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FUEL LEVEL DETECTOR

by

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ABSTRACT

A gamma-sensitive scintillation detector was developed to measure the liquid fuel height in an aqueous homogeneous reactor from a location external to the reactor structure.

INTRODUCTION

At a late stage in the development of an aqueous homogeneous reactor, the desirability of providing a means for determining directly the height of the fuel solution in the reactor became apparent. The fabrication of components had proceeded to a point where it was impractical to consider any means of fuel level detection requiring modification of the reactor structure; for this reason, design and development of a scintillation gamma-ray detector which could be used to indicate the fuel height from a location external to the reactor was undertaken.

The design of the level detection instrument was based on earlier work by D. M. Holm, who developed a collimated scintillation detector for examining the spatial distribution of fission product activity in irradiated plutonium specimens.¹

DESCRIPTION

The fuel level detector consists of (1) a scintillation probe which observes the reactor system through a narrow horizontal slit in thick lead shielding, (2) the auxiliary equipment necessary to position the shielded probe and indicate its position ± 0.010 inch, and (3) the electronic equipment necessary to indicate quantitatively the activity in the volume of the reactor subtended by the slit system.

The level detector layout is shown in Fig. 1. The scintillation probe is contained in the scintillation probe shield, as indicated in greater detail in Fig. 2, and is raised and lowered inside a 10 inch steel casing mounted parallel, and in close proximity, to the reactor safety enclosure. Vertical movement of the probe is accomplished by the probe drive motor through a sprocket and chain system; the position of the probe is judged by the position-sensing synchro, which is geared to

¹D. M. Holm, "Scintillators with Collimators as a Diagnostic Tool," paper presented at the American Nuclear Society meeting, October 1957.

Fig. 1 Level Detector Layout (Elevation)

Fig. 2 Scintillation Level Detector Head Assembly

the drive system. Position is indicated by a digital counter on the motor control panel (Fig. 3). The circuit of the motor control and position-indicating systems is shown in Fig. 4.

The level detector may be used in either of two ways, depending upon the intensity of the radiation source present in the fuel solution:

1. At relatively low source intensities (as for instance, during reactor startup, when the fuel solution would be "spiked" with some short-lived radioactive substance) the scintillation probe is operated as a pulse counter, using conventional amplifiers, etc. (Fig. 5). The fuel level may be determined by plotting counting rate vs probe position. An example of such a plot is shown in Fig. 6; data were obtained using a solution containing 0.18 curie/liter of Ba^{140} - La^{140} mixture.
2. With higher source intensities (for instance, at reactor power of 50 kw and up), the gross current output of the photomultiplier may be monitored. Liquid levels are then found by plotting current vs probe position in the region where the current is a steep function of position. The reactor power must of course be held constant while taking the current vs probe position data.

Procedure for the pulse-counting operational mode is described below. Modification of the system to permit its use with d.c. signals will be made when reactor operation has progressed to sufficiently high power levels.

OPERATING PROCEDURE

The level detector system is operated from the level detector instrument rack (Fig. 7). Motion of the probe is produced by moving the toggle switch on the motor control panel to the "up" or the "down" position, and the probe location relative to the lower "index source" is displayed (directly in inches) on the digital counter. Fuel levels

Fig. 3 Motor Control Panel

Fig. 4 Fuel Level Detector Control System

Fig. 5 Pulse Counting System Schematic

Fig. 6 Level Detector Indication of the Location of the Surface of a Radioactive Liquid

POWER LEVEL
RECORDER

MOTOR CONTROL
PANEL

COUNT RATE
METER

SCALER

SINGLE
CHANNEL
ANALYZER

LINEAR
AMPLIFIER

Fig. 7 Level Detector Instrument Rack

are determined by scanning rapidly until a large change in signal is noted, whereupon a plot of counting rate vs position in the region where the change occurred is made. The level of the liquid is nominally considered to be at the height corresponding to the midpoint of the region in which a rapidly changing signal is observed.

Normal operating voltages for the probe are in the range of 600 to 1000 volts, depending on preamplifier and amplifier gains, and on the cable attenuation. Proper high voltage and gain settings can be selected by observing the amplifier output pulses on a calibrated oscilloscope and making adjustments so the height of the output pulses of interest does not exceed 100 volts. The output pulse spectrum should cover the range from zero to about 100 volts; under these conditions maximum resolution is obtained and it is easier to obtain optimum discriminator settings.

The proper scaler discriminator setting is determined by obtaining curves of detector counting rate vs discriminator setting both with and without a source present. A third curve, the ratio of the two discriminator curves, is approximately the signal-to-noise ratio, and the discriminator should be set to the value corresponding to the maximum of this curve. Under this operating condition all gamma rays more energetic than the value corresponding to the discriminator setting are counted. It may, at times, be desirable to observe the spatial distribution of the source of gamma rays of some specific energy. Use will then be made of the single-channel analyzer to observe pulses of the specified height.

Subsequent operation as a gross current monitor will be accomplished by placing a sensitive galvanometer in series with the probe and the high voltage supply.

SUMMARY

The detector described will determine the location of the free surface of a radioactive liquid, such as the fuel solution of a homogeneous reactor, with an accuracy greater than ± 0.050 inch. It is

estimated that small changes in level can be detected and measured with an accuracy of ± 0.010 inch. Minor changes in the equipment permit its use with activity levels ranging from about 0.2 curie/liter of fuel to that corresponding to 50 kw reactor operation.