7-25

SANDIA REPORT

SAND95-1439 • UC-704

Unlimited Release

Printed July 1995

Description of a System for Interlocking Elevated Temperature Mechanical Tests

David T. Schmale, Gregory A. Poulter

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
under Contract DE-AC04-94AL85000

Approved for public release; distribution is unlimited.

SF2900Q(8-81)

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

NOTICE: This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government, any agency thereof or any of their contractors or subcontractors. The views and opinions expressed herein do not necessarily state or reflect those of the United States Government, any agency thereof or any of their contractors.

Printed in the United States of America. This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from
Office of Scientific and Technical Information
PO Box 62
Oak Ridge, TN 37831

Prices available from (615) 576-8401, FTS 626-8401

Available to the public from
National Technical Information Service
US Department of Commerce
5285 Port Royal Rd
Springfield, VA 22161

NTIS price codes
Printed copy: A03
Microfiche copy: A01

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Distribution
Category UC-704

SAND95-1439
Unlimited Release
Printed July 1995

Description of a System for Interlocking Elevated Temperature Mechanical Tests

David T. Schmale
Gregory A. Poulter
Mechanical & Corrosion Metallurgy Department
Sandia National Laboratories
Albuquerque, NM 87185

Abstract

Long term mechanical creep and fatigue testing at elevated temperatures requires reliable systems with safeguards to prevent destruction of equipment, loss of data and negative environmental impacts. Toward this goal, a computer controlled system has been developed and built for interlocking tests run on elevated temperature mechanical test facilities. Sensors for water flow, water pressure, water leakage, temperature, power and hydraulic status are monitored to control specimen heating equipment through solid state relays and water solenoid valves. The system is designed to work with the default interlocks present in the RF generators and mechanical tests systems. Digital hardware consists of two National Instruments I/O boards mounted in a Macintosh IICI computer. Software is written in National Instruments LabVIEW. Systems interlocked include two MTS closed loop servo controlled hydraulic test frames, one with an RF generator and one with both an RF generator and a quartz lamp furnace. Control for individual test systems is modularized making the addition of more systems simple. If any of the supporting utilities fail during tests, heating systems, chill water and hydraulics are powered down, minimizing specimen damage and eliminating equipment damage. The interlock control is powered by an uninterruptible power supply. Upon failure the cause is documented in an ASCII file.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

21

This page intentionally left blank.

INTRODUCTION

The digital interlock system (photograph, **figure 1**) was built to enhance the reliability of testing and maintain productivity in the Elevated Temperature Mechanical Testing Laboratory. Long term creep and fatigue tests at elevated temperature are susceptible to utility failures that occur after normal operating hours. Should a chill water hose fail a water spill could result. The furnace system could then overheat and cause a fire. Extensive environmental damage could result, along with the loss of the specimen and data.

Figure 1: Computer with junction box. Ribbon cables feed into D/A and A/D boards. Large bundle of wires leads to sensors and controlled systems.

The interlock system will not prevent failures but will prevent damage to equipment upon failure. Sensors detect water on the floor and water flow and water pressure in the lines to equipment. Sensors also monitor temperature and temperature error at the specimen. When the computer detects that something is wrong, it immediately turns off all water to all equipment. When a sensor detects no water flow, no pressure, over temperature or deviation from the correct temperature, the computer turns off furnaces and the hydraulic power supply.

TEST SYSTEMS

Two mechanical test systems have been modified to operate with the interlock system.

Figure 2 is a photograph of the "Northeast" system, an MTS closed loop servo controlled hydraulic 2 post test frame with a 156 KN actuator.

Figure 2.

Figure 3.

Specimens are heated with a 7.5 kW RF generator. **Figure 3** is a photograph of the "East" system, an MTS closed loop servo controlled hydraulic 2 post test frame with a 54 KN actuator. Specimens are heated with either a 5 kW RF generator or a quartz lamp furnace.

INTERLOCK COMPONENTS

National Instruments LabVIEW software runs on a Macintosh IICi computer with National Instruments D/A and A/D boards. The computer boards are interfaced to the lab sensors and controls through the main junction box shown in **figure 4**. The box contains a DC power supply that sends 5 volts to the sensor switches, several solid state relays to operate hydraulics and chill water supplies. When a sensor switch is closed returning 5 VDC to the junction box, the A/D reads the signal and the software reports that sensor as operational.

Figure 4: Cables from sensors and controls enter the two grommited holes and are connected to the SSR's, 5 VDC power supply and the terminal strips. The ribbon cables go to the computer A/D and D/A boards.

A typical water flow sensor is shown in **figure 5**. 5 VDC from the junction box is routed to each flow sensor. When flow is present the switch is closed, returning the DC signal to the computer A/D.

Figure 5: Flow switch mounted in system plumbing. Wiring is connected to "normally open" leads. The switch is closed only when water is flowing.

The Red Lion Controls digital temperature controllers, photograph, **figure 6**, house a switch that opens when the temperature deviates a fixed amount from the setpoint. Each system also has a controller which contains an over temperature switch that opens when a temperature is exceeded. If the specimen reaches this temperature, usually 25-50°C above the normal operating temperature, the interlock trips.

Figure 6: Two of the temperature controllers for the East test system. The one on the left controls the quartz lamp furnace and acts as the deviation from setpoint sensor. The one on the right is the system overtemp; when the temperature exceeds a value the switch opens.

A floor water sensor is shown in **figure 7**. The switch opens when water is present. The water solenoids valves are shown in **figure 8**. With no power present, they are closed and hold water pressure. They are activated by 115 VAC applied through solid state relays in the junction box.

Figure 7: Floor water sensor located behind test frame near system chill water plumbing.

Figure 8: 115 VAC solenoid water valves.

OPERATION

Software to control the system is written in National Instruments LabVIEW. A master panel/subprogram is written for the main chill water systems (called "Main") with two dependent subprograms for individual test systems ("East" and "Northeast"). The program/interface operates in two modes: "interlock on" and "interlock off." **Figure 9** is a photograph of the user interfaces.

Figure 9: Interlock user interface. "Main" and "East" are displayed. On "Main" only the "Main bldg chill water" control has been selected, but all three of the sensors are active. On "East" two of the controls have been selected and four of the sensors. Note that in the "interlock" mode, when a sensor has not been selected, the sensor is grayed out.

In the "interlock off" mode applicable controls are selected including chill water, heating systems and hydraulic systems. When a control button is "pushed" it turns from red to green. With the control systems activated the sensor indicators glow green, indicating, for instance, that the water is flowing where it is required to flow. Sensors that are going to be used for the test are then selected. The button next to the sensor indicator turns from red to green when the sensor is selected. The system can then be switched to the "interlock on" mode

with the switch in the lower center of each panel. If voltage from any of the selected sensors drops below 3 VDC the computer turns off the selected control systems and logs the occurrence in an ASCII file. When then switched to the "interlock off" mode, all the systems originally selected will be turned back on.

Figure 10: Main chill water interlock circuit. Pump system for deionized water is energized by SSR with a 10 VDC signal from D/A. The SSR energizes 2 heavy duty 240 VAC relays to turn on the pumps. The building chill water system (not deionized) pressure differential can be boosted with a pump controlled by another SSR circuit. Power failure is detected on a circuit with a DC-DC SSR and a separate 5 VDC power supply. AC power in the junction box supplies the chill water solenoid.

Figure 10 is a schematic of the "Main Chill Water" interlock circuits. There are 2 parts to the diagram: the sensor A/D circuit which is monitoring the voltages through the sensors and the control D/A circuits which turn on, in this case, the main chill water solenoid, the deionized chill water system pumps and the chill water booster pump. All circuits go through the junction box. **Figure 11** is a schematic of the "East Test Frame" interlock circuits. This sensor A/D circuit is monitoring voltages from overtemp, temp deviation (RF), temp deviation (Quartz), hydraulics, RF generator and chill water flow. The control D/A circuits make the

hydraulics operational, supply 240 VAC to the Quartz lamp furnace, and turn on chill water to the RF generator and quartz lamp furnace.

Figure 11: East test frame interlock circuit. One D/A 10 VDC channel controls three SSR's that switch power to the quartz lamp furnace and control the furnace and grip chill water solenoid. The Hydraulics D/A circuit allows the interlock to deactivate the hydraulic power supply.

Figure 12 is a schematic of the "Northeast Test Frame" interlock circuits. This sensor A/D circuit is monitoring voltages from overtemp, temp deviation (RF), hydraulics, RF generator and chill water pressure. The control D/A circuits make the hydraulics operational, turn on the Haskris mechanical grip chiller and turn on chill water to the RF generator.

Figure 12: Northeast test frame interlock circuit. The chill water control circuit energizes water solenoids for water to the RF generator and chill water for the Haskris chiller. The same control circuit also controls power to the Haskris chiller. The water system uses two pressure sensors to determine if chill water is present. Two sensor circuits use 2 M Ω resistors to draw the signal to ground when the sensor switch is open.

INTERFACE BOARDS

Computer interface boards from National Instruments were used. The NB-MIO-16 is a high performance, multifunction I/O board that provides sixteen Analog-to-Digital (A/D) and two Digital-to-Analog (D/A) channels. The NB-AO-6 is a six channel analog output board, providing an additional six D/A channels. These boards were used in conjunction with software written in LabVIEW to monitor and control various sensors and switches.

SOFTWARE LOGIC/DESCRIPTION

LabVIEW is a graphical programming environment for data acquisition and control. This environment allows the creation of attractive Graphical User Interfaces which control the underlying code. LabVIEW allows the developer to create Virtual Instruments, or VIs, which are analogous to subroutines in text-based programming. These VIs provide specific functionality such as handling file input/output operations or implementing equipment in software.

Figure 13: Flowchart for the Interlock software.

Initially, the user is presented with a screen (Figure 14) where any combination of the three systems may be selected for monitoring, controlling and ultimately, interlocking. Once the systems of interest have been selected, the user selects the "Go!" button, thus invoking a VI for each selected frame(s). Each "system" VI has several Controls and Sensors, and an Interlock switch.

The diagram, or code, for the Main Interlock is shown in Figure 15. After the log file is located, or created if it does not exist ①, the program enters a loop ②. The various control and sensors are now selected via the interlock user interface, or front panel (Figure 9). As this loop executes, any selected controls are energized, and each selected sensor is monitored for an "on" condition within the subroutine(s) denoted by ③. This subroutine checks to see if a sensor is selected for monitoring and if it is, then checks for a 5 ± 0.5 volt signal from the sensor. If 5 volts is detected, the subroutine outputs a true signal (indicating normal operation). Once the interlock switch is turned on, the "Interlock on?" True case structure executes ④. Each time through this outer loop each active sensor is checked and each subroutine output is "AND" gated together and fed into the "Sensor sensing ok?" case structure. As long as all of the subroutine outputs are true, the True case for "Sensor sensing ok?" executes, thus keeping the controls turned on (by sending the "On" Output level (V), ⑤). This continues until the test is over (Quit is selected), or a malfunction occurs. If a sensor detects a malfunction, the cascading "AND" gates will produce a false output causing the False case for "Sensor sensing ok?" to execute ⑥. Within this structure a shutdown equipment loop sends zero volts to each of the active controls, effectively turning them off. A "Write failure to file" loop also executes in parallel. This loop queries each active sensor to determine which one detected the malfunction, and then writes this information to the log file along with the time and date of the occurrence.

Figure 14: Initial Screen where the user selects a combination of frames to interlock.

Figure 15: Diagram for Main Interlock.

SUMMARY

A digital test interlocking system has been designed, constructed and tested for interlocking elevated temperature mechanical tests. The system consists of controls and sensors for water, hydraulic and electrical systems. The user interface is written in National Instruments' LabView computer software and runs on a Macintosh lici computer. The system 1) instills confidence in running tests after normal operating hours, 2) replaces noise sensitive analog equipment and 3) prevents ES& H mishaps such as fires and water spills.

DISTRIBUTION:

1	MS	0337	A. D. Romig, Jr., 1800
1		0342	R. Salzbrenner, 1805
1		1411	M. J. Cieslak, 1831
1		0340	W. Cieslak, 1832
5		0340	G. Poulter, 1832
10		0340	D. T. Schmale, 1832
1		0340	R. Bourcier, 1832
1		0340	J. Stephens, 1832
1		1411	D. Frear, 1832
1		0340	T. Crenshaw, 1832
1		1134	B. Damkroger, 1833
1		9044	W. Kawahara, 8746
1		0620	W. B. Jones, 12711
1		9018	Central Technical Files, 8523-2
5		0899	Technical Library, 13414
1		0619	Print Media, 12615
2		0100	Document Processing for DOE/OSTI, 7613-2