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S-SERIES TELEPERM CONTROLLERS
C CONTROLLER (MODEL S-ECC-N, S-ECC-D)
S CONTROLLER (MODEL S-ECS-N, S-ECS-D)

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I. INTRODUCTION

The importance of automation and automatic control in industry today is widely recognized for their contribution to the reduction of personnel expenses, highly efficient operation of plant, upgrading of quality and uniformity of products. Moreover, the realization of new devices heretofore regarded impossible won the automatic control an equally wide recognition. For this reason, it is more strongly demanded that the control device be superior, its handling and maintenance simpler.

We have already introduced all kinds of instruments based on the TELEPERM-TELEPNEU system which are in extensive use at the present time. Following that system, we have developed new parts and conceived a new technique to combine those parts and then have completed S-SERIES TELEPERAM system instruments by the transmission of a " dc two wire system " for transmitters, completion of computing elements and unification of instrument size on the basis of 160 mm for instruments.

This paper is devoted to the introduction of an outline of S-SERIES TELEPERM controllers as part of S-SERIES TELEPERM receiving instruments and to the concept and application of controlability as a feedback compensated on-off controller (S-controller) which has been known for its non-linear characteristics.

II. TYPES OF S-SERIES TELEPERM CONTROLLERS

S-SERIES TELEPERM controllers are largely divided into C controllers and S controllers by characteristics of output signal.

The C controllers are controllers for output TELEPERM unified signal current of 10～50 ma dc with diaphram valves and electro-pneumatic (-hydraulic) actuators as the manupulating element and work on the same functional principle as the conventional TELEPERM controller (model EKR). They are available in long time use for temperature control in proportional plus integral plus derivative (PID) control action to short time use for control of pressure and flow and they may be applied to any field of process control.

The S controllers are controllers of pulse output designed for electric motor drive actuators. The action of controllers is, in terms of the movement of the motor driving actuator, similar to the proportional plus integral (PI) control action of the foregoing C controllers. The S controllers are an improvement of the conventional TELEPERM controllers (model ESTR) and come in two type like the C controllers, one for long time use for temperature control and the other for short time use for pressure and flow control. With the addition of a simple sequence circuit, it is possible for this to control processes such as density, gas analysis, thickness in which there is usually a great deal of dead time involved and also other processes having reverse response such as Benson boilers in their super heated temperature control. Since it uses the motor driving actuator, it may realize the instrumentation of a fully electrical system and the actuator is easy to obtain big operating torque.

Looking at the C and S controllers from the viewpoint of handling, there are a standard type for operation mainly from the front of the panel board and a divided type chiefly for desk operation. By type of controllers, these are as follows:

C controllers	Standard type (model S-ECC-N)
	Divided type (model S-ECC-D)
S controllers	Standard type (model S-ECS-N)
	Divided type (model S-ECS-D)

The divided type is the blind controller which is taken away the manual control unit and the setting unit from the standard type. These manual control and setting unit are fitted to the desk as S-SERIES TELEPERM sub-panel, and these apparatus are combined with the divided type controllers (panel mounting) to acquire the same function as the standard type controller. Consequently, this paper will always deal only with the standard controllers.

III. CONSTRUCTION AND STRUCTURE OF S-SERIES TELEPERM CONTROLLERS

1. Construction

The S-SERIES TELEPERM controllers, whether this is of standard or divided type, are of the panel draw-out construction and all operations may be done from the front. *Fig. 1* shows the front view of the C controller, standard type.

In *Fig. 1* the upper front represents the set value and deviation amount. The setting point may be easilly altered by turning the setting knob (SET) and the knob is of one-touch construction and when setting change is not necessary it may be made to withdraw. When the setting change is required, this knob may be pressed only once and the setting knob pops out.

The deviation indicator, as the figure shows, may also be used as an indicating controller in fixed value control or fixed value-ratio control, fixed value-cascade control of TELEPERM input. That is to say, by reading directly the deviation amount in setting scale, the process value may be instantaneously read off without a separate indicator or recorder. (When the case is on fixed value-ratio or fixed value-cascade, the deviation indicator must be switched over to the position of local for reading the process value.) The deviation indicator has a separate graduation below that of setting when measuring direct input of thermocouple or program set value from outside of the controller, and thus the control deviation may be read off.

The indicator at the lower front of *Fig. 1* is the opening indicator for valve position. In the C controller there are two pointers. At the time of automatic control, the lower pointer is for autmatic control signal and upper one is for manual signal, and at the time of manual control, they are reversing. That is the lower easily visible pointer represents the value position at any time. In order to transfer the output without shock, when changing from automatic to manual, the manual control knob is turned to match two pointers, then auto-manual switch is changed over. When changing from manual to automatic, automatic signal follows manual signal at the time of manual control as will be explained later, and transfer may be done by one action from manual to automatic.

With the S-controller, the opening angle indicator has a pointor. Shockless auto-manual transfer may be carried out by one action in both directions.

Fig. 2 (a) and *(b)* show the picture in which the chassis of the S-controller and C-controller is drawn out of the case.

The chassis of the controller and the case, and the chassis and the control unit are connected by a multi-connector, while the setting unit and chassis are connected by screw terminals of the setting unit and in either case it is easily detachable. The relay of the S controller is a plug-in system and can be easily replaced.

The case can perform air purge as necessity arises.

2. Structure

As is seen from *Fig. 2 (a)* and *(b)* the S-SERIES TELEPERM controller consists of setting unit, manual control unit, control unit, dc supply and output unit. The constituent element of each unit is common to both C and S controllers although there may be some differences depending upon their function.

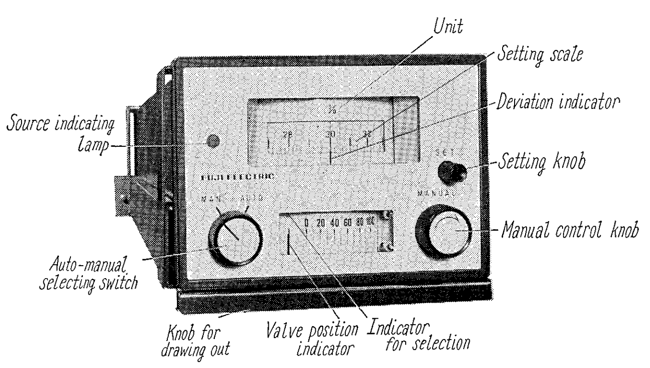


Fig. 1 Front view of C controller

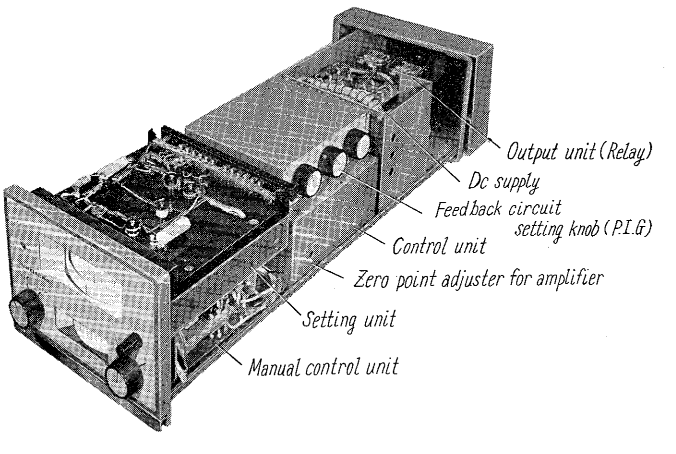


Fig. 2 (a) Inner view of C controller

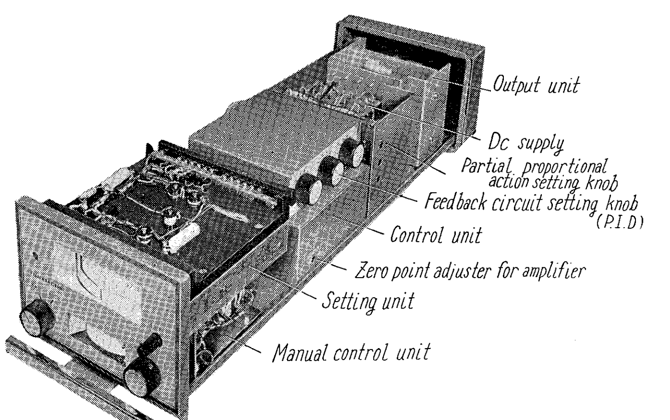


Fig. 2 (b) Inner view of S controller

Table 1 List of Contents

	C Controller	S Controller
Setting Unit	Setting resistance Input comparator Regulated power supply Deviation indicator	Setting resistance Input comparator Regulated power supply Deviation indicator
Controlling Unit	Low level dc amplifier and high frequency oscillator Feedback circuit	Low level dc amplifier and high ferequency oscillator Feedback circuit Three value on-off amplifier
Selector Unit	Auto-manual transfer circuit Manual controlling circuit Valve position dual indicator	Auto-manual transfer circuit Manual controlling circuit Valve position single indicator
Dc Supply	Rectifiying circuit Power supply transformer Fuse (Partial P action circuit)	Rectifying circuit Power supply transformer Fuse
Output Stage Unit	Output transistor circuit	Output relay circuit

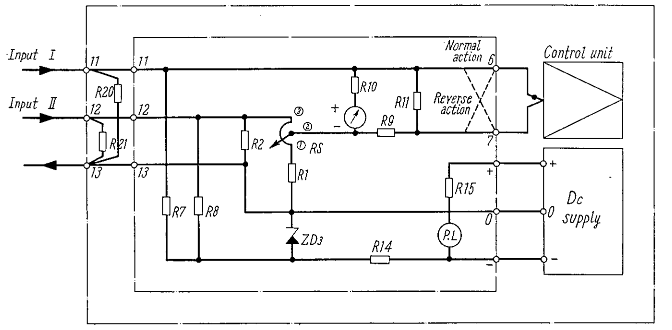


Fig. 3 Ratio control circuit

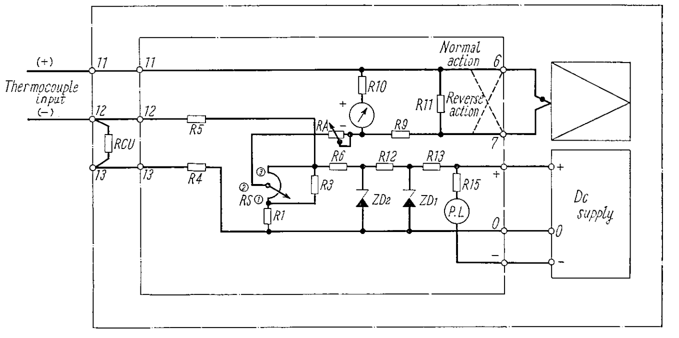


Fig. 4 Constant-value-control circuit of input thermocuple

Table 1 lists consituent elements.

That setting unit in *Table 1* may be used for the C controller, S controller and TELEPERM sub-panel.

In the control unit, low level dc amplifying circuit and high frequency source circuit are provided in the same printed circuit and only the joint at one point is different from the C controller to the S controller. For sure action of the output relay, there is a three-value on-off amplifier in the S controller. The feedback circuit and the control unit are different because of the difference in the working principle of the controller. At the dc suppley, the difference lies in the source transformer which is either for TELEPERM output current or relay actuating voltage but the rectifying circuit is composed of the same printed circuit. In the C controller, it is easy to fit as an additional device the limmited proportional action circuit which proves the most effective in batch control.

IV. SETTING UNIT AND LOW LEVEL DC AMPLIFIER

1. Setting Unit

The setting unit of the S-SERIES TELEPERM controllers is available in about 40 kinds as standard types, either with TELEPERM signal current, thermocouple or resistance bulb input, or computer.

When control is made with more than two currents as input like ratio control, the common line of the controller is provided on the minus side. The is because often the plus side of the input is earthed as the common point when the signal current is fed into a computer or logger and also because in the TELEPERM system is introduced "dc two wire system" from the common power supply as signal transmission system and the remaining common bus takes the minus side of the source.

However, when the signal current is fed to a computer and controller and the controller works upon the computer output signal, in many cases the computer output signal comes out in the plus side signal. Consequently, in such a case as this alone the comparative common point of the setting unit comes on the plus side.

Figs. 3 and *4* show a ratio control circuit and a fixed value control circuit of direct input of thermocouple. The actuating signal (input to the control unit) compared at the setting unit is designed to $\pm 40\ \mu a/100\%$.

2. Low Level Dc Amplifier

The low level dc amplifier, as shown *Fig. 5*, consists of the push-pull center tap doubler type magnetic amplifier on the first stage and a transitorized differental dc amplifier on the second. The source for these is about 400 cps 6 v generated by square wave oscillator from regulated dc voltage of Zener diode and one goes to the magnetic amplifier and the other gets rectified and supplied as the source of the transistorized amplifier.

The first stage magnetic amplifier is circuited in a

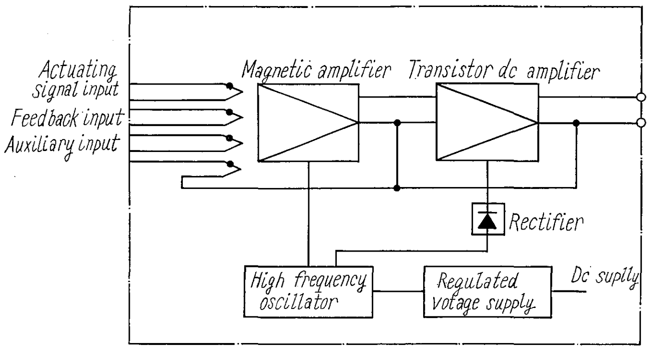


Fig. 5 Principle circuit of dc amplifier

push-pull connection and since its electric source is from a regulated supply, it is very stable and is suitable for the low level dc amplifier. The connection with the second stage transistorized amplifier does not cause the problem of temperature drift because the gain of the first stage magnetic amplifier is very high. Input of actuating signal 0.1% of the controller is 32 μAT as the magnetic amplifier input and the magnetic amplifier has the amplification of about 1 mV/μAT. To hold the drift under 10 mv/10 deg by the transistorized dc amplifier can be industrially done with relative ease. In other words, the drift of the transistorized amplifier becomes under 0.03%/10 deg and the drift of the whole is represented by drift 0.2%/10 deg of the magnetic amplifier.

A short ring is put in the magnetic amplifier and the construction is such that no drift will take place due to short-circuiting of input winding or its opening and the amplification is stable. Specifications of the low level dc amplifier are:

Amplification (average): 3 v/0.1% or more

Temperature drift (in equivalent input drift): 0.2%/10 deg or less

Voltage drift (in equivalat input drift): 0.08%/10%

The input windings of the magnetic amplifier are insulated and this low level dc amplifier may be put to various uses.

V. C CONTROLLERS AND CHARACTERISTICS

Fig. 6 represents the automatic control circuit of C controller, manual control circuit, automatic/manual change-over circuit and limited proportional action circuit.

1. Automatic Control Circuit Action

When the controller is on automatic, switches from *S1* to *S6* are connected as in *Fig. 6*. The actuating signal that is compared at the setting unit is amplified by the low level dc amplifier and drives the output transistor *T1*. Automatic output current goes through feedback resistors *R2*, *R1*, output transistors *T1*, *S2* and the load. On the otherhand, the voltage drop that has arisen at the feedback resistor *R2* and R1 goes through the feedback circuit and is fed back to the low level dc amplifier. In the case of *Fig. 6*, the output current is of prortional plus integral plus derivative (PID) actuating signal. The negative feedback to the input through the parallel circuit of R_F and C_F from the low level amplifier output is a circuit to filter action of the controller and to make integral gain 52dB (400 times). This is a circuit to make the response time of the low level amplifier large and to make derivative action inactive in regard to noise frequency because with the controller having derivative action when the input with noise in the actuating signal is reached this noise is faithfully amplified and it appears on the surface that the controller is generating a cycling. By making the capacity of C_F small for application to processes with quick response such as heavy electrical equipment,

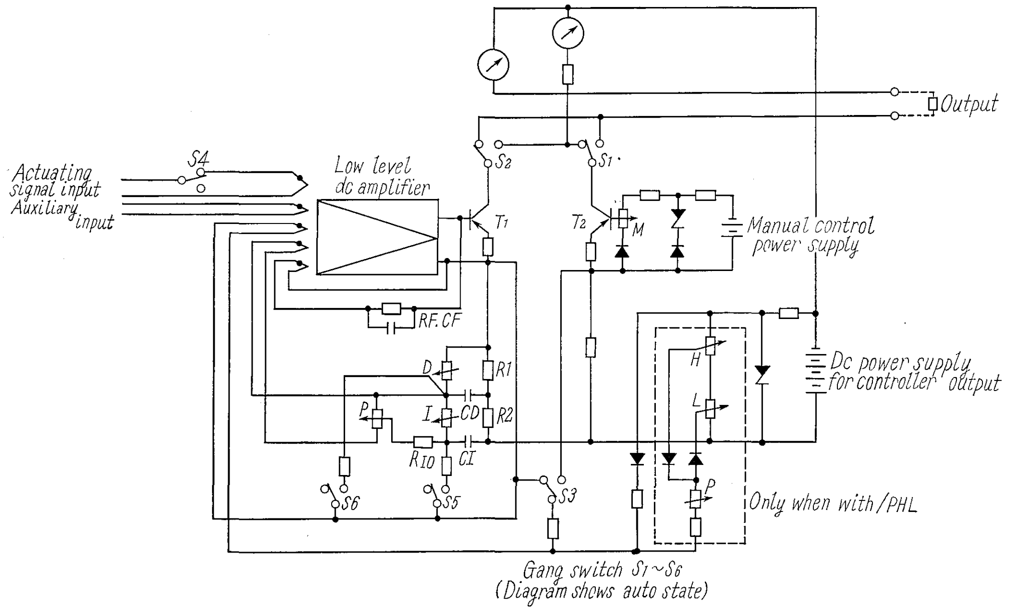


Fig. 6 Principle circuit of C controller

a wide field can be covered by this.

The PID action of the controller is determined by the transfer function of the feedback circuit. When in the circuit of *Fig. 6* the high frequency characteristics of the low level dc amplifier are disregarded, the transfer function of the controller from the is same of the feedback circuit is as follows:

$$K_P \cdot \frac{(1+T_D S)\left(1+\dfrac{1}{ST_I}\right)+\dfrac{T_D}{T_I}}{1+\dfrac{1}{K_D}\cdot T_D S} \quad \cdots\cdots\cdots\cdots (1)$$

K_P: Proportional gain

$K_D\left(=\dfrac{R_1+R_2}{R_2}\right)$: Derivative gain

$T_D(=(R_1+R_D)C_D)$: Derivative time constant

$T_1\left(=\dfrac{R_{I0}\cdot R_I}{R_{I0}+R_I}C_I\right)$: Integral time constant= intergral time

When formula (1) is put in order, therefore,

$$K_P\left(1+2\frac{T_D}{T_I}\right)\cdot\frac{1+\dfrac{T_D S}{1+2T_D/T_I}+\dfrac{1}{ST_I(1+2T_D/T_1)}}{\left(1+\dfrac{1}{K_D}T_D S\right)} \quad \cdots\cdots\cdots\cdots (2)$$

holds. And the coefficient of interference is:

$$1+2\frac{T_D}{T_I} \quad \cdots\cdots\cdots\cdots (3)$$

Fig. 7 represents the Bode diagram of C controller where an effect of R_F and C_F is shown.

The derivative gain is set to $\dfrac{R_1+R_2}{R_2}=10$

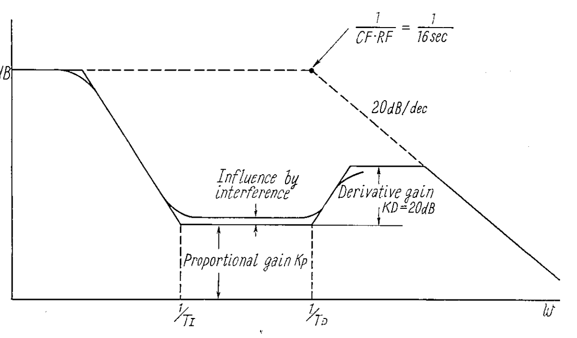


Fig. 7 Bode diagram of C controller

2. Manual Control Circuit and Following of Automatic Signal

The manual control circuit uses the same types of transistors as the automatic circuit and regulated voltage is put in the base with Zener diode so that when the voltage of the source should vary or load resistance should vary, output current remains at the fixed value by the manual control resistor.

When the automatic/manual change-over circuit is put in manual, the automatic/manual output circuit is changed and at the same time the input of the control unit is separated from the setting unit and puts in the manual /automatic output deviation in its place and holds the integral derivative time constant small. So automatic output signal always follows manual output signal during the manual control, and this follow-up speed is extremely fast and it may be changed over to automatic any time. When the change-over from manual to automatic takes place at some condition of the actuating signal from the setting unit, it shows the same response as when the setting value changes during automatic control.

3. Output Limited Proportional Action

By adding the circuit marked by dotted lines in *Fig. 6* it is possible to make the output limited proportational action. Regulate the dc voltage for output of the controller by Zener diode, compare the voltage as obtained from this constant voltage througugh output limit adjustable resistance with the automatic output voltage and negatively feedback to the low level amplifier through the diode. The output limit may be adjusted by adjustable resistance *H* within the output range 0~100% and within 0~100% by *L* and the proportional band after output limit may be adjusted by 30~300% by changing the negative feedback volume (see *Fig. 8*).

Such output limited proportional action as this is effective when we want to limit overshoot of process controled value when the set value is altered in batch processes, for instance. (see *Fig. 9*)

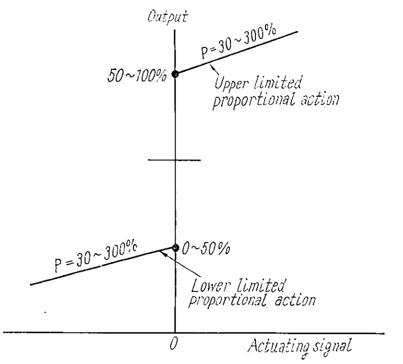


Fig. 8 Characteristics of partial P action

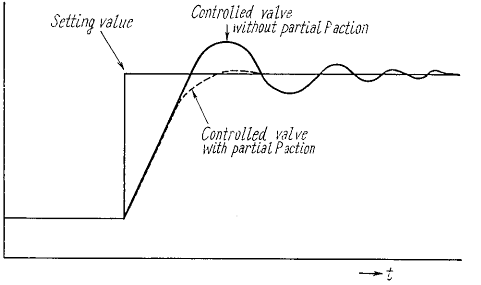


Fig. 9 Inditial response with partial P action

VI. S CONTROLLER AND ITS CHARACTERISTICS

Fig. 10 shows the principle diagram of autmatic circuit, manual circuit and change-over circuit.

1. Automatic Circuit and Characteristics

When the controller is in automatic operation, the auto-manual transfer switch is connected as indicated by the actual line in *Fig. 10.* The actuating signal compared at the setting unit goes through switch *S4* and is applied to the low level amplifier. With the S controller, this output is lead the negative feedback circuit of *G* and gets the amplifier of output 1 v by actuating signal of 0.5% (0.2 μa). By the double derivative circuit of the *G* circuit, this low level amplifier has characteristics of second order time lag and the characteristics of filtering noise of the actuating signal and amplifies the average value of actuating signal.

In other words, in flow control variation of flow by the pressure fluctuation (usually 10%/1 cps) the controller does not work due to the filtering characteristics, and, consequently the frequency of contact duty is less and good control is possible. The output of this low level amplifier drives the three value on-off amplifier and gets the relay on and off by the input signal irrespective of the charactiristics of the relay.

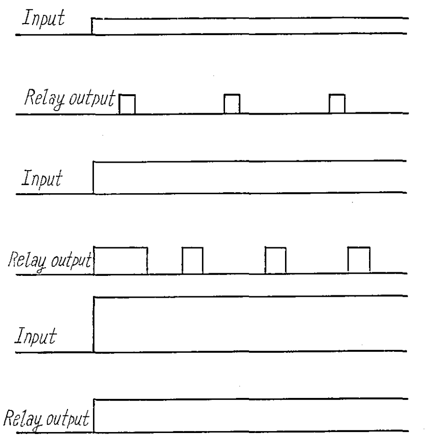


Fig. 12 Output vs. input, S controller

When the actuating signal gets 0.5% or more the low level amplifier produces more than 1 v output and puts on the three value on-off amplifier of either by the polarity of that signal, excites the relay and puts on the relay. When the relay turns on, one of its contacts is in for output and the other closes the feedback circut and negatively feeds back to input the first order time lag current, reduces the output of the low level amplifier and when this value reaches 0.5 v the relay turns off. By the off-action of the relay, the feedback current reduces and the low level amplifier output becomes 1 v and relay turns on again and the feedback current increases. Thus, at a constant actuating signal input, the relay repeats the on-off action. *Fig. 11* shows this in a diagram. It is easily presumed that the output pulse characteristics against the input will be as per *Fig. 12* because of the saturation characteristics of the feedback current.

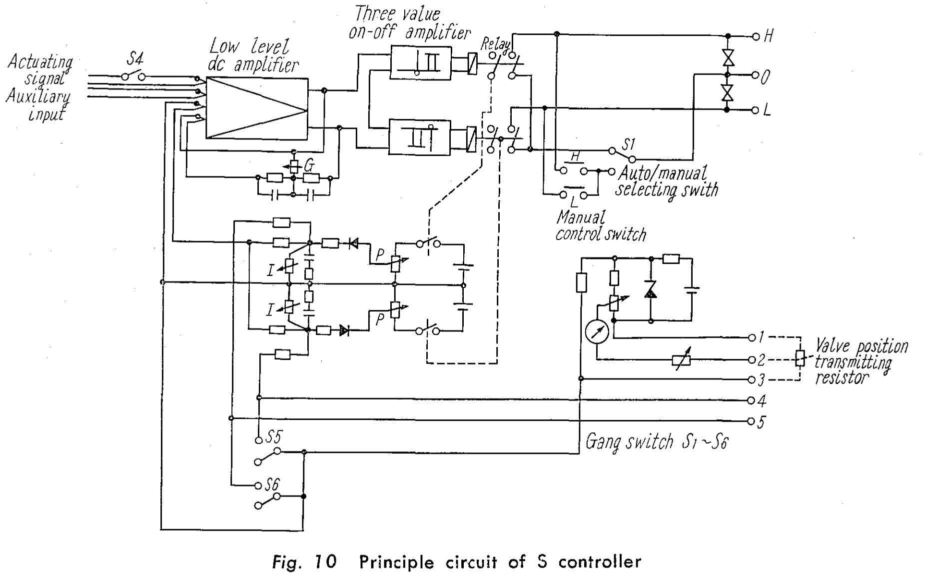


Fig. 10 Principle circuit of S controller

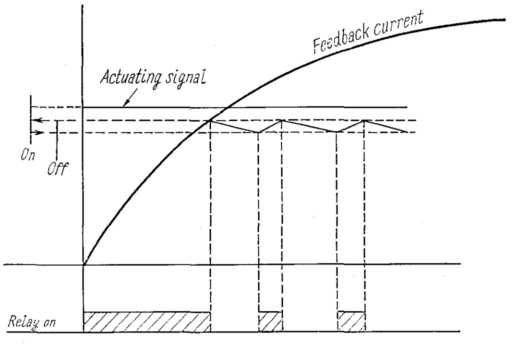


Fig. 11 Output pulses of S controller

2. Definition of PI Charactristics and Feedback Circuit Characteristics

When we integrate the output pulse of the S controllers by the motor and look at the initial responce of its rotating position, we get the operating characteristics like *Fig. 13.* From this we may define that the PI characteristics represent the avarage value characteristics as illustrated. Then, what is the relationship of the proportional band and the integral time to the feedback characteristics? From our past

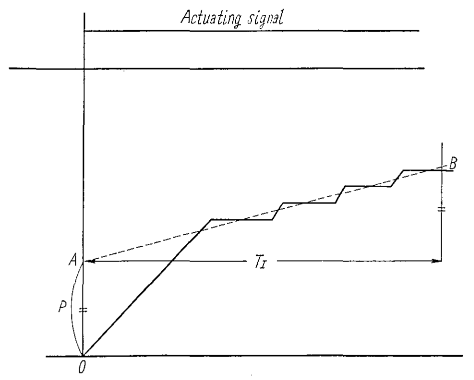


Fig. 13 Definition of P and T_I, S controller

experience, the proportional band P is related to the charging characteristics of the feedback circuit or the standing inclination of the charging current, and the integral time is related to the discharge time constant of the feedback circuit. When the actuating signal is not particularly large, the standing of charging and the discharging time constant are known to correspond to PI.

Consequently, the PI characteristics of the S controllers are designed with the standing inclination and the discharge time constant in mind. It is known that the non-linear characteristics of PI present themselves by the actuating signal due to change in the inclination of the exponential function characteristics of the charge current but details are not given here.

Charging characteristics of the feedback circuit and the discharging characteristics assume importance when we think about control action to be referred to later. When we consider a condition where a single pulse completes the control action, we can readily understand the control action with the charging time constant and the discharging constant in the same. With the S controllers, the feedback circuit is designed with this idea. In actuality, however, an extremely large value is required as the feedback amount for the longer integrating time, and the amount of setting variation cannot go beyond a maximum of 100% so that for the longer integral time the charging time constant is a little smaller than the discharging time constant.

3. Manual Control Circuit

When the control action is for manual control, the output pulse circuit is disengaged from the relay circuit and is connected to the manual increase/decrease operating contact. By the on-off action of the contact of increase/decrease of manual control, the actuator may be driven. By transfer to manual, on the other hand, the actuating signal input is switched off by switch *S4* and the low level ampliffer input becames zero and the feedback circuit becomes small time constant by switches *S5* and *S6* and rapidly discharge the feedback signal of automatic control. On the other hand, the actuator takes advantage of the rotating position of the motor and the operating output (rotating position) remains at the manual operation and when it is transfered to automatic again if the actuating signal is zero it does not send any output pulse and is switched over to it shocklessly. When the actuating signal exists it performs the same control action as the setting value variation and controls so that the control deviation may become zero. The output circuit of the S controller has a spark killing circuit by varistor in the output contact circuit on both automatic and manual in order to increase the life of the contact.

Valve position indication may be shown at the lower part on the front of the controller by connecting the valve position transmitting resistance from the actuator.

The feedback circuit of the S controller has exterior terminals 3, 4 and 5 drawn out for a wide range of adaptation as will be seen later.

VII. CONTROLABILITY OF S CONTROLLER AND APPLICATION

1. Concept of One-pulse Control

It is very interesting for a one pulse to completely control when we view it from the standpoint of less frequency of contact and stability of the control system. And the controller of this kind has a very clear conception under this condition. *Fig. 14* shows the first order lag and the dead time in its process control system. We shall consider that here the dead time is zero. *Fig. 15* shows the inditial response.

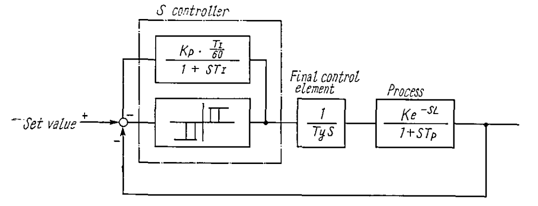
When the actuating signal X_W is added, the output contact of the controller is determined by $|X_W-F-Y|$. That is, $T_Y=60$ sec, $T_P=T_I$, $K=K_P$,

(Ragion I)

$$Y+F=\left(\frac{T_P}{T_Y}\right)K\cdot\frac{t}{T_P} \quad \cdots\cdots\cdots\cdots (4)$$

(Ragion II)

$$Y+F=\left(\frac{T_P}{T_Y}\right)K\cdot\frac{t_I}{P_P}=\text{constant} \quad \cdots\cdots\cdots (5)$$



K_P : Proportional band
T_I : Reset time (sec)
T_Y : Total driving time actuators full stroke······60 sec
K : Process gain
T_P : First order lag time constant of process
L : Dead time of S controller

Fig. 14 Block diagram of S controller

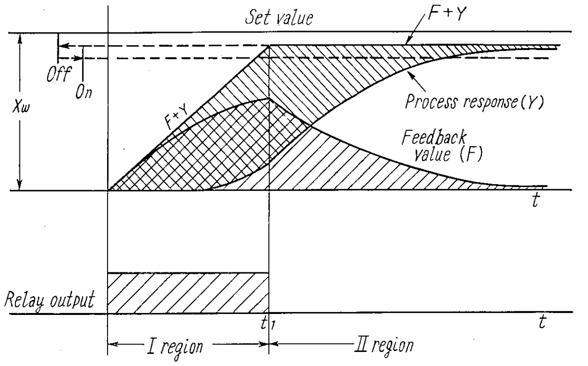


Fig. 15 One-pulse control

In region II the actuating signal $(X_W)-(F+Y)$ gets in the dead zone of the controller and the relay completes control with one pulse in region I. When these conditions are summerized, (1) to correspond the integral time with the lag time of process; (2) to correspond the proportional band knob to the value which represents process gain in 100% graduation.

However, in actual practice, one-pulse control is not the optimum control but it is near critical damping condition. Where the first order lag of process is within 1 min, it is considered better to set the proportional band to 60%~80% rather than process gain $K\times 100\%$.

2. Analysis by Describing Function

The describing function method has been for a long time as a method to analyze non-linear control. *Fig. 16* shows the descrbing function of the S controller under the conditions of $T_Y=60$ sec. $T_I=T_P$ and when there is only the first order lag to consider.

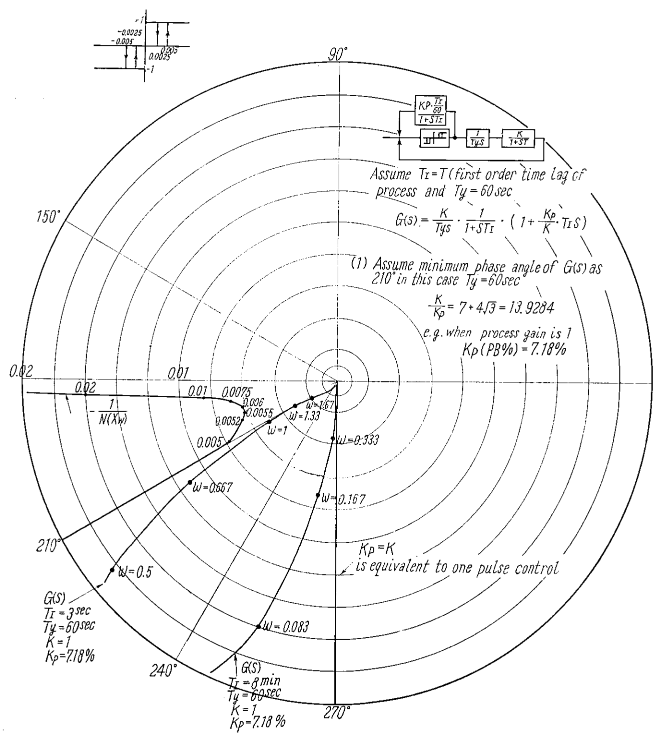


Fig. 16 Analysis by describing-function method

In the diagram, under the one-pulse control condition, phase of linear component reaches 270° position to attain stability of control. Cases of $T_P=T_I=3$ sec and 8 min are shown to see how the change appear by the process time constant when the proportional band of the controller is set for 7.18% at process gain $K=1$. Control characteristics are not very good to make the proportional band small in a system such as flow control where there is little lag of process, as this circular curve shows, but, when the time lag of process is large for instance, temperature control, good control results may be obtained even if the proportional zone may be fairly small. Good control is possible with a considerably smaller proportional band than the one considered under one-pulse control.

3. Analysys by Phase Plane Method

When we think of a system including dead time, the analysis of phase plane method is easy to understand. *Fig. 17* represents a modification of *Fig. 14*, but, $T_Y=60$ sec $T_P=T_I$.

In *Fig. 17*, input of on-off amplifier y is more than

$$\left.\begin{array}{ll} 0.5\%. & m=1 \\ |y|\leqq 0.25\% & m=0 \\ y \text{ is under } -0.5\% & m=-1 \end{array}\right\}$$

At this time the valve x means the setting value minus controlled value. The derivative equation from $(-m)$ to x is

$$-m=\frac{T_Y\cdot T_P}{K}\cdot\frac{d^2x(t+L)}{dt^2}+\frac{T_Y}{K}\cdot\frac{dx(t+L)}{dt} \quad \cdots\cdots (6)$$

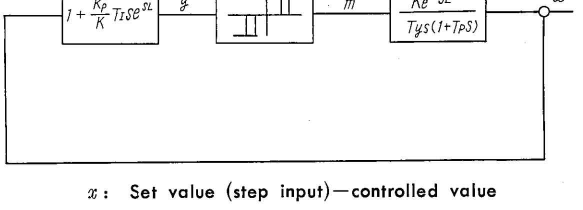
when $\dfrac{dx(t+L)}{dt}=\dot{x}(t+L)$ this becomes

$$T_P\dot{x}(t+L)+x(t+L)$$
$$=\frac{T_pK}{T_Y}\cdot m\log\left(m+\frac{T_Y}{K}\cdot\dot{x}(t+L)\right)+C \quad \cdots\cdots (7)$$

C: constant of integration

On the other hand, the derivative equation of input of on-off amplifier y is from control value x,

$$y=x(t)+\frac{K_P}{K}T_I\dot{x}(t+L)$$
$$=x(t+L)+\frac{K_P}{K}T_I\dot{x}(t+L)-x(t+L)+x(t) \quad \cdots\cdots (8)$$



x: Set value (step input)—controlled value

Fig. 17 Block diagram

When we put $x(t)-x(t+L)$ in equation (7) and we approximate the difference equation by the dead time L and the coefficient of derivation,

$$x(t)-x(t+L) \doteqdot -L\dot{x}(t+L) \quad \cdots\cdots\cdots\cdots\cdots\cdots (9)$$

That is to say, the equation (8)

$$y=x(t+L)+\left(\frac{K_P}{K}T_I-L\right)\dot{x}(t+L) \quad \cdots\cdots\cdots (10)$$

When formula (7) and formula (10) are shown on the phase plane, then *Fig. 18* is obtained.

When the setting variation of step function is performed at point P, we consider one-pulse control conditions as controlability (in the drawing it is two-pulse control at points A and B of change-over).

Then when the change over from $m=0$ takes place at point A, and the change-over curve and the curve of $m=0$ agree, there is no next point of change-over and it amounts to $\dot{x}=0$. In other words, this control becomes stable. This condition is

$$\frac{K_P}{K}T_I-L=T_P \qquad T_P=T_I$$

$$\therefore \quad \frac{K_P}{K}=\left(1+\frac{L}{T_I}\right) \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (11)$$

(1) to correspond the integral time with time constant of process first order time lag

(2) to set proportational band at process gain

$$(K)\times\left(1+\frac{L}{T_I}\right)\times 100$$

This conditional formula applies when the proximity formula (9) holds and when the L/T_I becmes extremely large, it will have errors.

When we calculate precisely, the right sector of equation (9) has term of $\dot{x}$ and constant term of L/T and by the influence of the constant term and the actuating signal, controllability may differ.

4. Application of S Controllers

There are some processes with long dead time which must avoid over shooting and some with reverse response.

With the S controller, in order to control these processes well, it is possible to use a sequence circuit established outside and to use it together.

By a time relay, when the controller produces output pulse the control action may be to stop until the response of the process nearly completes (not sending output pulse to actuator) and this sequence will correspond to a sort of sampled-data control. Difierences from sampled data control are :

(1) When the control is stable and outside interference happens then the control action immediately takes place (in sampled-control, no control action occurs until the sampling cycle is reached).

(2) This controller action utilizes the rotating position of the servo-motor to do integral action as an actuator. So in a kind of control action of this type the controller only sends proportional band pulse but by the actuator characteristics the offset is contained within the insensitive zone.

Fig. 19 shows an example of circuit of the sampling type control system. There is little trouble of non-linear type due to the amount of input of controller (actuating signal) when the proportional zone is set at process gain $K\times 100\%$ and the integral time set at a maximum value although it has no relationship with this control action. It is good to set the timer setting time to about $T_L+(4\sim 6)\ T_P$ in the dead time process.

Propotional band in the reverse response process should be set at a higher value than $K\times 100\%$.

With the divided type controller it is possible to do sampled data control of several processes by one S controller. This is possible by scanning the actuating signals made by respective setting boards and the actuators which correspond to them. Details are dispensed with due to shortage of space here.

Effective utilization of exterior terminals 3, 4, and

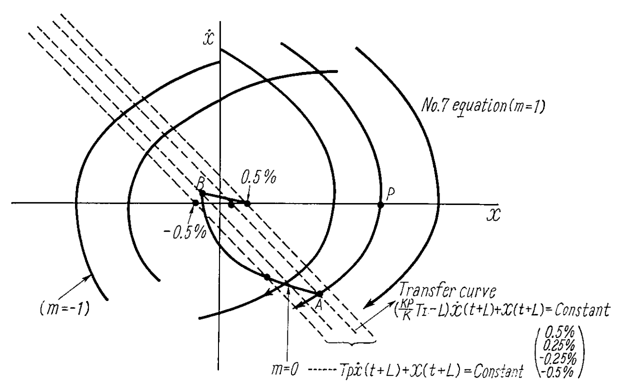
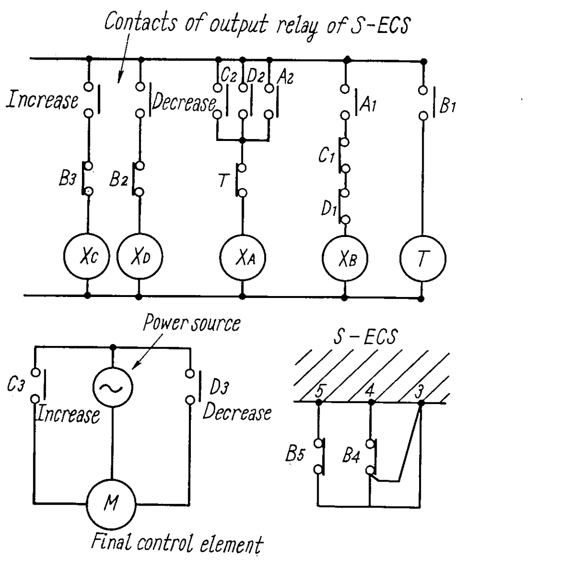


Fig. 18 Analysis of phase plane method



T: Timer $\quad XA, XB$: Auxiliary relay
XC, XD: Output contactor

Fig. 19 Sequence circuit

5 of the feedback circuit, in the S controller, gives various processes good results. When the blast furnace, the opening of valve is controlled by a relay sequence at the auto-change, in other period usual control is performed.

In a case like this when the feedback circuit terminals between 3 and 4 and 3 and 5 are short-circuited of the S controller, it serves the purpose of on-off controller and by setting the limit switch for the opening of the valve at a certain value, minimum flow may be effectively maintained by control.

By arranging two control actuators in a series to control temperature, for instance, heat wind at one end and cold wind at the other, response characteristics of the process may differ. In such a case, a sequence contact may be provided at the actuator side and by this contact resistance may be connected in a series between 3～4 and 3～5 with the sequence contact. This good control may be possibly by varying the integral time of the controller.

VIII. STANDARD SPECIFICATIONS OF CONTROLLER

C controller
Input: 10～50 ma dc or 0～10 mv dc
Output: 10～50 ma dc
Load: 0～250 ohms or 200～450 ohms
Feedback constant:
P=3～300%
I=0.1～20 min (for long time use)
1～60 sec (for short time use)
D=0～5 min
Temperure: 0～45 °C
Limit of P action: lower 0～ 50%
upper 50～100%
Source: ac 100 v: 50/60 cps

S controller
Input: 10～50 ma dc or 0～10 mv dc
Output: la each of increase/decrease contact
Load maximum votage ac 150 v
maximum current 1 amp
Feedback constant P= 0～300%
(for long time use) $I=1$～8min
P=10～300%
(for short time use) $I=1$～40sec
Ambient temperature: 0～45 °C
ac 100 v 50/60 cps

IX. CONCLUSION

This concludes the explanation of the C and S controllers. The controllability of the S controller is being tested in combination with a process simulator. We regret that we cannot report on its results at the present time but we think we can publish them subsequently with complete information.