

CHAPTER 4: NUCLEAR INSTRUMENTATION

MODULE 3: LINEAR RANGE DETECTORS

Introduction

Although ion chambers are very accurate neutron detectors, their relatively large size and delicate construction make them impractical to be used to detect flux distribution inside the reactor. For this purpose, simple and relatively inexpensive in-core detectors have been developed.

These in-core detectors (ICD) are self powered devices which produce a current signal proportional to the fission rate within the reactor.

This detector is selected for use over the last decade of flux to provide a linear measurement signal from approximately 10% to 100% FP.

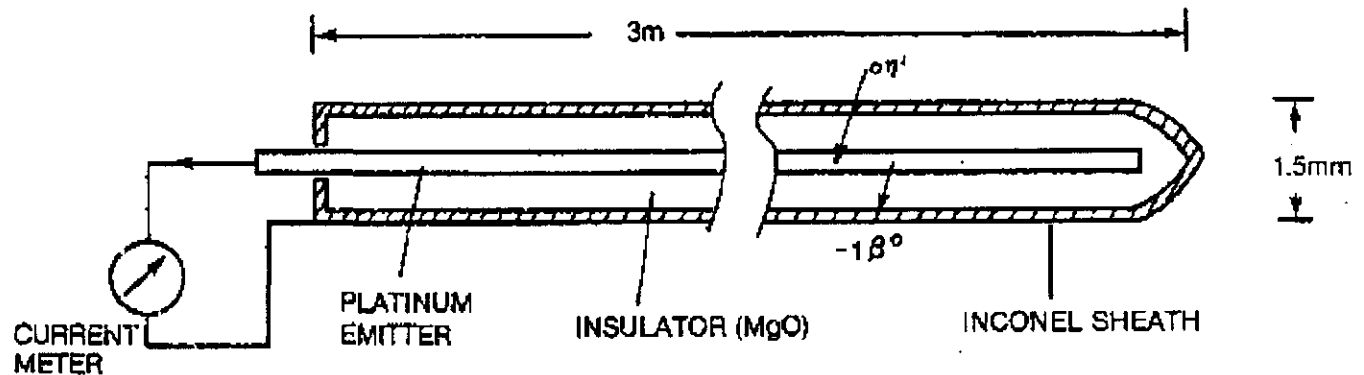


Figure 1: Simplified In-Core Detector Construction.

The in-core or Hilborn detector, as it is often referred to, consists of :

- an Inconel outer sheath
- an inner emitter wire, separated by a layer of insulation (usually magnesium oxide, MgO).
- Various materials can be used for the emitter wire, the most common being vanadium and platinum.

Operation of an In-core Detector

- When a thermal neutron is absorbed by the emitter, an energetic electron is released which has enough energy to exceed the dielectric strength of the insulator.
- The electron migrates to the collector producing a net positive charge on the emitter.
- The potential difference which exists between the emitter and collector will allow a current flow through a connected external circuit.
- A current of approximately one micro-amp will flow at 100% FP
- It should be noted that some types of ICD's are gamma sensitive which will affect readings considerably at low power levels where fission gammas are predominant.

When considering the operation and performance of in-core detectors most problems are caused (from an operational viewpoint) from a rapid change of source conditions. The principal sources of output current are as follows:

- (a) Beta emission following neutron capture by the emitter (neutron activation).
- (b) Beta emission resulting from neutron activation of detector hardware.
- (c) Compton and photo electrons produced by neutron capture gamma rays from the emitter (n, γ reaction).
- (d) Compton and photo electrons produced by gamma ray sources external to the detector.

Location in the Core

- In a 500 MW CANDU reactor the Hilborn detectors are wound on a zircalloy guide tube over a vertical distance of 55 cm and are located two per zone to provide a total of 28 ICD's for the RRS.
- The incore detectors generate a low-level current signal that must be amplified and converted into a voltage. This voltage is then fed into the control computer multiplexers to be input to the RRS.

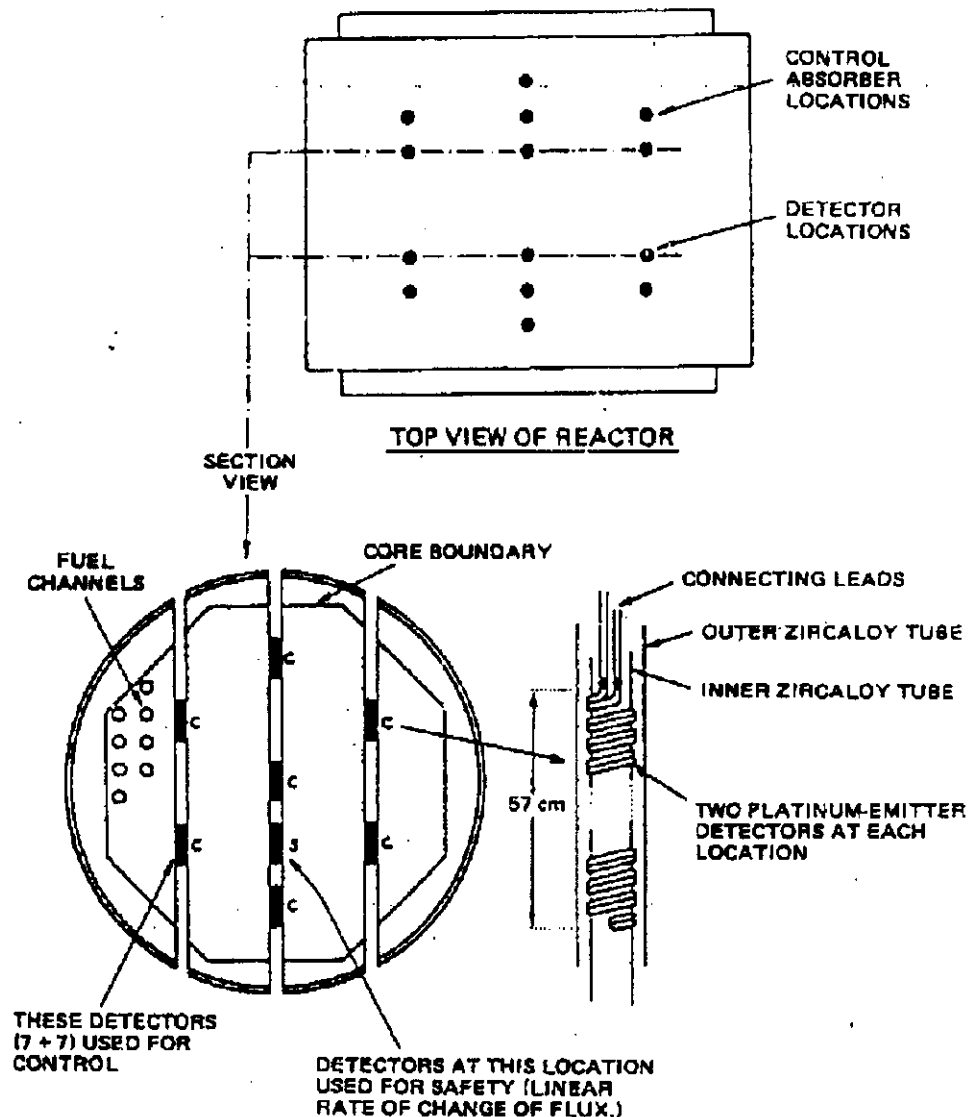


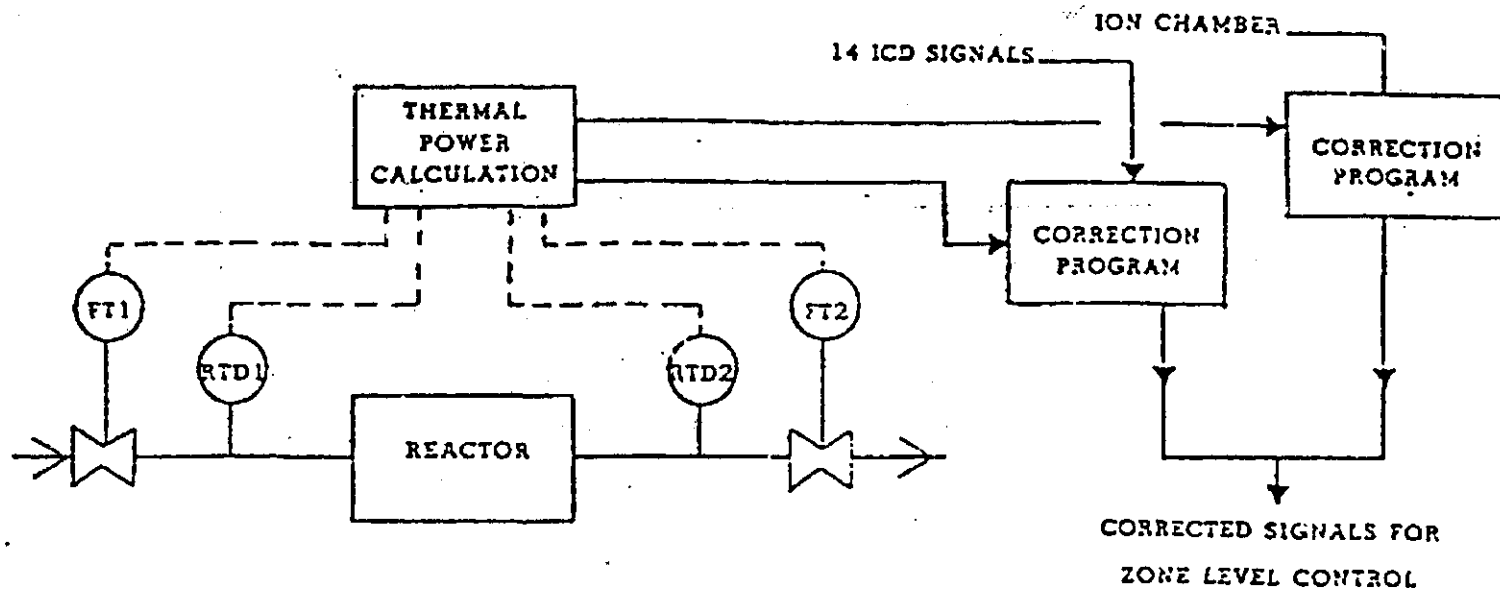
Figure 2: In-Core Flux Detectors (500MW CANDU).

Detector Calibration

- It is not possible to use a thermal power measurement as a means of reactor control due to the lags (≈ 25 seconds) existing between changes in neutron flux levels and the sensing of the associated temperature change at the reactor outlet headers.
- Temperature control is inherently slow and cannot be used as a practical method of reactor control.
- At low power, the decay heat from fission products effectively masks small changes in heat output due to changes in neutron flux.
- Measurements of neutron flux are prompt and wide ranging but it is important to establish the correct relationship between neutron flux levels and thermal output. For incore detectors, this correlation is achieved by taking measurements of reactor thermal power output.

Thermal Power Measurement

- 22 fuel channels are fully instrumented with flow and temperature sensing devices. The power produced in these channels (proportional to flow and ΔT) when calculated can be averaged and when multiplied by the total number of channels will provide an accurate figure for total reactor thermal power.
- ICD's also require calibration because they suffer burn-up under irradiation, although, with the use of platinum emitter detectors, this is a relatively minor factor being limited to approximately 1% per year. In addition ICD's are only 80 - 88% prompt when responding to a change in flux level.
- At stations where partial boiling is permitted in some channels the channel power is not directly proportional to mass flow and to ΔT . For these channels we need to know the proportion of steam. This is determined by using venturis on both ends of the channel to measure volume flows at the inlet and outlet.



(NOTE: 2 FLOW TRANSMITTERS REQUIRED AT ENGS-A FOR QUALITY CALCULATION)

Figure 3: Thermal Power Correction.