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LOAD-DEFLECTION CHARACTERISTICS OF SMALL-BORE INSULATED-PIPE CLAMPS

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OF SMALL-BORE INSULATED-PIPE CLAMPS

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ABSTRACT

High temperature LMFBR piping is subject to rapid temperature changes during transient events. Typically, this pipe is supported by specially designed insulated pipe clamps to prevent excessive thermal stress from developing during these transients.

The special insulated clamps used on both FFTF and CRBR piping utilize a Belleville spring arrangement to compensate for pipe thermal expansion. Analysis indicates that this produces a non-linear, directionally sensitive clamp spring rate. Since these spring rates influence the seismic response of a supported piping system, it was deemed necessary to evaluate them further by test. This has been accomplished for the FFTF clamps.

A more standard insulated pipe clamp, which does not incorporate Belleville springs to accommodate thermal expansion, was also tested. This type clamp is simple in design, and economically attractive. It may have wide application prospects for use in LMFBR small bore auxiliary piping operating at temperatures below 427°C. Load deflection tests were conducted on 2.54 CM and 7.62 CM diameter samples of these commercial clamps.

INTRODUCTION

During the 1980 ASME Pressure Vessel and Piping Conference - ASME Century 2, twenty papers and a special publication [1][1] were provided on the effects of piping restraints on piping integrity. The pipe clamp was shown to be a significant ingredient to the overall restraint. Its spring rates were often predicted to be nonlinear and significantly influence the overall pipe dynamic response during seismic events. Accordingly, experimental evaluation of these clamp stiffness characteristics are of interest to piping designers.

A typical pipe insulated clamp installation for a liquid metal high temperature pipeline is shown in Figure 1 [2]. Other similar insulated clamp designs and analyses [3-6], are described in the ASME PVP-40 publication [1]. The purpose of this paper is to provide the experimental findings from tests of two types of insulated clamp designs.

LOAD-DEFLECTION CHARACTERIZATION TESTS FOR 1-INCH AND 3-INCH SPECIAL INSULATED CLAMPS

Spring rate characterization testing was completed on a 1-in. and 3-in. liquid metal pipe clamp. Data was acquired while varying the clamping preload through a range of 50% to 150% of design preload. Tensile and compressive veritical and horizontal loads were applied. The vertical loading was imposed through the clamp split-time (single point loading) and through the clamp "elephant ear" flanges (trapeze or two-point loading), as shown in Figures 2 and 3. This test program was designed to provide characterization data on clamp spring rates, effects of clamp preload, and the effects of combined loading on clamp spring rates in tension and compression.

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[1] Numbers in parentheses indicate references listed at the end of the paper.

Test Setup, Data Acquisition

The pipe clamp was installed on a 2-foot length of pipe, following FFTF installation procedures. Pipe flanges were welded onto the ends of the pipe, and were used to bolt the assembly into a load frame. Hydraulic actuators installed in the load frame applied the desired loads to the pipe clamp via hand-operated hydraulic pumps. Loads were monitored with strain gage-based load cells, and clamp and pipe deflections were measured with dia indicators. (See Figures 2 and 3)

Loads were applied incrementally, holding one load constant while step-wise increasing the amplitude of the orthogonal load. The maximum loads in both axes were determined from the design load rating curves. The following parameters were varied during the test:

- Load amplitude
- Load direction (tension/compression)
- Clamping preload
- Single-point (along clamp split-line) and two-point (trapeze) vertical loading

Clamping preload was established by measuring the wrenching torque required to compress the Belleville washer stack to the design height. This torque was designated as the 100% preload torque and was subsequently extrapolated linearly to obtain the 50% through 150% preload torque values.

Dial indicator gages (Figure 2) were positioned to measure vertical and horizontal clamp displacements (Gages 4, 9, 1 and 3), vertical and horizontal pipe displacements (Gages 6, 8 5 and 7) and clamp rotation (Gages 4 and 9). Because clamp deflection measurements included the deflection of the pipe, corrections were applied to the clamp deflection data. For example, data from Gage 3 were reduced by the averaged value of Gages 5 and 7. However, because the pipe deflection was not measured at the clamp vertical centerline, the reported data remain in (Conservative) error by approximately 5%. An additional error, a tendency for the clamp assembly to rotate during some load configurations, was detected by monitoring Gages 4 and 9. During vertical deflection data acquisition, the effects of clamp rotation were removed by averaging the readings of Gages 4 and 9.

Test Findings and Discussion

During the application of horizontal tensile loads perpendicular to the clamp split-line, the clamp spring rate was observed to be quite nonlinear. This is shown in Figures 4 and 5. The vertical load had little affect on the horizontal stiffness as shown in Figure 6.

The vertical stiffness, loading along the split-line of the clamp, was much higher (see Figures 7 and 8) than that in the horizontal direction. When the loading is through the trapeze (two-part load) the stiffness is less and more a function of clamp preload.

During (vertical) trapeze loading, spring rate variations generally followed the results of (vertical) loading along the clamp split-line. The 1-in. clamp spring rate was more sensitive to trapeze loading than to single-point loading because the moment generated by the off-centerline vertical loading would compress either the top washer stack (tensile loading) or the bottom washer stack (compressive loading).

During load reversal, i.e., changing from tension to compression loading in either axis, the clamp was fully loaded and unloaded at least once to remove any mechanical "slop" from the system. The "slop" would manifest itself as a 20 to 30-mil zero shift; i.e., the dial indicator would not return to zero deflection after the initial load was removed. During subsequent load excursions, however, the data exhibited very good repeatability. The results were corrected for this zero shift.

LOAD-DEFLECTION CHARACTERIZATION TESTS FOR 1-INCH AND 3-INCH COMMERCIAL TYPE INSULATED CLAMPS

High temperature LMFBR piping is subjected to rapid temperature changes during transient events. Typically, this pipe is supported by insulated pipe clamps to prevent excessive thermal stress from developing during these transients.

The special insulated clamps used on both FFTF and CRBR piping utilize a Belleville spring arrangement to compensate for pipe thermal expansion. Analysis indicates that this produces a non-linear, directionally sensitive clamp spring rate. Since these spring rates influence the seismic response of a supported piping system, it was deemed necessary to evaluate them further by test. This has been accomplished for the FFTF clamps.

A commercial insulated pipe clamp has recently been marketed. This design does not incorporate Belleville springs to accommodate expansion. Nevertheless, it is economically attractive and may have wide application prospects for use in LMFBR small bore auxiliary piping operating at temperatures below 427°C. Load deflection tests were conducted on 1-inch (2.54 CM) and 3-inch (7.62 CM) diameter samples of these commercial clamps.

Load deflection data for these clamps is shown in Figure 10 thru 11.

CONCLUSIONS

This paper provides typical experimental data and findings obtained from the load-deflection tests of a 1-in. and a 3-in. diameter liquid metal pipe clamp.

The testing confirmed significant variation in clamp spring rate with changes in clamping preload associated with preload-induced compression of the Belleville washer stacks. Much smaller variations in clamp spring rate were produced with load variations - either tensile or compressive - along the clamp split-line, or with variations in compressive loads perpendicular to the clamp split-line.

This type experimental characterization of typical liquid metal pipe clamps should prove useful to guiding future clamp design testing and understanding of insulated clamp stiffness characteristics.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the help of Mr. R. W. White who carried out tests herein described.

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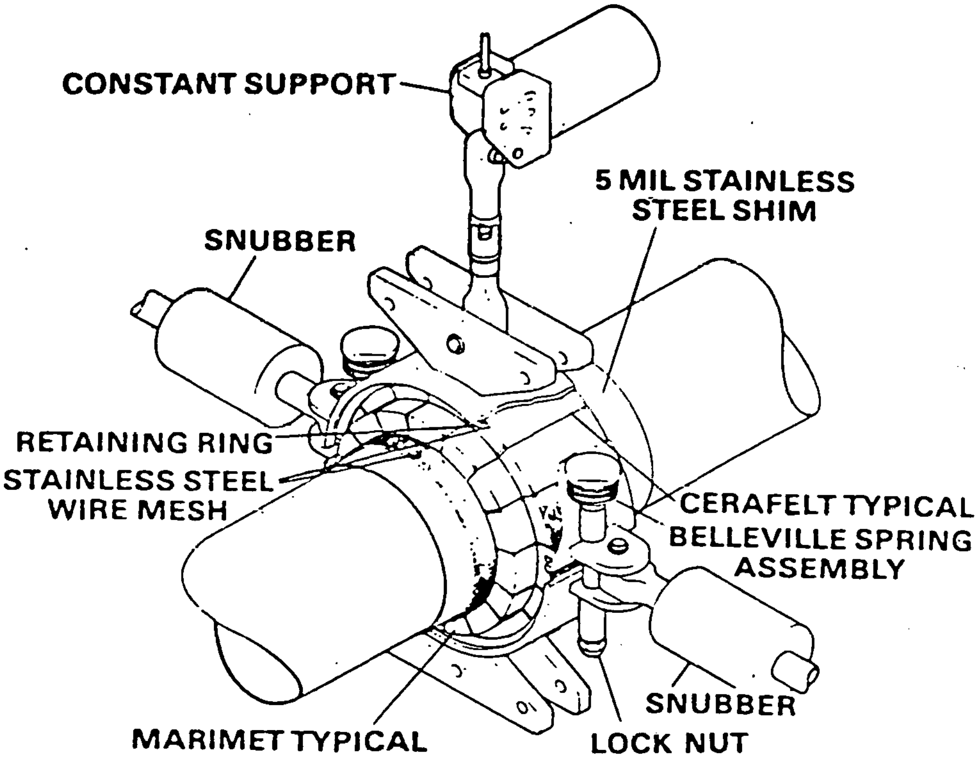

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materials manufactured by
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Fig. 1 Typical Pipe Clamp Installation

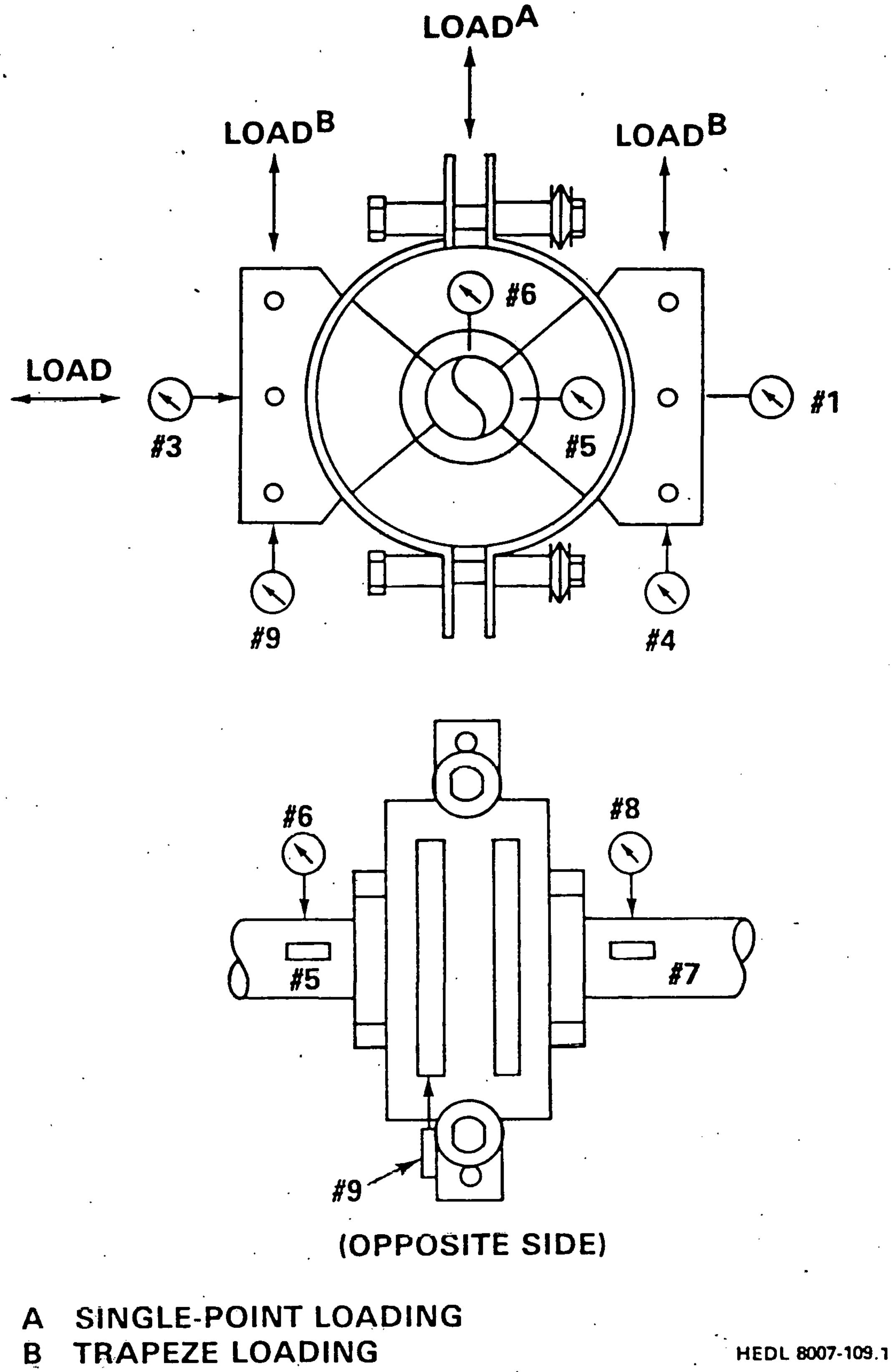

FIGURE 2. Dial Indicator Gage Locations.

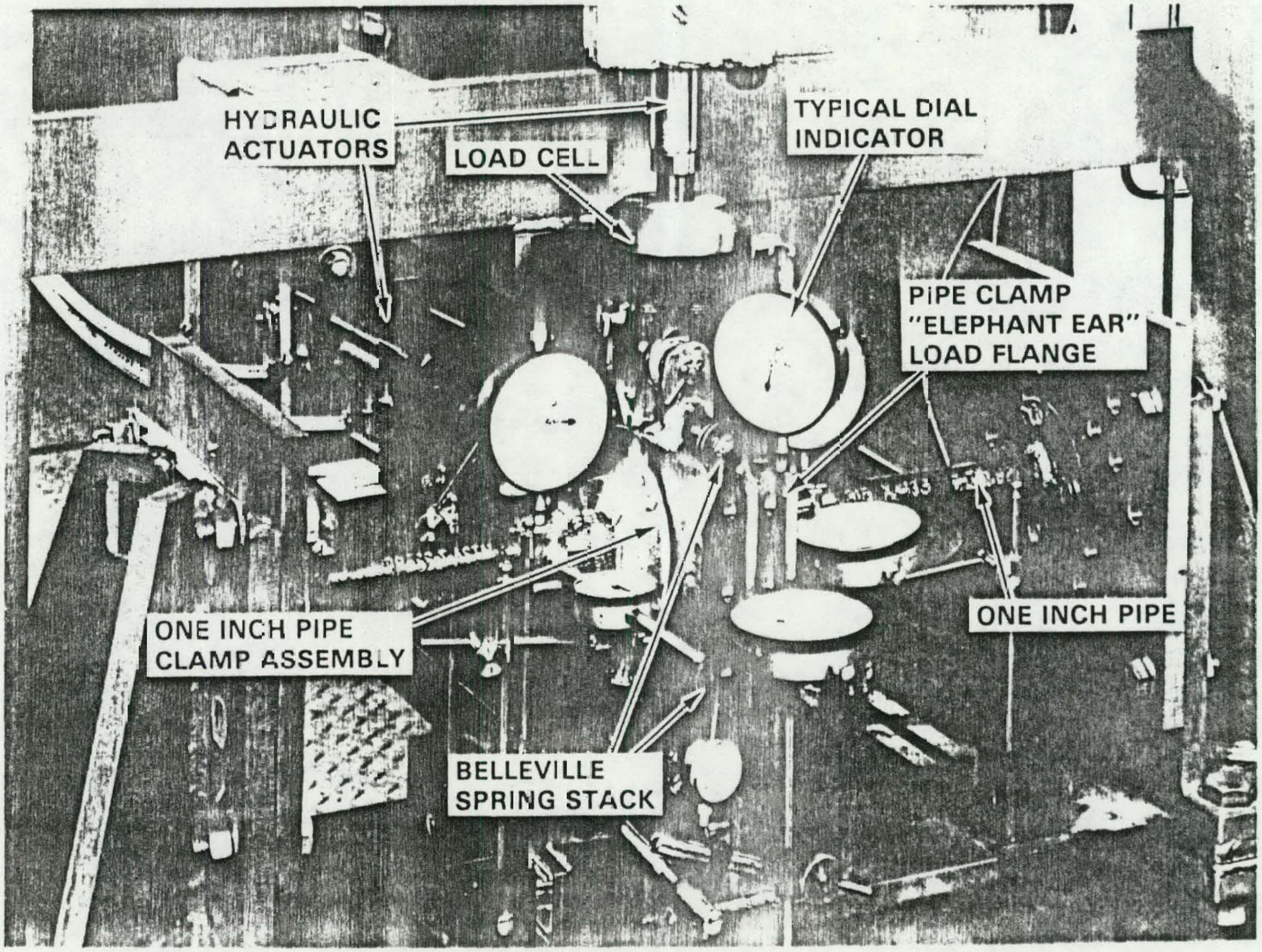

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FIGURE 3. Overall View of Test Setup of 1-inch Clamp: Vertical Loading Through Clamp Split Line. Neg 8007815-1

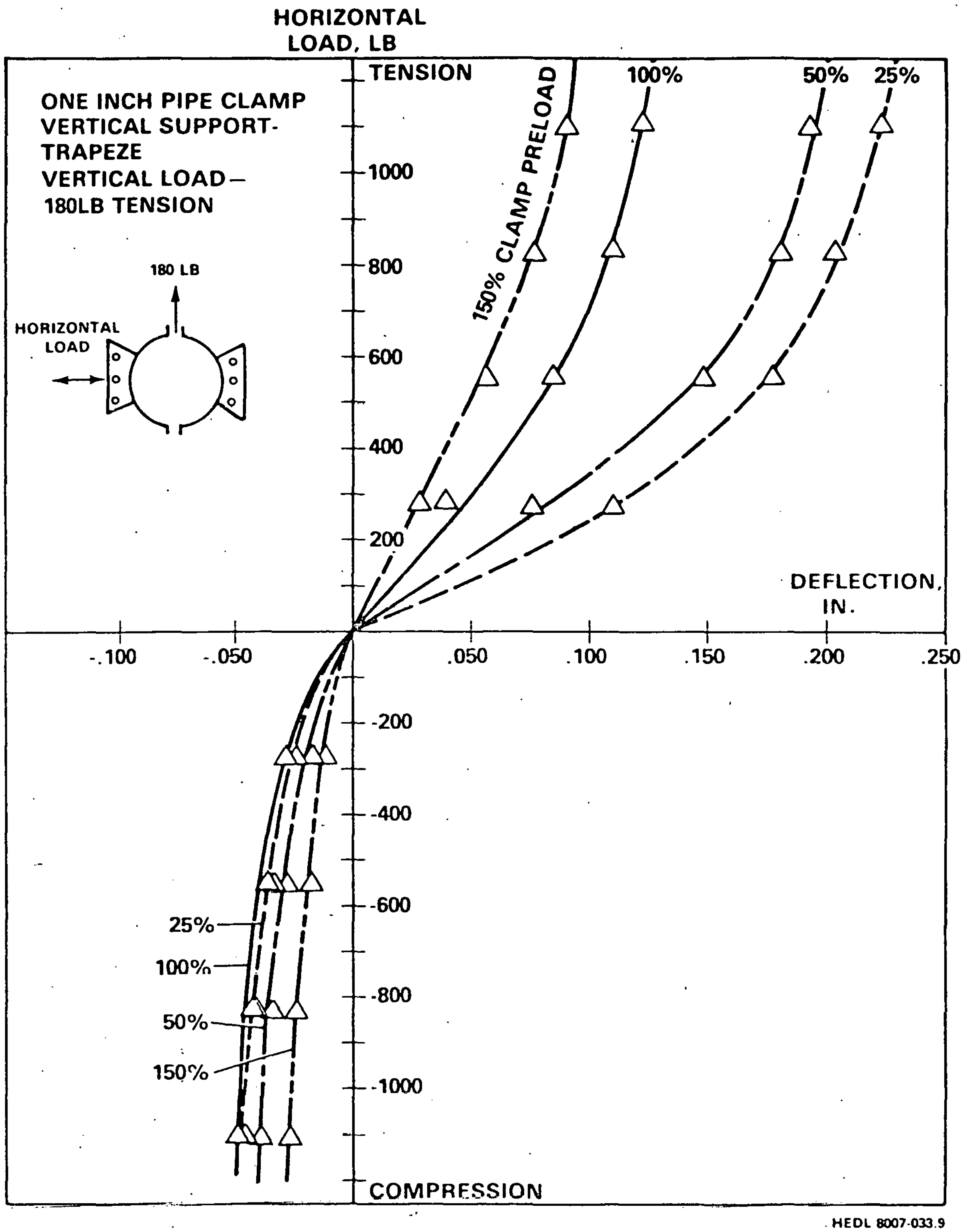

FIGURE 4. Horizontal Load Versus Deflection Curves for 1-inch Special Insulated Clamp

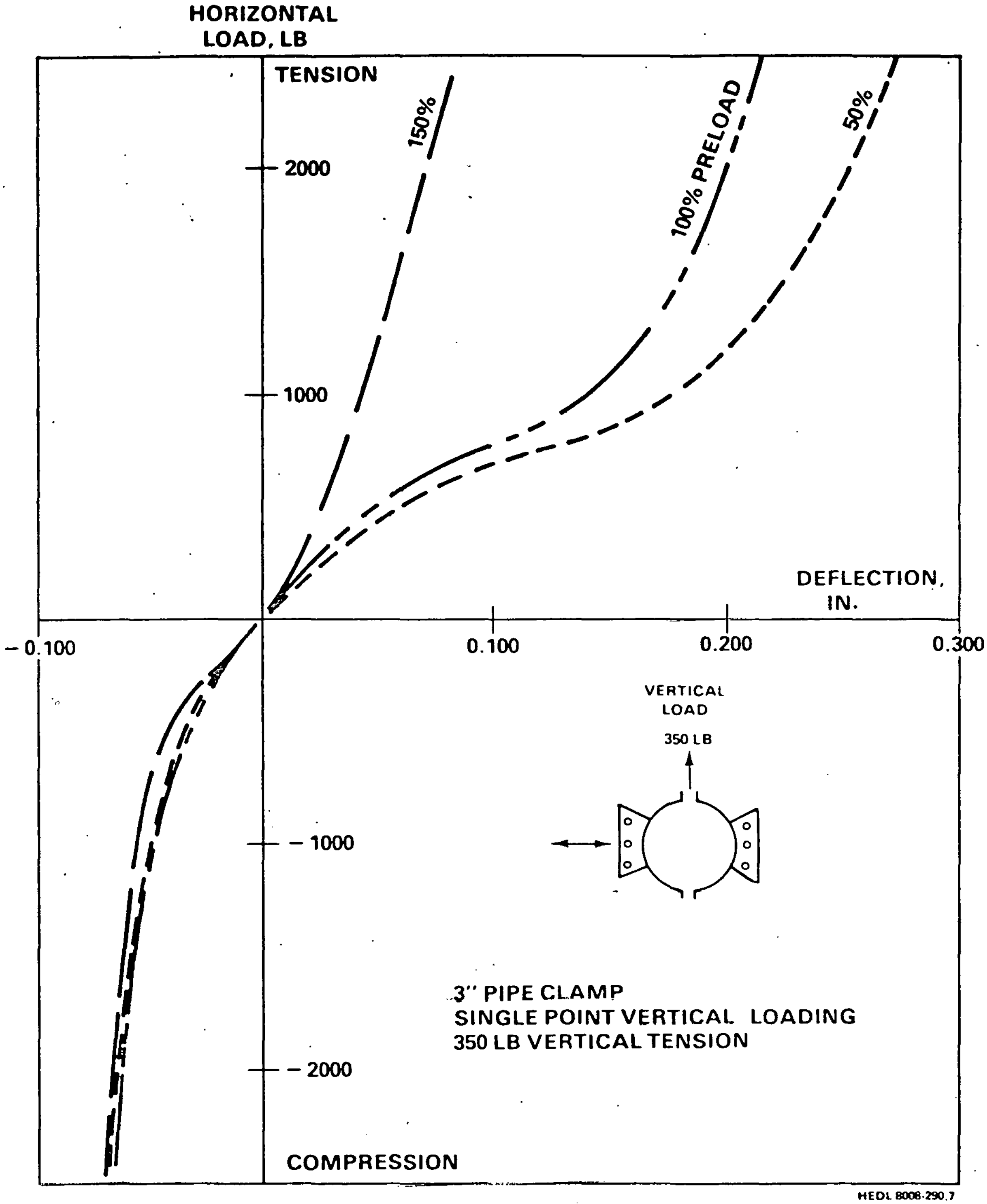

FIGURE 5. Horizontal Load Versus Deflection Curves for 3-inch Special Insulated Clamp

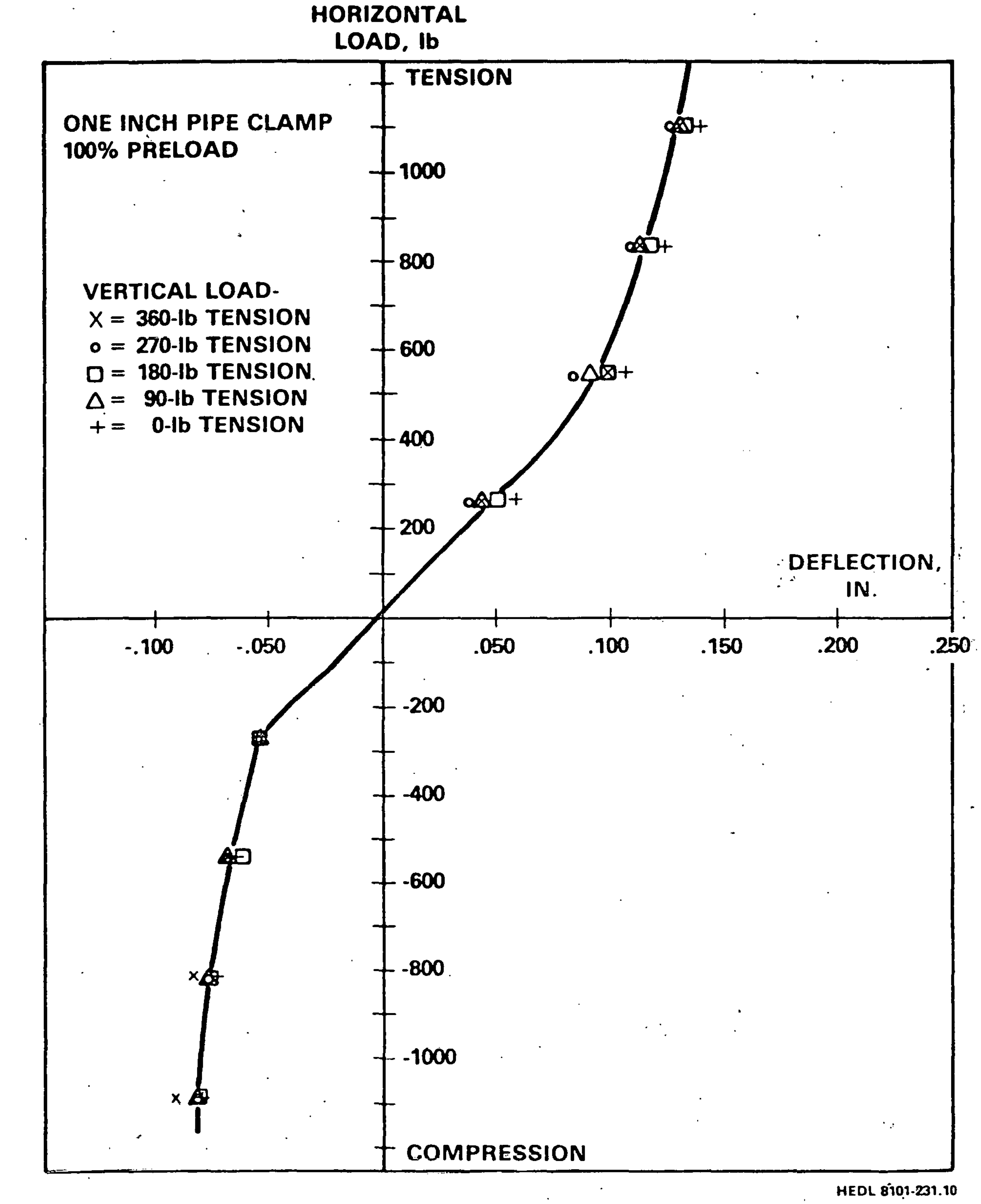

FIGURE 6. Typical Influence of Vertical Load Horizontal Stiffness

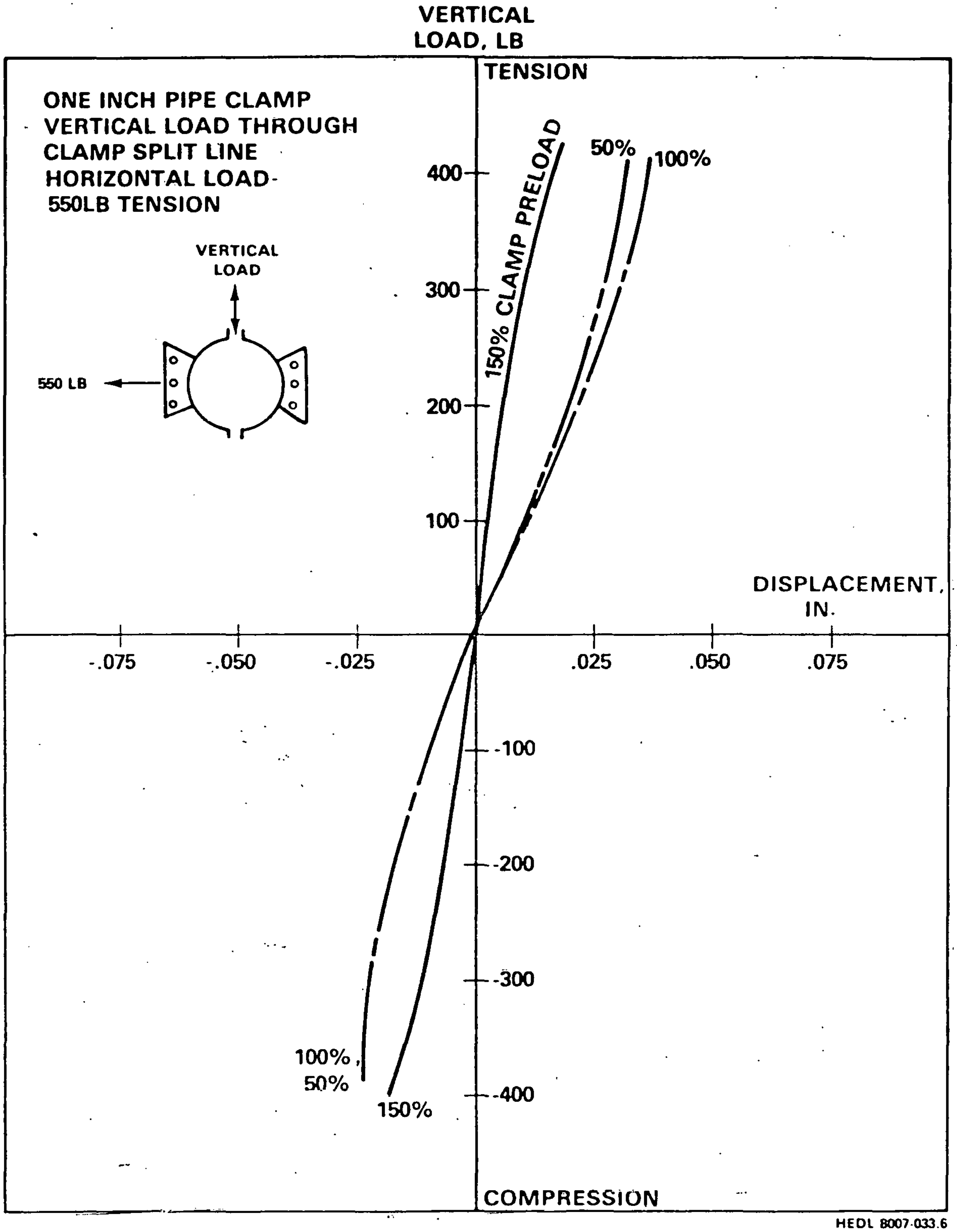

FIGURE 7. Vertical Load Versus Deflection Curves for 1-inch Special Insulated Clamp

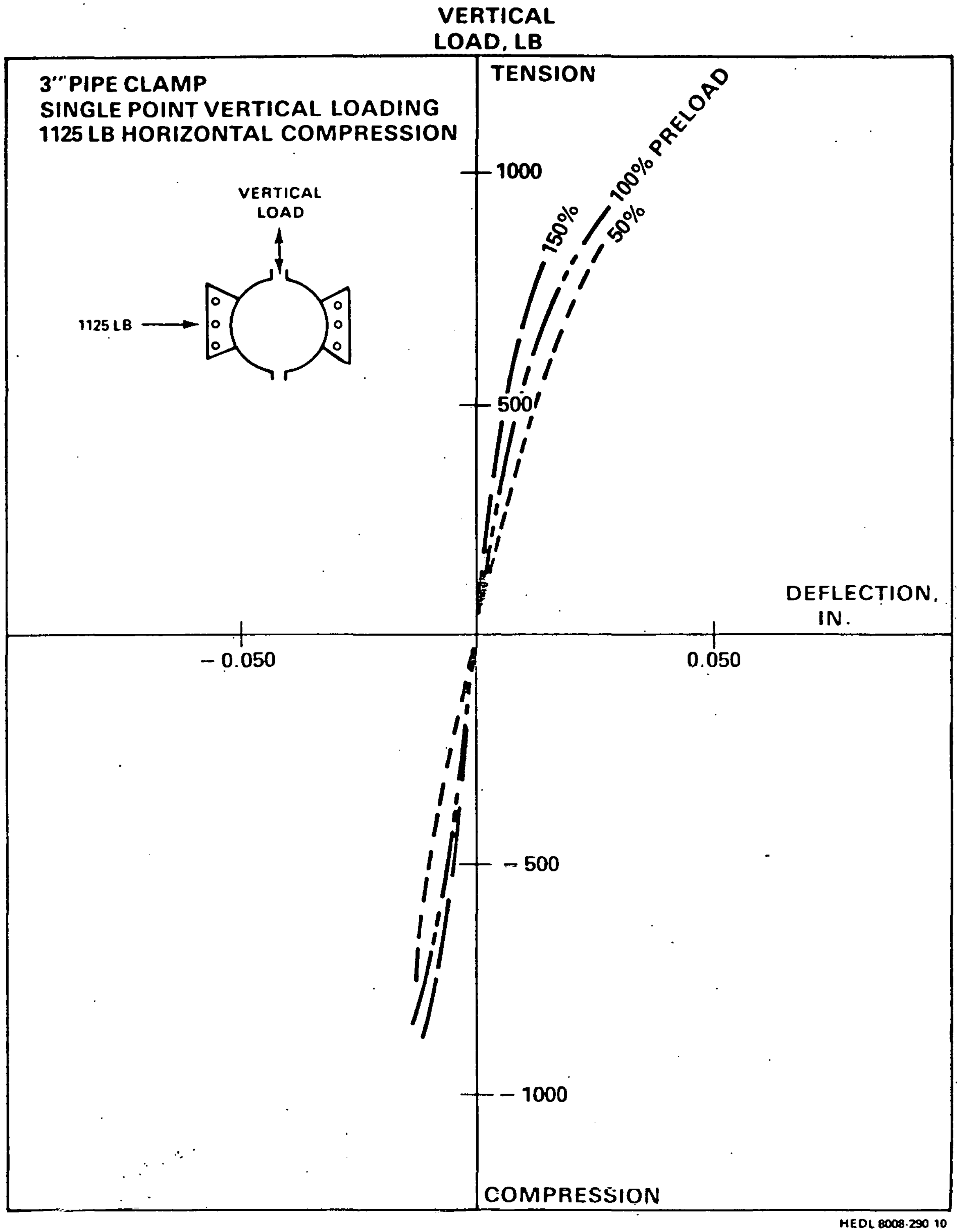

FIGURE 8. Vertical Load Versus Deflection Curves for 3-inch Special Insulated Clamp

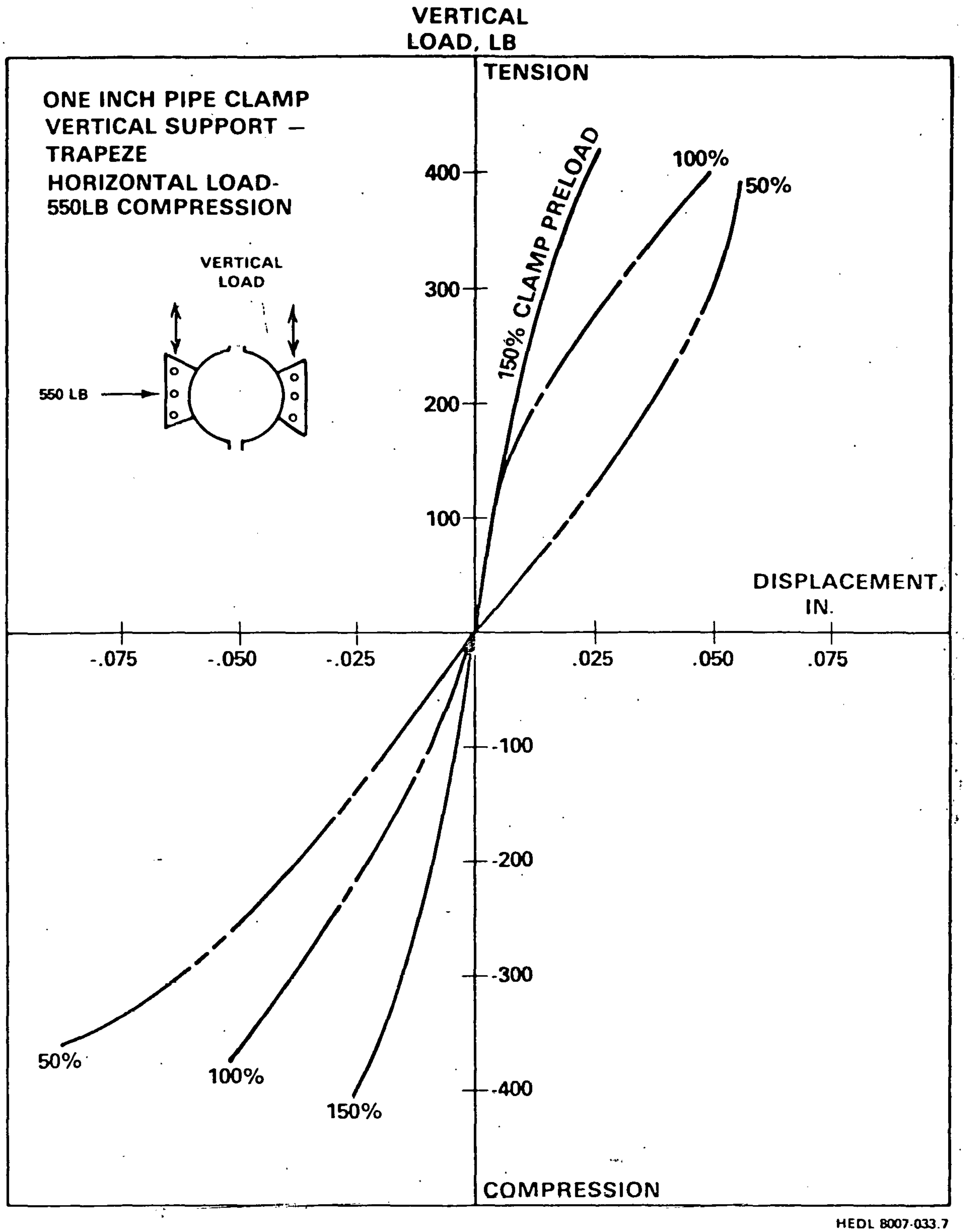

FIGURE 9. Load Versus Deflection Curves.

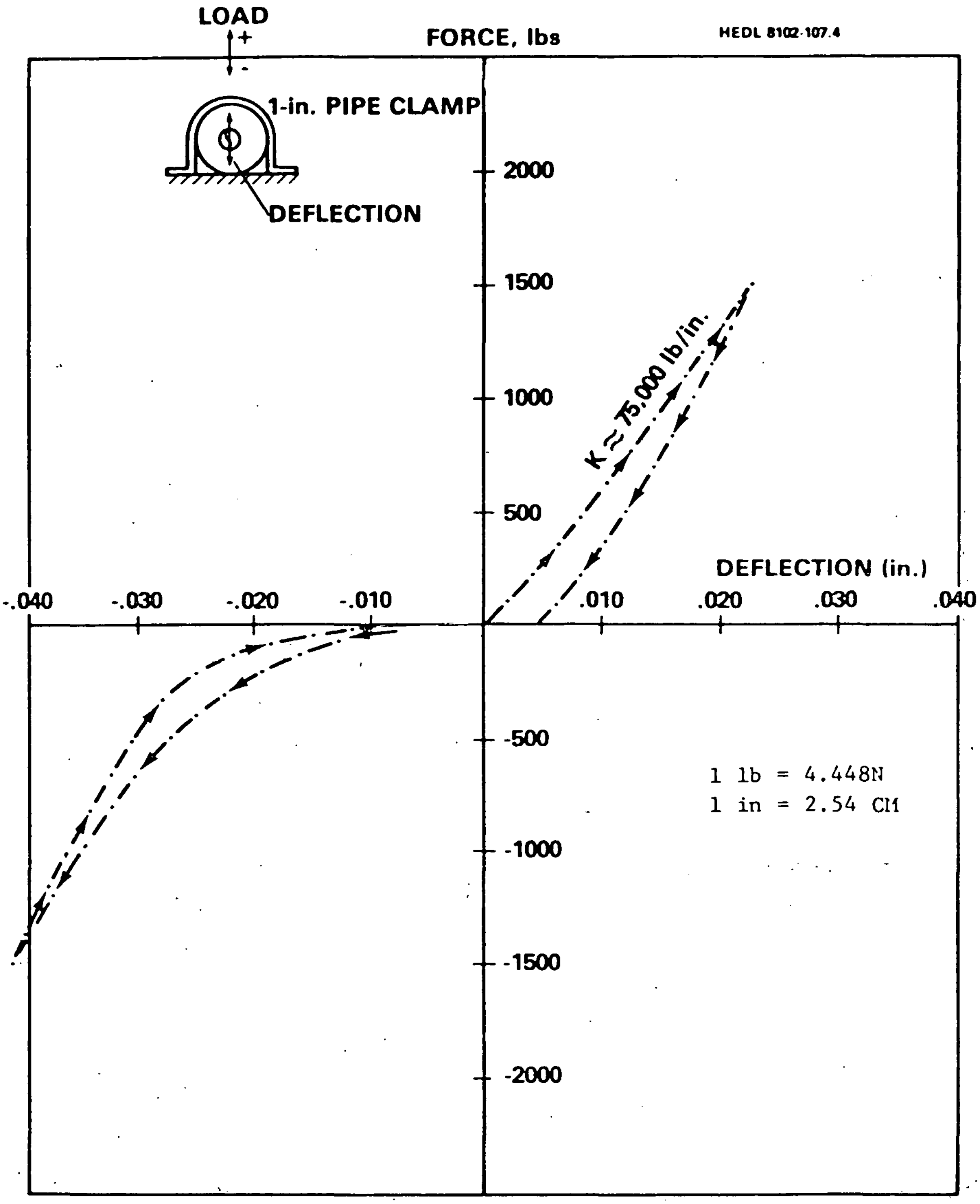

Figure 10. One-inch Clamp Stiffness. Vertical Load-Deflection Data for Commercial Type Insulated Clamp

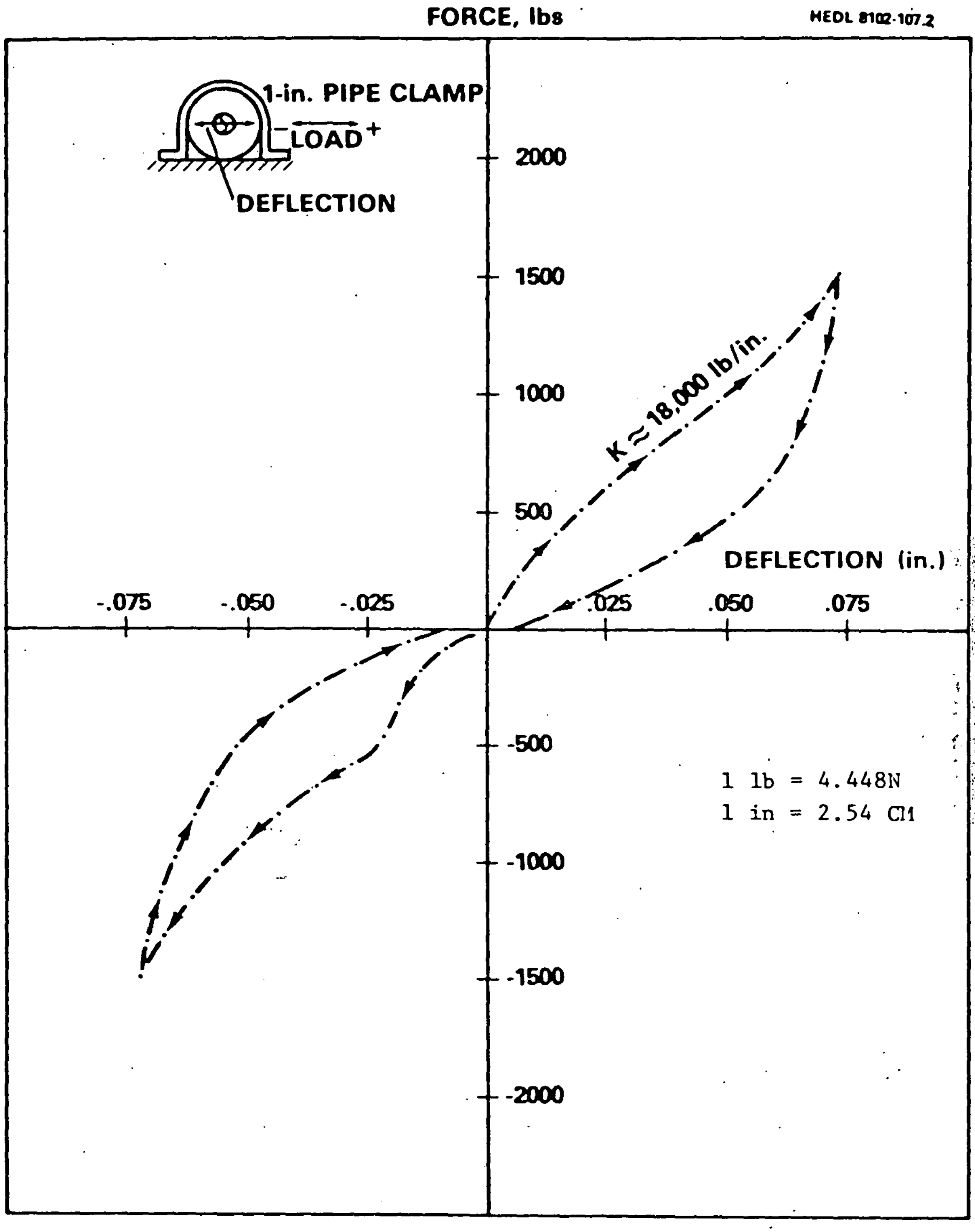

Figure 11. One-inch Clamp Stiffness. Horizontal Load-Deflection Data for Commercial Type Insulated Clamp

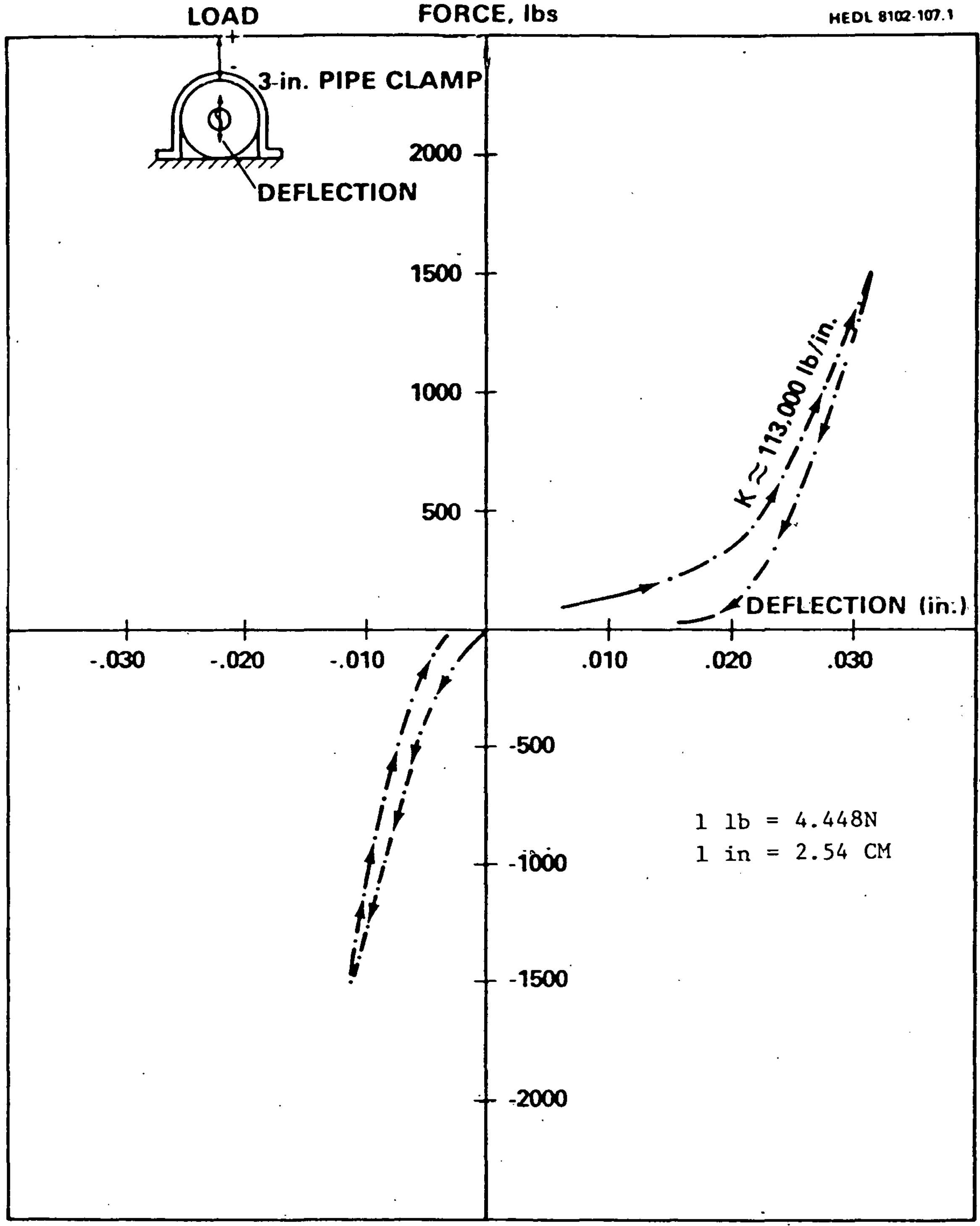

Figure 12. Three-Inch Clamp Stiffness. Vertical Load-Deflection Data for Commercial Type Insulated Clamp

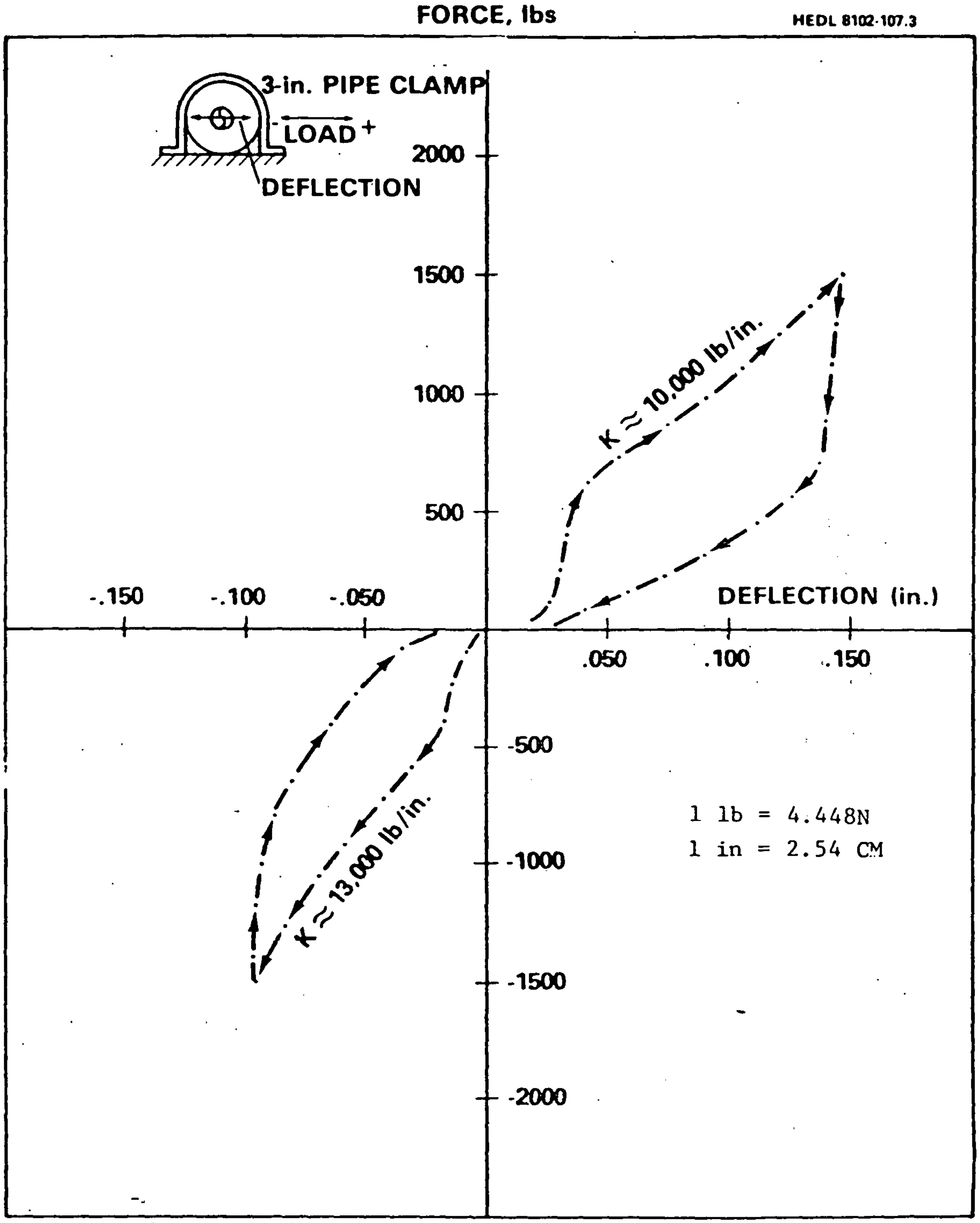

Figure 13. Three-Inch Clamp Stiffness. Horizontal Load-Deflection Data for Commercial Type Insulated Clamp