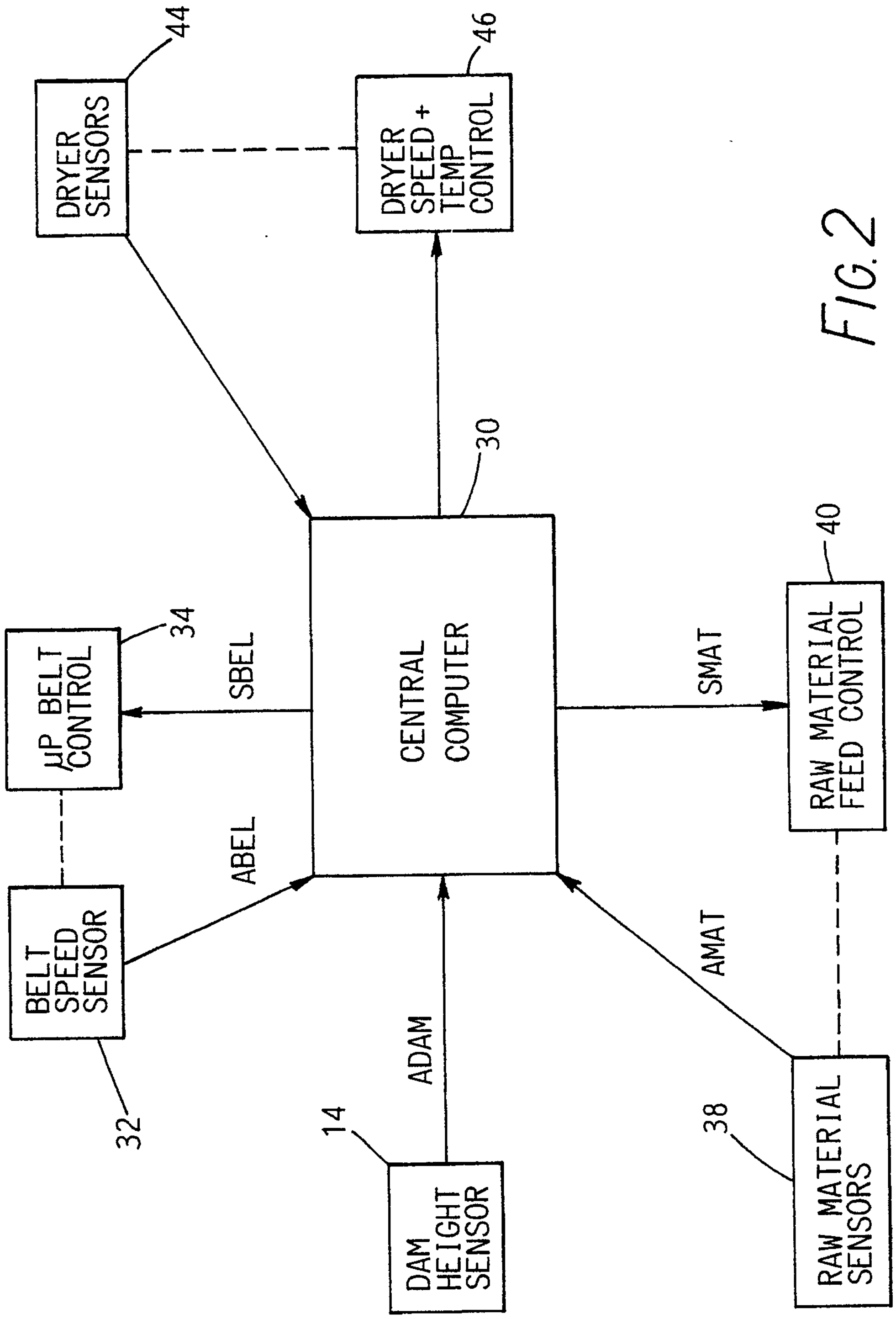
DRYER SENSORS
44
DRYER SPEED + TEMP CONTROL
46
30
µP BELT CONTROL
34
SBEL
CENTRAL COMPUTER
SMAT
RAW MATERIAL FEED CONTROL
40
BELT SPEED SENSOR
32
ABEL
ADAM
14
DAM HEIGHT SENSOR
AMAT
38
RAW MATERIAL SENSORS

FIG. 2

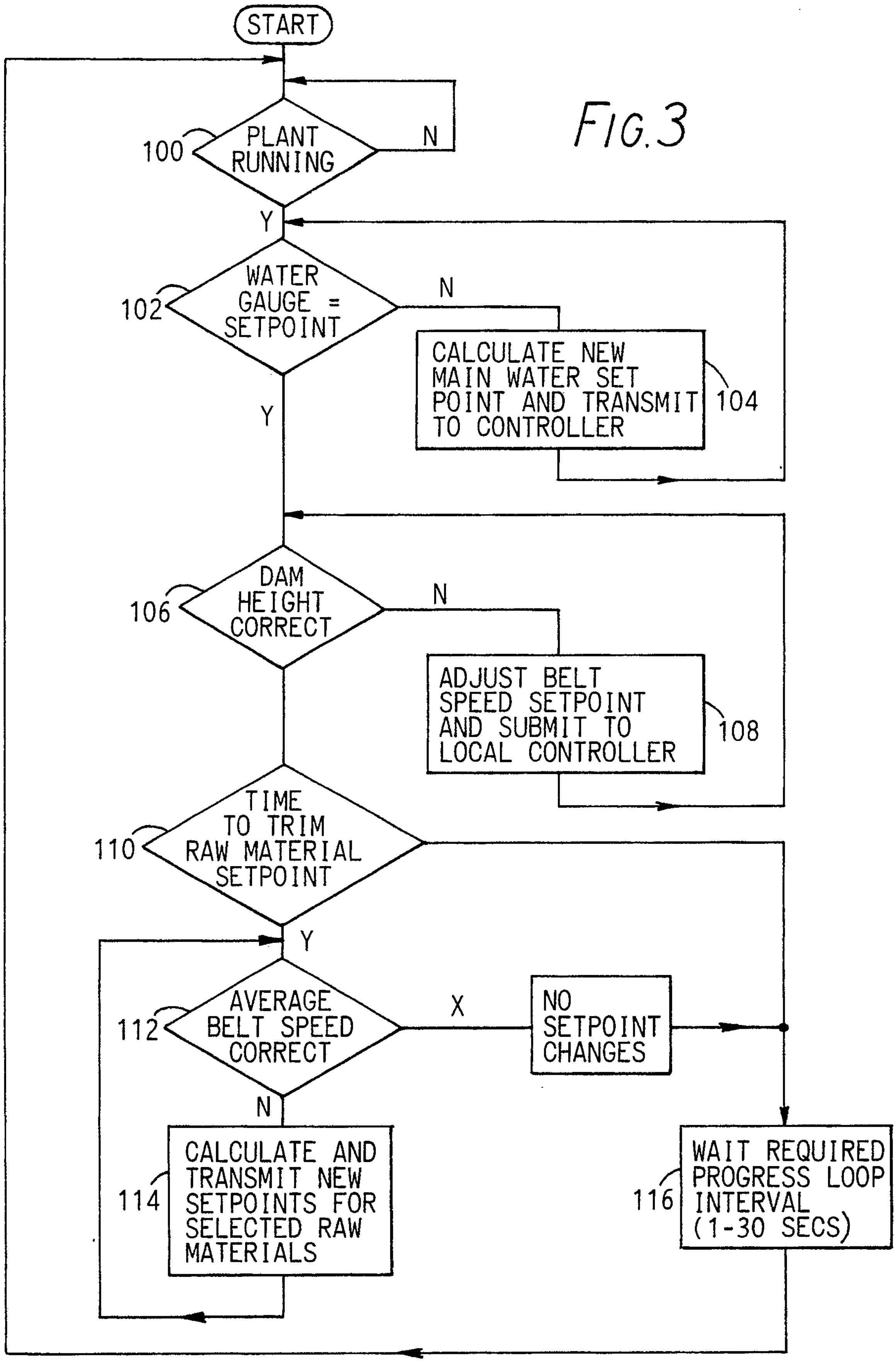
FIG.3
START
PLANT RUNNING
100
N
Y
WATER GAUGE = SETPOINT
102
N
CALCULATE NEW MAIN WATER SET POINT AND TRANSMIT TO CONTROLLER
104
Y
DAM HEIGHT CORRECT
106
N
ADJUST BELT SPEED SETPOINT AND SUBMIT TO LOCAL CONTROLLER
108
TIME TO TRIM RAW MATERIAL SETPOINT
110
Y
AVERAGE BELT SPEED CORRECT
112
X
NO SETPOINT CHANGES
N
CALCULATE AND TRANSMIT NEW SETPOINTS FOR SELECTED RAW MATERIALS
114
WAIT REQUIRED PROGRESS LOOP INTERVAL (1-30 SECS)
116