UDC 621. 317. 7 : 621-55

SELF-BALANCING INDICATING CONTROLLER (SERVOZET) & BLIND CONTROLLER (MINIZET)

By Kiyoshi Yamamuro

Tokyo Factory

I. INTRODUCTION

In recent years economy and cost reductions have become the most important factors in the instrumentation field. For this reason simple control system have increased in popularity. Fuji Electric compact controllers such as the moving-coil type indicating controller TRANZET (TZII) and the blind controller MINIZET (BZ) have been utilized widely during the past few years.

Recently Fuji Electric have developed and put on the market two new models for a wider range of applications. One is the self-balancing indicating controller SERVOZET (SZ) and the other is the blind controller MINIZET (BZII). These two new models will be described in the following article.

With both instruments, the input may be either from thermocouples or thermo-resistance bulbs. The control operation is of the on-off type or the on-off mode proportional type. For more precise control an integrating unit is also available in addition to the proportional type. Since a self-balancing system is employed in the indicating controller, the input impedance is high and the balancing torque is large. Therefore, no resistance adjustments in the external circuit are required and the instrument operate stably even when it is installed in a location where vibrations and shocks are rather large.

The blind controller also operates stably when it is installed in a location where vibrations and shocks are large, because it contains no moving parts. Since no resistance adjustments in the external circuit are necessary (as is the case with the above-mentioned self-balancing indicating controllers) operation and maintenance are very simple.

In addition to operation stability and handling simplicity, these instruments are compact and are housed in uniquely designed cases. We are confident that these instruments will be used widely in various fields in the future.

In the field of self-balancing indicators, SERVOZET are used in conjunction with input selectors to monitor the results of control operations using any number of MINIZET blind controller units. Front views of these instruments are shown in *Fig. 1*

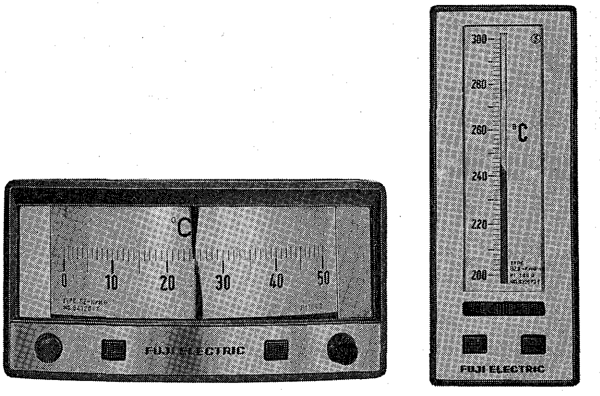


Fig. 1 SERVOZET (left) and MINIZET (right)

II. SELF-BALANCING INDICATING CONTROLLER (SERVOZET)

1. General

The SERVOZET is constructed so that its indicator is equivalent to that of ordinary self-balancing instruments with a simplified servo mechanism. Various control units can be attached to the indicator such as those for 2-position control, 3-position control, and proportional control operation. SERVOZET units can be classified as two main types—the indicator type and the indicating controller type. Each type is subclassified into two types (thermocouple type SZ-DJ, and resistance input type, SZ-K) depending on the input signal. The indicating controllers are classified into ten sub-groups according to their control operation as shown in *Table 1*. Each instrument is made compact by utilizing small component parts. The front dimensions are the same as those of the S-series instrument, i.e. 160 mm wide and 80mm high. The depth does not vary from that of ordinary industrial control instruments.

The basic operating principles of the indicator section are identical with those of ordinary self-balancing instrument. The unique feature is that a simplified dc motor is used for the self-balancing servomotor. This is described in the section dealing with the operating principles.

The control circuit in the control unit forms the largest part in this unit and is identical with that in the TRANZET moving-coil-type indicating controller. This circuit is employed since long experience has shown that it is the best one from the viewpoint of both operating principles and stability during actual operation. (The same applies to the blind controller MINIZET.)

2. Features

1) Since the driving torque of the pointer on the self-balancing mechanism is large, the instrument operates stably even when vibrations and shocks are considerable.

2) Since the operating characteristics are not affected by the installation angle, the instrument can be mounted vertically or at an oblique angle.

3) The internal chassis can be drawn out for easy maintenance and servicing.

4) Since no stopper for the setting pointer are employed, indication can be made over the full scale range.

5) Intermediate scales are readily available (for millivolt input).

6) No external resistance adjustment is required (for thermocouple input).

7) The 2-wire system is employed for the resistance input if the distance from the detector to the instrument is short, and the 3-wire system is employed if the distance is long. No adjustment for the external circuit is required.

8) For thermocouple input, a "burnout" circuit is incorporated as failsafe feature against hazards resulting from a break in the input circuit.

9) In the proportioning action, the proportioning cycle period can be varied over a wide range.

10) The offset in the proportioning action is compensated by variable resistance in the control amplifier.

3. Operating Principles

The operating principles of the SERVOZET for thermocouple input are shown schematically in *Fig. 2.* If the measured temperature increases and the input signal voltage increases, a differential voltage with a polarity as shown in the illustration is impressed to the input of the main amplifier. This differential voltage is converted into the ac voltage by the transistor chopper in the main amplifier, amplified by the amplifier, and then fed to the output circuit. The output circuit determines the direction of the current according to whether the output voltage of the main amplifier is in phase or 180° out of phase with respect to the ac power of the output circuit. If the polarity is as shown in *Fig. 2*, current flows in the exciting coil in the direction shown by the arrow in the illustration. Due to this current, the magnet turns in the direction shown by the arrow until the input voltage of the main amplifier becomes zero. In this state, the pointer indicates the input value.

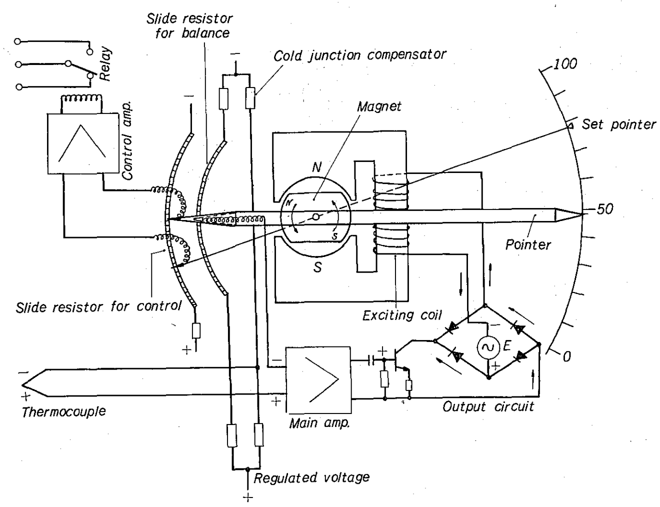


Fig. 2 **Principle of SERVOZET**

In the control circuit, the difference between the set value and the input value is converted into dc control voltage of which the value is made proportional to the difference by means of the control slide resistor. This control deviation voltage is applied directly to the control amplifier so that 2-position action and on-off mode proportioning action can be carried out.

For a resistance input (such as from thermo-resistance bulb), an ac bridge circuit is formed by the input resistance and slide balancing resistor, so that the variation of resistance is converted into an ac signal. This ac output of the bridge circuit is applied to the main amplifier (the transister chopper is removed from the main amplifier for the millivolt signal measurement) and indication and control actions are made in a similar way as with the millivolt input signal. For the proportioning and integrating controller, an integrating amplifier is inserted between the deviation detector and the standard proportioning control amplfier.

4. Construction

The SERVOZET consists of a main unit (chassis unit) and a case. The main unit consists of a servo assembly, measuring circuit, main amplifier, control amplifier, proprotioning control unit, control relay, setting mechanism, and scale plate. After removing the packing screw, the main unit can be drawn out of the case while power is being supplied, in order to facilitate inspection and maintenance. The internal construction is shown in *Fig. 3.*

1) Servo assembly

The servo assembly consists of a slide resistor, pointer arm with brush, and servomotor, mounted on a plastic frame. A slide resistor and a brush for detection of the differential control signal are used for the indicating controller. These components are mounted on a plastic frame. This assembly drives the pointer according to the output of the main amplifier and performs self-blancing. It also detects the differential control signal.

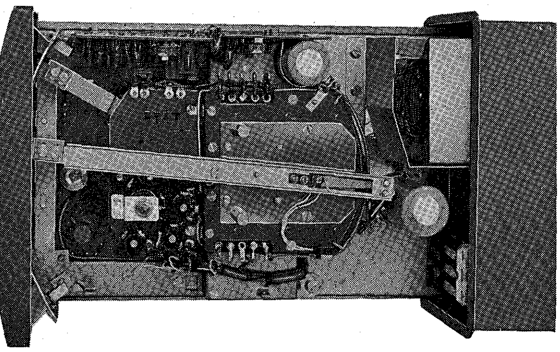


Fig. 3 Internal view of SERVOZET

(1) Balancing slide resistor and brush

The slide resistor is made by winding special alloy wire (high corrosion resistant and wear-resistant) around a copper wire. It is fixed to an arc device on the mounting frame made of plastic resin. The brush is made by fixing a contactor (made of special alloy) to a plate spring with high elasticity. These components are of the same design and are manufactured with the same materials as the potentiometers in the S-series and K-series self-balancing instruments and setting devices which have been used for many years in various fields and have proven their reliability.

(2) Servomotor assembly

As shown in *Fig. 4*, the servomotor assembly consists of an iron core magnet, exciting coil, and rotor. The rotor is a permanent magnet placed in a cylindrical brass case. The iron core magnet is square with two magnetic section connected by soft iron plates. The exciting coil is wound on the soft iron plates. This coil is inserted in the cylindrical gap provided between the two magnetic sections. The permanent magnet of the rotor is oval in shape and magnetized in the direction in which the diameter is the longest. The shaft is provided at the center of magnitization. Miniature bearings are used on the shaft in order to minimize the friction of rotation of the shaft. This sub-assembly is housed in a cylindrical case filled with silicone damping oil. Silicone oil provides excellent damping effects since variations in its viscosity due to temperature are small and its rate of evaporation is also small. The viscosity of the silicone oil is so selected that the revolutions of the rotor are dampended and the optimum damping effect is attained. Since O-rings are used on the bearing, the silicone oil does not leak and the instrument can be mounted in any angle.

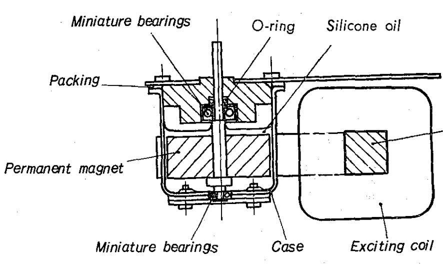


Fig. 4 Construction of servomotor

(3) Detector unit for differential control signal

This unit consists of a slide resistor and a detecting brush. The detecting brush detects the differential control signal. It is moved together with the indicating brush which is connected to the pointer arm. Therefore, its position signifies the value of the measured signal. The control amplifier and the relay are driven. By it deviation with respect to the setting brush. If the brush does not make proper contact, the relay is tripped to the off position.

2) Measuring circuit

There are two types of measuring circuits: One is the thermocouple input type and the other is the resistance input type. For the thermocouple-type input circuit, a dc potentiometric bridge circuit and a regulated power supply circuit with a zener diode are employed. The voltage regulating characteristics are such that the variation of the regulated voltage is less than 0.2% per 10% of line voltage variation. The reference junction temperature compensation for the thermocouple is effected by a copper wire connected to one of the bridge arms. To improve the compensation accuracy and compensation response speed, the copper wire is mounted on the terminal board which is exposed to the atmosphere. A "burnout" circuit is provided in order to protect against damage which could arise due to breaks in the thermocouple or its related circuit. Measurement is made with an ac bridge for the resistance-type input circuit.

3) Main amplifier

The main amplifier is also available either as a thermocouple input-type or a resistance input-type. In the thermocouple type, the differential signal detected by the bridge is converted into an ac signal by a transistor chopper. This ac signal is amplified by the the amplifier circuit and then rectified by the synchronizing rectifier circuit (output circuit) which feeds driving current to the exciting coil with a polarity determined by the polarity of the input signal. The circuit components are mounted on a printed circuit board. The amplifier of the resistance input-type is the same as that in the transistor chopper and the input transformer is eliminated from the amplifier of the thermocouple input-type.

4) Control amplifier and control relay

These units carry out various control actions when receiving the differential signal (control signal) from the control detector. The control amplifier consists of a transistorized amplifier circuit, switching circuit, and power supply circuit. The amplifier circuit contains silicon transistors arranged on a printed circuit board. A fixed resistor is added to the amplifier at the designated terminals for the on-off control action. For proportioning action, the proportioning control unit (as described in the next paragraph) is connected to the designated terminals. The control relay is manufactured by Fuji Electric. It has a long service life and its contact has a large current capacity. To improve the life of the contact, an arc-suppression varistor is connected across the contacts.

5) Proportioning control unit

This unit is used only when proportioning control action is required. It consists of a printed circuit board with a large-capacity electrolytic capacitor used to determine the period of the proportioning control action and a variable resistor for offset compensation. Offset compensation is made electrically by shifting the operating setpoint with the variable resistor. The range of compensation is approximately ±2%.

6) Setting mechanism

This mechanism is used to determine the set value of the control action. The setting shaft has a worm gear with which to change its direction of rotation. The turning movement is fed through a planet gear and a sector gear to the setting arm. The setting pointer and setting brush are linked to the setting arm.

5. Specifications

SERVOZET models and their major specifications are shown in *Tables 1* and *2*, respectively. The supply voltage characteristics of the indicating unit, the temperature characteristic of indicating unit, the supply voltage characteristic of the control unit, and the temperature characteristic of the control unit are shown in *Figs, 5, 6, 7,* and *8,* respectively.

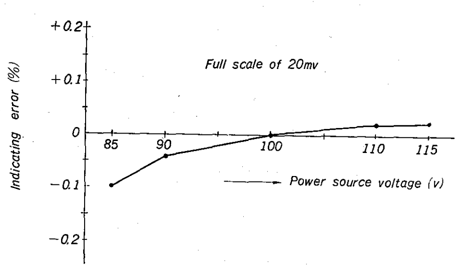


Fig. 5 Supply voltage characteristic of indicating unit

Table 1 **SERVOZET Models**

SZ-DJ (K)	Indicator only (DJ=Thermocouple input, D=Dc voltage input, K=Resistance input)
SZ-DJ (K)/H	Upper limit on-off action
SZ-DJ (K)/HP	Upper limit proportioning action
SZ-DJ (K)/L	Lower limit on-off action
SZ-DJ (K)/LP	Lower limit proportioning action
SZ-DJ (K)/HL	Upper and lower limit on-off action
SZ-DJ (K)/HPL	Upper limit proportioning and lower limit on-off action
SZ-DJ (K)/HLP	Upper limit on-off and lower limit proportioning action
SZ-DJ (K)/HPLP	Upper and lower limit proportioning action
SZ-DJ (K)/HH	Upper limit double on-off action
SZ-DJ (K)/HPH	Upper limit proportioning and on-off action

Table 2 **SERVOZET Specifications**

Input	DJ type...10 mv dc, minimum K type...50 deg. minimum at Pt 100 Ω
Scale length	115 mm
Indicating accuracy	Within ±1% of full scale
Sensitivity	Within 0.25% of full scale
Response time	Full scale operating speed...approx. 5 sec
Power source	100/200 v ac ±15%, 50/60 cps
Ambient temperature	−10 to +60 °C
Setting accuracy	Within 0.5% of full scale
Proportional band	3 to 4% of full scale.
Proportional cycle	Approx. 60 sec (continuously variable for 30 to 60 sec)
On-off operation gap	Within 0.5% of full scale
Reset time	Approximately 2 minutes
Output contact capacity	Maximum voltage 200 v ac, maximum current 8 amp, maximum power 1 kva (resistance load)
Power consumption	Indicator...14 va Controller...18 va
Weight	Approx. 3.5 kg

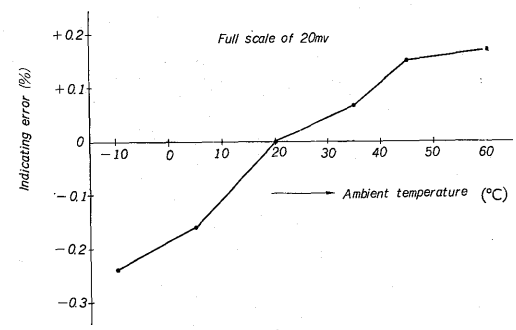


Fig. 6 Temperature characteristic of indicating unit

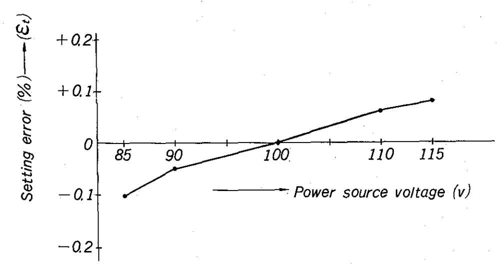


Fig. 7 Supply voltage characteristic of control unit

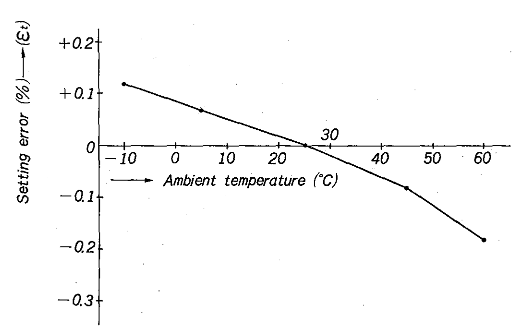


Fig. 8 Temperature characteristic of control unit

III. BLIND CONTROLLER (MINIZET)

1. General

There are two types of MINIZET: One is the BZII–DJ type for dc voltage input such as from a thermocouple and the other is the BZII–K type for resistance input such as from a thermo-resistance bulb or a thermistor. Each of the above types of controllers can be sub-classified into two types according to their control action: One is the on-off control type and the other is the proportioning control type. An upper and lower alarm device, and an integrating circuit to eliminate offset in the proportioning control also are available as optional features. In the past, no upper and lower alarm devices were available with blind controllers. We are confident that blind controllers will find wide application as alarm devices in the future.

In accordance with the prevailing trends in industrial instrumentation, this blind controller is designed to be installed in a vertical position. A single unit or several units in succession can be mounted for easy viewing on an instrument panel. A unique system is employed in the setting mechanism by which the set value is displayed in the form of a bar graph. The set value can therefore be read easily and, set values can be compared at a glance when several units are arranged in parallel.

2. Features

1) Since no moving parts are included and the amplifier is of the completely solid state type, the controller operates stably even in an environment where large mechanical vibrations and shocks are prevalent.

2) Since operating characteristics are not affected by the installation angle, the controller can be mounted at any oblique angle or even in the horizontal direction.

3) The setting device is newly developed. The housing is vertical, of refined design. Several units can be mounted in succession.

4) Maintenance and troubleshooting are facilitated by the fact that the internal chassis can be drawn out.

5) For thermocouple inputs, no resistance adjustment of the external circuit is required.

6) For resistance inputs, the connection between the detector and the instrument can be made with a 2-wire system for short distances and with a 3-wire system for longer distances. No resistance adjustment of the external circuit is required.

7) A burnout circuit is incorporated in the thermocouple-input controller as a failsafe feature against breaks in the input circuit, including the thermocouple.

8) With the proportioning-action controller, the on-off cycle is continuously variable over a wide range.

9) In the on-off-action and proportioning-action controllers, an upper and lower limit alarm device with a range of ±2 to 10% (continuously variable) on either side of the set value can be included as an optional feature.

3. Operating Principles

1) Amplifier and control circuit

There are two types of amplifier and control circuits: One is the thermocouple input type and the other is the resistance input type. The circuits are designed to resemble each other as much as possible. The resistance-input-type circuit differs in that it has an ac bridge circuit as its setting device (shown in *Fig. 9*), no dc to ac converter is employed since the differential signal itself is an ac signal, and the amplifier is not provided with a feedback circuit but carries out a stable amplifying operation.

The operating principles described here shall apply to the thermo-couple-input-type circuit. The operating principles are schematically illustrated in *Fig. 10*. The minute differential signal between the input signal (which is fed from the setting device) and the feedback signal is converted into an ac signal and then amplified. This amplified ac signal is rectified by a synchronizing rectifier circuit into a dc signal. Part of this dc output signal is fed through a operational circuit (negative feedback circuit) back to the input circuit. The proportioning or integrating control action is obtained from the operational circuit. The dc output is converted into a time-proportional output signal or an on-off output signal by a control circuit similar to that of the SERVOZET.

2) Alarm units

The output of the synchronizing rectifier is used as the input of the alarm unit. The alarm unit

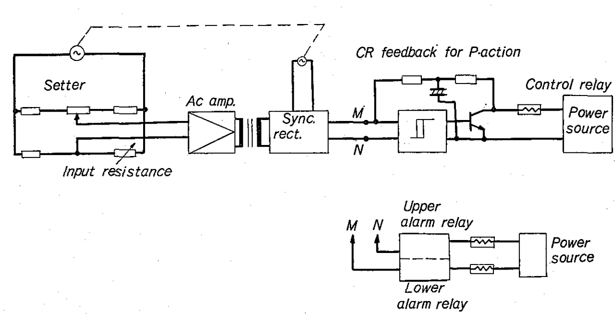


Fig. 9 Principle of MINIZET (Resistance input)

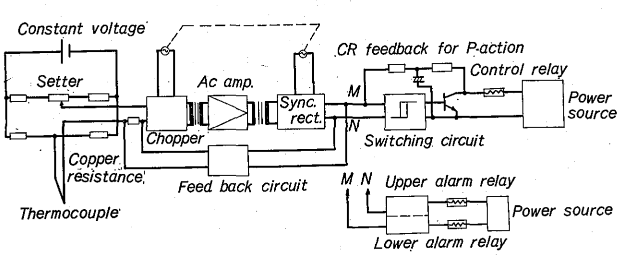
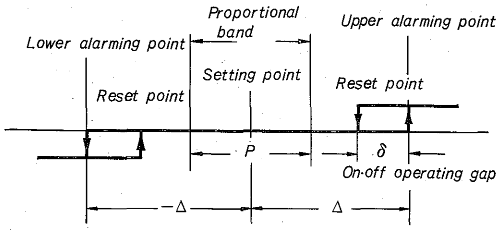


Fig. 10 Principle of MINIZET (Thermocouple input)



Δ: 2~10% of full scale continuously
δ: Within 1% of full scale
p: 2~3% of full scale

Fig. 11 Relation diagram of proportional position and alarm action

consists of a voltage comparator circuit and a switching circuit. When the input exceeds the upper or lower limit, an upper or lower limit alarm is generated. The setting device is ganged with the upper and lower limiters. The set range is continuously variable over 2 to 10% of full scale. A failsafe feature is incorporated in the alarm unit in order to guard against line failure or other irregularities. Since the alarm is generated when the relay is de-energized, it is generated even when the line power has failed. An example of the relation between the alarm point and the proportioning action is shown in *Fig. 11*.

4. Construction

Each controller consists of three major units: the setting unit which compares the input value with the set value; the amplifier unit which amplifies the differential signal (received from the setting unit) and drives the control relay; and the case unit in which the above units are housed. Each unit is constructed on a printed circuit board and is fixed with screws to the base plate so that it can be easily removed and replaced. All internal units can be removed from the case by drawing out the base plate. Special wires which can be folded over are used for electrical connections between the amplified and setting units and the external-wiring terminal board, so that the internal units can be drawn out of the case smoothly.

1) Construction of the setting mechanism

The setting mechanism consists of a variable resistor which converts the set value into a resistance value; a setter drum which indicates the set value; a measuring unit which detects the deviation between the input value and the set value; a setting knob; a scale plate; lamps to indicate the condition of control; and a frame on which these components are mounted. All of these components are shown in *Fig. 13.* To adjust to the desired set value, the operator turns the knob so that the setting drum turnes. The setting variable resistor connected to the shaft of the setting drum is then turned, and a resistance corresponding to the set value is transmitted. This variable resistor forms one of the bridge arms built into the setting drum. As shown in *Fig. 14,* the setting drum has a red section and a white section. As the setting drum turns, the height of the red section as viewed from the slit in the scale plate varies and, thus indicates the set value. Since vertical movement of the setting drum causes an error in the indicated value, spring plates are provided on the top and the bottom of the setting drum to prevent this. These spring plates also provide the appropriate friction on the setting drum so that the indicated value will not be shifted due to shocks or vibrations.

The amplifier unit consists of a main amplifier printed circuit board, a power transformer, and a frame on which these components are mounted. A printed circuit board for either the upper/lower limit alarm or the integrating circuit can be mounted as

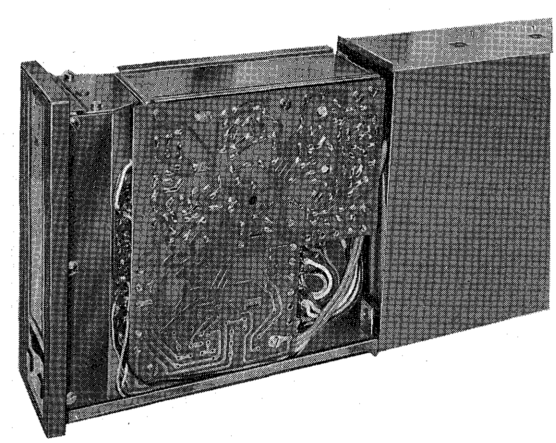


Fig. 12 Internal view of MINIZET controller

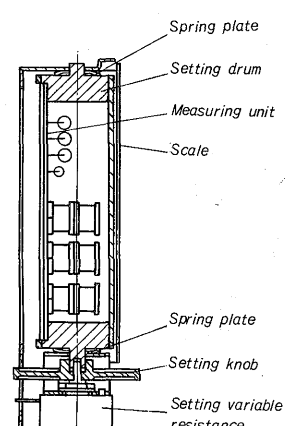


Fig. 13 Construction of setting unit

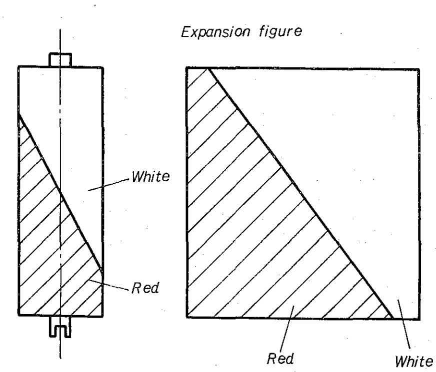


Fig. 14 Setting drum

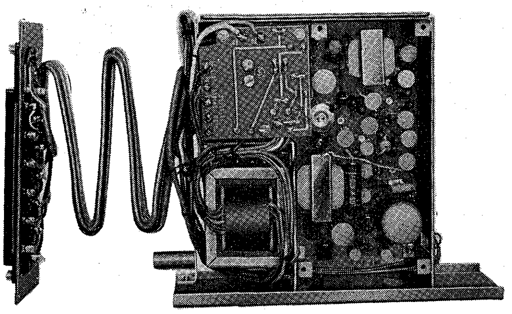


Fig. 15 Amplifier of MINIZET

an attachment (See *Fig. 15*). The main amplifier printed-board has an ac amplifier circuit, a synchronizing rectifier circuit, a switching circuit, and a control relay.

The upper/lower limit alarm unit is also provided with a printed-board. The required amplifier circuits and relays are mounted on this board. Which can in turn be installed easily on the frame.

MINIZET models and specifications are listed in *Tables 3* and *4*, respectively. The supply voltage characteristic and temperature characteristic of the MINIZET are shown in *Figs. 16* and *17*, respectively.

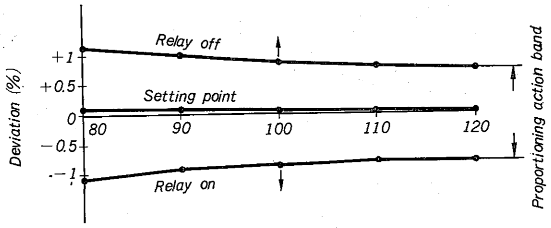


Fig. 16 Supply voltage characteristic of MINIZET

(Proportional controller BZII-D/HP 20 mv span)

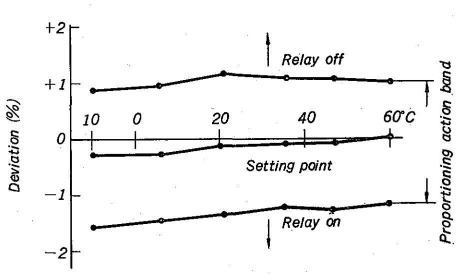


Fig. 17 Temperature charateristic of MINIZET

(Proportional controller BZII-D/HP 20 mv span)

Table 3 MINIZET Models

DJ Thermocouple input, D=voltage input, K=resistance input	
BZII-DJ (K)/H	Upper limit on-off action
BZII-DJ (K)/HP	Upper limit proportioning action
BZII-DJ (K)/L	Lower limit on-off action
BZII-DJ (K)/LP	Lower limit proportioning action

Table 4 MINIZET Specifications

Setting Accuracy	±2%
Scale Length	100 mm
Input	Dj type...10 mv, minimum K type...50deg., minimum at pt 100 Ω
Power Requirements	100/200 v ac±15%, 50/60 cps
Ambient Temperature	−10°C to +60°C
Proportional Band	2 to 3% of full scale
Proportional Cycle	15 to 45 sec., adjustable with the amplifier
On-off Operation Gap	Within 0.5% of full scale
Output Contact Capacity	Maximum voltage 200 v ac, maximum current 8 amperes, maximum wattage 1 kva (resistance load)
Power Consumption	7 va
Weight	Approx. 2 kg
Attachment	Upper/lower limit alarm device can be installed (−H.L.) • The upper lower limit is continuously variable over a range of ±2 to ±10% of full scale with the set value as center. • The on-off operating gap of the upper/lower limit is less than 1% of full scale. • Contact capacity...Maximum voltage 200 vac, maximum current 0.3 amperes, maximum wattage 30 volt-amperes γ/(resistance load)
Integrating Action Unit	Reset time(T_1)...Approx. 2 minutes (not available with the controller on which the alarm device is used)

IV. SUMMARY

We have described the operating principles, construction, and features of the Self-Balancing Indicating Controller (SZ) and Blind Controller (BSII). We believe these instruments will be used widely in the future, due to their excellent capabilities and advantageous features.