June 1, 1965 C. O. BADGETT 3,186,596

CONCRETE BATCH BLENDING CONTROL SYSTEM

Filed Jan. 25, 1962

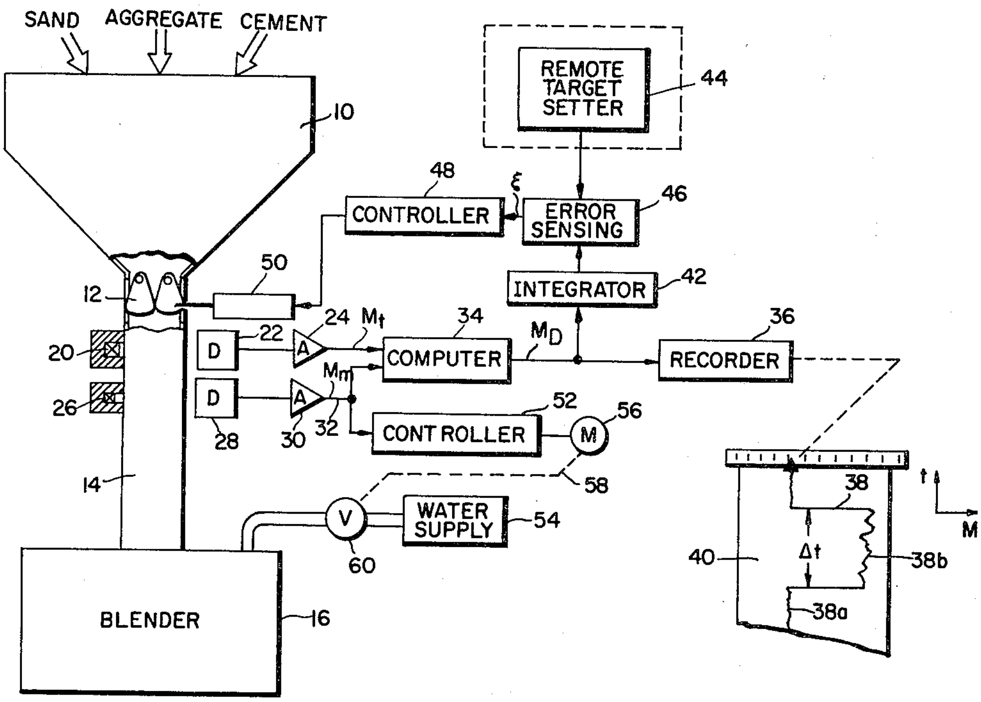

Fig. 1

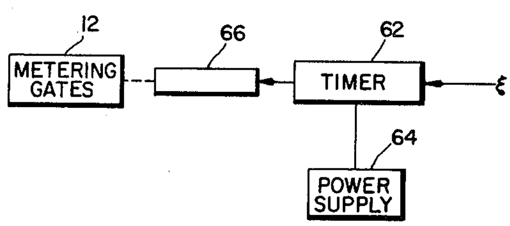

Fig. 2

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United States Patent Office

3,186,596

Patented June 1, 1965

3,186,596

CONCRETE BATCH BLENDING CONTROL SYSTEM

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Filed Jan. 25, 1962, Ser. No. 168,689
6 Claims. (Cl. 222—14)

This invention relates generally to cement blending processes and more particularly to a system for measuring and controlling a batch concrete blender.

In batch concrete blending, dry aggregate, sand, and cement materials are individually weighed and admitted to a blender where water is added to provide concrete having a certain desired consistency and preferred strength characteristics. The weigh hoppers commonly used are only as accurate as good maintenance of the knife edges will permit. These mechanical weighers malfunction due to cement and dust deposits which build up and must be removed. The weigh hoppers must be placed below the feed bins and expensive supporting structure is required to provide clearance below the weigh hoppers for trucks or other blending equipment.

In addition, there is always present a certain indeterminate amount of moisture present in these materials admitted to the feed bins. The amount of entrained water varies with the weather and other environmental factors which are usually uncontrollable. As a result the concrete produced may be entirely too wet. In the manufacture of building block this could result in blocks of inferior strength due to the inability of the equipment to cope with the overdampened mix.

The present invention provides means for performing a non-contacting measurement of mass flow of the material as it falls by gravity from the supply or feed bin into the blender. The amount of moisture is determined and the two measurements are used to compute the mass flow of dry material and water. The mass flow measurements are integrated over a period of time to drive a signal proportional to total mass. The flow is cut off when sufficient time has elapsed for a desired total mass to be transferred to the blender.

Accordingly, it is a primary object of the present invention to provide an improved measuring and control system for a batch concrete blending process.

It is another object of the present invention to provide a system which is more accurate and more reliable than similar devices used heretofore.

It is still another object of the present invention to provide a system which is completely automatic and capable of increased throughput.

It is yet another object of the present invention to provide a system which requires less space and fewer supporting structures than similar devices used heretofore.

These and other objects and features of the present invention will become more apparent when the following description is taken in conjunction with the attached drawings, in which:

FIG. 1 is a block diagram of a measuring and controlling system for a batch concrete blending process constructed in accordance with the present invention; and

FIG. 2 is a diagrammatic view of a controller for use in the system shown in FIG. 1.

With reference now to the drawings and specifically to FIG. 1, the system of the present invention is embodied in a batch concrete blending process including a storage bin **10** for feeding or supplying either aggregate, sand or cement. A pair of swingable metering gates **12** serve to admit the material contained in the bin **10** to a chute **14**. The material falls by gravity down the chute **14** into a blender **16** which may comprise a mixing truck used to transport concrete to the construction site.

The mass flow M of material into the blender **16** is a function of the bulk density ρ of the material, the cross-sectional area A of the stream of material and the velocity v. Mathematically,

$$M=\rho A v \qquad (1)$$

In accordance with the invention a radiation density gauge is provided by a source of gamma radiation **20** and a detector **22** therefor mounted on opposite sides of the chute **14**. The detector may comprise one or more Geiger-Müller tubes responsive to radiation passing through the chute and falling material. An amplifier **24** provides a signal M_t which is a function of the total mass of material intercepting the gamma radiation beam passing from the source **20** to the detector **22**. The radiation beam passes through substantially the total cross-sectional area A′ of the chute, even though the actual cross-sectional area A of the material stream is generally less than A′ and dependent on the selected width of the opening provided by the metering gates **12** in their open position. Hence the signal M_t is a function of an apparent bulk density ρ' proportional to the mass per unit volume of the measured region of the chute including air spaces therein. Equation 1 may thus be replaced by the equivalent expression $M=\rho' A' v$, wherein A′ is constant. Particularly if the source **20** and detector **22** are placed as close as possible to the metering gates **12** as shown, the free fall velocity is also substantially constant, and hence the signal M_t varies essentially only with ρ' and is in fact an accurate indication of the mass flow M.

It is inevitable that the total mass flow signal M_t include a component due to the moisture entrained in the material. To measure this component a source **26** of neutron radiation and a detector **28** are mounted near to the gamma ray source and detector units **20**, **22** and connected to an amplifier **30**. A signal M_m proportional to the moisture mass flow is provided by amplifier **30** on line **32**.

A computer **34** provides a signal M_D proportional to the mass flow of the dry material alone and transmits it to a chart recorder **36**. The chart recorder presents a continuous trace **38** on a moving chart **40**. The chart trace **38** may be interpreted as mass flow vs. time as indicated by the coordinate axes to the right. The left-hand line or trace portion **38a** is indicative of the empty chute while the displaced curvilinear portion **38b** represents measurements of the falling material. The time of fall Δt is indicated and may typically extend for 20 to 40 seconds.

The dry mass flow signal M_D is also transmitted to an integrator **42** which in turn provides a signal proportional to the total dry mass transferred to the blender. This signal is represented as

$$m=\int_{T_1} M\,dt$$

where

$$T_2-T_1=\Delta t$$

A remote unit **44** may be used to enable dispatching personnel to dial in a preferred value for m. The selected value for m is converted by unit **44** to a constant analog signal that is delivered to an error sensing unit **46**. Unit **46** compares this signal with the output signal from integrator **42** and provides an error signal proportional to the difference therebetween. When the integrator output signal becomes equal to the signal representing the selected value for m, the error signal is reduced to zero. Controller **48** responds to the condition of zero output from the error sensor **46** to operate an air cylinder **50** adapted to actuate the metering gates **12**. The controller **48** described in detail hereinafter basically determines how long the gates **12** remain open by closing the gates when the proper amount of material has been transferred to the blender. If a large mass flow M_D is measured, the gates are not open for nearly the duration as if a smaller mass flow were being measured.

Another controller **52** serves to control the amount of water added to the blender from a supply **54**. A servomotor **56** is mechanically linked as indicated by the dotted line **58** to a valve **60** connecting the water supply **54** to the blender **16**. The controller **52** may include suitable integrating, error sensing and set point adjusting units similar to those described above. The controller operates the servomotor **56** in such a direction as to keep the entrained moisture and added moisture to the blender at a preferred value consistent with good operating practice.

Referring to FIG. 2, the controller **48** may include a timer **62** operative to apply electrical power from a supply **64** to a solenoid **66** mechanically coupled to the metering gates **12**. The timer is usually required to shorten or lengthen the variable integration period Δt by a fixed amount which depends on either or both the time required for the material to fall from the gates **12** to the source detector or the time required to compensate for an inherent mechanical delay in the closing of the gates. Briefly, the timer may be influenced by the error signal ξ to shorten or prolong the period of operation of the solenoid **66**. The timer **62** may comprise a thyratron whose period of cutoff is determined by the bias caused by the error signal leaking off of an R-C network. Other timing expedients of equal utility may be suggested.

While certain and specific embodiments have been described herein, many changes and modifications may be made without departing from the true spirit and scope of the invention as is set forth in the appended claims.

I claim:

1. Batch concrete blending apparatus which comprises:
a storage bin for a nominally dry ingredient having an unknown moisture content,
a blender,
a chute leading directly from said bin to said blender and having a measuring section provided in said chute,
gate means located between said bin and said measuring section for admitting said ingredient to said chute whereby said ingredient passes to said blender;
said gate, said chute and said measuring section therein being arranged so that said ingredient passes through said measuring section at a relatively constant velocity;
means responsive to the apparent bulk density of material in said measuring section for providing a signal indicating the rate of mass flow of said ingredient therethrough,
means responsive to the moisture contained in material in said measuring section for providing a signal indicating the rate of moisture mass flow accompanying the flow of said nominally dry ingredient therethrough,
computer means for mathematically combining said moisture mass flow signal with said ingredient mass flow signal to provide a compensated mass flow signal indicating the mass flow of said ingredient in a dry state,
means for computing a time integral of said compensated mass flow signal, and
means for closing said gate when said computed integral exceeds a predetermined value,

2. Batch concrete blending apparatus which comprises:
a storage bin for a nominally dry ingredient having an unknown moisture content,
a blender,
a chute leading directly from said bin to said blender and having a measuring section provided in said chute,
gate means located between said bin and said measuring section for admitting said ingredient to said chute whereby said ingredient passes to said blender;
said gate, said chute and said measuring section therein being arranged so that said ingredient passes through said measuring section at a relatively constant velocity;
means responsive to the apparent bulk density of material in said measuring section for providing a signal indicating the rate of mass flow of said ingredient therethrough,
means responsive to the moisture contained in material in said measuring section for providing a signal indicating the rate of moisture mass flow accompanying the flow of said ingredient therethrough,
computer means for mathematically combining said moisture mass flow signal with said ingredient mass flow signal to provide a compensated mass flow signal indicating the mass flow of said ingredient in a dry state,
means for computing a time integral of said compensated mass flow signal,
means for closing said gate when said computed integral exceeds a predetermined value,
adjutsable means for delivering water to said blender for combination with said ingredient therein, and
means responsive to a function of said moisture mass flow signal for adjusting said water delivery means in accordance with the amount of moisture entrained in said nominally dry ingredient.

3. Batch concrete blending apparatus which comprises:
a storage bin for a nominally dry ingredient having an unknown moisture content,
a blender,
a chute leading directly from said bin to said blender and having a vertical measuring section provided in said chute wherethrough said ingredient can fall freely under the influence of gravity,
gate means located at the top of said measuring section for admitting said ingredient thereto whereby said ingredient passes to said blender after falling at a substantially constant velocity through said measuring section,
means responsive to the apparent bulk density of material in said measuring section for providing a signal indicating the rate of mass flow of said ingredient therethrough,
means responsive to the moisture contained in material in said measuring section for providing a signal indicating the rate of moisture mass flow accompanying the flow of said ingredient therethrough,
computer means for mathematically combining said moisture mass flow signal with said ingredient mass flow signal to provide a compensated mass flow signal indicating the mass flow of said ingredient in a dry state,
means for computing a time integral of said compensated mass flow signal,
target setting means for providing a target signal indicative of a desired mass of said ingredient in said dry state, and
a controller including timer means having a time setting biased by a combination of said integral and target signals for initiating closure of said gate when said desired mass of said ingredient plus the moisture entrained therein has passed through said gate.

4. Batch concrete blending apparatus which comprises
a storage bin for a nominally dry ingredient having an unknown moisture content,
a blender,
a chute leading directly from said bin to said blender and having a vertical measuring section provided in said chute wherethrough said ingredient can fall freely under the influence of gravity,
gate means located at the top of said measuring section for admitting said ingredient thereto whereby said ingredient passes to said blender after falling at a substantially constant velocity through said measuring section,

means responsive to the apparent bulk density of material in said measuring section for providing a signal indicating the rate of mass flow of said ingredient therethrough,

means responsive to the moisture contained in material in said measuring section for providing a signal indicating the rate of moisture mass flow accompanying the flow of said ingredient therethrough,

computer means for mathematically combining said moisture mass flow signal with said ingredient mass flow signal to provide a compensated mass flow signal indicating the mass flow of said ingredient in a dry state,

means for computing a time integral of said compensated mass flow signal,

target setting means for providing a target signal indicative of a desired mass of said ingredient in said dry state,

a controller including timer means having a time setting biased by a combination of said integral and target signals for initiating closure of said gate when said desired mass of said ingredient plus the moisture entrained therein has passed through said gate,

adjustable means for delivering water to said blender for combination with said ingredient therein, and

means responsive to a function of said moisture mass flow signal for adjusting said water delivery means in accordance with the amount of moisture entrained in said nominally dry ingredient.

5. Batch concrete blending apparatus which comprises:

a storage bin for a nominally dry ingredient,

a blender,

a chute leading directly from said bin to said blender and having a vertical measuring section provided in said chute wherethrough said ingredient can fall freely under the influence of gravity,

gate means located at the top of said measuring section for admitting said ingredient to said chute whereby said ingredient passes to said blender after falling at a substantially constant velocity through said measuring section,

a source of gamma rays mounted on one side of said measuring section,

means including a detector for said gamma rays mounted on the opposite side of said measuring section for providing a signal indicating the rate of mass flow of said ingredient therethrough,

means for computing a time integral of said signal, and

means for closing said gate when said computed integral exceeds a predetermined value.

6. Batch concrete blending apparatus which comprises:

a storage bin for a nominally dry ingredient having an unknown moisture content,

a blender,

a chute leading directly from said bin to said blender and having a vertical measuring section provided in said chute wherethrough said ingredient can fall freely under the influence of gravity,

gate means located at the top of said measuring section for admitting said ingredient to said chute whereby said ingredient passes to said blender after falling at a substantially constant velocity through said measuring section,

a source of gamma rays mounted on one side of said measuring section,

means including a radiation detector mounted on the opposite side of said measuring section for providing a signal indicating the rate of mass flow of said ingredient therethrough,

a source of neutron radiation mounted on one side of said measuring section,

means including a second radiation detector on the other side of said measuring section opposite said neutron source for providing a signal indicating the rate of moisture mass flow accompanying the flow of said ingredient therethrough,

computer means for mathematically combining said moisture mass flow signal with said ingredient mass flow signal to provide a compensated mass flow signal indicating the mass flow of said ingredient in a dry state,

means for computing a time integral of said compensated mass flow signal, and

means for closing said gate when said computed integral exceeds a predetermined value.

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