LOAD LIMITING BANNER BRACKET (FFT-LLBB)

PROOF OF CONCEPT AND TECHNICAL STUDY
AUGUST 20, 2018

FAR FIELD TELECOM

A rendering of the LLBB on a NYC light pole with telecommunications equipment

Introduction

Banner attachments to light poles are commonplace in many cities. By nature, these banners are located in the most populated areas to serve their purpose of conveying a message to the public. Deployments of light pole mounted telecommunications equipment are also becoming commonplace, driven by the network users' ever-increasing demand for high speed data. This type of telecommunications equipment must also be in close proximity to these users, driving the need to locate it on light poles.

In fact, light pole mounted radio equipment is often needed in the exact same areas where banner installations already exist, as both the telecommunications and the banners are intended to reach the same population. Moreover, due to the frequency of banners in these areas (at times on every single pole), it is often necessary to collocate telecommunications equipment on the same poles that support banners.

However, when these installations are not up to structural code design requirements, their presence may pose a significant safety risk to the very population they intend to reach.

Recognizing the potential for structural deficiencies arising out of the collocation of telecommunications equipment and banners, Ahead Engineering completed a study of the NYC light poles, for a variety of typical scenarios, to assess the impact of banners and telecommunications equipment, both independently and simultaneously. The results of this study raised concerns.

While all NYC light poles are capable of supporting typical telecommunications installations independently, many NYC light pole types are overstressed with the presence of banners alone, and still more types would be overstressed when banners and telecommunications equipment must be collocated on the same pole. Based upon this ever-increasing occurrence, it is necessary to mitigate the wind loading on the banners.

Discussion of Existing "Solutions"

There are several products currently on the market intended to address the "banner overload" problem. The general principal behind their function is to allow the banner arm to deflect, thereby reducing the wind load on the banner through reductions of projected area and changing the banner's shape from an un-aerodynamic flat surface to a more aerodynamic curved surface (changing the "shape factor").

These could be separated into two main categories; Flexible Arm Banner Brackets and Spring-Loaded Hinged Banner Brackets, as per *Figure 1*.

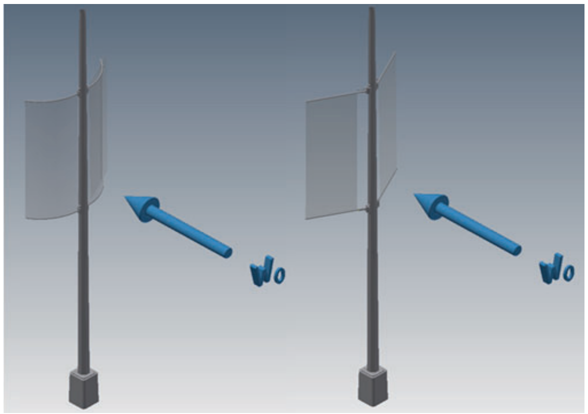


Figure 1: Two Back-to-Back Banners on Pole - Flexible Arm Banner Bracket (Left) vs. Spring-Loaded Hinged Banner Bracket (Right)

Flexible Arm Banner Brackets

Flexible arm banner brackets are designed to use deflection of the cantilevered banner arm to "spill" wind from the banner. Unfortunately, due to the nature of cantilevered arm deflections, this type of bracket is limited in its "wind spilling" capability.

From a technical standpoint, and assuming the banner arm mounting bracket is perfectly rigidly attached to the pole, flexible arm banner brackets behave as cantilevered beams, and must obey boundary conditions at the pole end of the flexible arm.

In plan view, this results in the banner arm achieving roughly the below depicted shape:

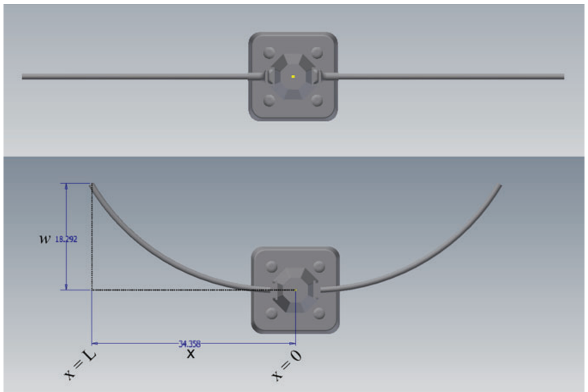


Figure 2: Flexible Arm Banner Bracket – Undeflected (Above) Deformed Shape (Approximated with Arc; Below)

The wind spilling capability is derived from the curvature in the arms, which allows a portion of the wind to exit the edge of the banner (changing the shape factor), while also benefitting from a reduction in the projected area of the banner.

However, flexible arm banner brackets must attempt to obtain a balance between having sufficient structural capacity to support wind loads, without breaking, while maximizing flexibility to "spill" wind. Since these two parameters are essentially diametrically opposed, and adequate structural capacity isn't negotiable, the resulting designs tend to have limited wind spilling capability, governed by banner arm strength and stiffness.

One such banner bracket manufacturer has published technical data on their product which shows reductions in wind load of up to 51.49% at 100 MPH* maximum wind speed. While this wind load reduction would prove sufficient for some considered scenarios, further structural analysis has determined this reduction is insufficient for all common scenarios, across the full range of NYC light poles.

* The published maximum allowable wind speed of 100 MPH is also insufficient for the NYC requirement of 110 MPH.

Spring-Loaded Hinged Banner Brackets

Spring loaded hinged banner brackets function on a similar principle to the flexible arm banner brackets, but instead of the banner arm itself deflecting in response to wind load, a spring-loaded hinge allows the banner to fold backwards to a maximum deflected angle of ~90° from the hinge's starting position. In principle, this concept offers superior results to the flexible arm banner brackets, in that higher angles of deflection are possible.

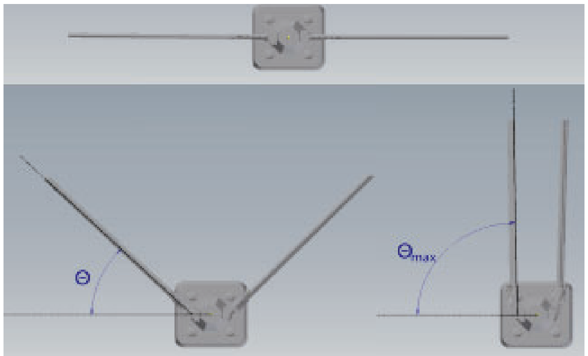


Figure 3: Spring-Loaded Hinged Banner Bracket - Undeflected (Top), Partially Deflected (Bottom Left), and Fully Deflected (Bottom Right)

The deflection of the hinged arms allows a substantial reduction in projected area. Since the banner arms themselves are rigid, and the banner remains essentially a flat plate, this type of banner bracket does not substantially rely on changes to the shape factor.

Based upon published data by the manufacturer, the claim is made that the spring-loaded banner bracket can reduce wind loads up to 87%. Seemingly, this wind load reduction would be sufficient to "solve" the banner wind load problem in almost all scenarios, however, the published data only tells part of the story. The remainder of the story raises great concerns about the viability of both existing solutions.

Existing "Solutions" Missing Data, Fundamental Design Flaws, and Misleading Representations

Spring-loaded banner brackets and flexible arm banner brackets are substantially similar in their functional principles and in a very important, often neglected, Achilles heel. Notably, the published data for both *only* considers the one idealized scenario where the wind direction is perfectly normal to the undeflected banner.

Unfortunately, engineers cannot design for the rare case when wind occurs from the ideal direction that offers the most favorable results for a banner bracket's performance. Engineers must consider multiple wind directions, as required by the governing codes, including, but not limited to, the American Association of State Highway and Transportation Officials (AASHTO), Telecommunications Industry Association (TIA) and National Electrical Safety Code (NESC).

Inquiries were placed with the two largest flexible and spring-loaded bracket companies requesting the missing wind load data for various angles of incidence. Unfortunately, both companies gave the same reply: The only wind data available is for wind normal to the undeflected banner.

However, in reality, wind from alternate directions drastically effects these banner brackets ability to function as intended and will dramatically increase the loads on the banners.

Flexible Arm Banner Brackets with Wind at 45°

Flexible arm banner brackets utilize the cantilevered arm as a spring. As the load on the banner increases, so too does the deflection of the banner arm. The maximum loads are experienced when the highest deflection occurs, which, logically is just prior to the maximum rating of the bracket. Therefore, the amount of load that the bracket can transfer onto the pole isn't actually limited by wind spilling deflection of the banner arm. Rather, the maximum load is limited only by the structural capacity of the banner arm.

If the wind initially approaches the banner at an incidence angle of 45°, then the deflection of the banner arm will turn the face of the banner in a direction *more normal* to the wind and the banner bracket will respond with ever-increasing resistance, causing the wind to exert a **minimally reduced** load on the pole. This relationship is depicted in *Figure 4*.

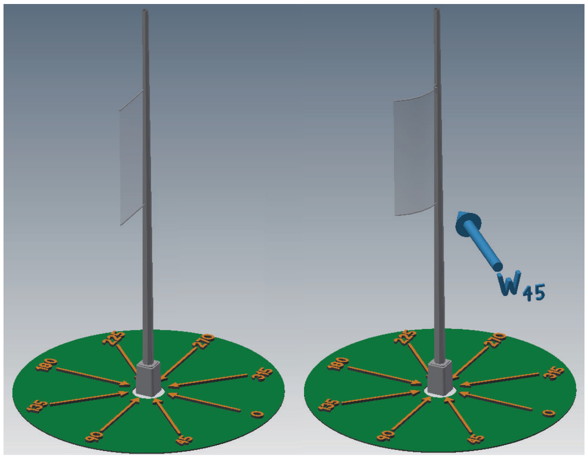


Figure 4: Flexible Arm Banner Bracket Undeflected (Left) vs. Flexible Arm Banner Bracket Maximum Deflection (Right)

While the curvature of the arm will assist shedding wind, it is our opinion that this effect would be largely counteracted by the *increased* projected area of the banner, deflected into a position more normal to the initial 45° wind. As such, this type of banner bracket likely has limited effectiveness, unless the wind strikes the banner normal to its undeflected face.

Spring-Loaded Hinged Banner Brackets with Wind at 45°

Spring loaded hinged banner brackets behave similarly to flexible arm banner brackets except that as the banner arm deflects, there is no significant curvature to the banner arm/banner, which would aid in wind shedding. The hinge has a maximum limit of rotation that is roughly 90° from its undeflected position.

As such, when the 45° wind initially acts upon the hinged bracket, the banner first will turn completely normal to the wind, thereby increasing the loads imparted on the pole. With further increasing wind speeds, the banner bracket hinge, which can rotate a maximum of ~90° from its resting position, will then “lock out”, holding the banner in a fixed position at -45° angle to the wind, thereby offering minimal wind shedding. As with the flexible arm banner bracket, the maximum loads imparted on the pole are not limited by the spring mechanism but are only limited by the banner arm’s structural capacity.

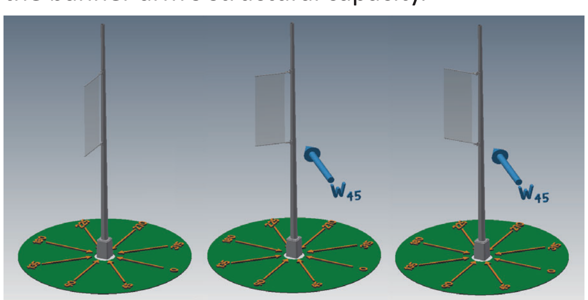


Figure 5: Spring-Loaded Hinged Banner Bracket with Wind at 45° - Undeflected (Left) vs. 50% Deflected, Normal to 45° Wind (Center) vs. 100% Deflected – “Locked Out” on Hinge (Right)

Questionable Wind Tunnel Test Reports and Interpretation of Results

In addition to the omission of varying the wind direction, the wind tunnel test data for both kinds of brackets is furthermore questionable. Both wind tests only consider two-banner, “back to back”, arrangements. Two-banner data is NOT linearly scalable for one banner situations, despite what the manufacturer’s literature may imply. When wind strikes a surface which is not normal to its direction, such as a deflected banner, it generates both a drag force, in the direction of the wind, and a resultant force, relative to the angle of the wind to the deflected banner.

In the two-banner, back to back arrangement, the positive X direction reaction cancels with the negative X direction reaction as per *Figure 6*.

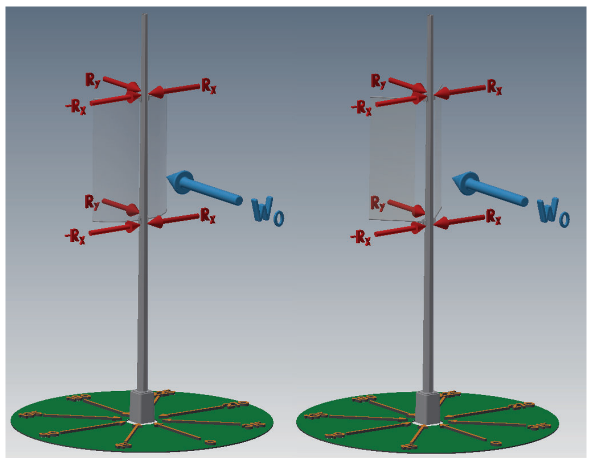


Figure 6: Two Banner Back to Back Installation: Rx Cancels with -Rx Flexible Arm Banner Bracket (Left) and Spring-Loaded Hinged Banner Bracket (Right)

When only one banner is present, the actual force experienced by the pole is the vector sum of the X direction reaction and the Y direction reaction. This will yield loads significantly higher than the loads implied by the manufacturer literature, as per *Figure 7*.

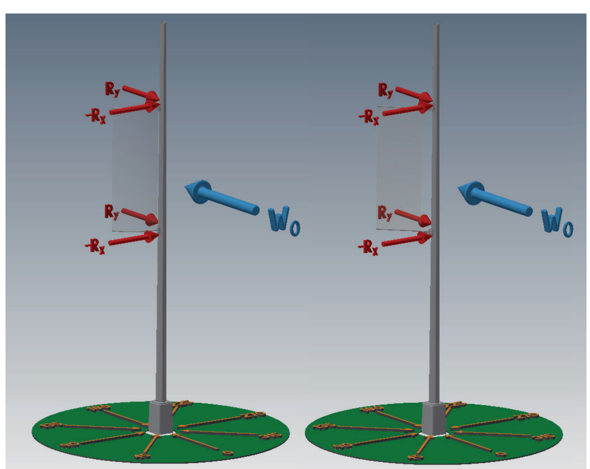


Figure 7: Single Banner Installation: Total Pole Reaction to Banner is Resultant of -Rx and Ry Flexible Arm Banner Bracket (Left) and Spring-Loaded Hinged Banner Bracket (Right)

Studying the geometry, when a single banner is deflected to 45° to the wind, the actual resultant force is ~141% of half the published loads for a two-banner scenario, or approximately 71% of the two-banner scenario, not 50%.

Based upon these observations, Far Field Telecom (FFT) concluded that the banner load problem was not yet solved.

Far Field Telecom Develops a True Load Limiting Banner Bracket

In response to the uncovered deficiencies, FFT has proposed an alternate solution to the banner loading problem, henceforth known as the Load Limiting Banner Bracket (LLBB). The *patented* LLBB, does just that, irrespective of wind direction, and in a predictable fashion, that allows a design engineer to specify a predetermined allowable load for the supporting pole, and then calibrate the banner bracket to not transmit more than the allowable load onto the pole.

The principle behind the LLBB is simple and effective. In reference to *Figure 8* below, the banner arm is attached to a rotating shaft and interlocked with a cam. A spring-loaded cam follower sits within a detent, located along the circumference of the cam, which restrains the banner arm while it is in the detent.

The spring force on the cam follower is adjustable, which determines the magnitude of torque imbalance necessary to force the cam follower from the detent, which will thereby allow the banner to rotate away from the wind. When the banner rotates away from the wind, it behaves more like a flag than a banner, reducing the wind load to a fraction of what is permitted by the predetermined setpoint. The shape of the cam and the spring force of the follower causes a slight counter-rotating force, after the follower is forced from the detent, such that when the wind dies down, the banner will return to its resting position and reset. The banner bracket functions identically if the wind approaches from the opposite direction.

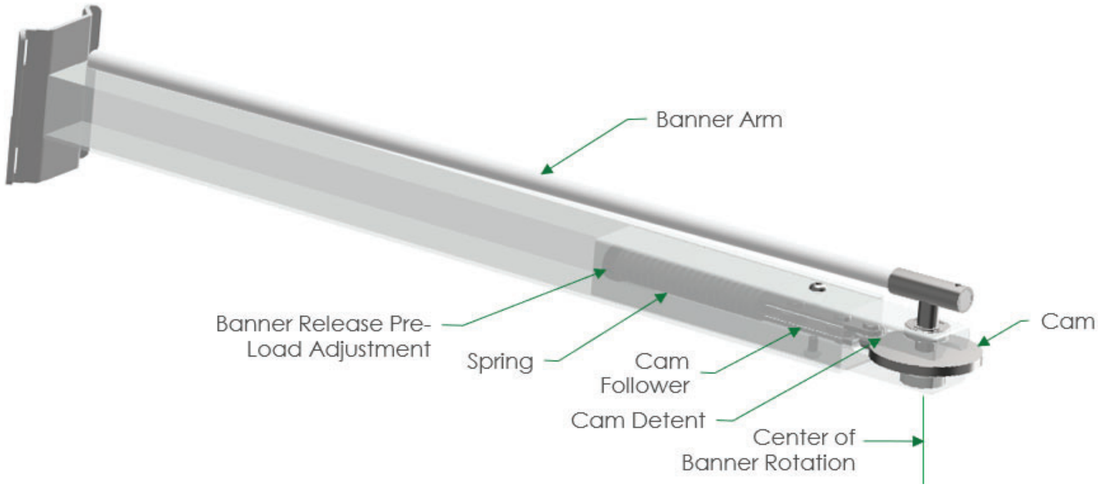
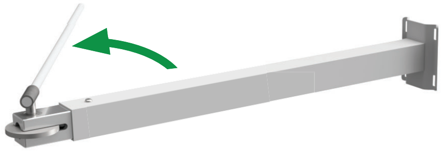


Figure 8: Load Limiting Mechanism of the Far Field Telecom Load Limiting Banner Bracket (LLBB)



FFT-LLBB Wind Tunnel Test

This principle of the LLBB was tested in the University of Maryland Glenn L. Martin Wind Tunnel on July 30, 2018.

The LLBB was attached to the test fixture within the wind tunnel's test section. The test fixture consisted of a floor to ceiling pipe, which is connected to a balance below the floor of the wind tunnel, to record the drag on the banner installation.

A pair of banner brackets were attached to the test fixture and a 3' wide by 6' tall vinyl banner was stretched taught between the two LLBB supports. The test setup is depicted in *Figure 9*.

Prior to the wind tunnel test, a simple calculation was completed based only upon the desired allowable load to determine the torque setting. The torque setting was easily calibrated into the banner bracket, using an ordinary torque wrench, by adjustment of the cam follower's spring preload.

With the LLBB set to a calculated release point, the wind tunnel's velocity was slowly increased until the banner released. Time averaged load measurements were recorded just prior to the predicted banner release and just after release of the banner.

The test results yielded that the LLBB released the banner load within 1% of the predetermined setpoint, reliably and predictably. This setpoint was consistently within 5% of the predicted wind speed, which deviates due to variances in the shape factor for the banner, as it is deflected by the wind. Extracted video frames from the LLBB mechanism in action are shown in Figure 10.

The video may be viewed on our website at: www.FarFieldTelecom.com/LLBB

Figure 9: Far Field Telecom Load Limiting Banner Bracket (LLBB) - Wind Tunnel Test Setup

Figure 10: Far Field Telecom Load Limiting Banner Bracket (LLBB) - Wind Tunnel Test – Moments Prior to Tripping (Left), Moments After Tripping (Center) and Fully Turned away from the Wind (Right)

Based upon the test results, the following LLBB load curve was established (*See Figure 11*), for comparison to the other existing banner brackets on the market. The upper curve, in red, represents the loads on the banner prior to the bracket tripping. The lower curve, in green, represents the loads on the banner after the bracket trips.

Since the LLBB is adjustable, the trip points for 20, 30, 40 and 50 MPH are represented by the gray, orange, blue and purple vertical lines, respectively. The engineer can select any of these points, or any point in between, for the banner bracket limit loads, which would entail a switch from the red "Before LLBB Trips" curve to the green "After LLBB Trips" curve.

While the graph is represented in wind speed versus drag, in order to be consistent with other banner brackets on the market, FFT does not suggest that the bracket is set up based upon wind speed. The design engineer should only calculate the maximum allowable load on the banner, to ensure structural integrity of the supporting structure.

This is necessary since the wind speed is actually irrelevant. In fact, the function of the LLBB is not governed by numerous variables which contribute to the banner load, such as the banner size, wind direction, air density, the banner material and how tightly the banner is installed. Since the LLBB mechanism effectively measures the amount of load on the banner, and releases the load if it exceeds the setpoint, one only needs to establish the maximum allowable load for the supporting structure and correlate that to the setting of the banner bracket, using the following equation:

Total Allowable Banner Load = L_T

Calibration Torque = $T_{cal} = \sin(45)\, L_T/3 \approx 0.236\, L_T$

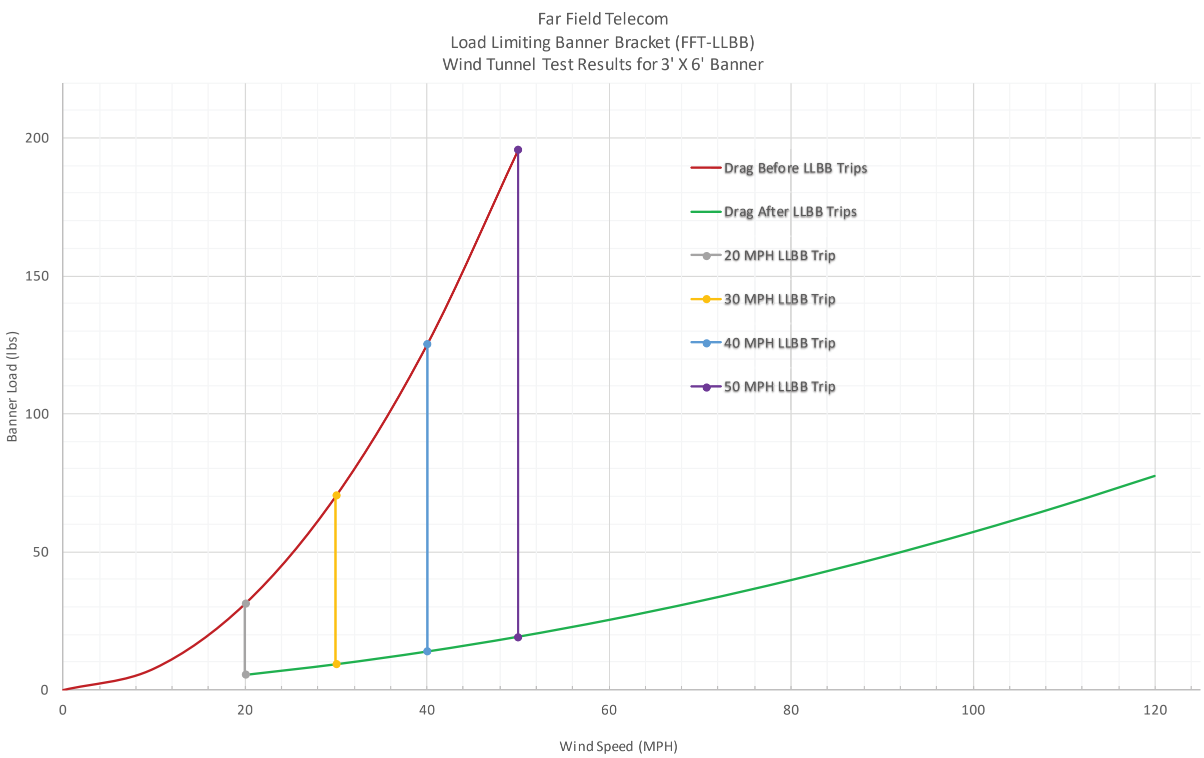


Figure 11: Far Field Telecom Load Limiting Banner Bracket (LLBB) - Wind Tunnel Test Results

It should be noted that limitations were discovered in the testing itself.

The wind tunnel speed is set by the propeller's angular velocity and is also relative to the obstructions within the test section. When the LLBB trips, the obstruction in the test section changes rapidly, while the propeller maintains constant angular velocity. This causes rapid 75 – 85% increase in the tunnel wind speed. Therefore, it was not possible to record all necessary data during a single test run. However, based upon analysis of all collected data points, between multiple runs, the banner load curves were established.

Additionally, when the wind tunnel's propeller stops, the wind does not, due to the inertia of the air mass within the closed loop test system. In fact, the wind continues to recirculate, slowly decreasing in speed, for as much as 20 minutes. This slowly decreasing wind prevented the banner bracket from resetting at the end of a test run. However, we were able to demonstrate the resetting capability when the wind tunnel was brought to a rest. In the real word, lulls between wind gusts or even slight changes in wind direction would allow the bracket to reset without difficulty.

The video of the bracket resetting is included on our website at:

www.FarFieldTelecom.com/LLBB

Nonetheless, the testing at the Glenn L. Martin wind tunnel proved successful, in order to gather the necessary test data and to provide a proof of concept for the viability of the LLBB. Based upon the results of the wind tunnel testing, we have proven that it is possible to predictably and reliably limit the loads imparted on supporting structures by banners. The advent of the LLBB has opened up the possibility of collocation of telecommunications equipment and banners on ALL light poles and has applications where it is now possible to install banners on poles which were never, in the past, capable of safely supporting a banner.

For more information on the LLBB and other innovative FFT products, please contact:

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