Recent I&C Improvements at the Missouri S&T Reactor

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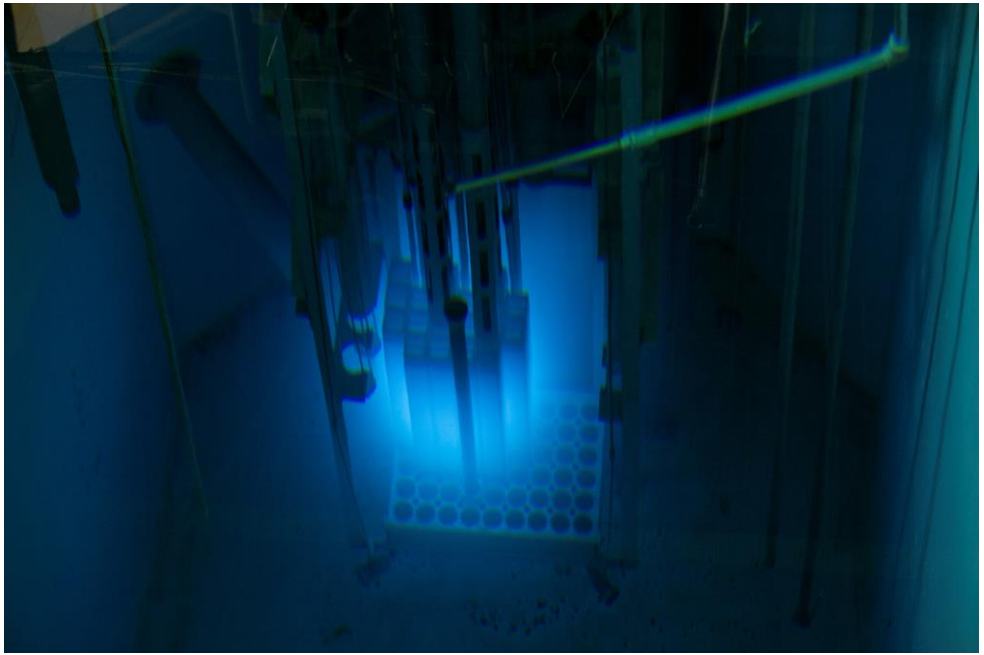
TRTR-IGORR 2023 Conference

About the MSTR

The Reactor

- 200 kW pool-type
- Fuel
  - MTR-type
  - Silicide (U_3Si_2-Al)
  - Curved plate
  - 19.75% U-235
- Variable core configurations



About the MSTR

The Facility

- **Training, Research,** and **Education** facility
- Part of Missouri S&T's Department of **Nuclear Engineering and Radiation Science (NERS)** and **College of Engineering and Computing (CEC)**
- **First** reactor in the State of Missouri (1961, R-79).
- **~1,000** visitors per year.

About the MSTR

The Staff

- Primarily a **student-operated** facility.
  - Very active student operator training program (10-40 students)
- One full-time employee (Reactor Manager)
- Second full-time employee (Reactor Engineer) hired* October 2022
- **SRO:** 1-4 (1 as of Summer 2023)
- **RO:** 5-10
- **Student Assistants:** 1-4

Instrumentation and Controls of the MSTR

As of 2018

- 5 NI Channels
  - 2 Safety (Linear, UIC)
  - Startup (Log, FC)
  - Linear (Scaled, CIC)
  - Log and Linear (CIC)
- PLC-based Control System
- Relay-based Safety System

Instrumentation and Controls of the MSTR

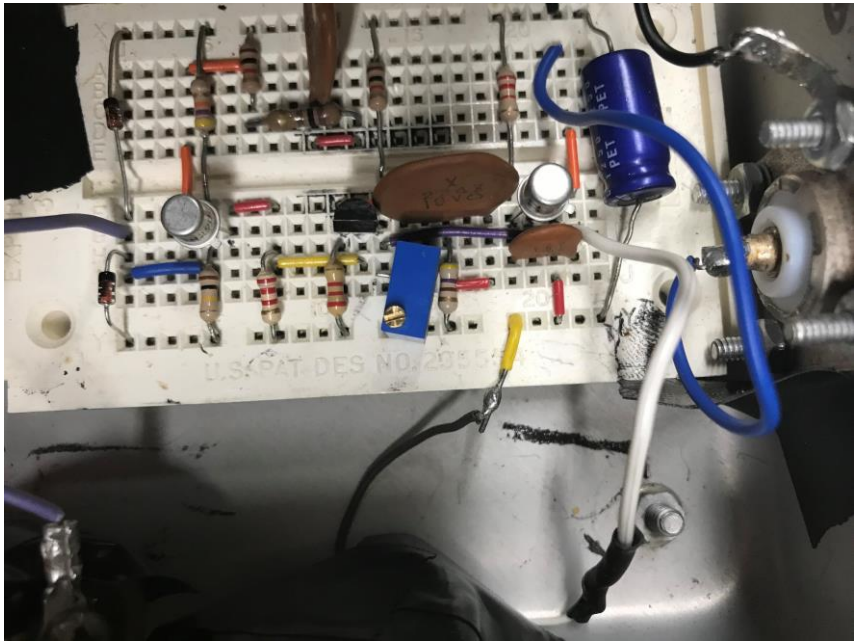
As of Today

- "New" Linear Channel signal processing drawer
- All digital recorders
- Control system modifications
  - Refactored ladder logic
  - Inter-PLC communications simplified
  - Dense I/O

Startup Channel Preamplifier

As Found

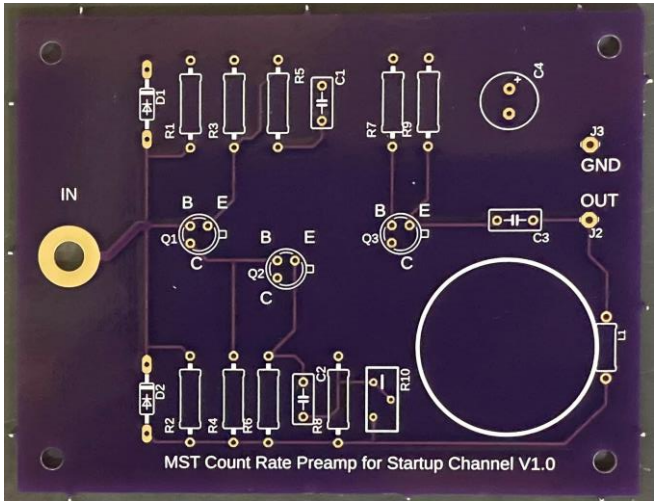
- Original (from GA) was rebuilt numerous times
- Design implemented in 2014
- Breadboard
  - Loose connections
  - Contact corrosion/oxidation



Startup Channel Preamplifier

Modification Process

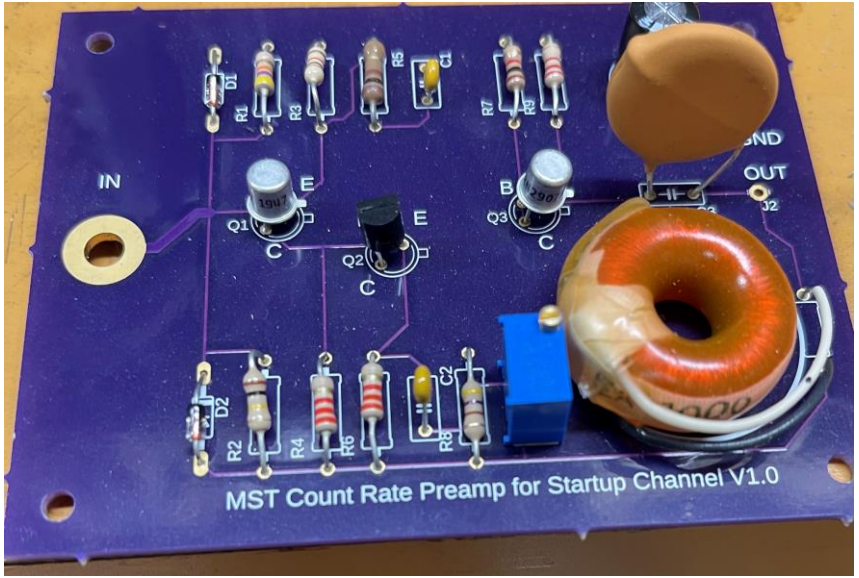
- Re-use 2014 design
  - Import to ECAD
  - Establish BOM
- Find suitable US PCB maker
- Get new components
- Treated as “Like-for-like”



Startup Channel Preamplifier

Modification Process (Cont.)

- Assemble in house
  - Need to establish good procedures
  - Solder, flux, and cleaning
  - Lead length and consistency
- Install
  - Reuse existing enclosure
  - 3D printed mount
- Test and Calibration



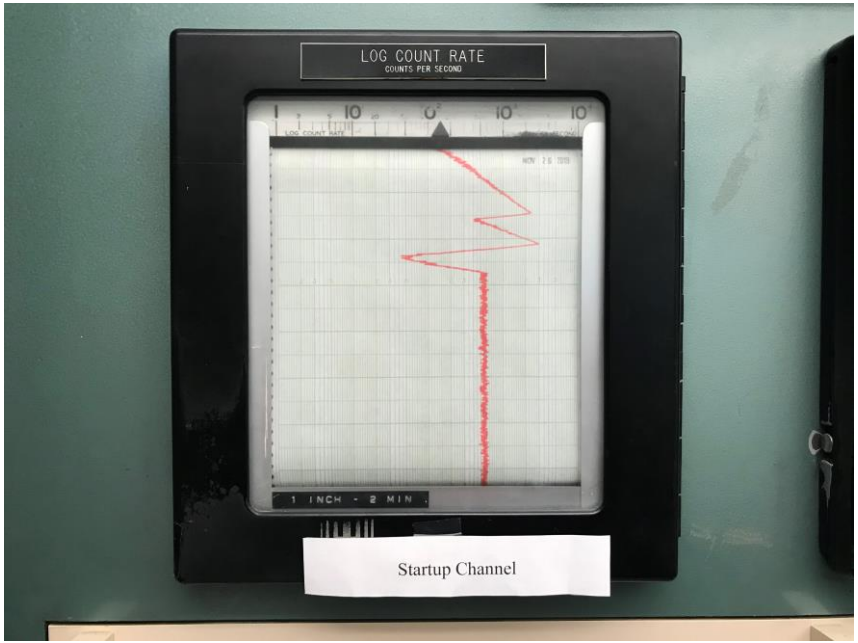
Startup Channel Preamplifier

Lessons Learned

- Use new enclosure
  - Better control over bulkhead connectors
  - Better control over grounding
- Should have incorporated HV components into design
  - Original HV resistors and capacitors soldered to enclosure
  - Would eliminate weak connection
- Assign serial numbers to new/manufactured components

Startup Channel Recorder

Historical Aspects



- Trace relied upon for startup (over drawer)
- Plant original
  - Vacuum Tube-based
  - Only four decades of range
  - Input: 0-10 mV
- Paper and Marker
  - $50/roll (up to $110 as of June 2023)
  - 33 hours of runtime

Startup Channel Recorder

Impetus and Modification

- Ran out of paper in February 2022
  - Very long production timeline from US vendor (NET April)
  - Right before first commercial project in over a decade
- Significant work already towards project (academic break was original target)
- Yokogawa DX2000 on-hand
  - Needed watchdog and math modules
  - Capture Startup (log count rate) and Log N Power signals
  - 8 decades (inner 5 for LCR)
- 10 CFR 50.59
  - Non-safety-related
  - Screened-in (MSTR digital)
  - Evaluation, Committee Review

Startup Channel Recorder

Modification Process

- Startup Channel Drawer
  - Already internal 0-10 VDC signal for log count rate
  - Installed signal conditioner
  - Calibration “de-skewed”
- Rod Withdrawal Prohibits
  - Recorder Off (fail and stop)
  - <2 CPS
- Log and Linear Recorder
  - Pull leads for Log Power
- Reactor Control System
  - HMI Cleanup
  - Calibration Screen
  - Interlock logic

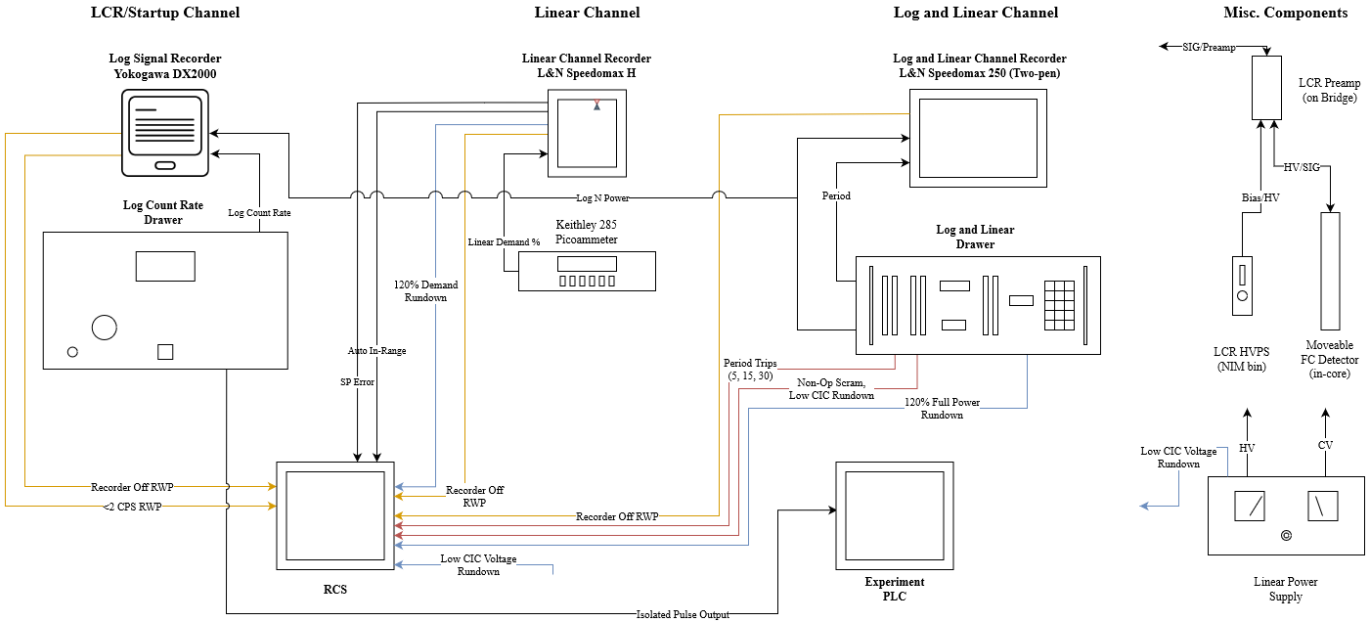
Startup Channel Recorder

Lessons Learned

- Old wire stock
  - During testing, break in connection for interlock
  - Spare wires in bundle
- Drawer circuit protection
  - Only signal processing side of drawer was fused
  - Later installed fast breaker

Linear Channel and Recorders

NI Pre-modification



Linear Channel and Recorders

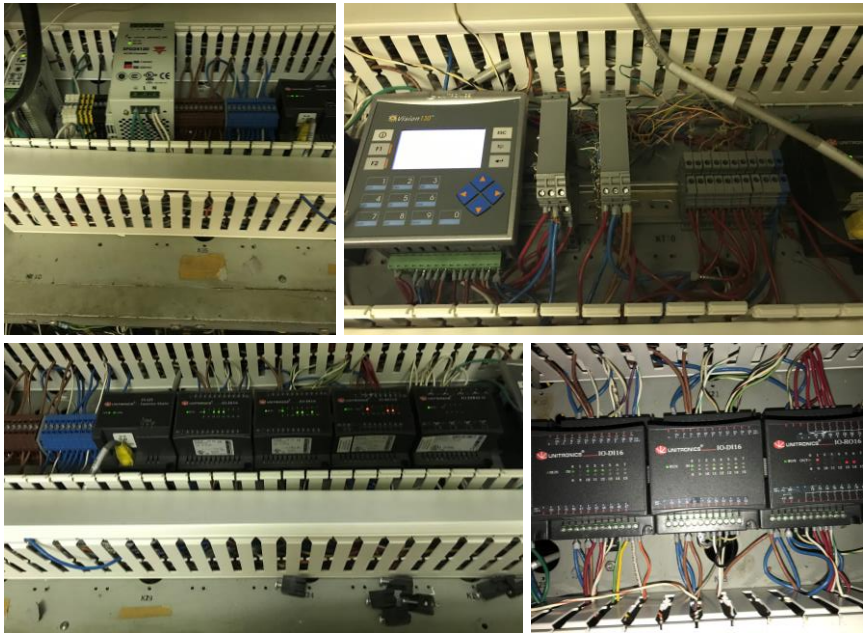
Old Linear Equipment

- Keithley 485 Picoammeter
  - Inverted ± 2 VDC signal output
  - Very noisy range switching
- Curtiss-Wright CIC power supply
  - Repaired but effectively original
  - Vacuum tube-based
- Recorder (L&N)
  - Original, vacuum tube-based
  - 0-10 mV
  - “Inject” test signals by manually repositioning cam
  - Autocontrol setpoint and error signal

Linear Channel and Recorder

Reactor Control System

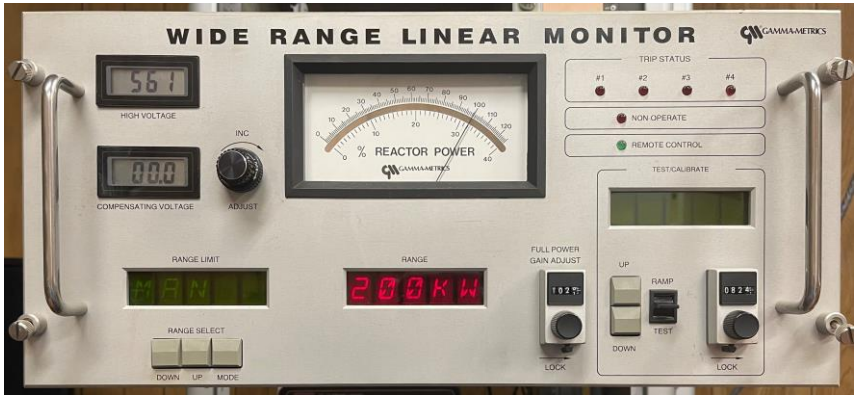
- Wiring
  - Almost no color standardization or labeling
  - Poor practices in ferrule use
  - AC and DC adjacent (noise)
- I/O Modules
  - Sparse/low density
- Ladder logic



Linear Channel and Recorders

Signal Processing Drawer

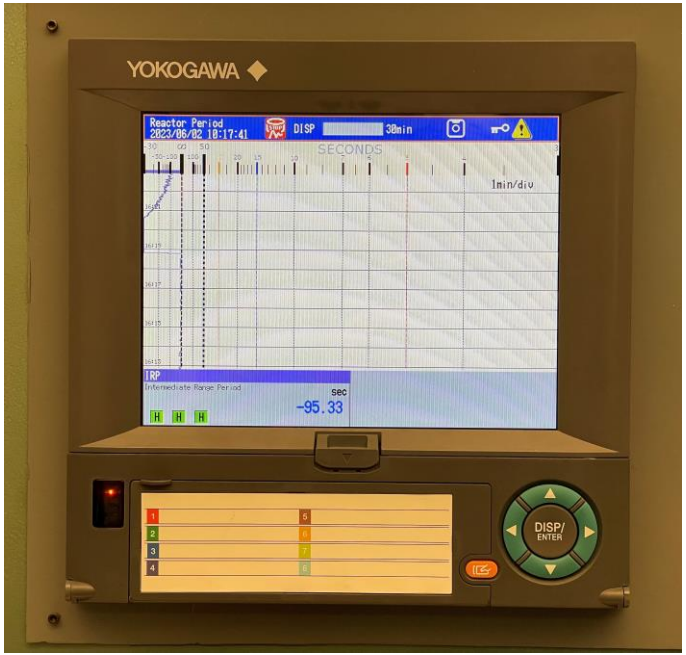
- Gamma-Metrics built 1992 (2002 refresh)
- Substantial testing in 1990s
- Only ever used as temporary CIC power
- Internal trips and test signals
- Servo control and interface (currently unused)
- Isolated analog outputs



Linear Channel and Recorders

Recorders

- Yokogawa DX2000s on-hand
  - Yes, more of them
  - Also needed watchdog and math modules
  - 125 ms record interval (25 ms)
- Period
  - Native trace 0-10 VDC
  - Custom display and sightlines
  - Calculate period



Linear Channel and Recorders

Recorders

- Linear
  - 0-10 VDC: 0-125%
  - Capture Linear Demand (scaled)
  - Capture Linear Power
  - Process 0-40% and 0-125% switching

Linear Channel and Recorders

Improved Reactor Control System

Linear Channel and Recorders

Improved Reactor Control System

Linear Channel and Recorders

Lessons Learned

- Lack of vendor/manufacturer support is tough
  - Initial support for testing picoammeter board (leakage currents)
  - No support for “remote control” functions
- Unused equipment still ages
  - Switch-mode power supplies (Linear Channel CIC boards)
- Very big project for MSTR
  - Staffing limitations
  - Tight budget (excluding original equipment purchases, ~$4k)

Linear Channel and Recorders

Lessons Learned

- Transferring PID control between different systems can be challenging
- Sometimes you have to rip off the band-aids
  - Technical debt does not stop accumulating and it accrues interest
  - Patches and repairs can impede replacements
- Drawings lie
  - NC wiring to annunciator panel was missed on several revisions
  - Field inspection and tracing is the only real way to check

Linear Channel and Recorders

Lessons Learned

- Electronically-available data is great
  - Improved power calibrations
  - Alternate rod worth determination methods (inverse kinetics) and boost previous approaches
  - Expanded physics measurements (recent oscillator experiments)
- Staffing is now biggest limitation to operating hours

Acknowledgements

- Missouri S&T
  - Reactor Operators and Staff
  - Mines and Metallurgy Academy
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  - DE-PS07-91ER13058
  - DE-NE0000463
- TRTR
  - USGS
  - UMD

Questions

Extra Slides

Reactor Staff

Next Steps

Startup Channel/Wide Range

- Gamma-Metrics Wide Range
- Purchased 1992
- Significant testing in 1990s
- Failed preamp, plasma displays
- No Thermo Fisher support, but Paragon?
- Do we just abandon?

Next Steps

Synchronization and Timing

- Existing system
  - Residential alarm clock
  - No DST support, battery backup
- Masterclock GMR5000
  - Can be Stratum 1
  - Sync all datastreams
  - Experiment timing support
- Network/switching install

Next Steps

Other Projects

Pool Height Measurement

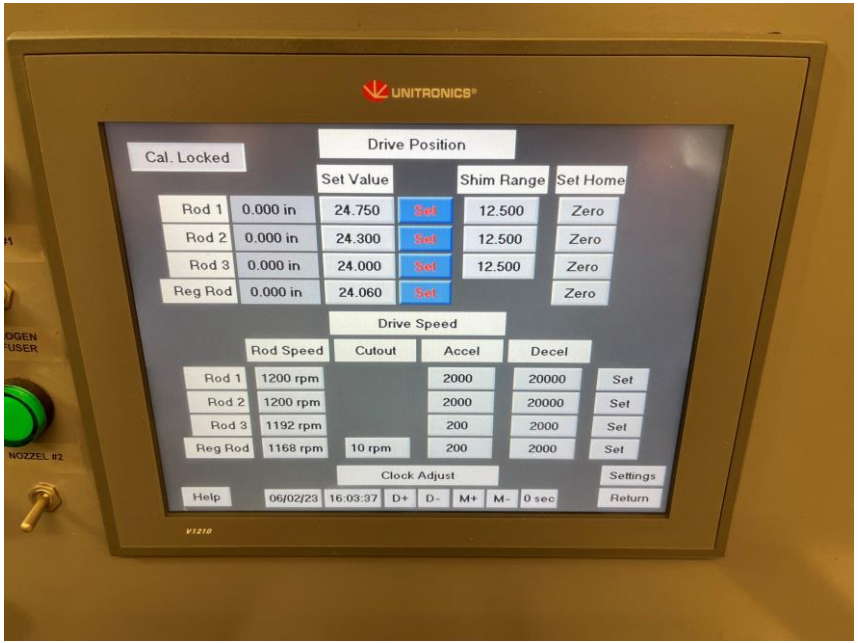
- Current approach
  - Measuring stick mounted to skimmer
  - Power calibration uses dial indicators and floats
- Next system?
  - High-precision ultrasonic
  - Realtime data -> recorders

Bridge Accelerometer

- No current system
- Rod drop time tests
  - Conducted using microphone and significant amount of setup
  - Accelerometer could report impact to PLC

Linear Channel and Recorders

Improved Reactor Control System



Linear Channel and Recorders

Improved Reactor Control System