LISTING & TESTING DIVISION

PRODUCT: VECTOR DYNAMICS FOUNDATION SYSTEM

LISTEE: TIEDOWN ENGINEERING, INC.
5901 Wheaton Drive
Atlanta, GA 30336

CATEGORY: DESIGN - FOUNDATION

APPLICATION: MANUFACTURED HOME - FOUNDATION

SECTION 1: INTRODUCTION
At the request of Tiedown Engineering, Inc., RADCO has examined their Vector Dynamics Foundation System Installation Design Instructions to determine that the designs contained therein provide the lateral and overturning resistance requirements for manufactured homes as outlined in the Federal Manufactured Home Construction and Safety Standards. The system is designed for use under manufactured homes in Wind Zones I, II and III on selected soil classifications.

SECTION 2: DESCRIPTION
The Vector Dynamics Foundation System is designed for placement under the longitudinal rails of each manufactured (mobile) home. The system supports the home by anchoring the longitudinal rails. The installation Design Instructions (last release date: 5/01) may be used on single or multi section homes. The system may be used as part of the vertical (or gravity) support system of the home. Each Vector system consists of concrete or steel piers resting on the galvanized Vector pads with Vector system components including inside tie brackets, outside tension brackets, center compression member, Vector “X” straps, attachment hardware and anchors where specified.

SECTION 3: APPLICATION
The Installation Design Instructions are for the use of the home manufacturer in preparing the design of a foundation support system for its manufactured homes that utilize the Vector Dynamics Foundation System. The system shall be installed in accordance with the home manufacturer's installation instructions.

SECTION 4: EVIDENCE SUBMITTED
a) Test reports are on file with RADCO which substantiate the load carrying capacity of the system.
   b) The Vector Dynamics Foundation System Installation Design Instructions are on file at RADCO.
   c) Test report for full scale testing of the "Vector Dynamics" Manufactured Housing Foundation System by K2 Engineering. Test report No 00-MH03-TDE, 00-MH17-TDE and 00 - MH21 - TDE.
   d) Test report of swivel connector as alternate to hook connector in "Vector Dynamics" Manufactured Housing Foundation System by K2 Engineering. Test report No 00-MH05-TDE.

SECTION 5: RECOMMENDATIONS
RADCO recommends that the Vector Dynamics Foundation System Installation Design Instructions by Tiedown Engineering, Inc. be accepted for use by home manufacturers in designing their foundation system. The designs contained therein meet the requirements for windstorm protection contained in Section 3280.306 of the Manufactured Home Construction and Safety Standards, provided that:

a) The home manufacturer follows all Installation Design Instructions for the Vector Dynamics Foundation System.

b) The Vector system components are of the same quality, size and grade as specified in the Installation Design Instructions and as originally used when tested by Wiss, Janney, Elstner Associates, Inc. and RADCO.

c) The home manufacturer is responsible for the foundation design of each home.

SECTION 6: APPROVAL
This listing is subject to approval on an annual basis by RADCO. Updating of data and further information will be submitted as necessary.
FULL SCALE TESTING OF THE ‘VECTOR DYNAMICS’ FOUNDATION SYSTEM FOR MANUFACTURED HOUSING

Prepared for

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INTRODUCTION

A total of fifteen tests were performed using the “Vector Dynamics” foundation system. A series of nine tests were performed to confirm that the Vector system would resist wind loads as required in the Manufactured Home Construction and Safety Standards Part 3280 (MHCSS). Each of these tests were performed with 96" main beam spacing set up on the test apparatus. Six additional tests, were performed at working loads, three of which were conducted with 75-1/2" main beam spacing, and three others conducted with 96" main beam spacing and 56" high pier sets.

Witnessing the Field Tests
Mr. Ray Tucker, P.E., RADCO

TEST APPARATUS

All tests were performed using a test rig that represents a single-section housing unit (See Fig. 1). The test rig consists of a frame that is 150" long X 72" wide X 54" high from the bottom of the I-beam to the top of the frame, and main beams. The height was selected to replicate the approximate location of the overturning wind forces on the manufactured home. The main beams are designed for flexibility of positioning in order to allow for replication of spacing with different model homes. For the purpose of the tests (three each) referenced by drawings 91898Z2,R-1, 91898Z1C,R-1, 91898Z3,R-1, and 91998Z1H (high pier set), the I-beams were positioned 96" on center, 27" from the ends. The three tests referenced by drawing 91998Z1 were conducted with modified main beam spacing of 75.5".

The test rig has a hydraulic winch, which applies a lateral load to the frame to simulate the wind drag load on the unit. The winch slides between the top members of the frame of the rig. The winch frame is attached by cable to a dynamometer (See Fig. 2), used to measure the force, which in turn is attached by cable to the drag load side of the test rig.
Uplift loads were applied through the axle arrangement by means of a hydraulic cylinder. During tests that require uplift, instrumented scissor compression blocks were positioned under the wheels on each side of the test rig (See Fig. 3) in order to measure the (incremental) loads during testing, and gages were used to read the loads. When the test rig is supported on concrete block piers, the wheels are moved up by means of hydraulic cylinders. When the test rig is anchored and supported on piers, the wheel frame is used to apply a vertical uplift load to the test rig.

The test rig weight is 2570 lbs.

During each test, the test rig was supported by six concrete piers. The piers were single stacked, consisting of two 8" X 8" X 16" blocks with one 4" X 8" X 16" cap block, 20" high. The high pier test was the only exception, where each pier was double stacked with 8" X 8" X 16" concrete blocks 56" high (See Fig. 4). Plastic pads (TDE 59300) were used under the outside corner piers, while "Vector Dynamics" foundation pads (TDE 59275) were used under the internal center piers.

The test rig was anchored, using a 30" double helix anchor with a 12" stabilizer plate at each center pier. In addition, one "Vector System" was used between the beams of the center piers.

A "Vector System" consists of four components (See Fig. 5). First, two "Vector Dynamics" foundation stabilizer pads (TDE 59275) are positioned into the ground at each pier location where the "Vector System" is being installed. After the piers are built and the test rig is positioned, a compression member made of two, 2X4 wood pieces was installed between the piers, on the ground (3 1/2" sch. 40 PVC can be used in place of the wood). The compression member is made from pressure treated wood and is attached to the interior ends of the stabilizer pad by means of a 3/8" diameter U-bolt (See Drawing No. 10973) through a diagonal connector(TDE 59276). On the outside of each pier, a tension link (TDE 59282) is connected to the outer end of the stabilizer pad by means of a 3/8" diameter U-bolt(See Drawing 10999) clamping a short (4" to 6") piece of 2X4 at each end.

Steel strapping extends diagonally from the diagonal connector over the upper flange of the I-beam and down to the tension link. Tension in the straps is induced by a take-up bolt in the tension link. The tension in the strapping was hand tight. Engineered drawings of all components can be found in the table of contents.
The anchors are also attached to the frame using steel strapping. Tests for Zone I was performed with frame ties extending from the I-beam to the anchor. Take-up bolts were used to tension the strapping. Tests for Zone II and Zone III were done with frame ties and vertical ties (Figure 6). The tension in all ties was hand tight.

OVERVIEW OF THE VECTOR DYNAMICS SYSTEM

Wind drag load causes a lateral and overturning moment on the home. The Vector Dynamics foundation system uses the weight of the home and the transfer of that weight in wind load situations to stabilize the home. As the wind load increases, the load on the windward pier decreases, and the load on the leeward pier increases. The Vector system uses this increased load on the leeward pier to reduce the homes' horizontal displacement through the use of cross strapping between the Vector piers. As the wind load increases, tension in the leeward pier diagonal tie increases, which induces a compressive component of force into the pier and into the compression member (see Figure 5A). This causes several things to happen. First, the leeward pier compression forces the Vector foundation pads into the ground so that the cleats in the pads resist movement. Second, the compression from the Vector pad through the strap to the main beam causes the pier to act as an extension of the home rather than as pieces acting separately (similar to a site-built home). When anchors are required, the tension in the Vector diagonal tie reduces the frame tie strap tension at the anchor, thus reducing the anchor horizontal load. This allows the anchor to provide improved resistance to the uplift load. Tests have shown that an anchor's performance is best when it is subjected to the direct pullout that is associated with uplift. So, in the Wind Zones that require protection against uplift loading, the result of using Vector is that the use of the anchor to resist uplift allows the Vector System to resist horizontal displacement.
Test Results Summary

Test results for tests 1, 2, & 3 show that the average horizontal anchor displacement was 0.75 inches and 0.58 inches of movement at the design loads for Wind Zone II. These results confirm that six “Vector Dynamics” Foundation Systems are needed to resist the Wind Zone II loads on a 72’ home. Basically, one system resists 12’ of a homes’ length. (See Wind Zone II Single Section and Double Section Instruction Sheets in the appendix)

Test results for tests 4, 5, & 6 show that the average horizontal anchor displacement was 3.27 inches and 0.48 inches of uplift at the design loads for Wind Zone I. These results confirm that three “Vector Dynamics” Foundation Systems are needed to resist the Wind Zone I loads on a 72’ home. Basically, one system resists 24’ of a homes’ length. (See Wind Zone I Single Section and Double Section Instruction Sheets in the appendix)

Test results for tests 7, 8, & 9 show that the average horizontal anchor displacement was 0.60 inches and 0.35 inches of uplift at the design loads for Wind Zone III. These results confirm that eight “Vector Dynamics” Foundation Systems are needed to resist the Wind Zone III loads on a 72’ home. Basically one system resists 9’ of a homes’ length. (See Wind Zone III Single Section and Double Section Instruction Sheets in the appendix)

Tests 10, 11, & 12 were conducted to confirm that three “Vector Dynamics” Foundation Systems would resist working Wind Zone I loads with main beam spacing at 75.5 inches. These tests resulted in average movement at design load of 0.81 inches horizontal anchor displacement and 0.125 inches uplift. These results confirmed that three systems will exceed the requirements for 75.5 inches main beam spacing.

Tests 13, 14, & 15 were conducted to show that high pier sets have no effect on the performance of the “Vector Dynamics” Foundation System. Average horizontal anchor displacement was 1.15 inches and uplift was 0.06 inches at working load. This confirmed that the Vector system performs similarly on high pier sets as with lower piers.
Conclusion:

The tests conducted were modeled to simulate a single-section home set, with minimal anchors per side. The “Vector Dynamics” Foundation System allows the anchor to resist uplift loads while reducing the horizontal loads on the anchor. The drag loads are resisted by the Vector diagonal tie and the frame tie. Since the frame tie has less horizontal load, anchor displacement is reduced. As a result, the homes’ displacement is less than a traditional anchoring system. The normal allowable anchor displacement, for traditional anchors is 3 inches horizontal and 2 inches vertical. This movement allows the piers to rotate as the home slides, resulting in the home toppling off of its piers. The average results for the nine design load tests show a horizontal displacement of 1.54 inches and a vertical displacement of 0.47 inches for the “Vector Dynamics” Foundation System. Reduced system displacement keeps the home on its’ piers. The “Vector Dynamics” Foundation System prevents failure caused from sliding or excessive rotation of foundation piers.

The “Vector Dynamics” Foundation System requires less anchors because the load resistance capacity is substantially greater than traditional anchoring. This eliminates the problem of overlapping cones of influence.

The effect of main frame spacing for a given width of home is that, as the frame width increases, the load on the leeward pier increases and the load on the windward pier decreases. For double-section homes, the effect of overturning force on the home is less than that of a single-section home. No testing is required to confirm “Vector Dynamics” anchoring for double-section homes since the single-section testing is the worst case. Wind Zone I multi-section homes do not require anchors as there is no net uplift. As the homes’ width increases, the net dead load also increases, providing more stability.

The series of nine tests to design loads confirmed that the “Vector Dynamics” Foundation System will resist the wind design loads required to meet the MHCSS.