UPGRADING A SCALER RATEMETER INTO LEVEL AND THICKNESS NUCLEONIC GAUGES

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ABSTRACT

This article presents an upgraded LUDLUM Scaler Ratemeter Model 2200 into a nucleonic thickness and level gauge. A vertical pipe scanning, consisting mediums such as SS-316, sand, wax, polyethylene, oil, water and air (empty) was done at Malaysian Nuclear Agency, Bangi, Selangor in order to obtain a shielding data as well as the corresponding voltage signals at the ratemeter. A simple comparator circuit with reference potentiometers and LED indicators was then designed and fabricated to work as a thickness or level gauge. The reference can be adjusted in accordance to type and thickness of the pipe/ container, the source intensity of X or Gamma ray, diameter of the pipe and also the distance between source and the NaI(Tl) detector.

ABSTRAK

Kertas kerja ini membentangkan sistem LUDLUM Scaler Ratemeter Model yang telah dinaik taraf 2200 kepada system pengukuran ketebalan nucleonic dan pengukur tahap. Pengimbasan paip menegak, mengandungi media seperti SS 316, pasir, lilin, politena, minyak, air dan mengudarakan (kosong) telah dibangunkan di Malaysian Nuclear Agency, Bangi, Selangor agar satu data perlindungan serta voltan sepadan memberikan isyarat di ratemeter. Satu litar pembanding mudah dengan rujukan penunjuk-penunjuk potentiometers and LED direka bentuk dan litar-litar ini berfungsi sebagai ketebalan atau pengukur tahap. Rujukan akan dapat diselaraskan mengikut jenis dan ketebalan paip / bekas, keamatan sumber X atau sinar Gamma, garis pusat paip dan juga jarak antara sumber dan NaI(Tl) pengesan.

Keywords: NaI(Tl) detector, nucleonic thickness and level gauge, ratemeter.

INTRODUCTION

Non Destructive Testing (NDT) using nuclear technique is a well-known method in industries for inspection of plant components and quality control of the products. The main advantage of the technique is that the plant doesn't need to shut-down while carrying the testing and so it will not deteriorate the product yields. IAEA has provided a reference database of nucleonic control systems available to potential users in the fields of exploration, exploitation and processing of natural resources and manufacturing industries [1]. Malaysian Nuclear Agency, Bangi has played major roles in promoting and offering the inspection services to various local and multinational industries in Malaysia using these techniques [2]. In NDT for pipe/ column scanning, a thickness gauge is used to inspect the pipe conditions whether normal, blockage or rusted and a level gauge is to know the level of medium inside a normally sealed container.

RADIATION SHIELDING

The dose read by the ratemeter follows three basic concepts, namely the accumulated dose or total counts is directly proportional to exposure time, but the dose intensity, I is inversely squared to distance, d and exponentially decay to shielding thickness, x [3] [4]. For shielding, it also depends on density and type of medium. In mathematical form for an empty piping of thickness x_p, the dose, I_e is written as [4]:

$$I_e = \frac{I_o}{d^2} e^{-2\mu_p x_p} \qquad (1)$$

where I_o is the dose intensity at one unit distant from the source and μ_p is the attenuation constant of the pipe's material. If the distant, d is kept constant and the medium inside the pipe has attenuation factor of μ_m then the dose intensity at the ratemeter will reduce to:

$$I = I_e \, e^{-\mu_m x_m} \qquad (2)$$

where x_m is internal diameter of the pipe. In the experiment, the measured dose intensity, I is mainly obtained from direct penetration of radiation through the medium as in Eqn. (2). As a matter of fact, this dose may also be contributed from scattered radiations and also skyshine effect [5] [6] but they are not dominant and can be further reduced these effects by proper design of collimator [7].

EXPERIMENTAL DATA

Experiments were carried out at Malaysian Nuclear Agency with set-up as shown in Fig. 1. The gamma source is 19 mCi (year 2000) of Cs-137, NaI(Tl) scintillator of 2x2 in.2 as the detector and other parameters are xp = 6.64 mm, xm = 101.63 mm and d = 200 mm. Since the activity of Cs-137 source is relatively high, a radiation safety procedure [4] has to be followed while performing the experiment. The scaler ratemeter is set at highest range (x1K) where its full scale deflection (fsd) is 500 Kcpm on 1 mA ammeter analog display. This current flows through a serial 1.2KΩ resistor produces 1.2 V at fsd [8]. Initially, the detector's operating voltage was calibrated and the appropriated value was found to be at 1.1 KV. The results of dose attenuation for different types of medium are presented in Table 1 where the result obtained is agreeable with Eq. (2).

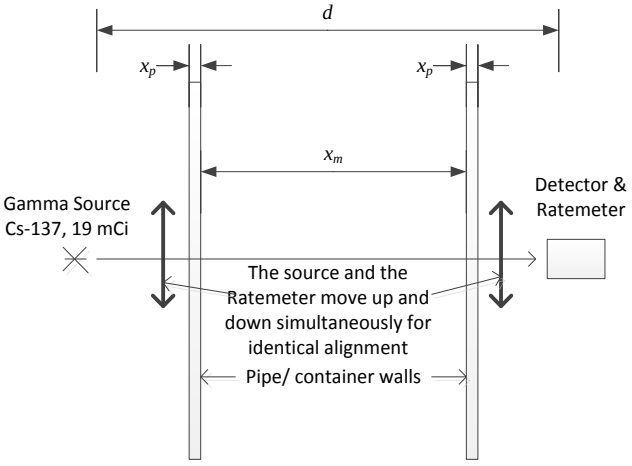

Fig. 1: Pipe scanning using nuclear technique

Table 1: Dose intensity and voltage for different types of medium with parameters as shown in Fig. 1

Medium	Counts Per Minute (cpm)	Ratemeter Output (mV)
Air (empty pipe)	430750	1030
Polyethelene	365230	880
Sand	299090	720
Wax	33626	810
SS316	211160	510

Another experiment result is shown in Table 2 where 1 μCi of Co-60 source, 1x1 in.^{2} NaI(Tl) detector and the setup as the above were used.

Table 2: The attenuated dose and voltage for 1 μCi of Co-60 source and 1x1 in.^{2} NaI(Tl) detector

Medium	Counts Per Minute (cpm)	Ratemeter Output (mV)
Air (empty pipe)	228600	500
Oil	16850	40
Water	11750	30
Sand	2390	6

THICKNESS AND LEVEL GAUGES

From these results, we can design a portable electronic gadget to act as a thickness gauge as well as a level gauge. A thickness gauge is used to identify the piping/ column whether in normal or abnormal conditions. The abnormality is normally due to blockage and corrosion of the pipe where a repair/ service maintenance is required to be done. This gauge can be realized by using two simple comparator circuits with upper (UT) and lower (LT) tolerances and the pipe's condition is indicated by LEDs. For a level gauge, it is used to know the level or quantity of a medium inside a sealed container where normally, the upper side contains air or empty. Data in Tables 1 and 2 can be used to set the reference of the medium's level. For example, as in Table 1, a reference level of 900 mV shall be set for mediums of sand (0.72V) and air (1.03V), and as in Table 2, the appropriate reference level between air and sand is 200 mV. The gauge's circuitry using comparator approach based on LM311 op-amps is shown in Fig. 2 [9]. This gauge is piggybacked to the Ludlum Scaler Ratemeter 2200 to function either as a thickness or a level gauge where it receives the ratemeter signal as well as the 8V power supply. This solution is very much simpler as compared to Zigic's adaptive method [10] [11].

RESULT AND DISCUSSION

We had done a sensitivity test for thickness gauge circuit where UT and LT were set at 1.1V and 0.9V respectively and it was found that the circuit worked as expected. The green LED for normal condition falls within [0.9, 1.1] volts. When the ratemeter signal is just above 1.1V (i.e. could be corrosion inside the container) or just below 0.9V (could be due to blockage), the 'Abnormal U' or the 'Abnormal L' yellow LED starts to light 'ON' respectively. For the level gauge, the red LED is 'ON' if the signal is above the 'Level' setting of the preset potentiometer P3 in the circuit.

This gadget is quite convenient to use because it can easily adjust the required references (UT, LT and Level) after doing a simple setup and experiment to characterize the ratemeter signal against the inspected container. If the signal is weak due to larger diameter and thicker wall of the container or lower radioactivity of the source or less sensitive of the detector used [12], we then increase its sensitivity by reducing the ratemeter gains (x0.1, x1, x100, x1K) so that majority of the signals shall fall at the middle of the CPM display. Note that the +5V supply must be very stable throughout the inspection work in order to avoid any unreliable data and the LM7805 regulator (U1) can maintain at +5V if the input voltage from the supplied 8V battery reduces to not less than 7.2V.

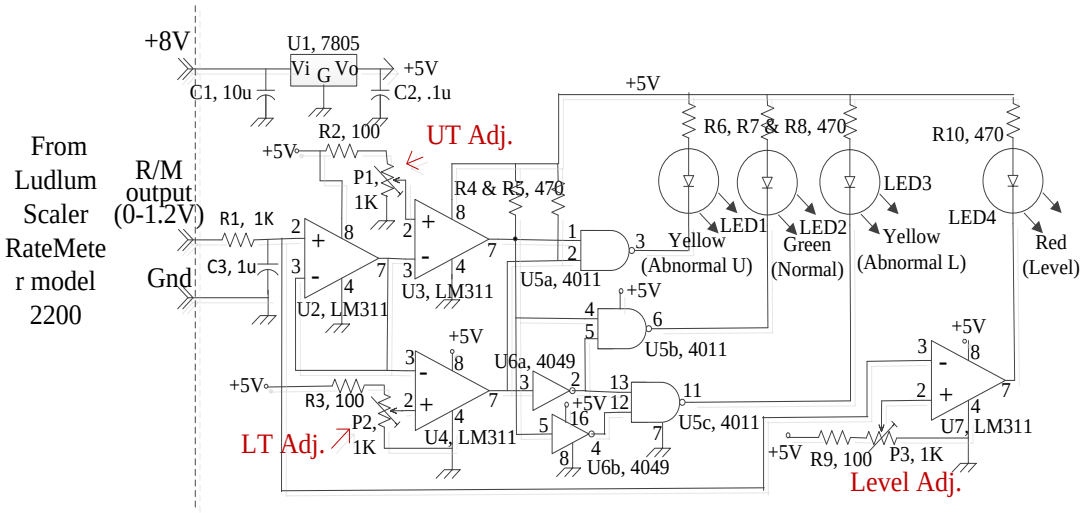

Fig. 2: A combined thickness and level gauges circuitry attached to Ludlum Scaler Ratemeter model 2200

CONCLUSION

In conclusion, this article shows that the designed circuitry for nucleonic thickness and level gauges can be connected to a nuclear scaler ratemeter of Ludlum model 2200 for on-site inspection of the container/ pipe conditions due to its portability and easy to use. Other model of similar scaler ratemeter can also be connected to this gadget if we are able to tap the signal of ratemeter output. For more convenient of usage and cheaper in fabrication, it is suggested to design a dedicated but simple complete circuitry that shall include the high voltage power supply and pre-amplifier for the detector and also its ratemeter plus the above gauges circuitries. It should be placed in one casing together with a handle to hold and to adjust the distance between the detector and the source in accordance to the inspected container/ pipe sizes [1].

REFERENCES

[1] IAEA. Technical data on nucleonic gauges. Volume 1459, *IAEA-TECDOC-1459*, July 2005.

[2] Jaafar, A. et al. PipeScanner, Columns and PolyScanner Brochures. Malaysian Nuclear Agency Report, 2010.

[3] IAEA. Radiation Protection and Safety of Radiation Source: International Basic Safety Standards, Interim Edition, Vienna, 2011.

[4] A. Akara, H. Baltas-b, U. C. Evikc, F. Korkmazb and N. T. O. lu. Measurement of attenuation coefficients for bone, muscle, fat and water at 140, 364 and 662 keV gamma-ray energies. *Journal of Quantitative Spectroscopy & Radiative Transfer*, 2006. Pp. 203–211.

[5] Bakar G., Rizal C., Rokiah S. and N. Kuksanov. Design of Radiation Shielding for 1 MeV, 50 mA ELV-type Accelerator at MINT (Nuclear Malaysia). 2006.

[6] Health Physics Society. Shielding Equation and Buildup Factors Explained. McLean, Virginia, 2000.

[7] B. Shapiro and A. Notea. Approximated total and full energy peak intrinsic efficiencies of gamma detectors for measuring systems design. *Nuclear Instruments and Methods*. Volume 228, Issues 2–3, 1 January 1985, pp. 496-505.

[8] Ludlum Measurements, Instruction Manual, Ludlum Model 2200 Scaler Ratemeter, Texas 2005, p. 40.

[9] Fairchild Semiconductor. LM311 Single Comparator Data Sheet. Rev. 1.0.1.

[10] A.D. Zigic. Preset time count ratemeter using adaptive digital signal processing. Nuclear Technology & Radiation Protection –1/2005. pp. 64-73.

[11] A.D. Zigic. Experimental verification of preset time count ratemeters based on adaptive digital signal processing algorithms. Nuclear Technology & Radiation Protection –2/2005. pp. 40-44.

[12] S.S. Kapoor and V. S. Ramamurthy. *Nuclear Radiation Detectors*. New Age International, New Delhi, 2008.