

ICENES 2007

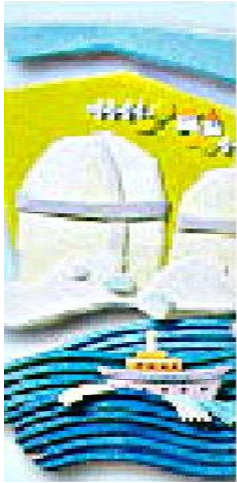
Sensory Systems for a Control Rod Position using Reed Switches for the Integral Reactor

2007. 6. 5

JE-YONG YU

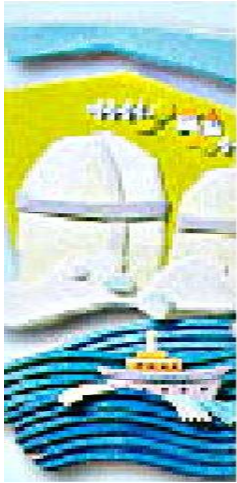


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 - Permanent magnet with MFC
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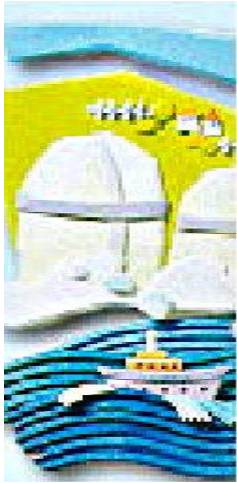
Introduction

■ Background

- Integral reactor under development at KAERI
- Operation requirements of integral reactor
 - Soluble boron free operation
 - Use of nuclear heating for reactor start-up
 - Development of CEDM with fine-step movement capability for fine reactivity control
 - Needs to measure control rod position

■ Objectives

- Development of PI and APD
 - Design of magnetic field concentrator (MFC)
 - Selection and arrangement of reed switches
 - Design of magnification device for angular position detector
 - Design of electrical circuit for output signal

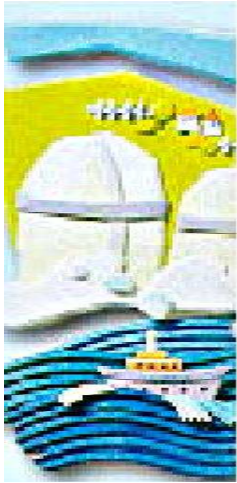


System Description

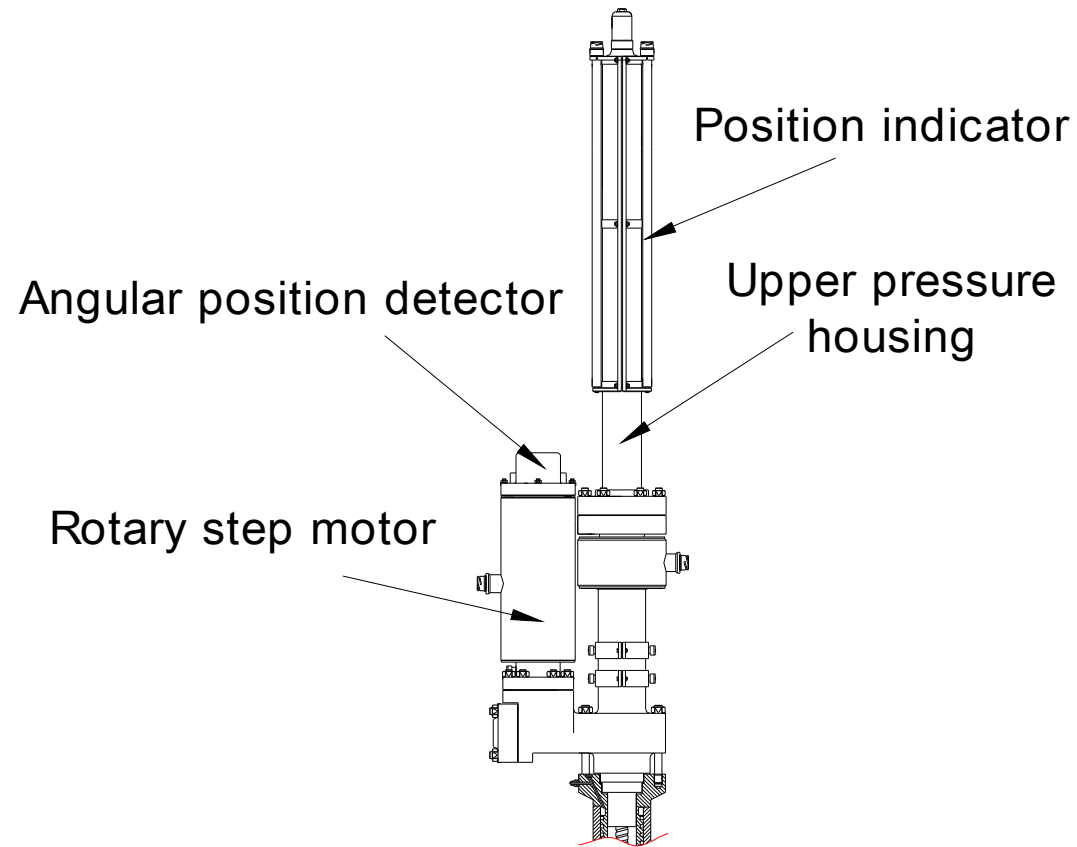
- **Control Element Drive Mechanism (CEDM)**
 - Raise and lower CEA
 - Ballscrew type mechanism driven by step motor

- **Position Indicator (PI)**
 - 4 channels, resolution : 20mm
 - Using reed switches and permanent magnet

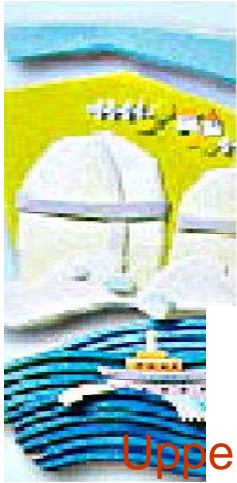
- **Angular Position Detector (APD)**
 - 2 channels, resolution : 0.25mm
 - Using reed switches and permanent magnet



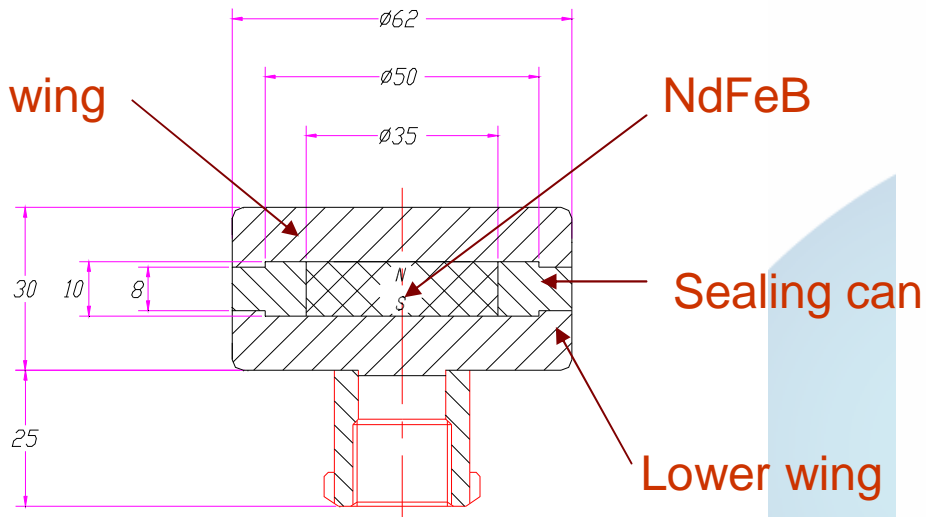
Overall View



Permanent Magnet with MFC



Upper wing

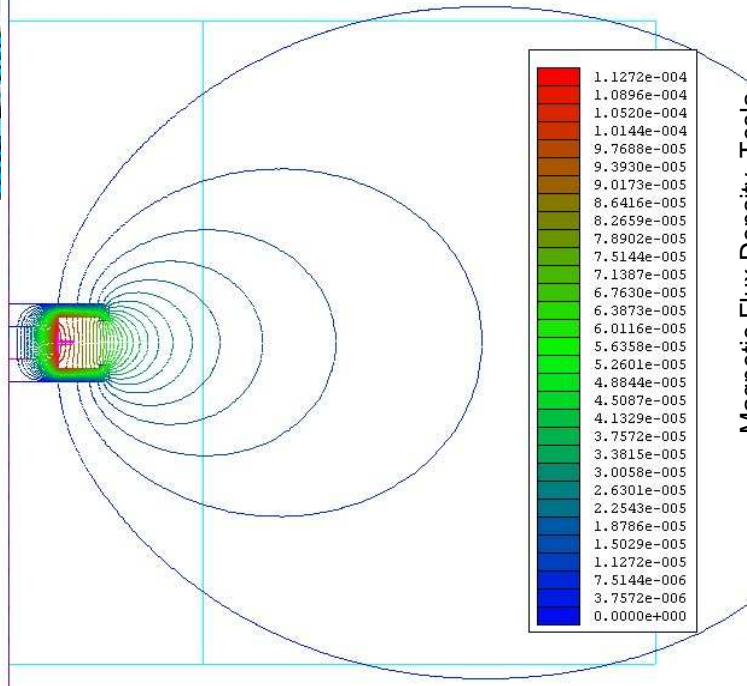


Permanent magnet assembly with MFC of Rev.01

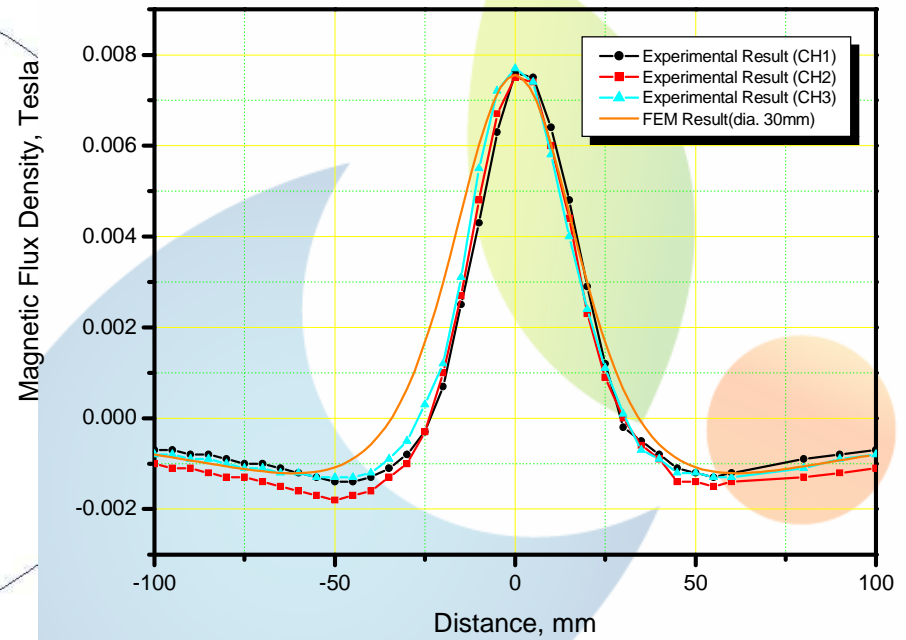


Permanent magnet assembly with MFC of Rev.00

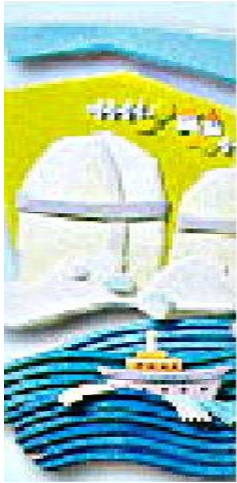
Magnetic Analysis



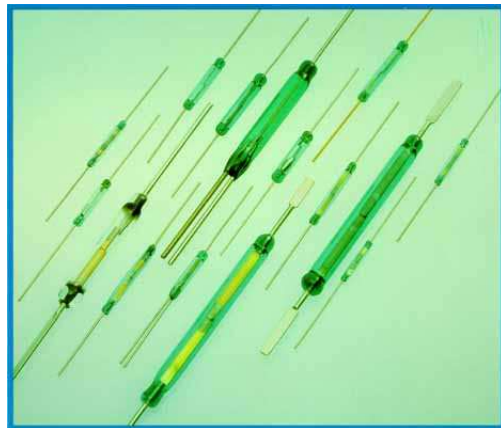
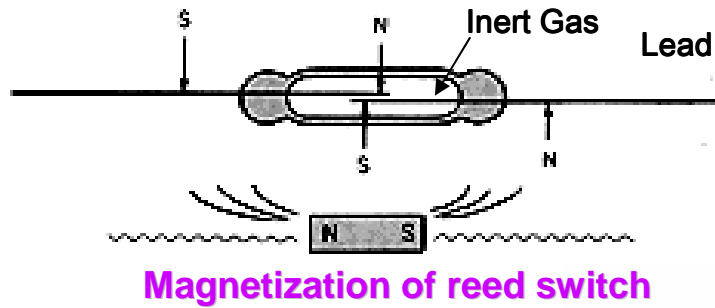
Distribution of magnetic flux density of magnetic flux concentrator



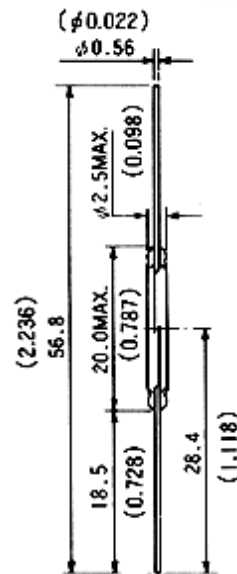
Experimental results of magnetic flux concentrator



Reed Switch

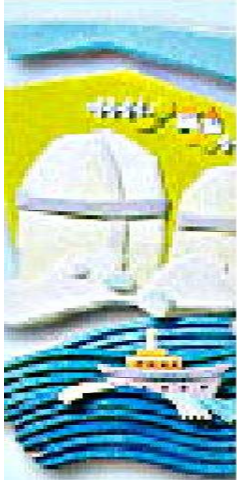


**Dimensions of reed switch
HYR-2001(Type3)**

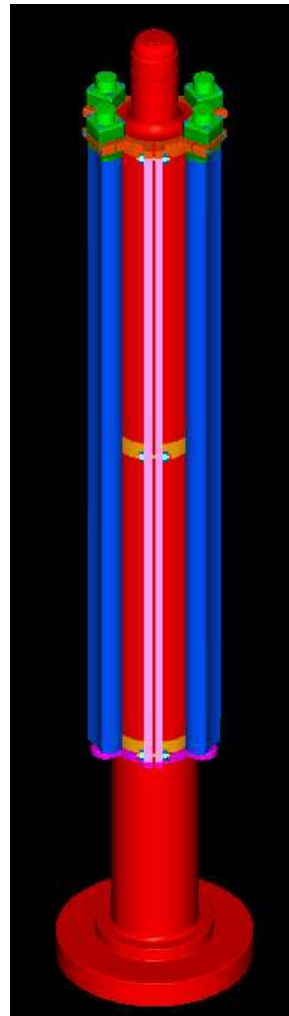


Characteristics of the reed switch HYR-2001 (Type3)

| | |
|-----------------------------------|---|
| Contact Material | Rhodium |
| Max. Contact Rating | 10W |
| Max. Switching Voltage | 200VDC |
| Max. Switching current | 0.5A |
| Max. Initial Contact Resistance | 100 mohms |
| Pull in Value (AT) | 40-45 |
| Min. Drop out Value (AT) | 6 |
| Min. Breakdown Voltage | 300 VDC |
| Max. Contact Capacitance | 0.4pF |
| Min. Insulation Resistance | 10 ¹⁰ ohms |
| Typ. Resonant Frequency | 3kHz |
| Electrical Life (Resistive loads) | 10 ⁷ (5VDC, 10mA) 10 ⁶ (100VDC, 100mA) |
| Test Coil | TC-0502 |
| Features | General application |

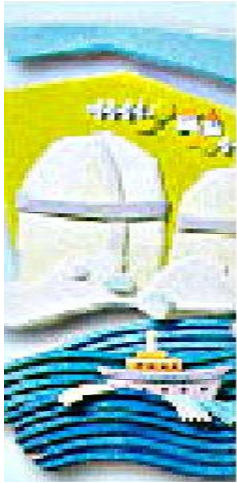


3D Model of Position Indicator

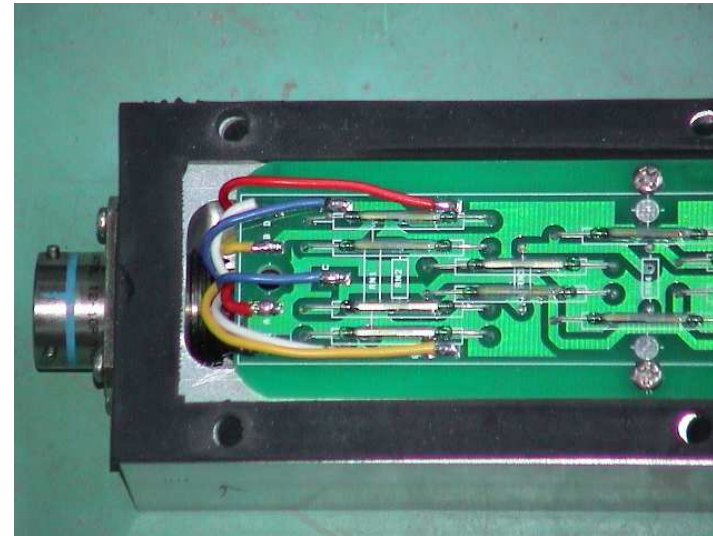
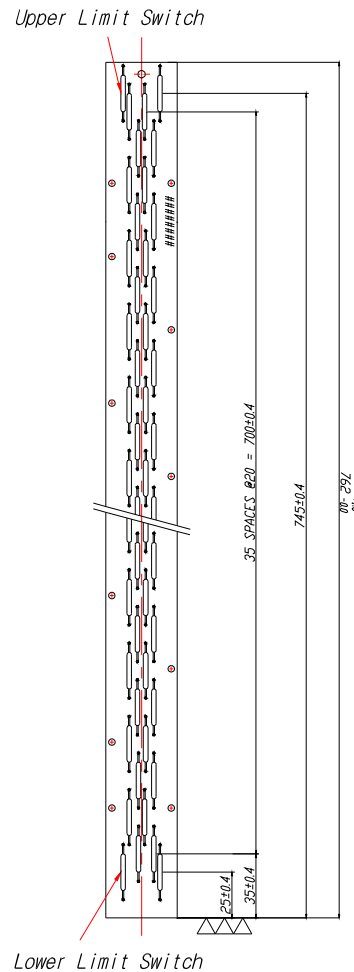


- Check of interference between each component before manufacture
- Check of configuration
- Check of fabricability

Using I-DEAS Program

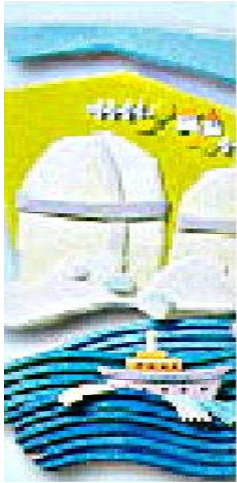


Arrangement of Reed Switches

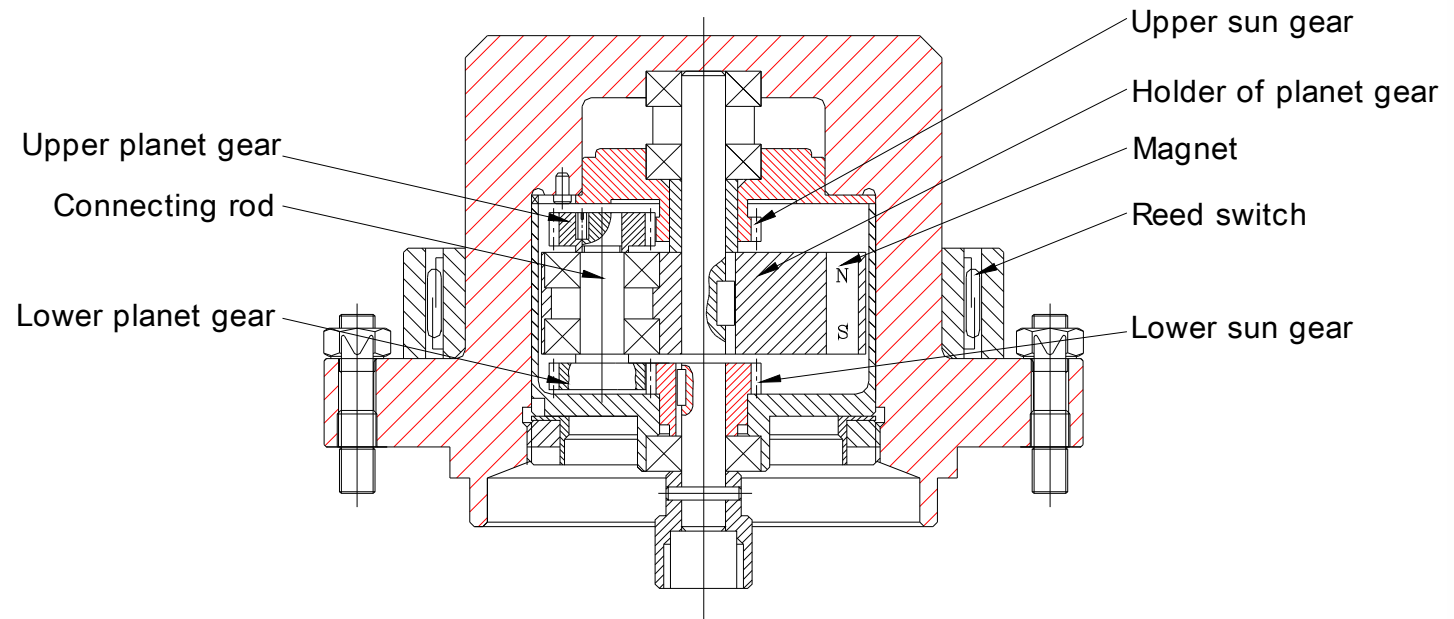


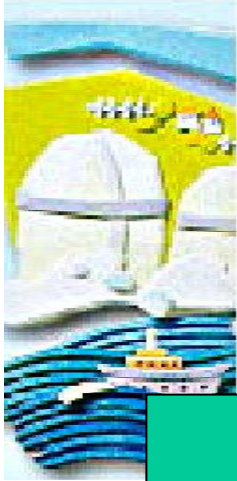
Compact arrangement

- Serially wired two reed switches are located every 20mm
- Range :
0 step (0mm) - 34th step (680mm)
- Precise resistors are behind terminal strip



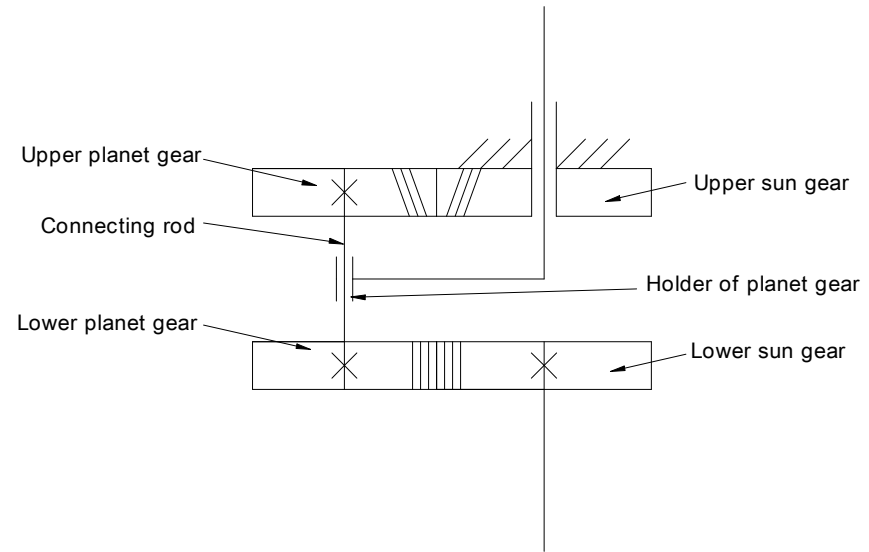
Overall view of APD





Planetary Gear System

$$i = \frac{Z_2 \cdot Z_4}{Z_2 \cdot Z_4 - Z_1 \cdot Z_3}$$



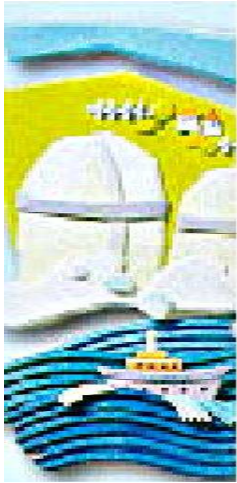
i : Magnification ratio (8)

Z_1 : Number of tooth of upper sun gear (30)

Z_2 : Number of tooth of upper planet gear (25)

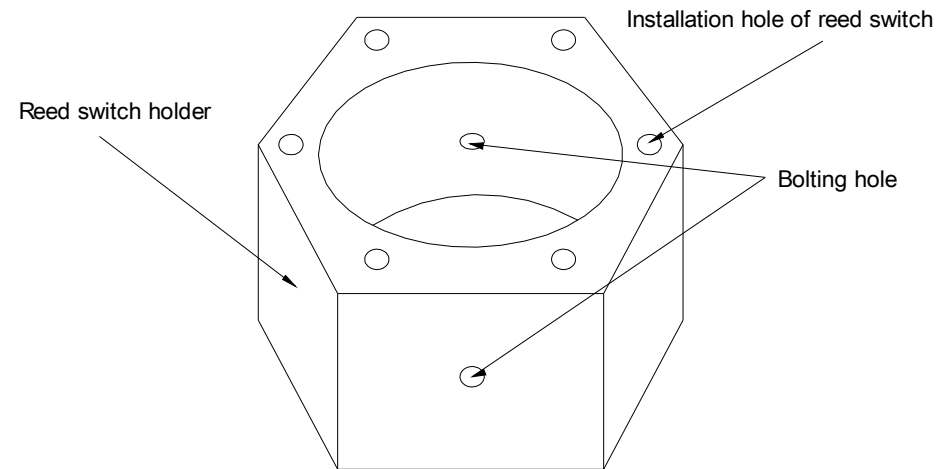
Z_3 : Number of tooth of lower planet gear (30)

Z_4 : Number of tooth of lower sun gear (32)

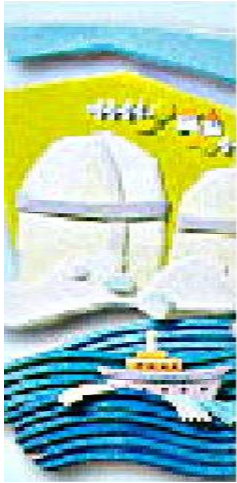


Reed Switches Holder in APD

- ✓ Easy installation
- ✓ Easy maintenance
- ✓ Easy calibration
- ✓ Vertical mount on APD

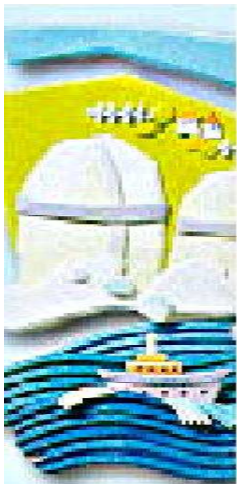


Performance Test of PI

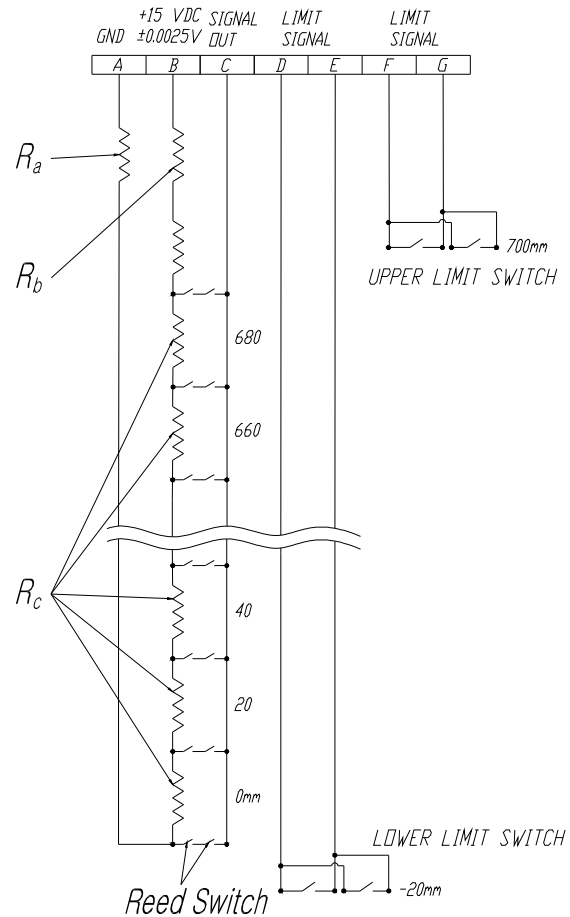


Photograph of upper pressure housing assembly and position indicator assembly





Voltage Divider Network



$$V_o = \frac{R_a + R_c \times SN}{R_a + R_b + 35 \times R_c} \cdot V_{in}$$

where

V_{in} : Applied Voltage (15VDC)

V_o : Output Voltage

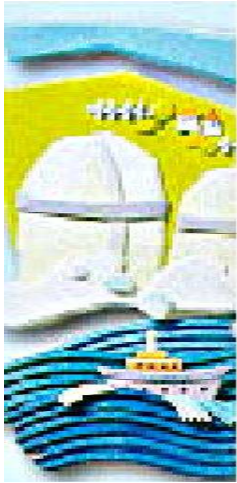
R_a : Resistor (600 Ω)

R_b : Resistor (1000 Ω)

R_c : Resistor (40 Ω)

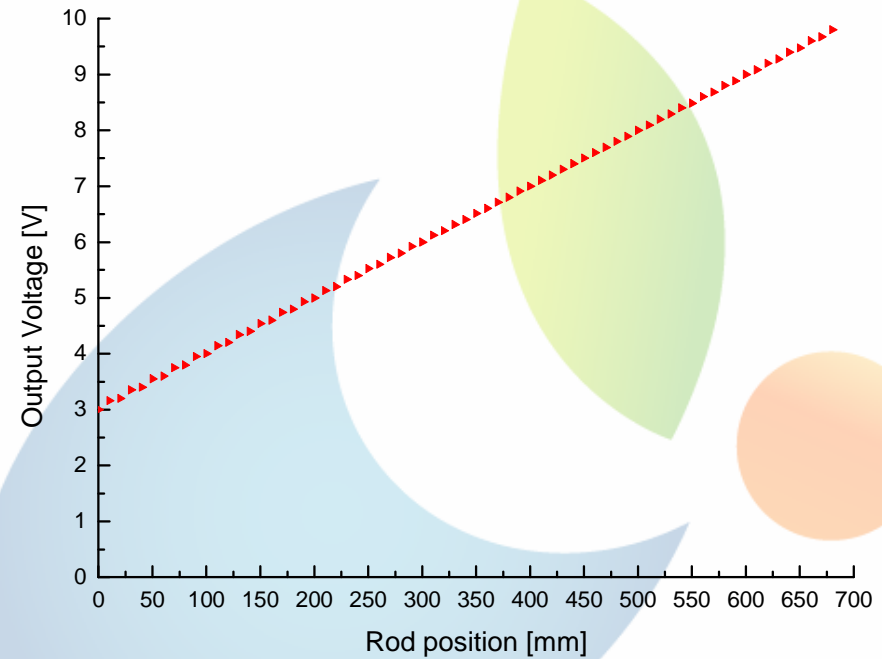
SN : Steps Number of Reed Switches

- Step-wise analog output signal :
3 VDC - 9.8 VDC
- Increment : 0.2 VDC

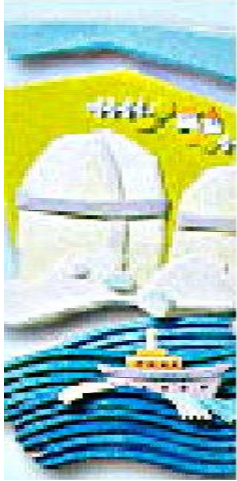


Calculation Results of Output Signal

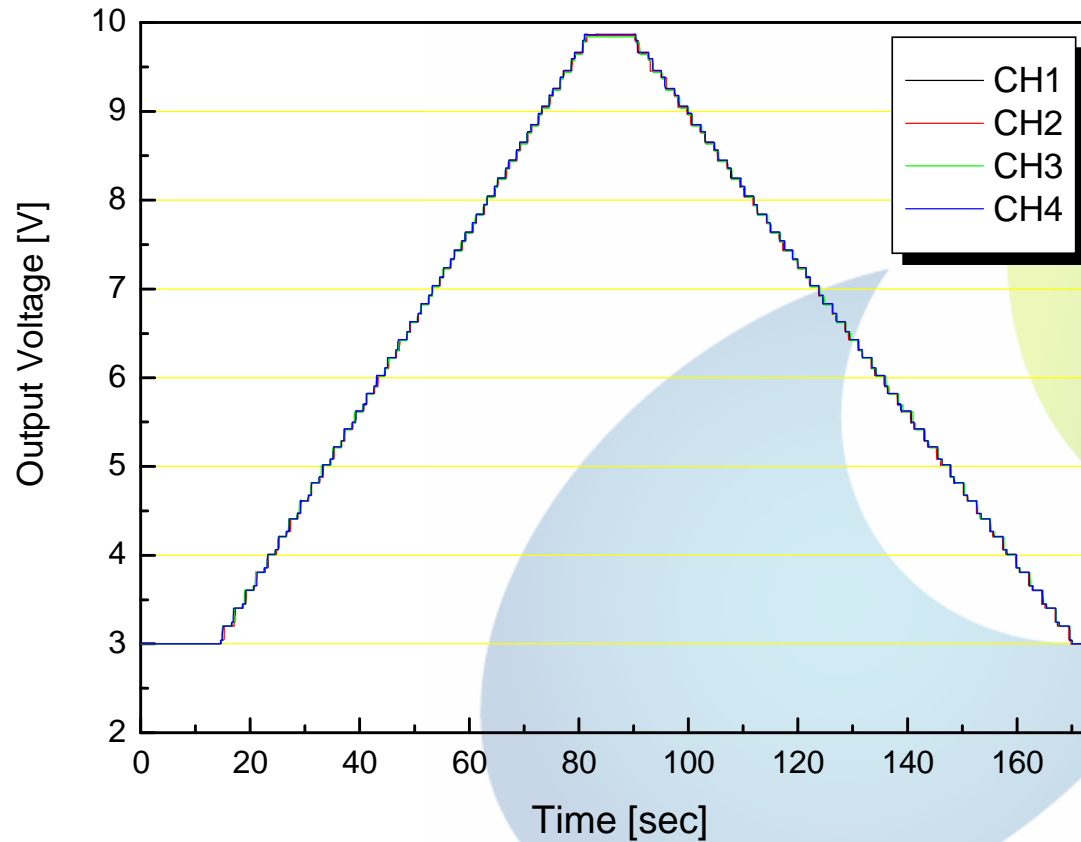
| Rod Position (mm) | Voltage (V) | Rod Position (mm) | Voltage (V) |
|-------------------|-------------|-------------------|-------------|
| 0 | 3 | 360 | 6.6 |
| | 3.0405 | | 6.6892 |
| 20 | 3.2 | 380 | 6.8 |
| | 3.2432 | | 6.8919 |
| 40 | 3.4 | 400 | 7 |
| | 3.4459 | | 7.0946 |
| 60 | 3.6 | 420 | 7.2 |
| | 3.6486 | | 7.2973 |
| 80 | 3.8 | 440 | 7.4 |
| | 3.8514 | | 7.5000 |
| 100 | 4 | 460 | 7.6 |
| | 4.0541 | | 7.7027 |
| 120 | 4.2 | 480 | 7.8 |
| | 4.2568 | | 7.9054 |
| 140 | 4.4 | 500 | 8 |
| | 4.4595 | | 8.1081 |
| 160 | 4.6 | 520 | 8.2 |
| | 4.6622 | | 8.3108 |
| 180 | 4.8 | 540 | 8.4 |
| | 4.8649 | | 8.5135 |
| 200 | 5 | 560 | 8.6 |
| | 5.0676 | | 8.7162 |
| 220 | 5.2 | 580 | 8.8 |
| | 5.2703 | | 8.9189 |
| 240 | 5.4 | 600 | 9 |
| | 5.4730 | | 9.1216 |
| 260 | 5.6 | 620 | 9.2 |
| | 5.6757 | | 9.3243 |
| 280 | 5.8 | 640 | 9.4 |
| | 5.8784 | | 9.5270 |
| 300 | 6 | 660 | 9.6 |
| | 6.0811 | | 9.7297 |
| 320 | 6.2 | 680 | 9.8 |
| | 6.2838 | | |
| 340 | 6.4 | | |
| | 6.4865 | | |

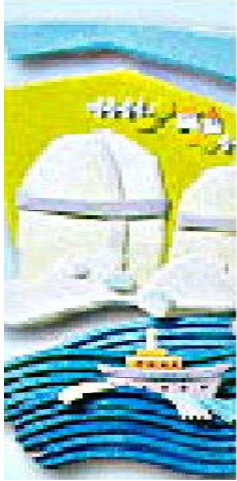


Output signal distribution from calculation



Experimental Results





Conclusion

- We have experience in all design processes related to position indicator
- Development of magnetic field concentrator (MFC)
- New arrangement of reed switches for position indicator
- Confirmation of performance of position indicator by magnetic analysis and experiments
- Conceptual design of angular position detector was carried out.
- Two sensory system can be effectively applied to integral reactor
- Environmental test of sensors should be carried out before application to integral reactor