Lightning Test for Retractable Roofs and Other Dynamic Structures

ByAndrew Cheng, Ph.D

Building Motion, Dynamic Grounding and other Redefinitions

Over the centuries, building and machine design has evolved in two parallel worlds, defining standards, techniques and accustomed practices known within their disciplines. In the recent creation of dynamic, mobile structures, and kinetic architecture, these two worlds of architecture and machinery have collided. Thus, a new demand for techniques and standards has arisen for once proven methodology and applications.

The beginning point for this new architecture has manifested over the last few years in retractable roof stadia. Retractable roof structures there are no fixed connections to ground, instead thousands of smaller moving contact points. Linkages, spherical bearings, roller bearing, bushings and wheels have replaced bolts, weldments and concrete. Given the fact that there is no precedent in moving 14 million pound civic structures, designers are required to re-examine construction standards.

One item of investigation was proper electrical grounding. Traditionally, for a building, or a fixed-roof stadium, lightning rods are grounded to the roof steel, the roof steel connected to columns, and the columns connected to a ground grid. In a static connection, it wouldn't really matter if lightning hits steel and a connection welds up. But if that building were a machine, it is likely that the current will find its way to ground via bearings or the machines electrical supply. A lightning strike could potentially result in a burr on bearing surfaces, a seized bushing or the loss of electrical control from the surge.

In the case of Minute Maid Park, home to the Houston Astros, and Reliant Stadium, where the Houston Texans NFL franchise play, two stadia featuring massive retractable roofs in a city with harsh climate and adverse weather, grounding became a priority. Uni-Systems, roof mechanization designers, decided to take the opportunity to study the effects of an electrical impulse through a machine-bearing surface.

Figure 1: Minute Maid Park, Photo by Russ Andorka

Beginning in 1997 with the transporter system requirements for Minute Maid Park, the problem confronted was the issue of getting a proper ground between the top of the stadium and the ground. Minute Maid Park was designed as two conventional buildings, one above, and one below, connected by a five-foot swath of actuating mechanism. This mechanism provided not only actuation of the roof, but also the proper load distribution that made conventional building techniques possible. The actuating mechanism provided load distribution through a system of independent wheels floating within a steel cavity,

supported on all sides by plastic bearings and a urethane suspension spring. This resulted in the upper building (roof) and lower building (rail supports and bowl) to be electrically insulated from one another by hundreds of smaller non-conductive contact points. Two issues arose, how to connect these two and how to get a lightning strike from a rolling object to a fixed rail.

Uni-Systems was confident that implementing conventional copper shunt grounding to bypass the non-conductive points would solve one problem. However, once the path was shunted, current was routed to the wheels and bearings. Testing would be required to identify the effects of a lightning strike in a greased bearing.

The test required a facility capable of 3,000-ampere testing for a proper simulation of a lightning impulse. The National Electric Energy Testing Research & Applications Center (NEETRAC) in Forest Park, Georgia, was chosen.

The Uni-Systems test assembly, sent to NEETRAC, consists of two taper roller bearings, an axle, a spacer and two end caps installed to a round mechanical tubing machined to house the bearings (see figure 2). The assembly was supported at the end caps. The assembly was insulated from the support frame by UHMW plastic plates. The test frame was also constructed to simulate loading of the bearings, as it would be in its final application. A 100-ton hydraulic ram applied a radial load of 150,000 lbs to the bearings through a platform welded to the bearing housing. The amperage pulse applied to one side of the frame is taken out on the other side via the bearing.

The test unit was subjected to what was considered a series of worst-case scenarios from the standpoint of a lightning strike after which the unit was disassembled and inspected for damage. A total of four 3,000-ampere lightning impulses were applied. Each impulse had a measured rise time of 8 microseconds followed by a fall to half value time of 20 microseconds.

The assembly was to be inspected both for deterioration as well as grease consistency. Disassembly of the frame revealed the axle, the outer races and the seals had no damage. Also, the grease

Figure 2: Lightning test assembly: Minute Maid Park

in the cavity between the retaining rings showed no noticeable change. The inner races were inspected and appeared unmarked and able to turn freely on the rollers. It was concluded that the electric impulse of a magnitude of 3,000 amperes had no adverse effect, short or long term, on the wheel bearings. It was therefore acceptable to use the wheel, and the greased bearing, as part of the grounding path for lightning protection.

Later, in 2000, with the knowledge that was gained from the experiments for Minute Maid Park, new problems arose for the Reliant Stadium transporter system. This configuration has a linkage system between the spanning roof trusses and the supporting transporter wheels. This maintenance-free hinge included a spherical bearing with a liner of very thin polymer coating. The concern was that the high current from a lightning strike would penetrate the coating and permanently damage it. The previously

designed shunting system would not alleviate concerns. Even if most of the current would bypass the bearing, would the residual heat be detrimental to the polymer lining?

Figure 3: Reliant Stadium, Photo by Russ Andorka

Uni-Systems returned to NEETRAC to test a new assembly, consisting of a plain spherical bearing with fibriloid liner, an axle and spacers, installed to an eye bracket machined to house the bearing and a clevis bracket (see figure 4). The eye and clevis brackets were bolted together through a pair of one-inch thick end plates with threaded rods. Two shunt wires were mounted between the clevis and eye brackets. The assembly was insulated from the end plates by three-inch thick UHMW plastic plates.

As with the previous test, the objective was to subject the stadium test unit to what was considered a series of worst-case scenarios. A series of four impulses were administered at 5 kA, 10 kA, 15kA and 20 kA. After each test, the assemblies were taken apart. The axle was removed and the clevis bracket was lifted off to provide access to the bearing. The inner race was turned and rotated to expose the inner surface of the outer race where the fibriloid liner was. After each test, in all cases, the inner race was free to move and turn, and the performance of the bearing had not been affected.

Figure 4: Lightning test assembly: Reliant Stadium

The tests showed that with the shunt wires installed, a current with an electric impulse up to 20,000 amperes that passes through the hinge, has no adverse effect – either short or long term – on the hinge bearing. Therefore, the hinge bearing assembly can be used as part of the grounding path for lightning protection.

As we see the emergence of new dynamic buildings over the next decade, Uni-Systems will continue to reexamine the requirements and define the emerging standards of kinetic architecture in the 21st century.

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With over a decade of engineering experience in the aerospace industry, Dr. Cheng's accomplishments include patents for aircraft docking *(PN: 5,375,283)*, aircraft maintenance *(PN: 5,671,567)* and stadium mechanization *(PN: 6,082,054)*. Dr. Cheng holds a B.S. in mechanical engineering, M.S. and PhD in aerospace engineering and is a registered P.E. in Canada.