Introduction of Products

LIQUID-LEVEL MEASUREMENT USING A RADIOACTIVE ISOTOPE

I. INTRODUCTION

Research on the utilization of radioactive isotopes, relative to applications in medical, agricultural and chemical fields, has been under way in Japan for quite a while and many successes have been accomplished. For industrial application, the isotopes used as radiation sources or as tracers are also producing excellent results. Research is also being carried out on industrial instruments, such as liquid-level gage, thickness gage, liquid densitometer, etc. using isotopes as radiation sources.

In liquid-level measurement, the fact that gamma rays, which radiate from isotope, have great penetrating power through materials is utilized to measure the level of liquid in a closed tank from outside without any contact with the liquid. As a result, difficulties experienced heretofore in the measurements of level of highly corrosive liquid within a tank, liquid-level in a high temperature-pressure tank or measurement of quantity of materials in powder or granular forms within a bin, have been eliminated and made it possible to continuously indicate and record or automatically regulate these quantities.

Although there are various types of liquid-level measuring instruments, the model described here is the liquid-level measurement of follow-up type and is most suited for industrial process.

II. LIQUID-LEVEL MEASURING SYSTEM OF FOLLOW-UP TYPE

Liquid-level measurement by follow-up, using penetration of radiation source, is very convenient in measuring level over a wide range with the same degree of accuracy.

1. Construction and principle of measurement

This measuring equipment consists of a radiation source unit, detector unit, counter unit, transmitter and electronic recorder. The radiation source unit, detector unit and transmitter are located at the job

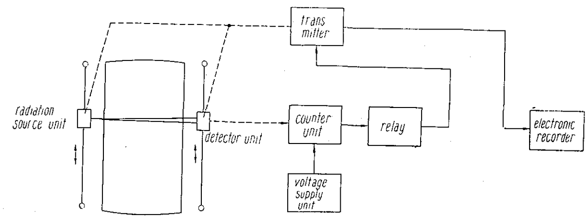

Fig. 1. Diagram for a measuring system

site and the remainder are installed on the panel. Fig. 1 illustrates the diagram for the measuring system. The gamma rays from the radiation source Co^{60} are collimated and projected against the tank. The rays penetrate through the tank walls and the liquid to be measured and are detected by the detector. The output from the detector in the form of voltage pulsations is led into a preamplifier and then fed into a counter unit on the panel located at a distance from the job site. Amplification and wave form shaping of the input pulse are conducted in the counter unit and by the use of integrating circuit, the quantity of gamma rays which have penetrated is transformed proportionally into direct current voltage and is measured by a vacuum tube voltmeter. The quantity is indicated and at the same time a motor attached to the transmitter is driven either in one direction or the other through a relay circuit predetermined to operate at an output corresponding to a certain quantity of gamma rays and is made to follow up the change in the liquid-level. The liquid-level is noted by the change in the resistance of a rheostat mechanically connected to the driving motor and as an electric quantity is indicated and recorded by the electronic recorder.

2. Radiation source unit

The radiation source unit consists of radioactive isotope Co^{60} contained in a lead shield. Gamma rays are collimated in one direction to obtain as narrow a beam as possible and projected through an opening in the shield. Except for the opening in the shield, the thickness of the walls of the shield is determined according to the quantity of Co^{60} used to insure safety. Transferring or mounting of the unit and various other operations when measurements are not being taken can be made without any hazard by attaching a shield cover to the opening. In case when the quantity of Co^{60} is large, the container should be designed in such a way that by operating a handle the isotope is allowed to be set in the shielded position. The isotope is placed in an anti-corrosive metal case for easy handling and to protect instruments and materials from contamination and decay.

3. Detector unit

Detector of gamma rays used is either a scintillation counter or Geiger Mueller counter(GM-tube)depending on the construction and dimensions of the tank to be measured and the speed with which the liquid-level is to be followed. Since the detecting sensitivity of the scintillation counter is extremely better than the GM-tube, it is used whenever the diameter of the measuring tank is large, wall is thick or when the change in the liquid-level is quite fast. Fig. 2 shows the relation between the liquid-level and the output of the detector unit.

4. Counter unit

A counter unit consisting of amplifier, pulse shaping circuit, integrating circuit, vacuum tube voltmeter and electronic tube relay circuit, is the heart of the liquid-level measuring instrument. Its construction and the vacuum tube circuits are simplified as much as possible so that maintenance and handling may easily be made. The pulse output from the counter unit is amplified in the main amplifier circuit and then is transformed into a rectangular wave having a fixed height and width by the uni-vibrator in the pulse shaping circuit. By selecting a suitable bias voltage in this circuit, the pulse input can be discriminated from the noise and therefore a discriminator is not required. The integrating circuit for converting the average value of pulse input in a unit time into corresponding value of direct current voltage consists of a diode, resistors and condensers. The condensers in the circuit are connected in such a way that capacitance can be made to change to six different values making it possible for the scale range of measuring the quantity of gamma rays and the time constant to be varied in six steps.

Since nuclear disintegration is entirely at random, there are statistical fluctuations near the average value of the strength of gamma rays from Co^{60}. Probability of this error is inversely proportional to the square root of the product of the number of radiation particles within a unit time and the time constant of the integrating circuit. Therefore, if time constant is made to increase, fluctuation will decrease. However, the time for the output voltage to reach a fixed value will increase. Thus there is always a time lag to some extent and since it is difficult to eliminate completely the fluctuations in the measured value, the continuous servo-mechanism for the driving method of following up the liquid-level is not used in this liquid-level meter but an "on-off" relay servo-mechanism having a fixed constant band is used. (Fig. 2)

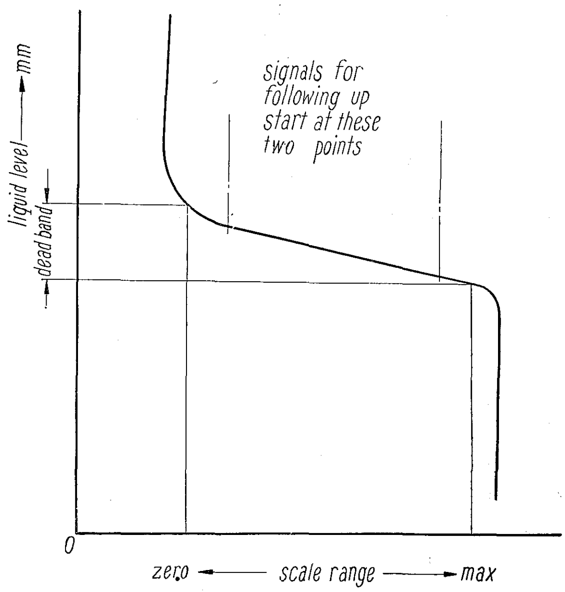

Fig. 2. Indication of supervisory instrument

In the vacuum tube voltmeter circuit, monitoring meters and meter relays having the same degree of sensitivity are connected in series. The d-c output voltage is measured by these meters. Rheostats for adjusting zero point and maximum value are attached to the meter relays. With these rheostats, the zero point and maximum reading of the meters are adjusted so that the indicating values of liquid-level will fall within the fixed constant band.

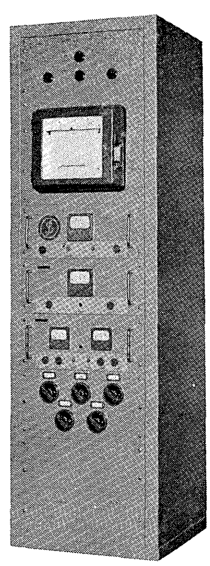
Fig. 3. Measuring panel

For "on-off" follow-up signals, meter relays, installed on rubber cushions to prevent mechanical vibrations, are used. Between the meter relays and the relay for driving motor, there are vacuum tube relays, communication relays and these relays are made to operate in a fixed sequence without any trouble

5. Voltage supply unit

Circuits to obtain high d-c voltage required for GM-tube and scintillation counter, constant voltage for counter unit and other necessary voltage circuits are incorporated in the voltage supply unit. A long life Fuji selenium rectifier is used in the d-c voltage source for making a small and lightweight unit.

6. Specification

Specification for the liquid-level meter is as follows:

Measuring Range: over 200 mm
Accuracy: ±5 mm
Follow-up Speed: 1 to 3 mm/sec.
Isotope: Co^{60} 1 mc to 50 mc
Power Supply: 110 V 50 cps or 60 cps
Meters Used: Standard Indicating Meter and Recording Meters.
Object of Measurement: Mainly to measure liquid-level and stock-level which hitherto have been difficult to measure.

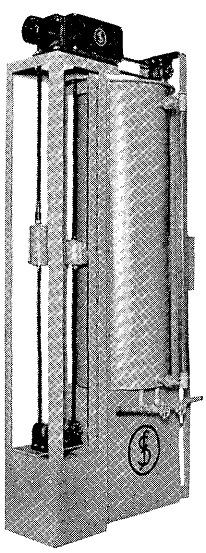

Fig. 4.
Transmitter, radioactive source, detector and motional mechanism

III. LIQUID-LEVEL ALARM METER

A liquid-level alarm meter is used to give out warnings when the liquid-level in the tank reaches the upper or lower limit or is used to regulate automatically the liquid-level at a constant level. The principle of operation is exactly the same as that of the follow-up system of liquid-level measurement and consists of radiation source unit, counter unit and voltage supply unit. The signal to operate the driving motor in the liquid-level follow-up system is used to operate the alarm bell or signal lamp for upper and lower limits of liquid-level or to operate the final control element. Although it is possible to set the liquid-level positions for alarms to within a range of 5 mm minimum to approximately 500 mm maximum (normal range), the settings can not be made easily at the panel as is done with general type of meter controls. Thus it is necessary to plan before-hand the relative positions of the radiation source unit and the detector unit and also the types of construction of these units to suit the object of measurement. It is also difficult to change at will the settings of the limits widely at the job site. If the liquid-level position for alarm is above 500 mm, it is necessary to install two sets of detector units. The specification in this case will be in accordance with paragraph II. 6.

IV. OTHERS

The radiation source unit is safely located inside a shielded container since the dose becomes less that the maximum permissible quantity at points 30 cm distance away from the direction of gamma ray projection. In installing this instrument, the quantity of gamma rays is at first measured in air. Also Co^{60} decays at a half life of 5.3 years and after a certain length of time cannot be used as a radiation source for the measuring instrument. However, by the use of a decay compensation circuit, it can be used for approximately six years. When replacing Co^{60} with a new one or returning it because of having become unnecessary, the company assumes responsibility in its disposal.

(By Ichizo Tajima and Hiroshi Ishizuka,
Designing Div., Toyoda Works)