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Upgrade of Instrumentation for Purdue Reactor PUR-1

Final Report – 07/01/1999 – 06/30/2000

**S. T. Revankar
E. Merritt
R. Bean**

August 2000

Work Performed Under Contract No. DE-FG07-99ID13799

**For
U.S. Department of Energy
Assistant Secretary for
Energy Efficiency and Renewable Energy
Washington, DC**

**By
Purdue University
West Lafayette, IN**

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Final Report
(July, 1999 to June, 2000)

S. T. Revankar, E. Merritt and R. Bean

PURDUE UNIVERSITY
SCHOOL OF NUCLEAR ENGINEERING

U. S. Department of Energy University Nuclear Science and Reactor Support

Upgrade of Instrumentation for Purdue Reactor PUR-1

**Final Report
July, 1999 to June, 2000**

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EXECUTIVE SUMMARY

The major objective of this program is to upgrade and replace instruments and equipment that significantly improve the performance, control and operational capability of the Purdue University nuclear reactor (PUR-1). Under this major objective two projects on instrument upgrade were implemented. The first one was to convert the vacuum tube control and safety amplifiers (CSA) to solid state electronics and the other was to upgrade the electrical and electronic shielding. This report is the annual report and gives the efforts and progress achieved on these two projects from July 1999 to June 2000.

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1. INTRODUCTION

The Purdue University Reactor (PUR-1) is the first and only operating reactor in the state of Indiana. Purdue University operates it under the direction of the School of Nuclear Engineering. PUR-1 is a 1 kW swimming pool reactor that was built in the early 1960's for research and training. The current usage of the reactor is primarily education of the public and teaching reactor concepts to students in nuclear fields (Nuclear Engineering, Health Physics, etc.). This includes classes taught in the reactor room, classes in the adjoining radiation laboratory, students operating the reactor for experiments, and tours for the general public.

The reactor and its counting laboratory are used by the School of Nuclear Engineering to teach undergraduate and graduate level radiation detection techniques and procedures, as well as to teach reactor physics. The reactor is an integral part of the education for bachelor's degrees, and many graduate students choose the reactor course as part of their plan of study, making it necessary for their graduate degree as well. During the reactor kinetics portions of the courses, the students operate the reactor while making period and reactivity measurements. The reactor is also used to assist the School of Science in teaching their Reactor Health Science laboratory course. Those students use the reactor to irradiate samples for reactor flux and detector efficiency calculations, as well as learning how to calibrate area monitors and change the filters on the continuous air monitor. The reactor is often the subject of student design projects. The students create computer models and use the reactor's experimental data to compare the accuracy of their models.

The public is often invited for tours of the reactor facility. The Student Chapter of the American Nuclear Society hosts a Nuclear Week each fall semester that includes a reactor tour. The School of Nuclear engineering actively participates in summer programs at Purdue for Junior High and High School students to learn more about science and engineering. These programs involve approximately 150 students each summer. Additionally, the reactor is used for a DOE Reactor Sharing Program. Groups of high school students (6-10 groups of 12 students each) spend a day learning how to do neutron activation analysis. They irradiate samples in the reactor and use scintillation detectors to identify the elements present in their sample. All of these programs have been in place and operating successfully for at least the last six years

2. OBJECTIVES

The major objective of this program is to upgrade and replace instruments and equipment that significantly improve the performance, control and operational capability of the Purdue University nuclear reactor PUR-1.

In order to achieve this objective the instrument upgrade and replacement is planned in several phases. The first phase of this objectives is the replacement of vacuum tube based Control and Safety Amplifiers (CSAs) to solid state electronics. Partial upgrading the electrical and electronic shielding is also considered in this phase. These two projects were carried out during period from July 1999 to June 2000.

3. CURRENT INSTRUMENTATION

3.1 Reactor Control System

The current instrumentation at PUR-1 consists of four channels. Channel is the word used by the technical specifications to denote a neutron sensitive detector, its cabling connections and the associated electronics to analyze and display the output. Channel 1 is the startup channel. It consists of a fission chamber with the output converted to log count rate and period information. Channel 2 is a compensated ionization chamber that produces Log N and period information. The safety circuits switch over to Channel 2 (from Channel 1) when the Channel 2 level meter comes on scale. Channel 2 remains on scale up to 120% of power. Channel 3 is a BF_3 (uncompensated) detector that inputs to a linear level meter. This allows the operator a linear readout as well as providing linear input to an automatic leveling control system. Channel 4 is the safety channel. Channel 4 is a BF_3 (uncompensated) detector that does not display its output directly to the operator at the console. The safety channel output is used only for monitoring by the scram circuitry.

The important components of the scram safety system are two Control Safety Amplifiers (CSAs). CSA-1 is the level safety system. It monitors Channel 4. CSA-1 supplies the electromagnet power for Shim Safety rod 1 (SS1) and will trip both safety rods on a Channel 4 reading at 120% power level. CSA-2 is the period safety system. Taking input from Channel 1 and Channel 2, CSA-2 will trip the shim safety rod magnet at a period of 7 seconds. A bus connects the two CSA chassis such that a trip condition on one will result in a trip of the other, dropping both SS1 and SS2. Additionally, other scram trip alarms are routed through CSA-1 and CSA-2. 120% power from Channel 2, 120% linear range from Channel 3, trouble (disconnected

cable), high radiation alarm from the area monitors, low alarm from the area monitors, etc., will all cause a scram trip condition in CSA-1 and CSA-2.

3.2 CSA Electronics Status

The electronics of the CSA's consists of 1950's vacuum tube technology. There are serious problems with this old technology; specifically, lack of availability of replacement parts and repairs. Many of the vacuum tube devices are obsolete. Some of the tubes are not available in the standard electronics outlets and are difficult to procure. It is hard to find maintenance technicians for this vintage electronics. The vacuum tube electronics is based on a high voltage system (~120 volts DC), and signal outputs are not available. Thus, these units can not be easily interfaced to computer (PC) based data acquisition systems and display. It should be noted that the CSAs are the key safety system of the reactor. They control the magnet currents for the shim safety rods. The trip signals from all other instruments, such as the reactor period meter and the linear level channel are fed into the CSAs. All scram trip signals must pass through CSAs to effect the scram. Thus, replacement of the CSAs with integrated solid state devices has been the highest priority task. There are a number of advantages with the integrated solid state devices in particular, longevity, reliability, procurement, maintenance, and direct PC interface capability.

4. PROJECT DESCRIPTION

In this chapter the general information of the reactor safety trips and interlocks, start-up and other procedures, design requirement for the replacement of the CSA, and design of the CSA, are summarized.

4.1 Reactor System Safety Trips

In Table 4.1 the list of all trips and interlocks are given. These trips enable reactor to operate safely.

Table 4.1 List of All Trips and Interlocks:

Scram: (Slow)		
Overpower Scram (120%)	Period Scram (7 sec)	
Ch 2	Ch 1	
Ch 3	Ch 2	
Area Monitor Scram	Manual Scram	Trouble Interlock
Scram		
Console	Console	Ch 1
Process System	Hall	Ch 2
Pool Top	Key Switch	Ch 3
		Ch 4
		Trouble Loop
Scram: (Fast)		
Overpower Scram (120%)	Period Scram (7 sec)	
Ch 4	Ch 4 via Ch 2 signal	
Runin: (Setback)		
Overpower Runin (110%)	Low Level Runin (5%)	Period Runin (12 sec)
Ch 3	Ch 3	Ch 1
Ch 4		Ch 2
Inhibit:		
Source Missing Inhibit (5cps)	Jam Inhibit	Period Inhibit (15sec)
Ch 1	Rod Drive Jam	Ch 1
		Ch 2

4.2 Pre-Startup Check-out Procedure

The followings are the pre-start check out procedure for the Safety Chassis.

- 1) Annunciator test (i.e., Lamp and Buzzer Test.)
- 2) Turn on the magnet power.
- 3) Examine and adjust the set point as necessary for 110% setback.
- 4) Examine and adjust the set point as necessary for 120% scram.
- 5) Examine and adjust the set point as necessary for 7 sec scram.
- 6) Raise the rods a small distance (6 cm) and press the "120% SCRAM" button and both rods should drop.
- 7) Reset.
- 8) Raise the rods a small distance (6 cm) and press the "7sec. SCRAM" button and both rods should drop.
- 9) Reset.
- 10) Write down the readings of all (currently there are 22) monitor (Go/NoGo) test points.
- 11) Adjust the magnet currents to the prescribed value and note that both are stable.
- 12) Press the console scram button and assure that both magnet currents drop to zero current. Reset
- 13) Press the hallway scram button and assure that both magnet currents drop to zero current. Reset.
- 14) Check that all lamps show normal and all meters are stable and reading normal.

In addition to these other functions involve,

- 1) Trouble lamp on the console. (CSA trouble). (Open relay contacts 24VDC.)
- 2) High-Level scram lamp on the console. (Open relay contacts 24VDC.)
- 3) Period scram lamp on the console. (Open relay contacts 24VDC.).

The following features are added for new chassis design.

- 1) Lamp test push button.
- 2) Scale linearity test function for 50%, 100%, 150%, 30sec, 12sec, and 3sec.
- 3) Reset for scram and setback trip circuits.

4.3 CSA Design Requirements:

The design requirements for the CSA are given here.

Definitions: Shall, Will, Should, and May

The words "shall" and "will" are used to denote a requirement; the word "should" to denote a recommendation; and the word "may" to denote permission, neither a requirement nor a recommendation.

Table 4.2 High Voltage Power Supply:

Output to the detector:	HV:	+400 +/-20 volts DC
	Current:	0.5 ma. for detector.
	Impedance:	5k ohms
	Ripple:	1.0 volt P-P or less
	Input Regulation:	6% (Input power varying from 100vac to 140vac)
	Interlock:	Detector interlock giving a trouble output (i.e., opening the trouble loop) and lighting the red (HV TROUBLE) LED extinguishing the green (NORMAL) LED.
	Connector:	Three (3) MHV connectors. One with isolated ground for the interlock system.
	Trouble Circuit:	If the H.V. power supply increases or decreases more than +/- 20 volts a trouble signal is generated.

Table 4.3 Low Voltage Power Supply:

Outputs:	Internal power:	+15 volt, current limited, monitored, and crowbared power supply. -15 volt, current limited, monitored, and crowbared power supply.
	Trouble Circuit:	If either low voltage power supply increases or decreases beyond acceptable limits, a trouble signal is generated.

Level Safety System:

Table 4.4 Current to Voltage Converter:

Input:	<p>Detector current: 22.0 to 38.0 micro amps. For 100% power indication.</p> <p>Gain Range: 6 to 160 micro amps for 100% power indication. Is expected to cover all needs.</p> <p>Course Gain control: Solder in range jumpers are O.K., switches are not preferred. Variable gain is also required (board edge not front panel.)</p> <p>Zero control: +/- 30 microamps. To adjust for any detector leakage current (board edge not front panel.) There is currently 16 microamps of leakage current.</p> <p>Connector: The isolated ground MHV connector noted above.</p>
Outputs:	<p>Trip: At or before 110% (Setback) Front panel screw adjust from about 90% to 150% with meter indication. Yellow LED indicated on front panel labeled (SETBACK 110%) extinguishing the green (NORMAL) LED. Open relay contacts on cannon type connector on rear panel for remote indication.</p> <p>Analog output: 0 to 10vDC isolated and buffered output indicating the trip point of (0 to 150%).</p> <p>Trip: At or before 120% (Fast Scram) w/ front panel screw adjust from about 100% to 150% with meter indication. Red LED on front panel labeled (FAST SCRAM 120%) extinguishing the green (NORMAL) LED. Open relay contacts on cannon type connector on rear panel for a remote indicator. This shall reduce <u>both</u> magnet currents to zero milliamps.</p> <p>Analog output: 0 to 10vDC isolated and buffered output indicating the trip point of (0 to 150%)</p> <p>Trouble: One open relay circuit on a cannon type connector for remote indication of any trouble condition within the chassis and front panel LEDs to indicate the cause of the trouble.</p> <p>Meter: Front panel meter to indicate power from 0% to 150%. This meter shall also indicate the set-points for either "SETBACK" or "FAST SCRAM" as selected by front panel switch.</p> <p>Analog output: 0 to 10vDC isolated and buffered indicating (0 to 150%) of the meter reading.</p> <p>Connector: 25 pin "D" type with machined pins, one connector per chassis (placed on the rear panel) for all analog outputs.</p>

Period Safety System:

Table 4.5 Period Amplifier:

Input:	From Channel 2:	23.38 volts per decade (0.0001%=37.2vDC to 100%=177.5vDC, 12k ohm or greater input impedance, this input might exceed 200v as Ch-2 saturates at 198.3 volts.) Board edge adjustable gain from about 15v/decade to 35v/decade. And include both adjustable gain and zero. This period circuit must have a jumper so that it may also operate from equipment which gives: (+10 volts out with 151mV per sec. giving a full scale 3sec. period). And include both adjustable gain and zero.
	Connector:	BNC jack.
Output:	Trip:	At or before 7sec (Fast Scram) w/ front panel screw adjust from about +30sec to +3sec. red LED on front panel labeled (FAST SCRAM 7sec.) extinguishing the green (NORMAL) LED.
	Analog output:	0 to 10vDC isolated and buffered output indicating the trip point of (-30 to +3sec.).
	Relay output:	Open relay contacts on cannon type connector on rear panel for remote indication (i.e., annunciate).
	Other action:	Additionally this 7sec. trip reduces <u>both</u> of the magnet currents to zero milliamps.
	Meter:	Front panel analog meter to indicate period from -30 to +3sec. This meter shall also indicate the set-point for "FAST SCRAM PERIOD" as selected by a front panel push button.
	Analog output:	0 to 10vDC isolated and buffered indicating (-30sec to +3sec or greater)

Table 4.6 Magnet current Supply:

Outputs:	Currents:	Two (2) each 50ma. into 200 ohm 8.5 Henry solenoid coil. Normally adjusted for 30ma.
	Meters:	Two (2) each 0 to 50 ma. analog meters with the smallest division of 1ma.
	Analog outputs:	Two (2) each 0 to 10 vDC isolated and buffered outputs corresponding to 0 to 50ma.
	Connectors:	Two (2) circular "UHF" type connectors.
Inputs:	Trips:	Slow Scram: Loss of 120vac power to the slow scram input thus dropping both rods. A key switch on another panel kills this 120vac power input. Red LED indicated on front panel of this safety chassis labeled (SLOW SCRAM) extinguishing the green (NORMAL) LED.
	Trip:	Fast Scram: Electronic trip from the "Level" signal. Dropping both currents to zero thus dropping both rods. See the section on "Level Safety" above.
	Trip:	Fast Scram: Electronic trip from the "Period" signal. Dropping both currents to zero thus dropping both rods. See the section on "Period Safety" above.
	Adjustments:	Recessed front panel adjust (Similar to: Clarostat RV4N) for magnet current. Range: 0 to 50ma.

Trips:

Either 120% level or 7sec.period shall drop both rods (i.e., reduce both magnet currents to zero) via a diode protected transistor similar to or better than 2N-2222A. All other trips shall open the associated relay and light the associated LED as necessary. All electronic trip circuits shall be of the "Bistable" type.

The "Bistable" type trip circuit is essentially a comparator with very large hysteresis so that it is stable in either state.

The 120vac slow scram circuit may be of the relay type. This slow scram shall drop both rods.

Each trip point will be able to be shown on the respective (power or period) front panel meter so that the actual trip point settings data may be recorded during instrument checkout (before each run). This shall be a front panel switch function and the trouble loop shall open during any monitor function.

The following trip points shall be recessed front panel multi-turn pots (similar to: Bourns type 3590S M-S):

- 1.) 110% (Setback).
- 2.) 120% (Scram).
- 3.) 7 second (Scram).

Scram Reset:

Button on the front panel to reset any trips or circuits. This and any push button shall be of the positive mechanical click type with good tactile feedback similar to the Grayhill type 2202.

Buffered Outputs:

Isolated and buffered outputs shall not allow any external circuit signal (i.e., high voltage, lightning, or transient) or short to enter the chassis in such a way as to compromise any circuit function or render this chassis inoperable. All isolated and buffered outputs will terminate to a 25 pin "D" type connector on the rear panel.

Test Switch or Circuit Test:

This chassis shall have a switch system to test all trips manually, one at a time, and independently. This test system shall apply its signal to the "input" and test the "entire circuit from input to the final trip" and also deflect the associated meter the required amount. Testing trips and linearity at 50%, 100%, and 150% level, and for periods of +30, +12, and +3sec. All trips shall open the respective relay circuits, light the respective LEDs.

The fast scram (i.e., 120% and 7sec.) trip of the magnet current shall disengage both magnet currents dropping both rods as the result of either trip. Board edge ten turn pot adjustments of sufficient range shall be included for all test signals and trip points.

Trouble loop:

The chassis shall have a trouble loop sensing all power supplies, front panel switch position or positions, board seating, the detector and its connector interlock, and various circuit parameters (under or over voltage, under or over current). The design of this trouble sensing system shall be able to do detect any system malfunction considered to be a reasonable and necessary (i.e., That a skilled and knowledgeable trouble shooting technician or engineer would

typically test.) test or tests. The trouble loop and its associated circuitry shall be designed to assure safe operation (i.e., tripping action) of the safety chassis. Any "trouble" when detected will extinguish a green LED labeled, "NORMAL", and light a red LED labeled "TROUBLE" on the front panel. This "trouble" circuit must also light a numbered red LED labeled, "ABNORMAL (TROUBLE) LAMPS" extinguish a numbered green LED labeled, "NORMAL", and shall present an "open" on an isolated two wire output. This output may be relay contacts etc. and presented to the outside circuitry on a round cannon type connector on the rear panel. A relay contact able to switch 28 volts D.C. may be used. This trouble loop shall be an isolated circuit capable of switching 28 volts D.C.

The "TROUBLE LEVEL AMPLIFIER" and "TROUBLE PERIOD AMPLIFIER" signal shall indicate trouble if the amplifier circuit draws more or less than acceptable current, or if the output signal is out of bounds (i.e., latched up or down).

All circuit boards shall be checked for seating by a continuous loop circuit into and out of each board connector at opposite corners of the connector. If this loop opens "TROUBLE" shall be sent to off chassis circuits. Additionally "TROUBLE" shall output an open circuit if no power is applied to the chassis.

Note: When trouble is sent to the external circuit this external circuit kills the a.c. power to the 'slow scram' input.

Note: This chassis shall be able to simulate two (2) independent input signals to drop both rods without sending out a trouble signal to the external circuit, because the test of the chasisis function shall test the actual rod dropping due to the loss of magnet current as a direct result of either a 120% or 7sec. trip not due to the trouble trip (i.e., loss of the 120vac of the slow scram circuit). So, it appears that for the 120% and 7sec. tests there should be independent push buttons for each test.

Go/No Go Meter:

One front panel meter which in conjunction with a front panel switch will monitor and/or test various circuit parameters and test points. These test points shall include but are not limited to:

- 1.) All DC power supply voltages.
- 2.) The ac ripple on each of the power supply voltages.
- 3.) Each power supply current.
- 4.) All zener or stable element voltage /or voltages.
- 5.) Each amplifier output.
- 6.) The current flow of each power supply into each circuit board or card.

7.) And any other test points or circuit parameters considered to be a reasonable and necessary (i.e., That a skilled and knowledgeable trouble shooting technician or engineer would typically test.) test /or tests to assure safe operation (i.e., tripping action).

This meter shall have graduated markings because our staff will record data from this meter during our pre-operation check-out procedure (called a pre-startup). This meter shall be of the analog type so it is easy to observe "stable circuit operation". Any switching associated with this "Go/No Go" function shall be done such that the meter does not appear to be "noisy" or "unstable".

Board Edge Connectors:

All board edge connectors shall be of the 25 pin (or pin count as necessary) "D" type machined pin connectors. Wherever possible connectors should be soldered directly to the edge of the board (solder cup type connectors fit sixteenth inch boards directly).

Relays:

All relays shall be of the sealed military type and installed in sockets with spring type hold down clips. Circuit relays shall be similar to the Seimens (Potter & Brumfield) KHS or better. This design shall use contacts rated as required for the current or circuit as required by good engineering practice including gold bifurcated contacts in any low level signal circuits.

Mechanical Assembly:

The chassis shall be of the "highest" grade chassis type. Noise shielding shall be considered at all chassis levels. Steel shielding of the power supply shall be used.

The actual chassis width is to be 17" to 17-1/4" by 7", 8-3/4", or 11" tall. The depth shall not exceed 20" including any and all cables and cable connections as connected on final installation.

Chassis rails shall be included so that the chassis is easily removable each month for PM checks (voltage and current measurements).

Front panel:

The front panel shall be logically laid out so that usage is intuitively obvious. As much as possible the front panel layout shall be left to right respectively following the flow of our check-out (i.e., per-startup) procedure. This instrument is our direct safety control circuit. Items and controls shall be grouped together in logical groups as necessary.

The front panel shall have two (2) handles for ease of removal and shall have a method of affixing the unit into the relay rack. The width of the front panel shall be 19" the height shall be 7", 8-3/4", or 11" high.

Front panel labeling shall be of the permanent type.

Switches and Controls:

No switches or front panel controls of the miniature type shall be used. All switches and controls shall be as rugged as necessary to operate for more than 20 years. No power switch will appear on the front panel. (This chassis plugs directly into the 120vac supply.) No membrane type switches shall be used in any part of this chassis.

Front Panel Rotary Switches:

All front panel rotary switches shall be of the ceramic open frame design similar to Electrosch type PA, PS, or 2500 series or better.

Magnet Circuits:

Any relays in the current supply for the magnet circuit shall contain two contacts in series so that a single stuck contact will not defeat the intended purpose (i.e., drop the rod or rods) of

this chassis. Wiring bundles for the magnet circuits shall be separated so that any inadvertent short or shorts do not defeat the intended purpose (i.e., drop the rod or rods) of this chassis.

Point to point wiring:

Any low level signal wiring shall be shielded cable. All wires shall be gauged at least one size larger than necessary for any normal or fault current expected to flow. All wiring shall be stranded silver coated copper of 22 AWG (19X34) or greater size (i.e., lower gauge number) the insulation of which shall be TFE Teflon. Only one strand may be broken or missing on one end of each wire if more than one strand is missing or broken the wire shall be replaced during construction. Where required, connections shall be soldered and clear heat-shrink tubing shall be applied. Due to maintenance problems no wiring is to be crimped.

Soldering:

All soldering shall be bright in appearance and all flux, splashes, and splatters shall be removed. The solder shall be of high grade 62/48 alloy or better.

Derating:

All circuit elements and/or components shall withstand continuous power application for a period of time exceeding 20 years of operation. This includes all power supply parts and relays. Worst case shorts or opens shall be considered. Unless specifically required by the circuit: all resistors shall be $\frac{1}{4}$ watt 1% or better of the "established reliability" type, all large (one micro farad or greater) capacitors shall be metal foil tantalum (military) type unless for high voltage then oil filled type may be used.

Derating specifications shall be:

Resistor, transistor, diode, and any power or current derating: A minimum of times four (4) derating of the maximum power or short circuit.

Surge Current: A minimum of times eight (8) surge current derating.

Voltage: A minimum of times four (4) for any aluminum electrolytic capacitor. A

minimum of three (3) for all tantalum type capacitors. A minimum of times two (2)

for any other parts. Oil filled high voltage capacitors may be rated the next step above any expected voltage value.

Capacitor Current Rating: A minimum of times four (4) of the expected ripple current.

For any part use the above guidelines or "good engineering practice" or whichever is the most conservative.

Component Failure Analysis:

A documented analysis of each component failure mode and the resultant discovery mechanism shall be included in the manual. If on analysis it is found that a particular failure will cause any unsafe condition the individual component or system will be derated, backed up, protected, or etc. so that the most probable failures will all fail safe.

Sockets:

All active components shall be in sockets of the gold plated, machined pin type or on stake type stand-offs unless specifically required to be otherwise because of circuit parameters. Only passive components may be soldered into the circuit board.

Circuit Board:

Only type G-10 glass epoxy circuit board shall be used. If required by circuit parameters double-sided boards shall have plated through holes. All circuit boards shall have epoxy solder mask with contrasting labeling as needed.

Note: A minimum of one each spare unpopulated boards of each type will be required because Purdue will be maintaining our equipment for at least 20 years.

Cards, Boards, and Modules:

All active components shall be placed on removable circuit boards. All associated passive components shall be mounted on the same circuit boards with its logically associated active components. Exceptions to be reviewed prior to the time of circuit drawing acceptance.

Although all circuitry could be placed onto only one card, this design requires functions to be separated into logical circuit units of about 16 boards.

Boards: (Probable distribution of circuitry between 16 cards.)

- 1.) High voltage power supply.
- 2.) Low voltage power supply.
- 3.) Level amplifier with test inputs.
- 4.) Level trips.
- 5.) Period amplifier with test inputs.
- 6.) Period trip.
- 7.) Magnet current supplies (2 cards).
- 8.) Go/No Go test circuitry.
- 9.) Isolated and buffered analog output (7 cards).

The analog cards may have two circuits per card thus reducing the total cards to 13.

Stability:

All circuit designs shall be of the "low drift design" and stable for more than 12 months because Purdue is currently on an annual (12 month) recalibration schedule and do not wish to calibrate more frequently due to a new chassis.

Warm Up:

Warm up to stable operation shall not exceed 30 minutes. The manual shall state the actual warm up time.

Adjustments:

Unless specifically required by the circuit: all internal adjustments shall be of the 10 turn (or greater) military type (such as Bourns series 3057 or 3059 or better). All internal adjustments shall be either at the board edges or fully accessible to an uninsulated screwdriver when the chassis is pulled out. All adjustments (both front panel and internal) shall move the corresponding meter-needle or function upscale with clockwise rotation and downscale for counter-clockwise rotation. (Note: For period any adjustment downscale is negative period and

upscale is positive period.) Front panel adjustments shall be ¼" screwdriver slot multi-turn, military type. The front panel magnet current adjustment ¼" slot may be of the single turn type.

All circuits shall have more adjustment range than necessary so that the components will not need to be changed for at least 20 years. Any needed course and fine adjustment controls shall be included so that the calibration will be easily achieved year after year.

Labeling:

All front panel and internal labeling shall be of the permanent type. All test points, components, circuit cards, and adjustments shall have permanent labels immediately adjacent to (not under) each part so that no confusion of parts or adjustment shall exist. Chassis labels shall be of high contrast and of no smaller than 12pts. on the final assembly.

The front panel label shall be engraved or etched into the metal panel and filled with contrasting material.

Test points: (Including current flow test loops)

All voltage and signal test points shall be brought out to the accessible board edge, be of the color coded (resistance color code numbering) pin type connector, and also brought out to the back panel to a 25 pin "D" type connector so that monthly preventative maintenance tests can be performed manually or by computer. Additionally each shall be permanently labeled.

Voltage test points:

- 1.) Each power supply voltage.
- 2.) The complete signal path.
- 3.) All zener diodes or any stable element.
- 4.) All trip setpoints.
- 5.) Any other voltage test points which are considered reasonable and necessary (i.e., That a skilled and knowledgeable trouble shooting technician or engineer would typically test.) to assure the proper operation of all functions.

Current test point:

Where possible all current tests shall be designed as a voltage measurement across a calibrated resistor. Current test points shall be included in:

- 1.) Each power supply.
- 2.) Each magnet current circuit.
- 3.) At each active component power line.
- 4.) And any other test points or circuit locations where current tests are considered reasonable and necessary (i.e., That a skilled and knowledgeable trouble shooting technician or engineer would typically test.) to assure the proper operation of all functions.

Test points shall be included to assure safe operation (i.e., tripping action).

Note: Any current test loops shall be at least 1" wide and $\frac{3}{4}$ " tall with full circuit board clearance of 1" by 2" for a Tektronix model A622 AC/DC current probe. For any currents less than 10ma a coil of 10 turn loops of the same dimensions (1"X $\frac{3}{4}$ ") shall be provided.

Note: The monthly preventative maintenance (PM) tests measure both ac and DC voltages and include ac and DC currents as needed. Circuit test points are very important to the preventative maintenance on this instrumentation and the need for good, reasonable, and necessary test points cannot be stressed enough. At the actual development stage engineering help in circuit analysis and design will help with deciding which test points and parameters need to be measured for PM.

LEDs:

All front panel lamps shall be of the high brightness LED type. No front panel lamp shall show red when the circuit is operating correctly so green indicators shall be used for all "normal" indication. Provide two rows of LED indicators the bottom row being green and showing "normal" and above it a top row of indicators showing the yellow or red, fault or trip condition. The LEDs shall be of the replaceable type and shall be ultra-bright.

Front Panel Meters:

Meters (Power and Period) of the 270-degree type will most closely match the other new instrumentation. Any others may be of the 90-degree type. All shall be of the high torque taugt band or jewel type movement.

120 Volt a.c. Input Protection:

The power lines coming into this chassis shall have engineered protection for RFI, EMI, static, lightning, and or other faults as required by good engineering practice. At a minimum the input power cords shall be of the shielded type. Each a.c. input to this chassis shall be protected with at least 3 MOVs (Metal Oxide Varistor), 3 Transorb type solid state transient voltage suppressors, 3 gaseous type lightning arrestors (similar to C.P. Clare type CG2-230L), and an RFI/EMI type filter in the given sequence. All shall be grounded to a single point with at least #12 AWG wire.

Power Supplies:

The power supply sections of the chassis shall be isolated from the other chassis circuitry by contiguous steel chassis material.

Surgister type inrush current limiting shall be designed into each D.C. power supply as needed.

All power supplies shall be able to sustain any continuous short circuit without harm, over heating, or damage to itself. Other circuit components shall be protected as described in the "Derating" section. All low voltage power supplies outputs shall be of the "over voltage crowbar protected type" so that any failure or possible damage be mitigated.

Each power supply shall be independent from every other power supply (i.e., do not bootstrap the stable elements from supply to supply).

Inputs and outputs:

All chassis inputs and outputs shall have high voltage static discharge protection as required so that no simple discharge or miss-wiring will damage sensitive components.

Stable Elements (Zeners or other):

If a stable voltage is required at any point in any circuitry it shall be generated at that point in the circuit where it is needed unless it is "ORed" from several sources as a specific safety feature.

Schematics:

It is required by Purdue license to have a complete set of "as built" schematics and all mechanical drawings of any reactor equipment. Purdue assume this to also mean information on all parts procurement and vendors as well. Therefore all vendor information and any schematics shall be contained in the final manual or paperwork packet.

All schematic drawings shall be drawn so that the signal flow is from left to right and shall not be overly crowded.

Block Diagrams:

Block diagram of all circuit operation are required.

Manuals:

Description of the operation of all of our reactor equipment is required. Therefore a manual shall be written and submitted to the reactor staff as part of the final equipment approval and acceptance.

Calibration and Alignment:

Calibration and/or alignment procedure for each piece of reactor equipment is required. Original manufacturers calibration procedures are the best for our purposes. Therefore a complete set of calibration and/or alignment procedures shall be written and submitted to the reactor staff as part of the final equipment approval and acceptance. This chassis will not be accepted unless it can be reliably calibrated and /or aligned to operate in accordance with our final signed and approved specifications.

NRC Code of Federal Regulations Part 50.59:

Title 10 part 50.59 of the Code of Federal Regulations requires that any proposed change, test or experiment which involves a change in the technical specifications becomes an unreviewed safety question. Therefore, the policy at the reactor is that all new equipment shall abide by our current technical specifications.

Note: Title 10 part 50.59 of the Code of Federal Regulations is attached. Any questions should be directed to the reactor staff or the NRC.

As a general statement all equipment shall be designed and built using "good engineering practice".

Copy Requirements:

Due to requirement for extensive and in-depth training and repairability Purdue shall be allowed to copy in whole or in part any schematics, diagrams, block diagrams, layouts, circuit cards, manuals, and/or calibration and alignment procedures, and etc. for any in-house use or training as our need sees fit.

Approval:

All circuit schematics, functions, functional descriptions, block diagrams, manuals, procedures, mechanical assembly, component selection and specification, circuit boards, circuit board layout, and etc. shall be subject to approval by the reactor staff and/or any representative the reactor staff may wish to use. Approval is defined as a reactor staff signature with the word "approved" as in "manual approved", "block diagram approved", etc. None of the above listed items shall be considered "approved" unless there is a specific signed "approval" for that item.

Reporting requirements:

During the design, manufacture, or after the manufacture and/or acceptance it shall be the responsibility of the manufacturer to inform the Reactor Supervisor, at Purdue University of any:

- 1.) Discovery of any substantial variance from performance specifications contained in any manual, report, design, circuit, or specification.
- 2.) Discovery of any single condition involving a possible single failure which, for a system designed against assumed single failures, could result in a loss of capability of the system to perform its safety function.
- 3.) Discovery of an inadequacy in any procedure such that the inadequacy causes or could have caused the existence or development of an unsafe condition with regard to this safety channel.

Year 2000:

No part of this circuit shall fail to operate in the manner in which it is intended due to any date or specific calendar time interval.

4.4 CSA Design

The design of the CSA Chassis is shown in Figure 4.1. Figure 4.2 shows the actual engineering design of the front panel of the CSA provided by Phillips Electric.

Preliminary Block Diagram.

Preliminary Front Panel.

Figure 4.1 Block Diagram and the Front Panel Design of CSA

Figure 4.2 Front Panel of CSA

5 PROJECT STATUS

The following list highlights the status and the progress achieved on the project.

- (1) The detailed requirements on the replacement CSA including analysis of the reactor safety system were developed.
- (2) The initial design of the chassis was prepared as per requirements listed in section 4.3 and the electronic components were identified.
- (3) A vendor for manufacturing the instrument was identified and Phillips Electric, at Cleveland Ohio has agreed to manufacture the chassis, power supply and the front panel. An order has been placed with Phillips Electric (vendor), which is currently manufacturing the instrument. The vendor has completed the engineering design as per Purdue requirements. The vendor is manufacturing the instrument and has engaged in discussion with Purdue counterparts on the details of the system.
- (4) Purdue has contacted the technical advisor from Nuclear regulatory Commission to Purdue PUR-1. The requirement from NRC for new CSA design, installation and operation as per CFR50.59 has been evaluated and the Safety Analysis Report has been prepared accordingly to conform to CFR50.59.
- (5) A surge protector system for the electric power was procured and installed as part of the electrical noise and shielding project.
- (6) The following Table 5.1 gives the project schedule and progress.

Table 5.1 Project Status Summary

<i>Task</i>	<i>Period</i>	<i>Status</i>
1. Project Initiation Overall planning and resource identification	07/01/99- 07/15/99	Complete
2. CSA design requirement document CSA requirement list and evaluation of PUR-1 safety systems	07/15/99- 11/17/99	Complete
3. Vendor Search Due to the reduced budget it was difficult to identify the vendor. Finally Philips Electric at Cleveland, OH agreed to manufacture the CSA.	11/17/99- 3/20/00	Complete
4. Purchase order for CSA and agreement with Phillips Electric to manufacture the CSA as per Purdue requirements	3/20/00-5/1/00	Complete
5. CSA construction	5/1/00-6/30/00	Engineering Design complete. Construction underway. Tentative date of delivery to Purdue on 9/15/2000.