

Instruction Manual

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## Multi-Axis Wind Load Simulator

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# 1 Background - New large-scale dynamic wind pressure simulator

## 1.1 Design considerations

In September 2009, the University of Florida and Special-Lite, Inc. began the design of a large scale dynamic wind load simulator to replicate intense hurricane wind loading, i.e., Category 5 hurricanes, to load large/full-scale building components. The simulator was designed to apply spatially uniform, time-varying pressures on the specimen surface. The simulator was specifically designed for large cladding and component systems for a large range of leakage conditions.

The new system differs from the PLA in three significant ways. First, the entire system was integrated to expedite destructive testing of large cladding and component systems (~40 m<sup>2</sup>) and designed to operate continuously to recreate the entire record of a tropical cyclone. Second, the system was designed to operate over a wide range of leakage conditions and changes in volume caused by specimens deflecting out-of-plane. Third, the test chamber can be bypassed to drive air through a high-speed wind tunnel.

## 1.2 Components

There are four principle components for the simulator (Fig. 1a): fan, ducting, a control system, and the pressure chamber. The fan (Fig. 1b) is a centrifugal blower with maximum pressure of 22 kPa (90 in. wg.) at an airflow rate of 2832 m<sup>3</sup>/min (100,000 CFM). The pressure and flow requirements were determined from simulations of airflow movements in/out of the pressure chamber based on the Helmholtz model described in Oh (2004) and assumptions about air leakage through the test specimens. The Pressure coefficient data to calculate the pressure requirements were obtained from generic wind tunnel models archived in the National Institute of Standard and Technology (NIST) Aerodynamics Database. Details about the wind tunnel models can be found in (Ho et al. 2003) (see generic model test 2, exposure: open country).

A Caterpillar 3512 DITA diesel prime mover load rated at 1818 HP at 1750 rpm drives the fan. A Renold torsional vibration control coupling (Model No. SAE 21 SM 60 RB 3.86) is attached to the flywheel of the prime mover to transfer power to a 0.5 m (21 in.) Wichita Air Clutch (Model 6-12-382-313-9), which engages the fan driveshaft.

The ducts connecting the fan and the pressure chamber are made of 3/8 in. thick steel. The circular parts of the ducting have an internal diameter of 60 in. To isolate the noise while running the Simulator, two VAW duct silencers (Fig. 1b) with noise reduction at 20 dBA are attached to the fan – one is at the inlet of the fan (Model No. VRIB), and the other is at the outlet (Model No. VRDS).

Five dampers (valves) comprise the control system: four butterfly dampers and a custom-built fast-acting opposed blade louver damper. The purpose of the four butterfly dampers is to change the flow configuration so that pressure or suction can be applied to the specimen, or alternatively bypass the chamber to drive air through a high-speed wind tunnel section. The louver damper modulates the system resistance, which changes the airflow in/out of the pressure chamber and thus causes a corresponding change in the pressure acting on the specimen (i.e., the operating point on the fan curve changes). Honeywell AD115 Model KZ low range wet/wet differential pressure transducer measure

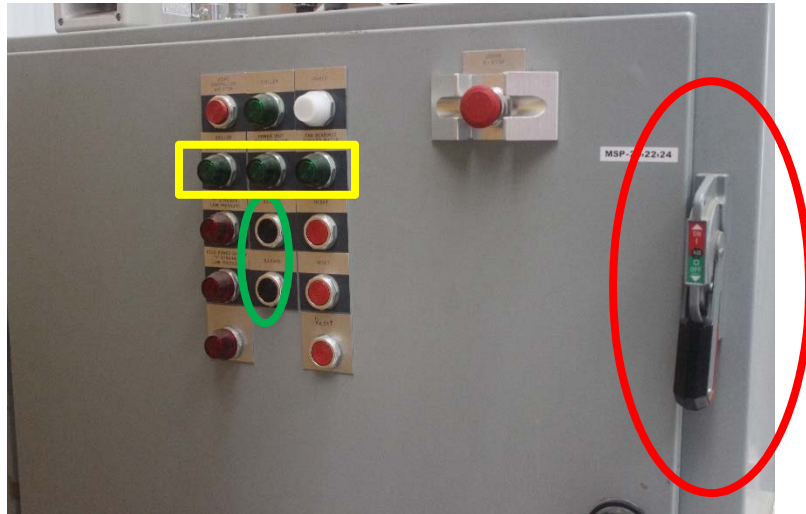
pressure inside the test chamber, a custom analog computer monitors pressure measurement, and a bus-powered isolated data acquisition (DAQ) module (NI USB-6218) interfaces between the measured pressure and the computer. The computer sends commands to an analog servo that actuates the hydraulic cylinder driving the louver damper. The control/feedback process is continuous; only analog feedback/control was implemented (i.e. no A/D or D/A occurs). The test specimen is mounted in the reaction frame (Fig. 1c) that is clamped to the open side of the pressure chamber (Figs. 1 d) to close the pressure chamber for testing. The pressure chamber is 7.3 m wide x 5.5 m high x 1 m deep (24 ft. x 18 ft. x 3 ft.). It is made of reinforced concrete with approximately 13 tons of mild steel reinforcements (Fig. 1e). In addition to mild steel reinforcements, 25 mm (1 in.) diameter post-tensioning bars (Fig. 1d) are used to decrease chance of concrete cracking. The reaction frame system consists of primary and secondary reaction frames (Fig. 1c). The primary frame resists the catenary forces developed from the test specimen subjected to wind pressure loading. The primary frame is made of HSS 406 x 406 x 9.5 mm (16 x 16 x 3/8 in.), and has a force capacity of 150 kN/m (10 kip/ft.). The primary frame is fixed, and the secondary reaction frame can be removed and resized to accommodate the dimensions of the specimen.

Post-storm investigations conducted by FEMA, NIST, and others have found that building envelope failures are a leading cause of wind and water damage to building envelopes.

## 2 Operational Instructions

### 2.1 Pre-Test Startup Procedure:

- 2.1.1 Verify that house air pressure is above 110 psi (at the air compressor).
- 2.1.2 Open the DFS garage door and connect the DFS.
- 2.1.3 Begin startup in control room.
- 2.1.4 Turn on main control panel. Confirm following indicator lights are lit before proceeding: 5kw & 3kw XFMRs (white) and control air (green).
- 2.1.5 Turn on operator panel at disconnect on west wall.
- 2.1.6 Proceed to process chiller.
  - a. Confirm air filters are in place and clean.
  - b. Confirm coolant level in tank is sufficient.
  - c. Confirm chiller disconnect is on.
  - d. Turn on chiller control panel (Fig. 1, red circle):



**Figure 1 – Chiller control panel**

- e. If power is cycled on and off, wait until VFD's inside panel have fully shut off (lights off) before powering chiller panel on again (Fig. 2, red circle):



**Figure 2 – Chiller control panel interior**

- f. Silence alarms (Fig. 1, green circle)
- g. Turn on chiller (Fig. 3, red circle):



**Figure 3 – Chiller front panel**

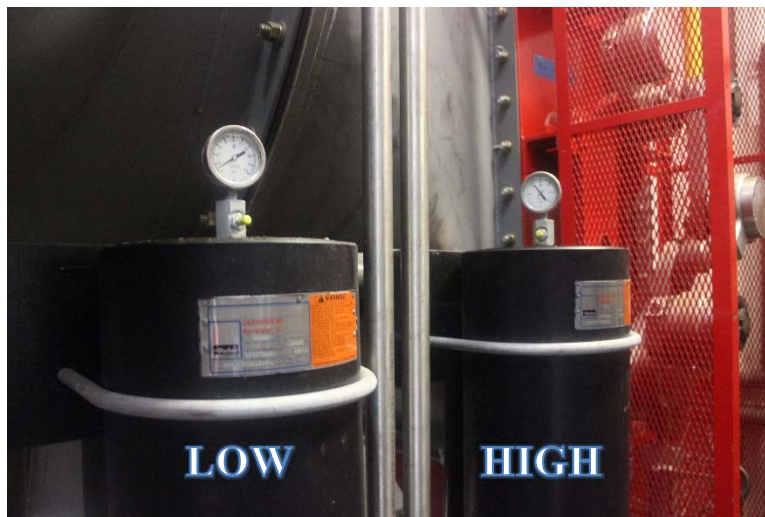
- h. Confirm row of green lights are lit (Fig. 1, yellow square)
- i. Verify that chiller coolant supply pump is running: 50 to 60 gpm at the meter:





**Figure 4 – Flow meter (behind chiller)**

- j. Verify that 5hp power unit coolant supply pump near opposed blade damper is running.
  - k. Verify that 3hp tempered loop coolant supply pump is running.
- 2.1.7 Proceed to opposed blade damper (aka louver valve).
- a. Check welds for cracks.
  - b. Confirm there are no hydraulic fluid leaks.
  - c. Confirm the safety pin has been removed.
  - d. Confirm that the safety cage is closed and secure.
  - e. Confirm accumulators are charged correctly: high pressure accumulator ~1400 psi (north) & low pressure accumulator ~10 psi (south).



**Figure 5 – Accumulators**

2.1.8 Proceed to pump room.

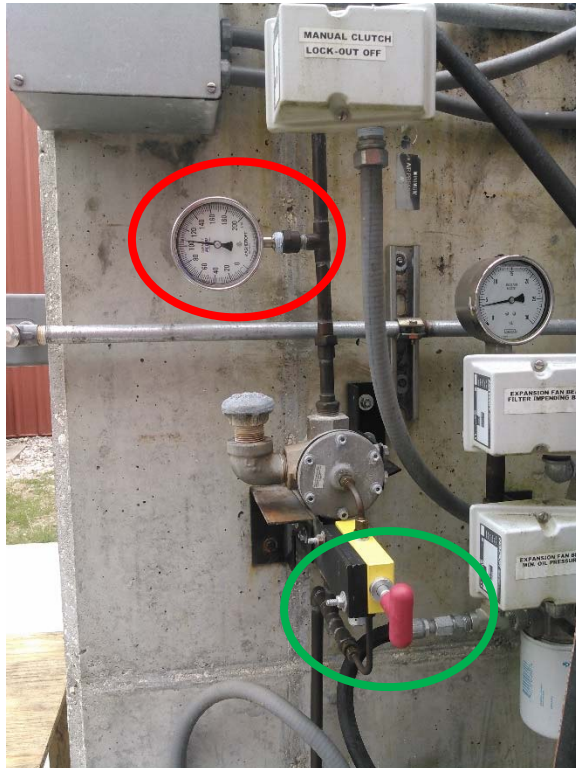


**Figure 6 – HPU Control Panel**

- f. Confirm area is free of oil & coolant leaks including pit south of HPU.
- g. Document hour meter reading on HPU.
- ~~h. Close ball valve at SS lines going to lab.~~
- i. Verify pressure are correct on process gauges on east wall at rear of HPU.
- j. Confirm disconnect is powered on at front of HPU.
- k. Turn on HPU and leave in low pressure setting.
- l. Turn on power to kidney loop panel.
- m. Silence low temperature alarm on power unit control panel and in the control room.
- n. Check filtration back pressure @ rear of HPU; if pressure is greater than 45psi switch to redundant filter.
- ~~e. Open ball valve at SS lines going to lab.~~
- p. Switch HPU to high pressure when the blue low oil temperature warning light turns off.



- 2.1.9 Proceed back to MAWLS control room.
- a. Silence Hydraulic Power Unit low temperature alarm on operator panel.
  - b. At left side of main control panel (always start at top).
    - i. Start drive shaft bearing oil circulation pump & reset low oil pressure alarm.
    - ii. Start fixed bearing oil circulation pump & reset low oil pressure alarm.
    - iii. Start fixed bearing water circulation pump & reset low water pressure alarm.
    - iv. Start fixed bearing water heater.
    - v. Start fixed bearing temperature controller & verify set point temperature of 110 °F.
    - vi. Start expansion bearing oil circulation pump & reset low oil pressure alarm.
    - vii. Start expansion bearing water circulation pump & reset low water pressure alarm.
    - viii. Start expansion bearing water heater.
    - ix. Start expansion bearing temperature controller & verify set point temperature of 110 °F.
    - x. Start pressure chamber & atmospheric valves (press and hold 20 sec)
    - xi. Place engine RPM switch in high idle on operator panel.
- 2.1.10 Proceed to outside west side of fan housing
- a. Verify that regulated pressure to the air clutch is set at ~110 psi (Fig 7, red circle):



**Figure 7 – Base of west side of fan housing**

Pressure to the clutch system can be regulated at the regulator located inside above the outlet duct (Fig 8):



**Figure 8 – Location of air pressure regulator**

- b. Disengage manual clutch lock out valve (Fig 7, green circle).
  - c. Expansion Bearing.
    - i. *Check oil level in pump.*
    - ii. *Verify oil is clean and free of moisture.*
    - iii. *Check for oil leaks.*
    - iv. *Check for coolant leaks.*
    - v. *Set oil pressure for  $\approx 8$  psi.*
- 2.1.11 Proceed to west side of fan housing.
- d. Confirm driveshaft / clutch area is clear of debris.
  - e. Driveshaft Bearing.
    - i. *Check oil level in pump.*
    - ii. *Verify oil is clean and free of moisture.*
    - iii. *Check for oil leaks.*
    - iv. *Set oil pressure for  $\approx 8$  psi.*
  - f. Fixed Bearing.
    - i. *Check oil level in pump.*
    - ii. *Verify oil is clean and free of moisture.*
    - iii. *Check for oil leaks.*
    - iv. *Check for coolant leaks.*
    - v. *Set oil pressure for  $\approx 8$  psi.*
- 2.1.12 Proceed into north side of engine enclosure.
- a. Confirm area is free of oil, coolant, and no debris is capable of flying into radiator fan or shroud.
  - b. Turn engine battery switch on.

- 2.1.13 Proceed to south side of engine enclosure.
  - a. Document fuel level.
  - b. Confirm area is free of oil / coolant leaks & mechanically ready for operation.
  - c. Document engine hours.
  - d. Check engine oil level.
  - e. Check engine coolant level.
  - f. Start engine.
    - i. *Verify oil pressure.*
    - ii. *Verify fuel pressure  $\approx 60$  psi.*
    - iii. *Verify oil differential pressure  $< 10$  psi.*
- 2.1.14 Proceed to control room and confirm there are no alarms.
- 2.1.15 Return to control room and switch engine rpm to low idle.
- 2.1.16 Once engine has slowed to 450 RPM and ok to engage clutch light (green) is lit turn key to engage clutch.
- 2.1.17 Switch engine RPM to high idle.

## 2.2 Testing Procedure

- 2.2.1 Switch control of dampers to LabVIEW control VI:
  - 2.2.1.1 Select testing mode (Positive pressure, Negative pressure or DFS) using the operator panel Mode Select key switch.



**Figure 9 – Mode Select Key Switch**

- 2.2.1.2 Verify that Input and Output cables on left side of operator panel are plugged into the appropriate ports.
- 2.2.1.3 Set dampers as needed to position indicator needle at top of operator panel into the green range.
- 2.2.1.4 Switch to Activate Input on the operator panel Louvre Valve Control.



**Figure 10 – Mode Select Key Switch**

- 2.2.2 Manually set motor RPM as needed to create needed pressure/wind speed (not to exceed 1,700 RPM under typical conditions).
- 2.2.3 Proceed with testing.

## 2.3 Post-Test Shutdown Procedure

- 2.3.1 Start shutdown procedure at operator panel.
- 2.3.2 To limit wind surge into DFS, switch engine to Low Idle.
- 2.3.3 Use JUDGE Controlled Fan Stop to end test.
  - a. Confirm engine RPM is decreasing.
  - b. Confirm fan RPM is decreasing.
  - c. Confirm clutch current is 0.
  - d. Reset clutch slip low alarm.
  - e. Reset clutch slip high alarm.
- 2.3.4 Proceed to outside west side of fan housing.
  - a. Engage clutch manual air release.
- 2.3.5 Proceed south side of engine enclosure.
  - a. Record fuel level.
  - b. Turn engine key to stop position.
  - c. Remove key and place in speed controller box.
  - d. Check area for coolant and oil leaks.
  - e. Check radiator fan/shroud for debris.
  - f. Record engine hours.
- 2.3.6 Proceed to north side of engine enclosure.
  - a. Check area for coolant and oil leaks.
  - b. Turn batteries off.

- 2.3.7 Proceed to DFS.
  - a. Disconnect DFS.
  
- 2.3.8 Return to main control room.
  - a. Stop pressure chamber & atmospheric valves.
  - b. Verify that expansion fan bearing is at a stable temperature.
  - c. Stop expansion bearing temperature control.
  - d. Stop expansion bearing water heater.
  - e. Stop expansion bearing water pump.
  - f. Stop expansion bearing oil circulation pump.
  - g. Verify that fixed fan bearing is at a stable temperature.
  - h. Stop fixed fan bearing temperature control.
  - i. Stop fixed fan bearing water heater.
  - j. Stop fixed fan bearing water pump.
  - k. Stop fixed fan bearing oil circulation pump.
  - l. Stop driveshaft bearing oil pump.
  
- 2.3.9 Proceed to HPU.
  - a. Record hours from HPU hour meter.
  - b. Turn off HPU by pressing stop on HPU control panel.
  - c. Turn of kidney loop by turning off disconnect at HPU kidney loop control panel.
  - d. Check area for oil/coolant leaks.
  
- 2.3.10 Proceed to process chiller.
  - a. Turn off chiller using the switch located on the front of the chiller.
  - b. Turn off chiller control panel.
  - c. Check area for coolant leaks.
  
- 2.3.11 Return to main control room.
  - a. Turn off operator panel at disconnect on west wall.
  - b. Turn off main control panel.
  - c. Confirm following indicator lights are off: 5kw & 3kw XFMRs (white) and control (green).