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DIGITAL BLENDING SYSTEM

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I. INTRODUCTION

In the petroleum refining, chemical, food and drug industries, ratio control in blending processes plays an important role in production and recently has become an essential factor. In order to rationalize the maintenance and operation of these processes, control the quality of the products and lower plant construction costs, Fuji Electric has developed a digital blending system containing the standard F–MATIC N series of digital control elements.

This digital blending system employs printed circuit boards for all control elements which greatly facilitate maintenance. System reliability is high since standard elements are used. As the elements and display portions can be separate, the panel is much more compact than in previous systems and convenient supervision of operation is possible. By combining the F–MATIC elements in various ways, it is possible to construct many different types of systems. These elements are especially effective in designing systems linked with control computers.

Recently there have been many examples of the use of computers in offsite locations for oil refinery batch and stock control. Since both blending control and batch control can be carried out mostly from offsite offices, computing control has become increasingly widespread.

This article will outline Fuji Electric's digital blending system.

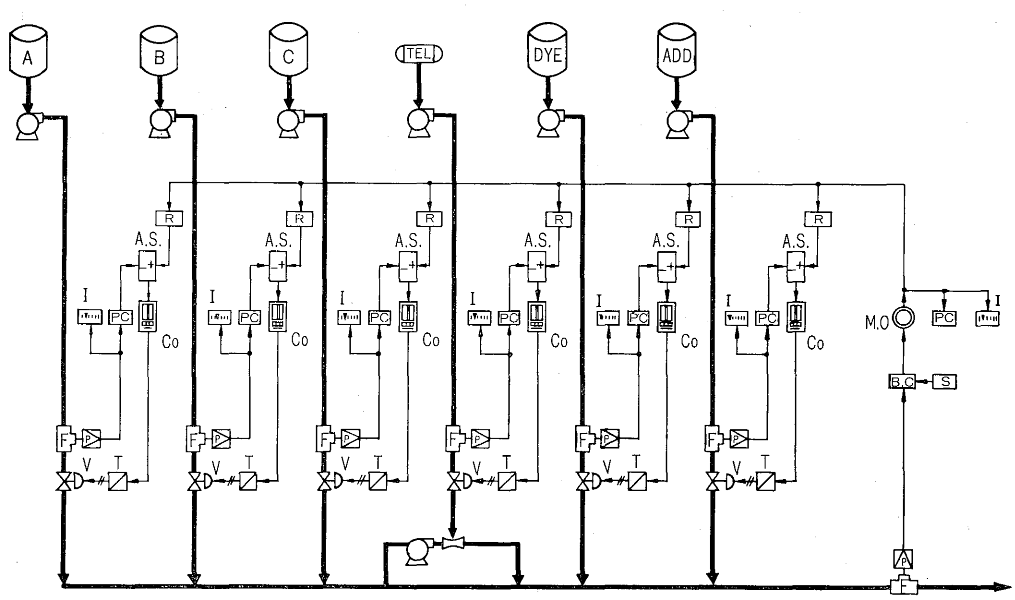
II. APPLICATIONS AND FEATURES OF THE DIGITAL BLENDING SYSTEM

1. Applications

Blending is the mixing together of specified raw materials in certain ratios, and both analog and digital systems can be employed in such processes. Analog equipment controls the ratio of an instantaneous amount of flow, while the digital system controls the ratio of an accumulated amount of flow.

This digital blending system can be utilized for all kinds of mixing processes including powders, liquids large amounts or micro-quantities, two components or many components. It can give the following benefits:

Reduction of plant installation costs
Reduction of operating costs
Savings in materials
Safe operation.



F: Turbine meter
P: Preamplifier for turbine meter
I: Flowmeter
PC: Calculator
R: Ratio setter
A.S.: Add-subcounter
Co: Controller
T: Electropneumatic converter
M.O.: Master pulse generator
B.C: Batch controller
S: Batch setter
V: Adjustable valve

Fig. 1 Skeleton diagram of gasoline blender

Typical examples of possible applications are as follows.

Oil refineries

Mixing control for gasoline, LPG, jet fuels, naphtha heavy oil, lubricating oil, asphalt, crude oil etc.

Chemical plants

Mixing control in polymerization processes, catalytic addition processes, paint mixing and chemical fertilizer plants.

Cement plants

Mixing control of limestone, clay, slag etc.

Food and drug plants

Mixing control in breweries, distilleries, and dairies as well as dilution processes.

Fig. 1 shows a skeleton diagram of the digital system used as a gosoline blender.

2. Features

The features of this system are as follows.

1) High precision blending is possible

If the flow is stopped for a short time for some reason in analog ratio mixing, the part which is not corrected causes an offset error after normal operation is resumed even if corrective measures are taken immediately. However, with the digital system, the offset portion is memorized by the operation of the digital comparator and finally compensated for so that highly accurate mixing is possible. Since the mixing processes are all digital and can be carried out at high speed, mixing accuracy is determined almost entirely by the accuracy of the flowmeters.

2) The mixing ratio can be set digitally over a wide range

The ratio can be optionally determined with high accuracy in accordance with need, over a standard range of 0.1% to 99.9% in units of 0.1%.

3) No influence due to interruptions in operation

Even if operation stops because of accidents or for some other reasons, operation can be resumed immediately since the integrated flow error is stored in the memory.

The following features result from the use of F–MATIC elements.

4) The equipment is economical

Besides the savings in initial equipment, operation and maintenance, the system is much more economical when compared with previous systems which had one device and only one function. Individual F–MATIC element can be used in different ways so that fewer circuits are needed. The larger the scale of the system, the more useful this feature.

5) Reliability is high and the equipment is compact

The F–MATIC elements are highly stable against noise over a wide range of permissible changes in circuit and operating conditions. High quality circuit components are used and tolerances provided. The special efficiency is high which makes the system compact.

The blending equipment itself possesses the following features.

6) It can be easily linked with a control computer

Recently there have been many cases of large blending systems using computer control. Connection of this system with real time computer control equipment is simple since the whole control circuits consist of F–MATIC elements.

Interlocking, automatic pump starting etc. are possible using the same elements, which makes the system highly versatile.

7) The control desk is compact and design is optional

Since the operation and display parts are arranged on the desk surface for easy use, the system can be accommodated compactly in accordance with plant requirements.

8) Maintenance is easy

Since printed circuit boards are standard equipment, all the main component elements can be freely interchanged even with boards used in other control systems. This greatly simplifies maintenance.

9) Enlargements or changes in design are both easy and arbitrary

Enlargements or design variations can be carried out easily and simply by adding more printed circuit boards etc. The number of material lines is also unlimited either before or after planning.

III. DIGITAL BLENDING PRINCIPLES AND METHOD

1. Principles

The basic principle of digital blending control is shown in *Fig. 2*. If the amount of liquid flowing through the pipe line is measured by a turbine-type or volume-type flowmeter, a pulse can be generated each time some specified volume flows through. The number of these pulses f_c is then proportional to the accumulated amount Q_c of liquid flowing through the pipeline and can be expressed by the following equation.

$$f_c = KQ_c$$

where K is a proportional coefficient known as the amount/pulse conversion coefficient.

It is also evident that the frequency of these pulses is proportional to the flow rate. As can be seen from *Fig. 2*, addition is carried out by providing a certain number of pulses from a pulse generator as

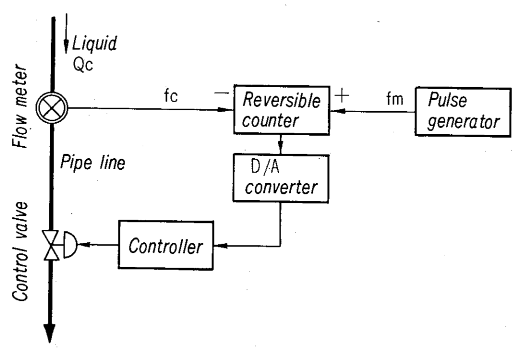


Fig. 2 Principle diagram of digital blending control

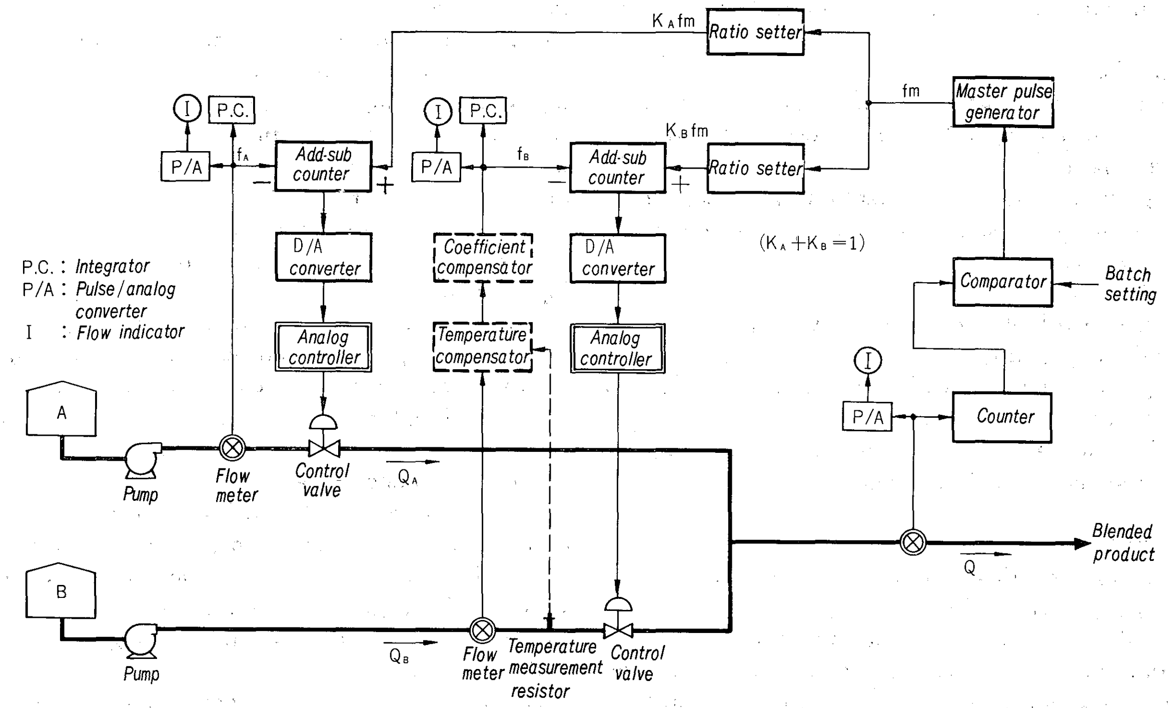


Fig. 3 **Construction diagram of digital blending system**

one of two inputs to a reversible counter. Subtraction is carried out by providing pulses generated from the flowmeter as the other input.

The controller is then operated by input converted from the reversible counter numerical value into an analog quantity which serves as a deviation input. If the pipeline adjustment valve is controlled so that the numerical value is 0, the number of pulses from the pulse generator f_m will become equal to the number of pulses from the flowmeter f_c thus giving the following relation.

$$f_m = f_c = KQ_c$$

Therefore, accumulated flow control can be carried out according to the value of f_m.

Under steady state control conditions,

$$\frac{d}{dt} f_m = \frac{d}{dt} f_c = K \frac{d}{dt} Q$$

which means that the flow rate can also be controlled according to the frequency of f_m.

The basic construction of the digital blending system is shown in *Fig. 3*, for an application where two liquid components are mixed together. As in *Fig. 2*, the output pulse from the flowmeters of pipelines *A* and *B* are sent to separate reversible counters. In practice, however, compensation due to volume changes caused by the temperature of the liquids is often necessary. In such cases the number of pulses must be adjusted according to the amount of compensation by the temperature compensation circuit.

When the flowmeter is of the turbine type, the flow pulse conversion coefficient is not an integer and therefore it is necessary to multiply some coefficients in order to make them into integers. When the conversion coefficients are not the same for both flowmeters *A* and *B*, this correction is necessary to make the coefficients equal.

When the output f_m of the master pulse generator is multiplied by the desired mixing ratios K_A and K_B for line *A* and *B* respectively, and used as addition inputs for the reversible counters, they become the control loop set values for the two lines.

If the amount of flow is controlled by operating the adjustable valve so that the reversible counter numerical content is 0 as described above, the final relations shown below will hold.

$$\begin{cases} f_A = K_A f_m = KQ_A \\ f_B = K_B f_m = KQ_B \end{cases} \quad \therefore \quad \begin{cases} Q_A = (K_A/K) f_m \\ Q_B = (K_B/K) f_m \end{cases}$$

The ratio of Q_A to Q_B is the same as the ratio of K_A to K_B.

If $K_A + K_B = 1$, then

$$Q = Q_A + Q_B = \frac{f_m}{K}$$

so that the overall accumulated amount of flow Q is determined by f_m and the momentary amount of flow is determined by the frequency of f_m.

In other words, the accumulated amount of flow in *A* and *B* is controlled by multiplying the overall accumulated amount by a ratio determined by K_A and K_B.

If the accumulated amount of flow of the blended product is measured by another flowmeter and the output pulse of this flowmeter is counted by a counter, the master pluse can be stopped when it is detected that this number reaches a predetermined value. In this way batch shipment control can be carried out in which the mixing process is automatically stopped.

This counter is known as a batching counter and gives out two signals: a precaution signal just before the set value is reached (slowdown signal) and a final stop signal.

The instantaneous flow of each component can be displayed on an indicator in an analog manner by converting the number of flowmeter output pulses to voltage and supplying this voltage to the indicator.

The accumulated flow is displayed by counting the number of pulses with a counter.

2. System

Generally in the type of blending systems shown in *Fig. 2*, the number of the output pulses of the master generator serves as a base and control is carried out by multiplying this by a mixing ratio for each component. Therefore, this system is known as a master-generator paced control system.

Fig. 4 shows a system in which one of the mixture components is used as a basis and the output pulses from the flowmeter in question are employed instead of master generator pulses.

In this case, the ratio of each component is set in accordance with the basic component. This is known as the master-line paced control system.

The amount of flow of the basic component is selected manually and the other component is controlled so that the desired ratio is attained. Therefore, this system is ideal for cases where the number of components is few and the required flow is not constant.

Fig. 5 shows the same master-line paced control system with the mixed flow amount as basis. The

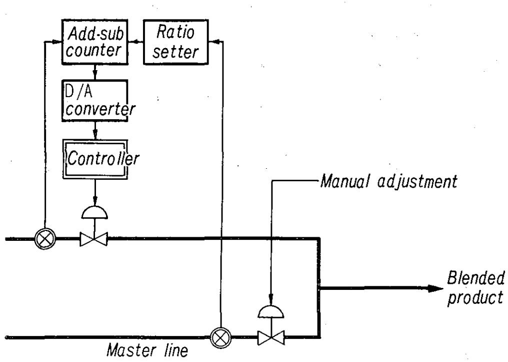


Fig. 4 Master-line paced control system A

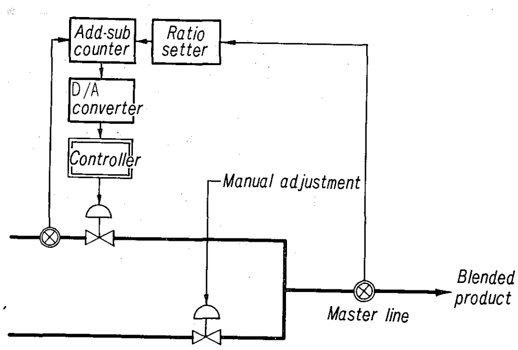


Fig. 5 Master-line paced control system B

mixed amount of flow is controlled manually, and the ratio in respect to the mixed amount of flow is set the same as in the master generator paced control system.

IV. COMPONENTS OF THE DIGITAL BLENDING CONTROL EQUIPMENT

In the Fuji digital blending system, the main part of the control equipment is in the form of printed circuit boards which can be accomodated in a common rack. Only the operating parts are arranged separately on an operating desk or panel.

An outline of the main components and their operation will be given here.

1. Master Pulse Generating Circuit

The master pulse generating circuit consists of a type of astable multi-vibrator which employs a Miller integrator in the timing circuit. The frequency of the pulse can be altered by the voltage supplied to the integrating circuit.

As shown in *Fig. 6* the circuit is almost the same as astable element AS 32, a standard element of the F–MATIC series.

When the level detection circuit shown in the figure is in the "0" signal condition, the transistor T is conducting and its output, i.e. the input signal of the integrating circuit becomes "1". This becomes negative in respect to the basic potential V_R of the integrating circuit. (In the F–MATIC system, when the signal condition is "1", this corresponds to a potential of 0 v and when the signal is "0", it corresponds to a positive potential.)

The output voltage v_A of the integrating circuit varies in respect to the input voltage v_E in accordance with the following equation:

$$v_A = -K\int v_E\,dt \quad (K \text{ is a proportional constant})$$

Therefore, if v_E is a set negative value, v_A will increase at a constant rate. When v_A reaches the operating value of the level detection circuit, the output becomes "1" and T is changed to the "off" condition.

Then the input potential of the integrating circuit becomes a positive voltage determined by the output voltage V_R from the constant voltage circuit. The input voltage then becomes positive value $(V_Z - V_R)$ in

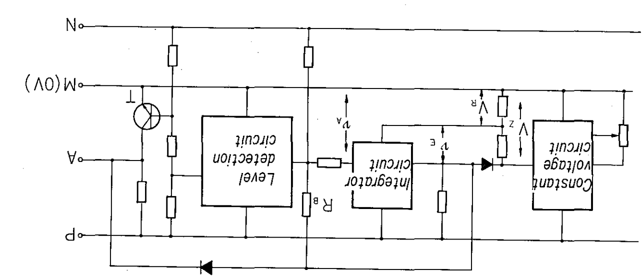


Fig. 6 Master pulse generating circuit

respect to V_R so that v_A begins to decrease at a constant rate.

However, when T is in the off condition, a positive bias voltage V_Z is applied via resistor R_B to the level detection circuit input and therefore this reset value is lower than the operating value. Until v_A attains this value, T remains in the off condition.

When v_A reaches the reset value, T begins to conduct and the integrating circuit input is again negative. The bias voltage to the level detection circuit also becomes 0 and v_A begins to rise again.

When the operation cycle mentioned above is repeated, the output of T becomes a constant frequency square wave pulse signal.

The gradient of v_A is determined by V_Z and the difference between the level input detection circuit operating value and the reset level is determined only by V_Z and B_B. Therefore the output frequency is constant no matter what the source voltage etc.

The constant voltage circuit output V_Z can be varied by means of a variable resistor. If the master pulse frequency is 10 kHz or below, it can be adjusted optionally in the 1 : 20 range. This setting is made from the operating desk and the master pulse frequency f_m is determined as shown below. If the overall mixed flow amount is Q m^3/hour and the flowmeter's amount/pulse conversion coefficient is K pulse/liter, the amount of flow per second becomes $Q/3600$ m^3 and the number of pulses generated per 1 m^3 is 10^3K. Therefore, the master pulse frequency should be as follows.

$$f_m = K \cdot Q/3.6 \text{ (pps)}$$

2. Ratio Setter

The master pulse must be applied to an addition/subtraction counter for control deviation detection as the reference pulse for each component after the desired ratios for each component are multiplied.

Fig. 7 is a block diagram of the ratio setter of this system. The master pulse is counted by the counter and from the counted values certain values, the number of which correspond to the set ratio, are read out and only at this time the pulse is selected. So this is a type of frequency divider circuit.

The *CT* 301 shown in the figure is a standard F-MATIC element. *Fig. 8* shows an outer view of a decimal counter constructed on a single printed circuit board.

The circuit shown here is for a set ratio in minimum units of 1/1000 and requires 3 *CT* 301 printed boards. The *FC* 301 elements connected to each counter are known as frequency divider gates. At their 4 terminals a total of 9 separate numerical values of 1, 2, 4, and 2 from the corresponding counter values are read out.

Therefore, from the 4 output terminals of the 10^0 column FC 301 unit, a total of 900 numerical values (100, 200, 400 and 200) in respect to an input of 1000 pulses or 90% of whole numerical values can be read out. When these numerical values are read out, the read out of the higher unit column is locked so that there will be no superimposition of the same values and read out is possible only for the remaining 10%.

In other words, in the 10^1 column, a total of 90 numerical values (10, 20, 40 and 20) are read out from the 4 terminals and from the 10^2 column, 9 numerical values, i.e. 0.9% of the total are read out.

In this way, a suitable combination is selected from among the 12 groups of read outs and an *OR* condition is achieved. If the gate is operated by the master pulse, its output is some fraction of the master pulse and any desired ratio can be obtained by this conbination method.

In *Fig. 7*, the divider ratio is $n = 0.341$. This setting can be made by a code signal from a computer or digital switch.

As is evident from the figure, 1 set of the *CT* 301

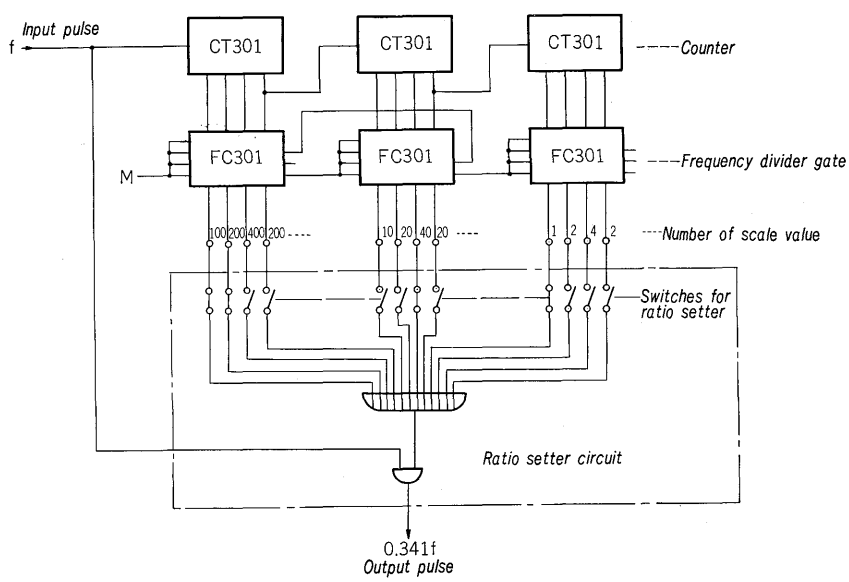


Fig. 7 Block diagram of blending ratio setter

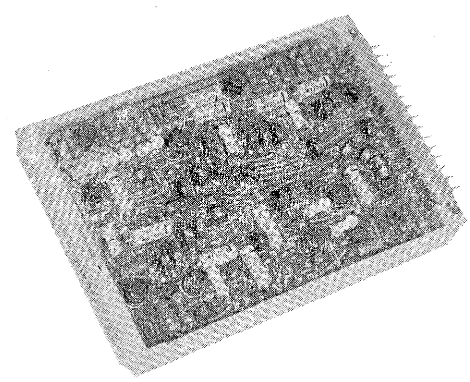


Fig. 8 Outer view of a F-Matic element

and FC 301 section is sufficient in the overall system. Only the gate portions which operate by readout output combinations are needed as many as to the number of mixing components.

3. Coefficient Compensator

The coefficient compensator corrects the flowmeter amount/pulse conversion coefficient into an integer by multiplying the number of input pulses from the flowmeter by some number less than 1.

Therefore, it is a frequency dividing circuit functionally the same as the ratio setting circuit.

Fig. 9 is a block diagram of this circuit. In addition to the *CT* 301 and *FC* 301 elements, an *FC* 351 divider control element is used for selection of divider output pulses synchronized with the input pulse.

As explained above, 1, 2, 4, and 2 values from the counter are read out at the four *FC* 301 output terminals and these numbers are in the form of a special binary coded decimal known as the Aiken code.

Each of these readouts can be controlled optionally by signals to the four corresponding input terminals. Therefore, merely by applying signals which exhibit a divider ratio in the Aiken code to these terminals, it is possible to set or change the divider ratio optionally.

An *OR* combination of the 4 sets of the read out values is lead out from the *FC* 301 via another output terminal. This combination is applied to the *FC* 351 from which a divider output pulse synchronized with the input pulse is obtained.

Since the coefficient setting is not varied so often, the setting can be made by rotary switches inside the control panel. *Fig. 9* shows a circuit for a setting range of 0.1~99.9%. However, if the number of columns is increased, even more precise settings are possible.

4. Temperature Compensator

The number of output pulses per unit volume of the liquid passing through the flowmeter is constant. Therefore compensation is necessary to relate the number of flowmeter output pulses to liquid temperature when the temperature differs from a standard value, and thus causes liquid expansion.

In other words, if the temperature difference from the standard value is ΔT for a liquid volume V, the liquid volume V_0 which is converted to the standard temperature can be expressed as follows.

$$V_0 = V(1-\alpha \cdot \Delta T)$$

Therefore, the flowmeter output pulse f must be converted to a corresponding f_0 as follows.

$$f_0 = f(1-\alpha \cdot \Delta T)$$

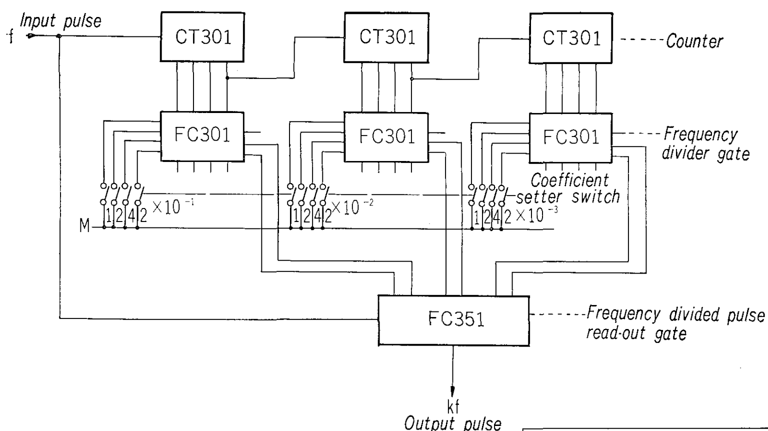


Fig. 9 Block diagram of flowmeter coefficient compensator

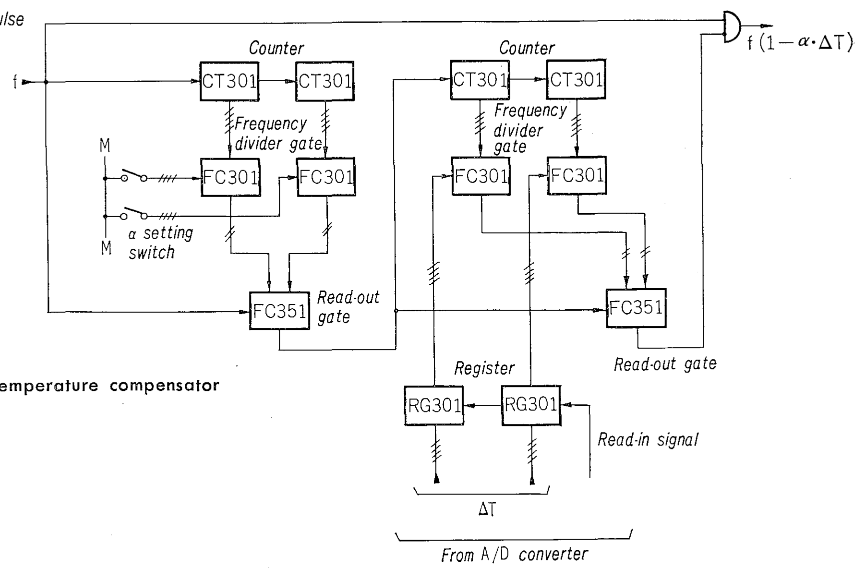


Fig. 10 Block diagram of temperature compensator

Generally α maximum is about 2×10^{-3}/°C and so even if ΔT is several tens °C, $\alpha\cdot\Delta T$ will be less than 1. Thus compensation can be carried out using a frequency divider circuit like that mentioned previously.

Fig. 10 shows a block diagram of the temperature compensation circuit, which consists of two stages of frequency divider circuits. In the first stage, if a divider ratio of $10^2\alpha$ (<1) is given in place of α, the input pulse number f is divided by $10^2\alpha\cdot f$. If a divider ratio of $\Delta T/10^2$ (<1) is used in the second stage in place of ΔT, the output pulse becomes $\alpha\cdot\Delta T\cdot f$.

Therefore, if this is compared to the original pulse by the gate circuit, and by opening the gate and allowing the original pulse to pass only when there is no frequency divider output, the final output becomes $f\,(1-\alpha\cdot\Delta T)$.

The liquid temperature is usually detected as an analog value by a resistance thermometer etc. but since ΔT must be set digitally in the form of an Aiken code, an analog/digital converter (A/D converter) is necessary.

However, since ΔT does not change much in respect to time, the A/D converter can be used in common and savings can be made by using a scanning system which switches over to each component in sequence. Therefore, ΔT is set via a *RG* 301 register element.

The value of α is constant depending on the liquid and optional setting can be made by means of rotary switches inside the control panel in units of 1×10^{-4}/°C.

Fig. 11 is a block diagram of the A/D converter for temperature compensation. After resistance changes from the resistance thermometer are converted into voltages in the bridge circuit, they are amplified and applied to the voltage comparator circuit.

The other input to the voltage comparator is supplied in the form of a sawtooth wave voltage which increases at a constant rate once the signal for the start of conversion is given. After this voltage rise has started, the output signal is given until both inputs become equal and therefore, this time is proportional to the temperature deviation.

Therefore if a constant frequency clock pulse from the gate which is open only while the signal is applied is counted by the counter, this counted value corresponds to ΔT. For the entire equipment, a precise compensation of ±0.2% can be made in respect to a tempeture range of 50°C.

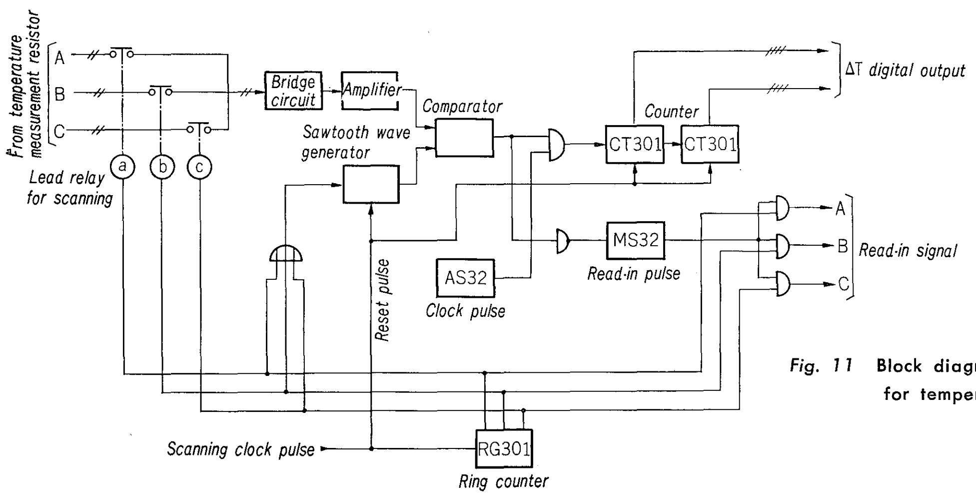


Fig. 11 Block diagram of analog/digital converter for temperature compensation

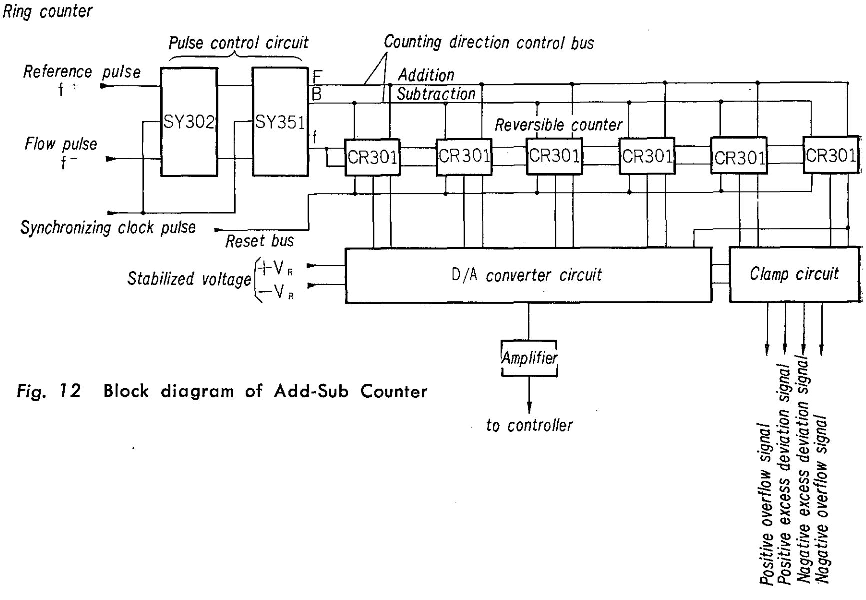


Fig. 12 Block diagram of Add-Sub Counter

The input from the thermometers is applied in sequence according to the operation of a scanner ring counter. After the A/D conversion is completed, the code output is read in the register of the temperature compensator for the corresponding component and is stored in the memory until the next cycle.

The scanning cycle is about 1 second per point. *Fig. 11* shows scanning for 3 points.

5. Digital Comparator (Add-Sub Counter)

The digital comparator is made up of reversible counters which use signals of the master pulse multiplied by the ratio as one input for addition. On the other side, subtraction is carried out by means of the pulse from the flowmeter. The difference between the two is converted to an analog signal and applied to the controller as deviation.

Fig. 12 is a block diagram of this circuit. The reversible counters are CR 301 elements arranged on printed circuit boards. Each element board contains 2 bits. *Fig. 7* shows a case with 12 binary bits.

Fig. 13 shows a block diagram of a unit (1 bit) reversible counter circuit. There are two gate circuits previous to the input of the T-type flip flop circuit. The gates select either the previous bit set output or reset output by signals which indicate the counting direction and generate at the signal edge a pulse signal which triggers the flip flop circuit.

The *SY* 351 control element in *Fig. 12* is used to control the counting direction. According to input pulses addition or subtraction, the internal flip flop circuit is switched over and the signal which controls the counting direction is applied to the *CR* 301 elements.

When the addition and subtraction pulses arrive at the same time, there is a possibility of erroneous operation. The *SY* 302 is provided to prevent such errors and is used for this purpose. After the two lines of pulse which enter at random are synchronized by a clock pulse in *SY* 302, the *SY* 351 performs control so that counting pulse will not be given to the reversible counters when two input pulses enter at the same time. The reversible counter value is converted into an analog value by the D/A converter circuit, and is applied to the controller in the form of a voltage.

Fig. 14 shows the principle of D/A conversion. The unit circuits are switches which operate in accordance with the condition of each bit in the counter.

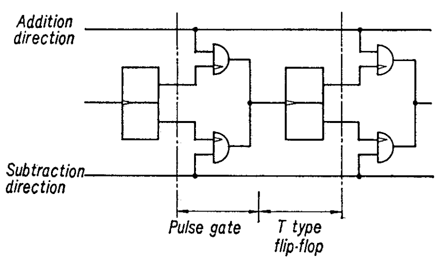


Fig. 13 Unit of reversible counter

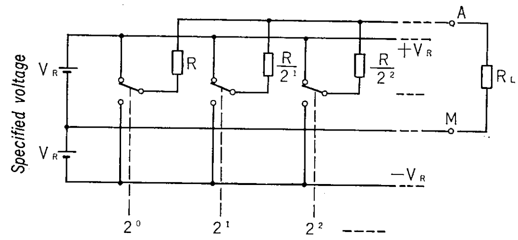
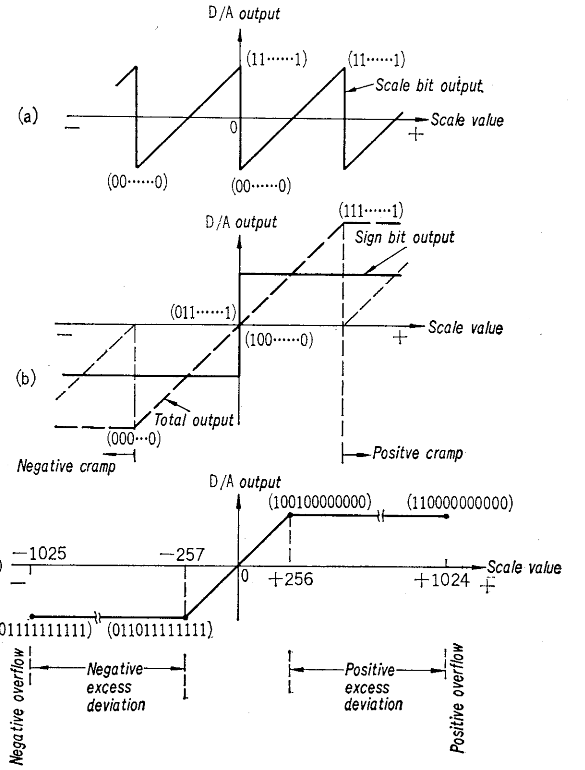


Fig. 14 Principle of digital/analog conversion

The resistors are connected to either a positive or negative standard source and the current flowing in the resistors of all these unit circuits is combined and serves as the output. The magnitude of each of the resistors is selected so that the current which flows is proportional to the weight of the corresponding bits.

Since the input-output characteristic as shown in *Fig. 15* (a) does not pass through the origin in this state, the highest level bit is used as the sign bit which is " 1 " when the counter value is positive. A constant positive or negative current which is switched over at the boundry between the 0 and −1 counter values as shown in *Fig. 15* (b) is applied by the " 0 " or " 1 " condition of this sign bit. In this way, the overall characteristics pass through the origin.

In addition to this, a clamp circuit is attached for control deviations over a certain level. This limits the output by a constant value, and the excessive deviation is logically determined from the signal conditions in each of the counter bits.



(a) Output of counter bit (b) Output of sign bit (c) Clamp of output

Fig. 15 Characteristics of digital/analog converter

For example as shown in *Fig. 15* (c), when the counter value is ± 256 or over $(=2^8)$ the output is clamped. If the sign bit signal is indicated as S and the counter bit signal as A_n (n is the number of columns), with the logical conditions $S(A_{11}+A_{10}+A_9)$, $A_8 \sim A_1$ are made forcedly simultaneously as " 1 " and in the $\overline{S}\cdot(\overline{A}_{11}+\overline{A}_{10}+\overline{A}_9)$ condition, they are given simultaneously as " 0 ". When these conditions arise, an alarm signal for deviation excess is given and if the counter value reaches the maximum unit of the counter bits, an overflow signal is given.

The output current of the D/A converter element is applied to a low input impedance amplifier for amplification and in the clamp condition, there is a voltage output of ± 1 v.

6. Batching Controller

In conjuction with the mixing ratio control, it is also possible to control batch shipments of the mixture using the batch controller.

This portion consists mainly of the batching controller. A predetermined amount is set in the counter and subtraction is carried out by means of the pulse generated from the flowmeter which is attached to the batch line. When the counter content becomes " O ", a stop signal is given and the master pulse generator stops.

A precaution signal can be given just before the required batch value is reached. Since this signal slows down the master pulse frequency, smooth control is possible when the set value is reached and the generator is stopped.

Fig. 16 shows a block diagram of this circuit. The set value, which is set beforehand by the switch on the operating desk, is read via the gate elements *ST* 301 into the *CT* 301 counter elements.

The value in the minimum value column of the counter is compared with the advance signal set separately in the CN 301 comparator element.

When the numerical value in the minimum counter column coincide with the advance signal and the upper columns all become " 0 ", an precaution signal is given via the output element. When all the counter columns become " 0 ", the stop signal is given.

In order to obtain a correct reading of the batch amount during or after the completion of mixing, a separate accumulated counter is provided by which the batch amount can be displayed numerically on Nixie tubes. This also makes possible the display of remainders when required.

In the accumulated counter, lower unit columns are added so that readings of odd values less than the minimum column can be obtained.

7. Master Pulse Controller

In order to set the master pulse frequency digitally or to perform automatic regulation of the master pulse frequency at the beginning or completion of control, a master pulse controller is provided as optional equipment.

Fig. 17 shows a block diagram of this circuit. The main component is a frequency divider circuit as described previously.

The pulse from the master pulse generator serves as input for the frequency divider circuit. The divider ratio of this circuit is given according to the counter value of the reversible counter, consisting of *CR* 301 elements.

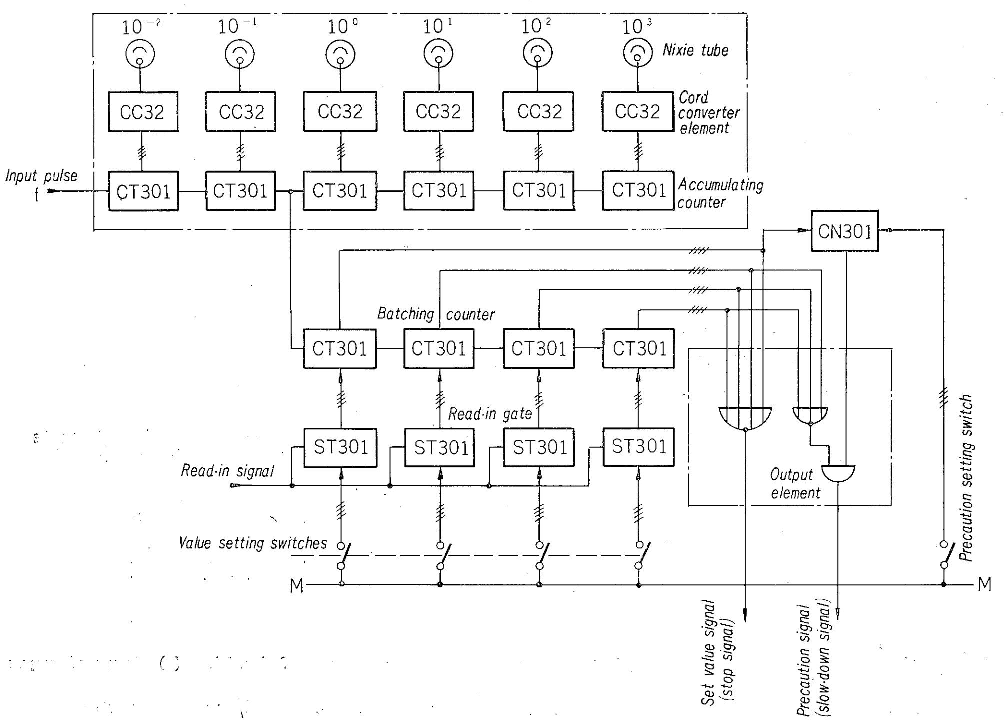


Fig. 16 Block diagram of batching controller

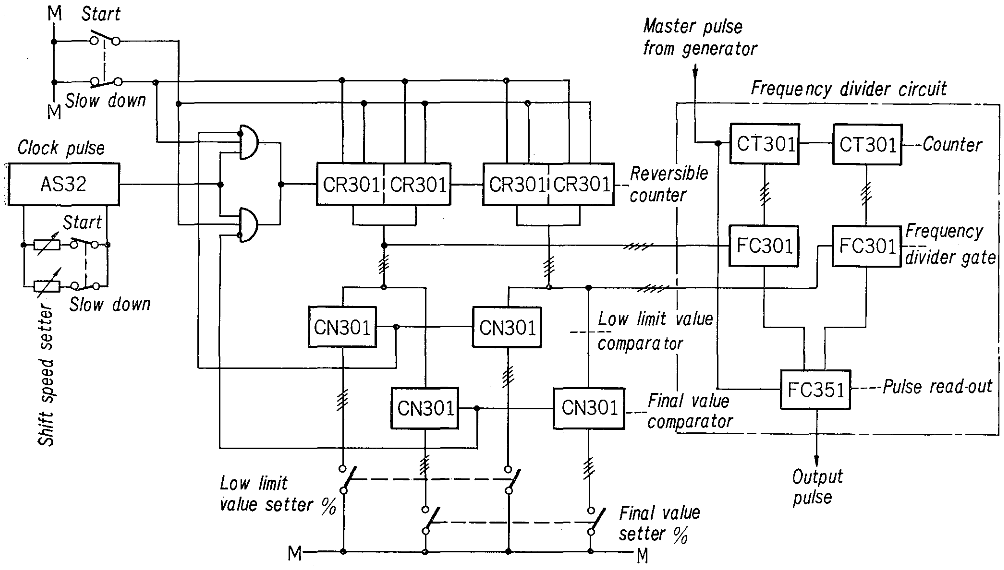


Fig. 17 Block diagram of master pulse controller

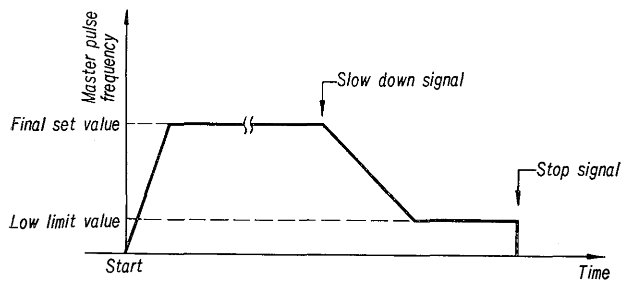


Fig. 18 Frequency control of master pulse

If another clock pulse is applied to the input of the reversible counter so that it passes through either the gate for substraction or the gate for addition, the divider ratio can be changed by regulation of the counter value with the clock pulse and the frequency of the divider output pulse can be controlled.

When the gate is in the plus direction, pulses are given to the counter until the counter value reaches a set value and when the gate is in the minus direction, pulses are given until a set lower limit value is reached.

These operation and low limit values can be set arbitrarily from the operation desk or can also be set by external signals.

The rate at which the master pulse is adjusted can be changed by changing the clock pulse frequency. *Fig. 18* shows a time chart in accordance with the above operation.

8. Controller

The controller is the same as the vertical-type controller used in the previous analog systems. The setting and operation portions and control circuit portions are separated. The setting and operation parts are thin so that the control desk is very compact.

The controller can perform either proportional or integral *PI* operations. *Fig. 19* shows an outer view of a component ratio setter and manual operator.

The top indicator indicates the analog output from the digital comparator via the D/A converter. However, when the deviation exceeds a constant range, the alarm lamp is illuminated by means of a deviation excess signal from the counter.

A switch can be made from automatic to manual and adjustment can be made manually.

The controller output is controlled by an adjustable valve as 10 ma to 50 ma of dc current by transmission to an electropneumatic converter.

The proportional band of *P* operation is 3～300% and the integrating time of *I* operation can be adjusted in a range of 1～60 sec.

9. Specifications and Auxiliary

The specifications of each component except the analog controllers are shown in *Table 1.*

The main components in addition to the above are a voltage/frequency converter for converting an analog signal from the flow generator into a pulse of proportional frequency, a frequency/voltage converter for indication of instantaneous flow amounts on the meters; various setting switches; numerical display tubes; power sources; and racks to accommodate the F–MATIC printed circuit boards. *Fig. 20* shows an outer view of the printed boards in a rack.

V. FLOWMETER

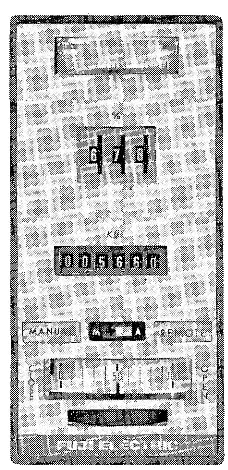


Fig. 19 Component ratio setter and manual operator

Generally, volume type or turbine type flowmeters with pulse outputs are employed but even magnetic type flowmeters with analog outputs are possible. In the latter case, the outputs are converted into pulses by a voltage/frequency converter so that control can be performed. Since in conventional turbine type flowmeters the amount of flow per pulse is not obtained in terms of an integer, coefficient compensators are required. The pulse frequency in turbine type flowmeters is about 2～3 kHz but in this

Table 1 **General Specifications**

Item	Specifications	
Master Pulse Generator	Pulse frequency setting	Continuously variable in the 1 : 20 range
	Pulse integrator	Decimal, 6-digits, reset by external signal
Ratio Setter	Ratio setting	Decimal, 3-digits (0.1～99.9%)
Coefficient Compensator	Coefficient setting	Decimal, 4-digits (0.0001～0.9999%)
Temperature Compensator	Temperature compensation formula	$f(1-\alpha \cdot \Delta T)$
	Temperature coefficient α setting	2-digits effective numbers in unit of 10^{-4}/°C
	Temperature input	Platinum temperature measurement resistor 100 Ω (0°C)
	Accuracy	±0.2%
Add-Sub Counter	Memory capacity	$\pm 2^{10}$ (±1024)
	Deviation analog output	±1 v
	Deviation alarm output	Upper and lower limit 1a, 1b contacts
	Flow integrator	Decimal, 6-digits, reset by external signal
Batching Controller	Value setting	Decimal, 4-digits
	Precaution setting	Decimal 1-digit
	Alarm output	Precaution and set value signal 1 a, 1 b contacts
	Set value integrator	Decimal 6-digits (photoelectric indicator), reset by external signal
Common Parts	Input pulse voltage	1 v or above
	Input pulse frequency	10 kHz or less
	Pulse input impedance	2 kΩ
	Ambient temperature	−20～+65°C
	Control source	±24 v dc ±20% or 100 v or 200 v 1φ or 3φ ±15%

blending system operation is possible up to 10 kHz.

VI. CONTROL DESK

Fig. 3 shows an example of the construction and principles of a two-component master generator paced system. *Fig. 21* shows a control desk with the same system used for 4 components.

The general specifications for each component and circuit are given in *Table 1*. The temperature compensator is suitable for all components (5 lines). The entire system contains about 150 F–MATIC printed circuit boards and the power source capacity is ±24 v, 8 amp.

VII. CONCLUSION

In previous digital blending systems, each function required a separate device (such as the master signal generator, ratio setter, etc.) and adaptability was poor in cases where computer control or interlocking with other control equipment was employed. In digital blending systems using F–MATIC elements, however, there is considerable versatility and the system can be used in all types of plants due to its compactness.

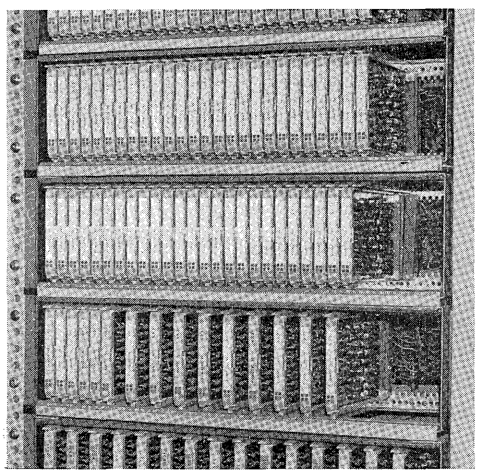


Fig. 20 External view of F-Matic system

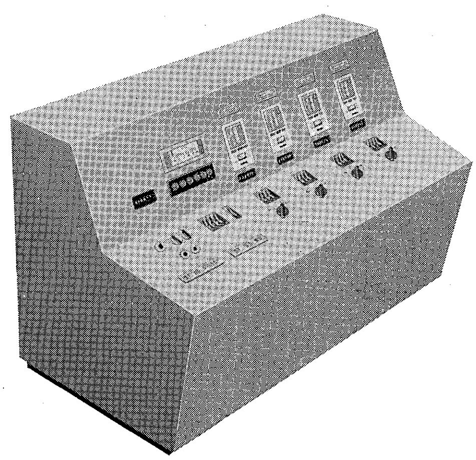


Fig. 21 Control desk