Warner Electric
Boston Gear
TB Wood's
Formsprag Clutch
Wichita Clutch
Marland Clutch
Industrial Clutch
Bauer Gear Motor
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Warner Linear
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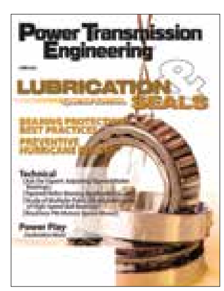
The Pressure Is On at the University of Florida

As seen in
Power Transmission Engineering
June, 2014



Wichita Clutch
An Altra Industrial Motion Company

The Pressure Is On at the University of Florida

Wichita Clutch Helps Drive a Massive Storm Simulator

Approximately $10 billion in damage occurs in the U.S. annually due to natural events, the majority from Category 3, 4 and 5 hurricanes. In 1992 Hurricane Andrew caused more than $25B in just Dade County Florida. In 2005, Hurricane Katrina caused more than $100B in total economic loss.

In 2009, Henry Upjohn, CEO of Special-Lite, Inc., a leading manufacturer of heavy duty entrance door systems, was approached by a business acquaintance that works with the insurance industry, and routinely tours post-storm environments. This professional explained that he regularly finds instances where roll-up and sectional garage doors, built to known standards and storm ratings, were consistently failing at levels below their rating. There was a need to develop better diagnostic tools to understand how building components and claddings respond to extreme wind effects.

During that initial meeting, it was suggested that Upjohn should meet Dr. Forrest Masters, Ph.D., P.E., Associate Professor of Civil & Coastal Engineering at the University of Florida (UF). The UF wind engineering program is one of the largest of its kind in the US. The group is well known for full-scale research, i.e. performing experiments in hurricanes or replicating their effects at a sufficient scale and realism, to evaluate the performance of complete building systems.

Upjohn and Dr. Masters met soon after, and decided to build a testing apparatus capable of simulating wind and wind pressure associated with some of the most severe weather known on the planet. Conventional solutions were not up to the task, so they formed a diverse engineering team encompassing civil, mechanical, manufacturing and industrial engineers to create a one-of-a-kind machine capable of simulating the damaging effects of hurricanes and other extreme wind events.

Conceptually, the system can be thought of as a means to replicate naturally-occurring wind and pressure caused by turbulence in the approach flow and flow distortion around a building. For example, if a pressure sensor recorded high-fidelity data on the wall of a commercial building in Homestead, Florida during Hurricane Andrew, the simulator can “replay” this pressure sequence in its entirety. Ideally, the measured and artificially-applied load would be virtually indistinguishable.

To meet the challenge, Upjohn developed the original simulator concept design drawings, as well as personally supervised the simulator construction and assembly at the Powell Laboratory on the University of Florida’s campus. He, and various members of his

Henry Upjohn, CEO, Special-Lite, Inc. (left) with Dr. Forrest Masters, PhD., P.E.

engineering and electrical fabrication team from the Special-Lite facility in Decatur, Michigan took many trips to Gainesville, Florida over the course of 18 months during the simulators construction.

Sectional roll-up door installed prior to test.

Damaged sectional roll-up door after test.

Simulations Get Real

The new simulator, officially referred to as the Dynamic Wind Velocity and Pressure Simulator (DWVPS), is a unique machine that creates dynamic simulated Saffir-Simpson Scale Category 5 pressure events that produce rapidly fluctuating positive and negative pressures on a test specimen to determine at what level failure, if any, occurs.

The simulator's primary function is evaluate the performance of large component and cladding systems with the goal of designing better, more robust products that will endure all classes of hurricane and tornado events.

Some of the examples for the use of the simulator relating to the construction industry include testing for both sectional and roll-up garage doors, entry doors, windows, curtain walls, siding, shingles and soffits. Other exterior components affected by extreme wind loads caused by hurricane and tornado events can also be tested.

The system operates in two modes. The apparatus has a simulation range capability of 460 psf at 70,000 cfm leakage in the pressure chamber and 230+ mph in the high-speed test section.

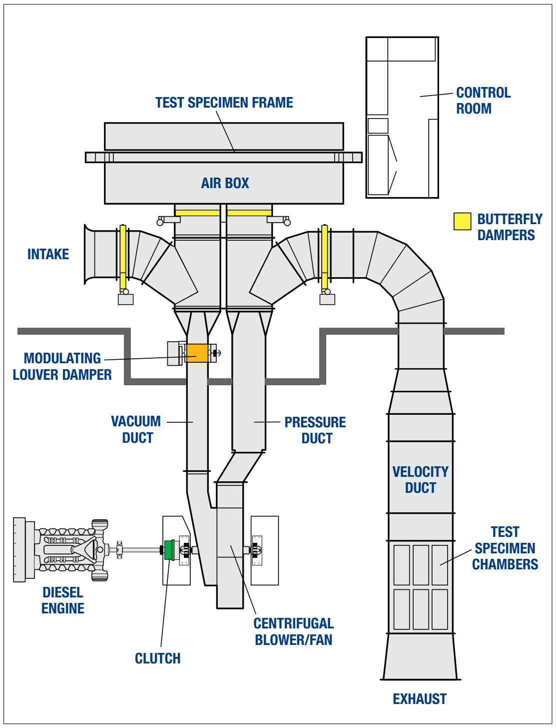
"We can replicate wind effects expected on buildings expected to occur during an entire hurricane passage," Dr. Masters said. "A strong Category 5 hurricane is not a problem. We haven't run a simulation yet, but I'm confident we can also simulate loads on a low-rise building in an EF4 tornado."

The DWVPS also features a velocity simulation area which subjects smaller specimen samples (typically shingles and siding) to high speed wind flow with rapid fluctuations.

Funding for the simulator was provided primarily by Special-Lite, with support from the Florida Catastrophic Storm Risk Management Center at FSU, the Florida Building Commission, Oak Ridge National Laboratory and the University.

"The new simulator complements multiple modeling and testing apparatuses, ranging from universal testing machines, to the boundary layer wind tunnel. Its specific purpose is to apply out-of-plane loading to large-scale building components and cladding to understand how they behave under dynamic wind loading. The findings (data) are used to verify computational modeling and rational engineering analysis," Dr. Masters said.

Test data is captured on the DWVPS with load cells, strain gauges, photogrammetry and HD video. Deliverable data includes forces (reactions), strains, 3D displacement, and video of the entire test to identify time and degree of damage.



The Dynamic Wind Velocity and Pressure Simulator (DWVPS) is a unique machine that creates simulated Siffar-Simpson Scale Category 5 pressure events.

The principal construction took approximately18 months. There were other activities leading up to the main phase of the construction and also verification/commissioning. The first trials occurred in August 2012.

Complex Engineering and Construction

The simulator consists of the following primary components:

- 1800 hp Caterpillar diesel engine
- 100,000 cfm @ 80" diameter w.c., 1750 rpm fan
- Heavy-duty 60" duct work
- (4) 60" dampers to change function of air system (Butterfly Valves)
- 4-blade opposed louver to modulate air flow through the fan
- Post-tensioned, reinforced concrete pressure chamber and accompanying reaction frames
- Analog control to drive louver valve

The 20'-5" tall x 26'-6" wide x 4'-8" deep air box is a unique component of the simulator. It is capable of housing a 24' wide and 18' tall test specimen. 100 tons of concrete and 10 tons of rebar were used to build the air box with 16" thick side walls and a 22" thick backwall to withstand the forces upward of approximately 450 lbf/ft^2. The pressure exhaust bell and the vacuum inlet bells are cast permanently in the back wall of the air box. The test specimens are mounted to the front of the air box and can be tested in either pressure or vacuum modes.

Function through the simulator is controlled by dampers. The simulator has (4) 60" dampers, one on the inlet, one on the exhaust, one on the pressure side of the air box and the other on the vacuum side of the air box. Closing off the vacuum damper in the air box and closing the exhaust damper creates a pressure build up in the air box. Closing the inlet damper and the pressure damper in the air box creates a vacuum in the air box.

The modulating louver valve is the key to recreating the rapid pressure fluctuations that occur in a real hurricane. The louver valve is operated by an analog control that allows the louver to open and close very quickly to disrupt flow through the simulator causing varying pressure in the air box and on the test specimen. Data (voltage) sent to the analog control will be actual pressure traces recorded from a model structure in a wind tunnel or a field measurement from a real building in a storm. The modulating louver valve can function anywhere between fully closed to fully open. This rapid movement in the louver will cause an interruption in the airflow, causing the test specimen attached to the air box to react accordingly.

The variable speed of the engine and fan required a novel approach to the fan's plain bearing temperature control. The control features a tempered heat transfer fluid (HTF) loop with 9kW of heat as well as an outside charging loop of 35º F chilled HTF for each fan bearing. Control is executed as PID, 0-10 VDC driving 3-phase, solid-state relays for heat and 4-20 ma driving 50:1 turndown controls for cooling. Prior to engine start up, the driveline oil temperature of 70º F must be achieved. Safe guards are in place in case of accidental overheating or overcooling of the system.

A clutch was required to provide a frictional interface which brings the fan up to the same rpm as the engine. The engine was coupled to a drive shaft. The clutch coupled the drive shaft and the fan shaft.

Wichita ATD-321-X Standard Ventilated Clutch mounted to bearing assembly adjacent to blower.

Wichita Clutch Meets the Challenge

Jeff Baillairge, application sales engineer at Torque, Inc., a major Wichita Clutch distributor, was called in to help determine an ideal clutch solution for the project. "Accelerating a fan with a large inertia is always a challenge, as there is an abundance of heat that the clutch must deal with during slipping. After studying the HP and torque curves of the Caterpillar 12-cylinder, 1800 HP diesel engine, we recommended engaging the clutch at a very low idle rpm to limit initial heat buildup," Baillairge said.

The layout of the drivetrain changed several times during the project's design phase, resulting in different clutch models to be considered along the way. Initially, the clutch was to be mounted directly to the back of the Cat engine, but later changed to a shaft coupling clutch positioned farther down the drivetrain.

Engine/Blower drivetrain features (left to right), engine, coupling, bearing assembly, shaft drive ring, Wichita clutch, bearing assembly and blower asembly.

Baillairge worked closely with Al Smith, applications engineer at Wichita Clutch, to determine that a Standard Ventilated clutch with 3 plates would be an excellent choice due to the large amount of frictional surface area available to deal with the extremely high heat of engagement. Also, the relatively small 21" diameter was able to rotate at the high 1750 rpm of the engine.

The Wichita ATD-321-X Standard Ventilated clutch acts as a combination clutch and shaft coupling which is designed for reliable in-line power transmission. The simple air tube design, with small air volume, effectively speeds engagements and disengagements. It is unaffected by centrifugal force and has no self-energized effects like drum clutch designs. This clutch is ideally suited for large inertia loads where smooth controlled starts are required.

The Wichita air tube disc design combines all the best features of a disc type clutch with all the advantages of direct air engagement. Full-width molded composition teeth on friction discs minimize wear on the drive ring. It is the simplest and most trouble-free method of applying air pressure yet designed.

J. Alex Esposito, M.E., E.I.T, lab manager, Powell Family Structures and Material Lab at the simulator's analog control panel. Monitors and equipment for digital test data capture are seen in background.

Strain gauges are attached to subject door prior to testing.

"We designed and manufactured a modified Wichita Standard Ventilated clutch to meet the unique performance expectations. The clutch was dynamically-balanced and featured a torque rating of 350,000 lb-in and 1,086 in^2 of lining area with special high-energy linings, a custom bored hub, high-speed hoses and a high-speed air tube and steel pressure plate," Smith said. "While competitor clutches could not handle either the excessive heat nor the high speed requirements, the Wichita Standard Ventilated dry friction clutch is designed to be punished and can stand up to the massive inertia of the 17,000 lb. blower fan assembly."

Upjohn explained the elaborate control system that feeds air to the clutch bladder. The air feed system is comprised of a manual 3-way block and bleed valve, some check valves, a regulator, the air tank, 3 filters, a proportional valve, an emergency release valve and finally a rotary union. Several pressure switches determine that no pressure is on the clutch at engine start-up. The manual lockout is off. The clutch pressure is not less than the predetermined minimum and full air pressure is available before the clutch engagement begins.

Electro Hydraulic Analog Servo Control was Critical

The design and development of the elaborate analog control system was quite complex. Henry Upjohn enlisted the help of Dr. Bob Nicholson, an analog controls engineer out of Birmingham, MI, who has more than 40 years experience of developing high-speed control systems for hydraulic and pneumatic servo applications.

According to Upjohn, PLC's are an easy and very cost-efficient way of implementing industrial control. They also run on a program that is very easy to alter leading to lots of flexibility. The ladder logic programs that are run by PLC's run in sequence, from top to bottom. The time required to run the program is short, on a step-by-step (rung-by-rung) basis.

Some outputs do not work as intended if there are even small delays between calculations of the output valve. As an example, the calculations of two different RPM's whose difference is needed at a very high frequency on an almost continuous basis. In order to accomplish this, the calculation of each RPM and their difference is inserted into the PLC ladder, not once, but every 10 or 20 rungs to keep the output current. Several of these fast calculations may be required resulting in a greater time needed to run through the ladder. Greater, in this case, means one to a few seconds.

Obviously, this technique only works for a few time-critical outputs. The outputs that are not required to be so fast are significantly delayed. In the vast majority of systems these delays have little or no meaningful effect. However, in this system, where there are a large number of safety systems that must react quickly to prevent damage, this delay is not tolerable. Thus, the entire safety control was accomplished with hard-wired, heavy-duty industrial control relays and industrial machine switches. As a result, the "program" is very robust since rewiring is required to make a change. It is not easy to make a logic change, which is desirable in safety systems that must be shut down in certain specified orders, to prevent other damage such as melting the fan's babbitt bearings. Finally, each reduction to out-of-tolerance safety values happens just as fast as any other, usually as quick as a magnetic field in the relay can be collapsed.

The complexity of the simulator sub-systems requires a 20 minute start-up sequence. "We like to run the engine at 1200 rpm to warm everything up and then we take it down to 450 rpm to engage the clutch," Upjohn noted. "We go from totally disengaged to totally locked up in 17 seconds. And during that time, we're using the absolute maximum amount of torque that the engine can produce. So the engine isn't producing any extra torque and making it slip. We are actually loading the clutch as heavily as we can and not stalling the engine."

Upjohn and Nicholson personally designed the elaborate control systems. All the control panels were assembled, per Upjohn's original drawings, at a facility in Michigan. The final wiring was completed by his team when the panels were installed on site.

The analog control for the simulator uses absolute pressure transducers to measure the pressure in the air box that has the device under test (DUT) fastened to it. The transducers are analog feeding an analog control receiving analog commands. Thus, several A/D and D/A converters, with their associated time delays, were eliminated. The transducers measure the pressures in two separate locations. These signals are then averaged.

The command is a recording of the pressure on a model in a wind tunnel. Alternatively, real pressure measurements on existing structures can be replayed. The recording is characterized as large pulses (up to 400 lbs/sq ft) at a low frequency (~.3 Hz) decreasing continuously to ~10 lbs/sq ft at ~10 Hz. 10 Hz is faster than the control is expected to be able to maintain a 1:1 relationship between the input and output. For this reason, from ~3 Hz up to ~20 Hz, the command will be increased proportionately, e.g. doubled at 6 Hz.

The pressure feedback is compared to the modified command to generate an error signal. The error signal goes to both an integrator and proportional amplifier. The integrator gain is adjustable, but the midpoint of the adjustment pot is set to coincide with the fan output characteristics. That is, the amplitude of the integral and proportional amplifiers will be the same at the frequency where the relationship

Pre-assembled drive shaft, with Wichita Standard Ventilated Clutch, is lifted into place during final drivetrain installation.

Wichita Clutch installed with drive ring.

between the louver position and the pressure stops being proportional and becomes integral.

Since it's installation, the simulator has proven to be a real work horse, performing tests on discontinuous roof cover systems such as asphalt shingles and roofing tiles, and sectional doors. Special-Lite, recognized as one of the most innovative companies in the composite building products industry, considers the machine to be a major step forward in the research and development of residential and commercial building systems intended for high-wide areas. The simulator will soon be made available for use by any company or institution for materials testing.

View video at:
https://www.youtube.com/watch?v=QRv5IeJexMo&feature=youtu.be

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