

Furnace Temperature Control & Calibration of Thermocouple Using Digital Temperature Controller

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ABSTRACT

In industrial applications it is quite essential to maintain and control the temperature of furnaces at certain predetermined Value for the sake of proper functioning of the system. Failing which may lead to loss of huge amount of capital. So this project basically deals with the temperature control of the furnace for which a digital temperature controller has been used which is actually a PID controller. Thermo – emf generated by the thermocouple acts as an input to the PID controller & the temperature of the furnace is maintained according to the pre-set value by increasing or decreasing the amount of electrical input given to the heater of the furnace.

Keywords: PID, controller, furnace, heater, emf

1. INTRODUCTION

Apart from temperature control this setup can also be used for the calibration of contact & non contact type temperature measuring instruments like thermocouple & radiation pyrometer in this case. Calibration is a comparison between measurements – one of known magnitude or correctness made or set with one device and another measurement made in as similar a way as possible with a second device. The device with the known or assigned correctness is called the standard. The second device is the unit under test, test instrument, or any of several other names for the device being calibrated.

Temperature measurement is done in various ways which can be broadly classified as contact & non contact type of measurement Thermocouple is used for contact type of measurement & radiation pyrometer is used for non contact type of measurement. Thermocouple is a device which consists of two dissimilar metal wires joined end to end and the junctions thus formed are kept at different temperatures because of which an emf is generated which is known as thermo-emf and this emf is proportional to the temperature difference between the two junctions. A proportional–integral–derivative controller (PID controller) is a generic control loop feedback mechanism (controller) widely used in industrial control systems – a PID is the most commonly used feedback controller. A PID controller calculates an "error" value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process control inputs. The PID controller calculation (algorithm) involves three separate constant parameters, and is accordingly sometimes called three-term control: the proportional, the integral and derivative values, denoted P, I, and D. Heuristically, these values can be interpreted in terms of time: P depends on the present error, I on the accumulation of past errors, and D is a prediction of future errors, based on current rate of change.^[1] The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve, or the power supplied to a heating element.

2. PROBLEM IDENTIFICATION

CASE STUDY

Temperature measurement is very important parameter for steel industry. In Steel Plant our main units **BF, SMS-I, SMS-II, PM, RMZ, COKE OVEN, SP-I, SP-II, RMP-II** and other shops need temperature measurement & calibration which should be accurate & ISO certified. Any malfunctioning in temperature measurement furnace (process) can cause reduction in quality of steel, hamper rolling, cause material damage. So we can imagine the importance of furnace temperature in Steel Plant. In Steel Plant Instrumentation Deptt. plays vital role for temperature calibration & testing under QMS. We have ISO certified temperature equipments. With the help of our Master equipments we do temperature calibration & testing as per their calibration schedule. We have only one furnace horizontal type which has facility of testing radiation pyrometer & TC Range : 0 – 1000 deg.c., Make – LAND INFRARED LTD. Dornfield Sheffield S18-6DJ ENGLAND, which is 25 years old. This Deptt. Completely depends on this furnace for testing and calibration as per ISO requirement of below mentioned items.

<u>Details of works</u>	<u>Every year</u>
1. "S" Type Thermocouple Testing and calibration	123 nos.
2. "K" Type Thermocouple Testing and calibration	150 nos.
3. "RTDs" Testing and calibration	100 nos.
4. Radiation Pyrometer testing and calibration	88 nos.
5. General "S" and "K" Type Thermocouple and Radiation Pyrometer jobs	(approx.) 100 nos

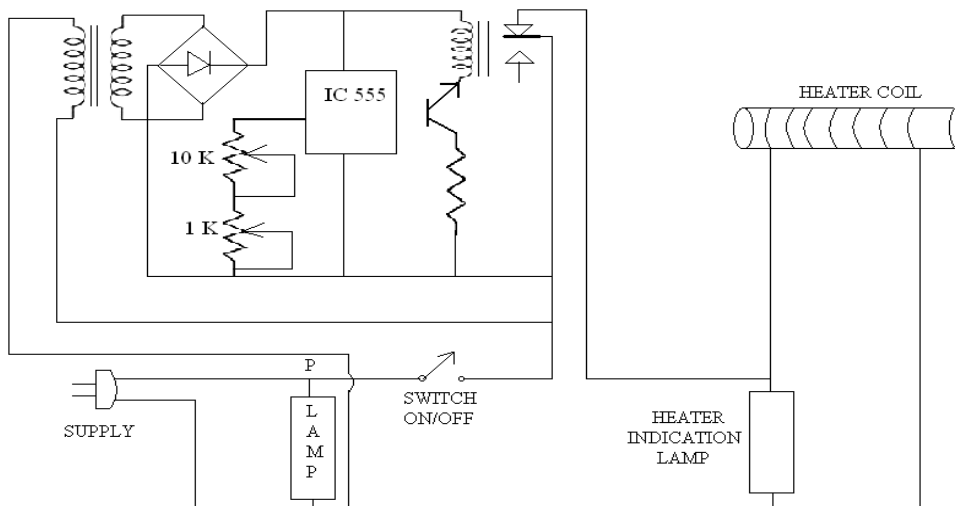
3. WHY THE NEED WAS FELT FOR MODERN CONTROLLER

In Plate Mill area if Radiation pyrometer fails, Rolling stops, which is a very great loss of production of Steel Plant. Like this other units are also affected due to failure in temperature measurement. Also great loss of Production of Steel Plant.

Some days ago this Land Furnace suddenly failed. A short circuit in the pulse control circuitry cause damage to power supply, transformer, solid state relay and heater coil thus making the furnace completely dead. Originally the furnace temperature was controlled by pulse control method.

This furnace is brought to required temperature by energizing the heating coil. This heating coil gets energized by pulse control method. But this method has a drawback as it is UNABLE to produce a stable output because in this method the furnace temperature keeps on increasing & the required temperature is reached only for a short period of time. So it requires constant monitoring because if it reaches the required temperature & it crosses, then furnace need to be cooled and reheated again thereby wasting a lot of time. The pulse control method is not an efficient means of controlling temperature & also its repairing was a time consuming and troubles some job.

OLD FURNACE SYSTEM



So an idea was put forth by the group to design a new system for temperature control in the furnace which satisfies the following requirement:

- (i) Safety of furnace
- (ii) Should give a stable output
- (iii) Should be reliable
- (iv) User friendly & easy to maintain

4. MODIFICATION OF LAND CALIBRATION SOURCE FURNACE IN CENTRAL LAB INSTRUMENTATION

For Modification we arranged from our internal sources

- (i) One small controller (Masibus)
- (ii) One SIEMENS 4 NO/ 4 NC relay contact
- (iii) “S” Type Thermocouple
- (iv) Cooling Fan (small)

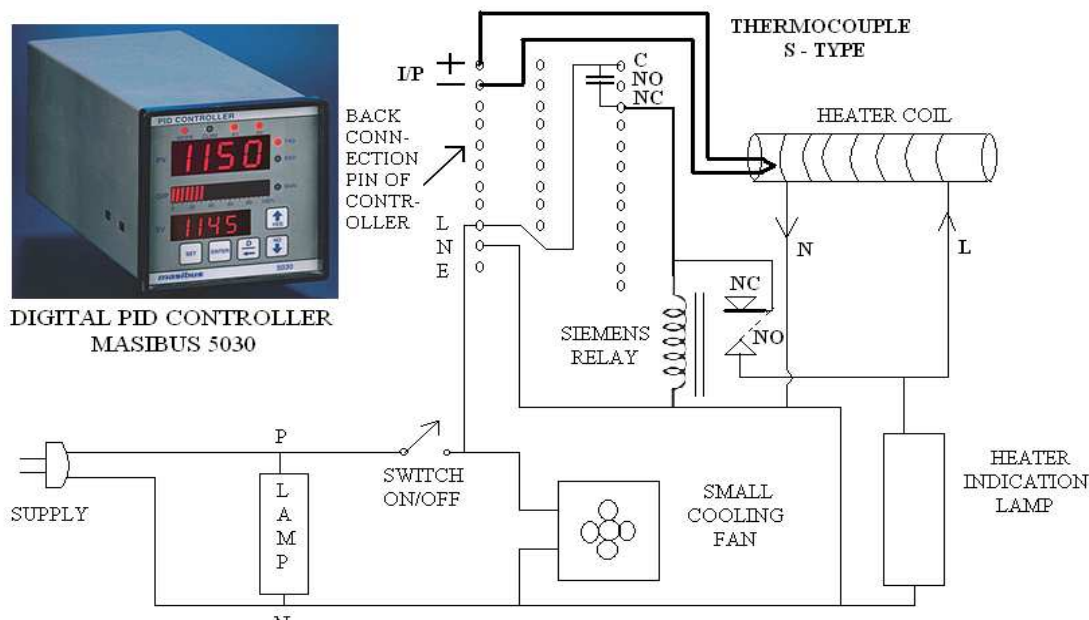
After arranging above things we repaired broken heater coil and “S” Type thermocouple with in-house sources. Masibus controller was originally programmed for 4-20mA DC input. We modified software programme for “S” TC input. After calibration and testing of controller we designed all wiring of furnace. We first time designed furnace “SAFE FACILITY”. We used controller relay contacts for external Siemens 4 NO/ 4 NC relay which is very rugged and useful. It can handle the heater coil load and temperature inside the furnace.

SAFE FACILITY is introduced for furnace safety and easy for operate (Range 0-1000 deg.c.)

- (i) First time introduced Furnace Process Temperature indication and SET VALUE Temperature indication.
- (ii) “S” Type thermocouple inside furnace to give mV DC signal for controller.
- (iii) SIEMENS 4 NO/ 4 NC relay contact
- (iv) Small Cooling Fan.

The required temperature is given as the Set point and the furnace temperature as process variable. When the furnace temperature is less than required temperature the controller energizes the relay hence power is delivered to the system. In the vice versa scenario the controller de-energizes the relay. Hence the furnace is maintained at the constant temperature as required. When needed the furnace temperature can be changed by changing the Set value. In case internal “S” TC fail (open) the furnace will be totally off, this way furnace will be safe. As well as we used automatic control system when temperature of furnace reaches to set value the relay will be off, so heater coil of furnace will be off. Hence furnace temperature will not go high this way saving of Electrical power and furnace will also get rest so that the life of equipment will rise automatically.

MODIFIED SAFE FACILITY FURNACE SYSTEM



5. WHY CALIBRATION OF THERMOCOUPLE

The thermocouple validation procedure is widely used for all furnaces and also in heating equipment. Thermocouples are non-adjustable measuring devices, so we cannot calibrate them. However, we can validate functioning for a range of temperature through using a thermocouple calibration bath. Usually, you don't have to calibrate a thermocouple. You just use the conversion equation, based on the type of thermocouple (eg B, J, K, etc), to convert the output voltage to a temperature. In my experience, this is quite accurate. My temperature usually only fluctuates 0.1 C or so. If I had to calibrate a thermocouple, I would build a calibration model with the voltage on the

Y axis and temperature on the X axis. Measurements can be made using a heated water bath and an accurate thermometer. Also, you could measure the boiling and/or freezing point of a series of pure solvents where those temperatures are well known at STP.[5]

5.1 Computer-Controlled Thermocouple Calibration

A thermocouple does not measure temperature, but measures temperature difference between two points. The points are sometimes called the "hot" or measurement junction and "cold" or reference junction. If the reference junction is not at 0 degrees C, you have to measure the temperature of the reference junction and convert that to an offset voltage, which is added to the sensed voltage. Both equations: temperature to voltage and voltage to temperature are non-linear high order polynomials and depend on the type of thermocouple being used. Instead of an equation, pre-computed tables can be used.

5.2 Thermocouple calibration procedure

The thermocouple validation procedure is widely used for all furnaces and also in heating equipment. Thermocouples are non-adjustable measuring devices, so we cannot calibrate them. However, we can validate functioning for a range of temperature through using a thermocouple calibration bath. Generally we use a temperature controller or SCADA to indicate thermocouple temperature. To validate thermocouple temperature on the display, we measure mV at the thermocouple end and by using standard ASTM E230-03 (Standard Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples. we can obtain Temperature in degrees Centigrade at a particular furnace location. We want to ensure that the same temperature will be displayed on SCADA or indicator and deviation, if any, will be recorded accordingly.

5.3 Thermocouple Calibration Procedure:

The following information is intended to give the reader a review, in some detail, of the equipment requirements and proper techniques needed to accurately calibrate thermocouples and thermocouple materials. Branom Instrument calibrates thermocouple and thermocouple wire in accordance with one of the following American Society for Testing and Material (ASTM) Standards: E207-88, standard method of Thermal EMF Test of single thermoelement materials by comparison with a secondary standard of similar EMF temperature properties. E220-86, standard method for calibration of thermocouples by comparison techniques. In general these standards describe the type of temperature source, measuring equipment, standards, and procedures needed to accurately perform a calibration. Each of these elements will now be looked at more closely.

6. CONTROLLED TEMPERATURE SOURCE:

The temperature source used in the process of calibrating should as a minimum be stable enough to provide a constant temperature (approx. +/- 2 degrees F) for a short length of time (approx. 20 mm.) at any temperature at which the temperature bath or other source is to be used. The temperature source should have a zone of uniform temperature into which the thermocouple measuring junction may be inserted. The length of the temperature source must be adequate to permit a depth of immersion sufficient to assure that the measuring junction temperature is not affected by a temperature gradient along the thermocouple wires.[5]

6.1 CONTROLLED TEMPERATURE SOURCES:

- (i) Fixed Point: When highly accurate measurements must be made, fixed point cells are used. A fixed point cell consists of a metal sample inside a graphite crucible with a graphite thermometer well submerged into the metal sample. When the metal sample is heated to the freezing point, it will

produce a very stable and constant temperature. In order to better understand the operation of fixed point cells, the following definitions are useful.

- (ii) Fixed Point: A reproducible temperature of equilibrium between different phases of a material.
- (iii) Freezing Point: The fixed point between the solid and liquid phases of a material.

6.1.1 REFERENCE JUNCTIONS:

A thermocouple's output is based on the difference in temperature between the measuring junction (hot junction) and the reference junction (cold junction). See Figure A.

6.1.2 REFERENCE JUNCTION TEMPERATURE:

A controlled temperature must be provided in which the reference junction is maintained at a constant chosen temperature. The reference junction temperature should be controlled to a better accuracy than that expected from the thermocouple calibration. The most commonly used reference temperature is 32 degrees F., but other temperatures may be used if desired.

6.1.4 AUTOMATIC ICE POINT:

The automatic ice point is an electrical refrigerated device in which an equilibrium between ice and water is constantly maintained. The change of volume of water in freezing is used to control heat transfer. Some commercially available devices provide wells into which the user may insert reference junctions formed from his own calibrated wire. Others are provided with many reference junction pairs brought out to terminals which the user may connect into his system.

6.1.5 ELECTRONIC COMPENSATION:

This method employs a compensation circuit containing a source of current and a combination of fixed resistors and a temperature sensitive resistor (TSR). This device can be designed to produce similar EMF to that of the thermocouple being calibrated. The Electronic Compensator will make EMF compensations to the thermocouple circuit based in the difference in EMF from 32 to ambient temperature.

6.1.6 MEASURING INSTRUMENTS:

The choice of a specific instrument to use for measuring the thermocouple output will depend on the accuracy required of the calibration being performed. In general, an instrument such as the Fluke 702 calibrator or Altek 422 is sufficient for most thermocouple calibrations.

6.1.7 REFERENCE THERMOMETERS:

The reference thermometer to be used for the comparison calibration of a thermocouple will depend upon the temperature range covered, the accuracy desired, the capabilities, or the preference of the calibration laboratory. The following are different examples of reference thermometers.

6.1.8 PLATINUM RESISTANCE THERMOMETERS:

A standard platinum resistance thermometer (SPRT) is the most accurate standard available, however, it is the most expensive standard, and other standards are acceptable alternatives depending upon the

temperature range covered, the accuracy desired, the capabilities, or the preference of the calibration laboratory. The following are different examples of reference thermometers.

7. TEST ASSEMBLY PLACEMENT IN THE FURNACE:

Depth of immersion is the most important consideration if accurate calibration results are to be obtained. The depth of immersion must be sufficient to eliminate the effects of heat transfer away from the junction. It is impossible to establish a minimum depth of immersion that would be useable under all circumstances since heat transfer characteristics are dependent on the mass of material being put into the temperature source.

7.1 WIRING CONNECTION FROM TEST ASSEMBLY TO READOUT INSTRUMENT.

The actual wiring necessary to connect the test assembly, reference junction and readout instrument will depend on the quantity of thermoelements in the test assembly, the type of reference junction used and whether or not a switching device is used, but the basic requirements are the same. Thermocouple extension wire is used to connect the thermoelements to the reference junction. Copper wires are used between the reference junction and readout instrument.

7.1.1 THERMOCOUPLE CALIBRATION WIRING PROCEDURE:

When calibrating thermocouples, it is faster and more convenient to use a thermocouple switching box. The extension wires from the thermocouples are placed into one side of the reference junction. Multiple pairs of copper leadwire will exit the reference junction and will be connected to the switch box. One pair of copper leadwires will run from the readout instrument to the thermocouple switch box.

7.1.2 JUNCTION LOCATION:

One of the primary advantages of calibrating thermocouple materials against a base-metal standard of similar EMF output is that the sample(s) to be calibrated are welded to the base-metal standard forming a common junction thus achieving good isothermal conditions between the test thermo-element and the standard. Furthermore, because the test thermo-element and the standard produce nominally the same EMF vs. platinum the EMF output changes little over a fairly broad temperature range, thereby reducing the need for precise temperature source control. See Figure B.

7.1.2.1 MEASUREMENT:

Set your controlled temperature source to the specified temperature and allow it to adequately stabilize. Immerse the test assembly into the test temperature medium and provide sufficient time for the test assembly to stabilize. Once the test assembly is stable the EMF generated between the test specimen and the reference standard can be recorded. Avoid soaking the test assembly at temperature for a prolonged period of time, as it can cause permanent changes to occur in the thermo-elements. Once the reading is taken, raise the test temperature to the next higher temperature, first removing the test assembly from the temperature source, or advance the test assembly to the next temperature source. Allow the temperature source and the test assembly to stabilize as before, and take a second set of readings at the new temperature. In all cases take the reading in sequence from the lowest to the highest temperature. A base metal reference standard shall be used for one series of temperature changes only.[5]

8. ASTM E 220 THERMOCOUPLE CALIBRATION:

The Test thermocouple junction should be located so that it is in intimate contact with the junction of the standard. Without making a radiograph of the thermocouple it is impossible to know exactly where the junction is located. A few generalizations can be made which enables junctions to be located quite closely. First, the cap weld on a metal sheathed thermocouple is normally about as thick as one-half the sheathed diameter. Second, a "U" junction is normally about one-half the sheathed diameter. Using these generalizations, a thermocouple .125" diameter, will have a grounded junction approximately .063" below the tip of the cap. The thermocouple standard should be tied to the thermocouple (s) with a fine gauge wire. The junction of the standard should be bent so that it is in contact or at least very close to the point where it has been calculated that the junction is located. See Figure C.

Figure A:

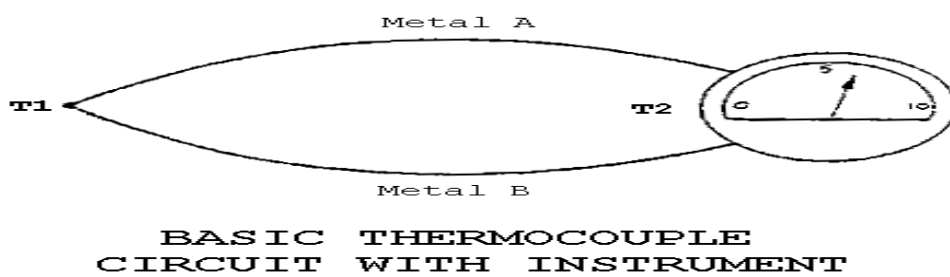


Figure A

Figure B:

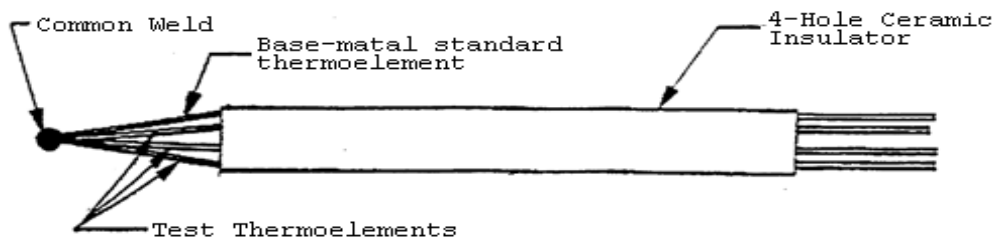
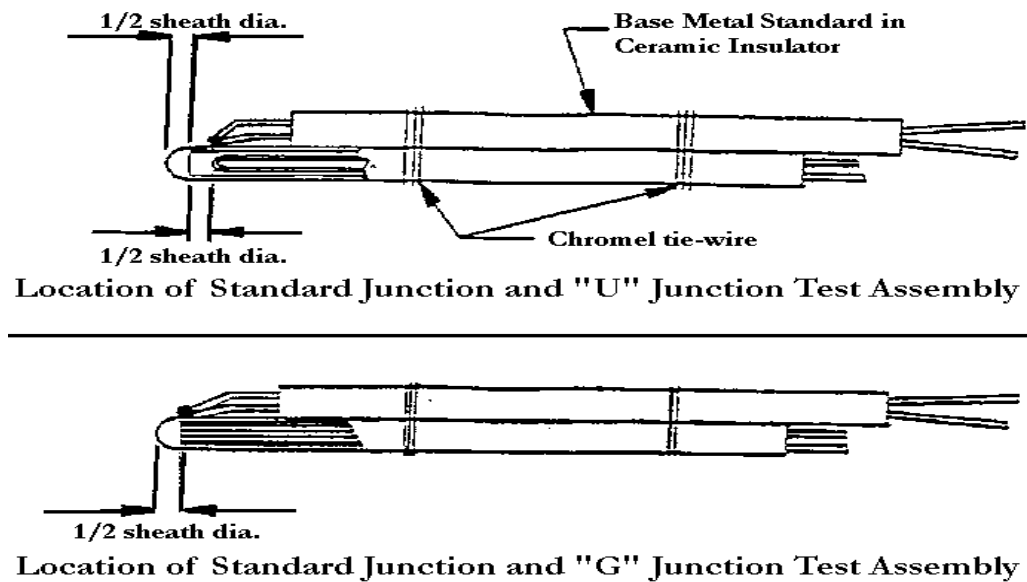


Figure C: Wire-to-wire Test Assembly

Figure C:



9. SIGNIFICANCE AND USE

For users or manufacturers of thermocouples, this test method provides a means of verifying the emf-temperature characteristics of the material prior to use. This test method can be used to calibrate a thermocouple for use as a reference, or it can be used to calibrate thermocouples representing a batch of purchased, assembled thermocouples. This test method can be used for the verification of the conformance of thermocouple materials to temperature tolerances for specifications.

10. SCOPE & RESULT

This test method describes the principles, apparatus, and procedure for calibrating thermocouples by comparison with a reference thermometer. Calibrations are covered over temperature ranges appropriate to the individual types of thermocouples within an overall range from approximately -195 to 1700 °C (-320 to 3100 °F). In general, this test method is applicable to unused thermocouples. This test method does not apply to used thermocouples due to their potential material in-homogeneity—the effects of which cannot be identified or quantified by standard calibration techniques. Thermocouples with large-diameter thermo-elements and sheathed thermocouples may require special care to control thermal conduction losses.

In this test method, all values of temperature are based on the International Temperature Scale of 1990. *This standard may involve hazardous materials, operations and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

By applying some modification in old furnace system When the furnace temperature is less than required temperature the controller energizes the relay hence power is delivered to the system. In the vice versa scenario the controller de-energizes the relay. Hence the furnace is maintained at the constant temperature as required. When needed the furnace temperature can be changed by changing the Set value. In case internal "S" TC fail (open) the furnace will be totally off, this way furnace will be safe. As well as we used automatic control system when temperature of furnace reaches to set value the relay will be off, so heater coil of furnace will be off. Hence furnace temperature will not go

high this way saving of Electrical power and furnace will also get rest so that the life of equipment will rise automatically.

ABBREVIATIONS

PID	-	proportional integral derivative ,	BF	-	blast furnace
SMS	-	steel melting shop ,	SP	-	sinter plant
EMF	-	electromotive force	RM	-	rolling mill
TC	-	thermocouple			

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