WASHINGTON PUBLIC POWER SUPPLY SYSTEM
NUCLEAR PROJECT NO. 3

EVALUATION OF THE ITT/GRINNEL FIG. 215 STIFF CLAMP APPLICATION ON SAFETY RELATED PIPING SYSTEMS

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RECORD OF REVISIONS

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INDEX (cont'd)

I - PURPOSE

The purpose of this report is to present a complete and detailed evaluation and resolution of the safety concerns regarding the application of the ITT/Grinnell FIG. 215 STIFF CLAMP on piping. It also addresses the concerns raised by USNRC IE- Notice 83-80 (Ref 1) relative to the use of specialized "STIFF" pipe clamps.

II - SCOPE

This report applies to the use of the ITT/Grinnell FIG. 215 stiff clamp in safety related piping systems for the WPPSS Nuclear Project No. 3.

III - BACKGROUND INFORMATION

1) DESIGN CONCEPT

Washington Public Power Supply System's Technical Specification 3240-4 for Piping and Piping Supports,paragraph 4.11y, requires that "clamps used as the non-integral attachment to the piping component in a snubber strut assembly shall have as a minimum a spring rate greater than five times the spring rate of the snubbing device." This requirement for a specific clamp stiffness was included in the design specification to eliminate the concerns relative to the realistic characterization of snubber mechanical properties (i.e. spring rates)in the structural analytical models. By specifying a certain clamp stiffness, the combined effective stiffness of the snubber and support assembly could then be properly considered in the evaluation of the structural response of the piping system. This subject was later on addressed formally in the USNRC Standard Review Plan 3.9.3 (Ref. 2). As stated in the SRP there was a concern that "...the snubber response characteristics may be washed out by the added flexibility in the support structure (including the clamp)". R1

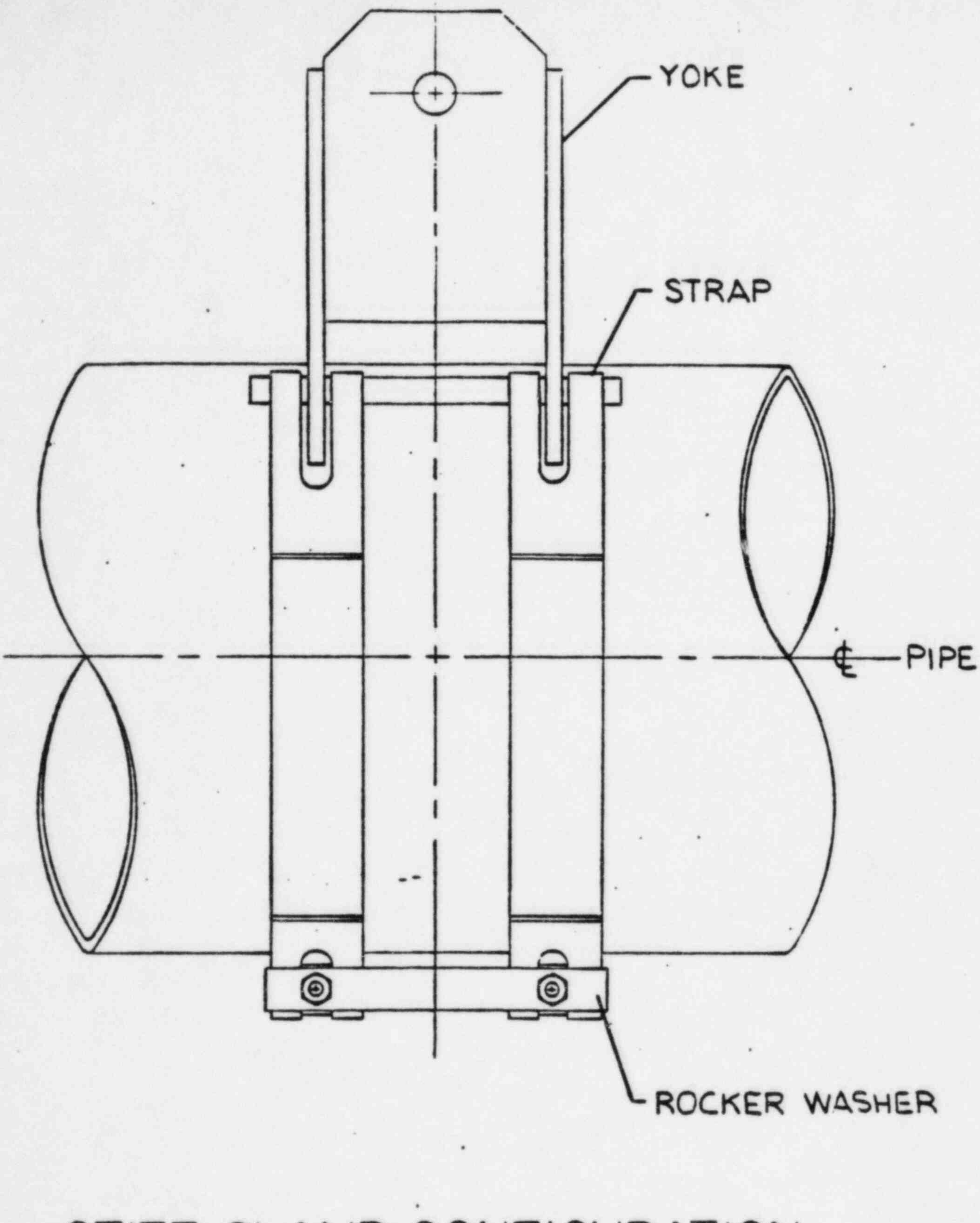
2) ORIGINAL DESIGN

In response to this requirement ITT/Grinnell designed the Figure 215 Stiff Clamp, shown in Fig.1. The stiff clamp consists of 2 or 4 sets of high alloy steel straps with riveted loops at each end. One end of the straps is attached by pins to a yoke assembly which bears against the pipe wall, the other end of the straps is attached to tie rod assemblies which are torqued for tightening. The tie rod assemblies consist of tie rods, trunnion, rocker washers and hex nuts as shown in Fig. 2. To obtain the desired stiffness, the strap assemblies are pre-loaded by torquing the hex nuts against the hardened rocker washer which pulls on the straps to provide enough pretension so that the load required to lift the yoke off the pipe is equal to the faulted load of the largest snubber/strut assembly that is attached to that clamp. R1

3) ORIGINAL PROBLEMS

On May 20, 1981 the installing contractor reported significant tie rod bending on the ITT/Grinnell Figure 215 clamp assembly (MK No. FDC-1151 R1/R2) when installed in accordance with the manufacturer's instructions. Engineering assessment confirmed the tie rod bending and further revealed that a relaxation of the specified 240 ft. lb. torque had occurred after installation. Failure to achieve full and equal tension in the strap loop around the trunnion was also evident, as well as apparent binding between the tie rod and trunnion which resulted in a bending moment that caused deformation of the tie rod. These nonconforming conditions reoccurred in other stiff clamp assemblies during mockup installations performed under the supervision of Ebasco (the Engineer) and ITT/Grinnell (the Supplier) at the site on June 1 and 2, 1981.

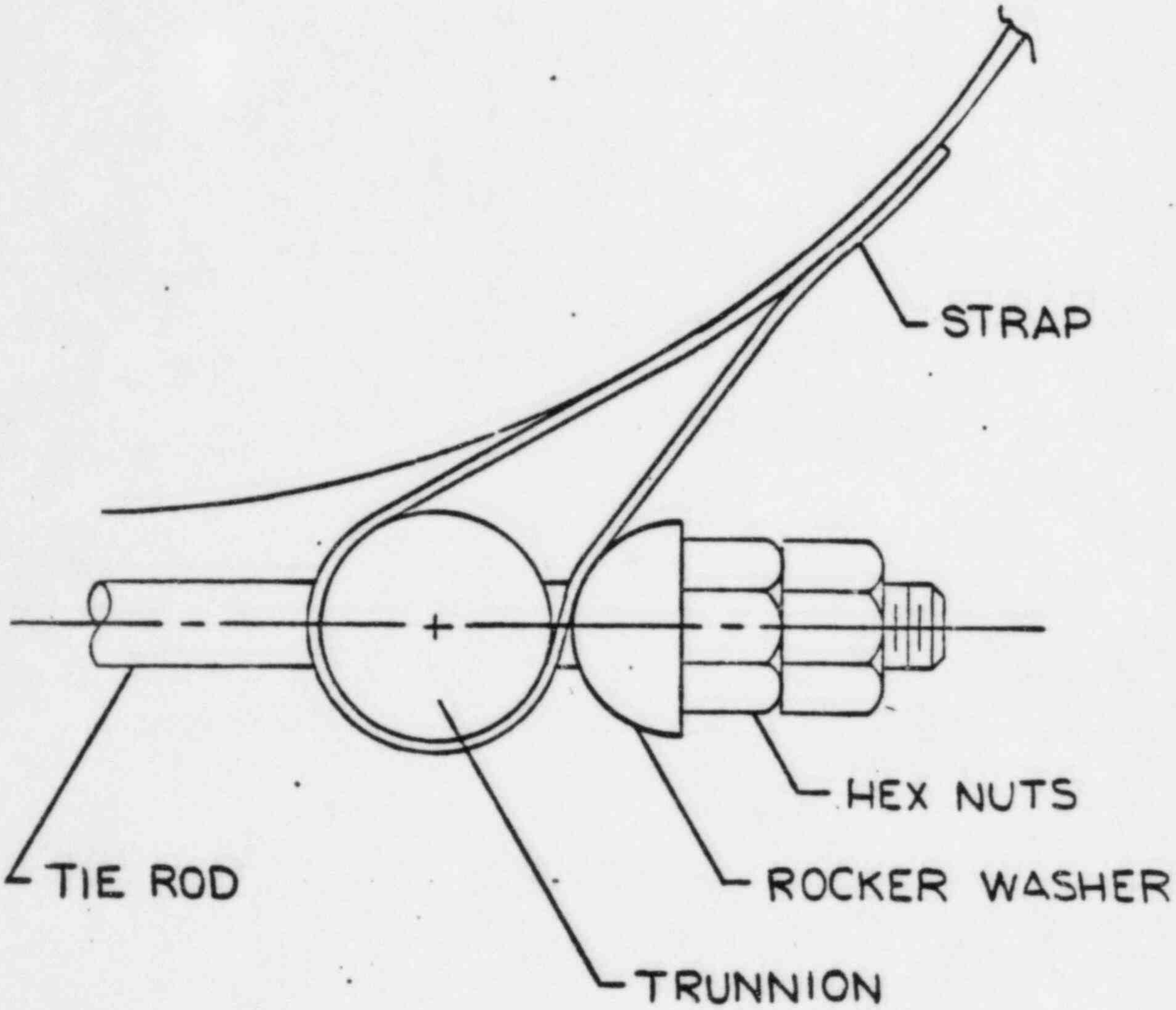
On June 4, 1981 the Engineer initiated a nonconformance report (NCR No. 14020) to formally notify the supplier of the nonconforming conditions. On June 11, 1981 the NRC was notified of the deficiencies pursuant to the requirements of 10CFR50.55(e) (Ref. 3).



STIFF CLAMP CONFIGURATION
ORIGINAL DESIGN

FIG. 1

STIFF CLAMP CONFIGURATION
ORIGINAL DESIGN



ENLARGED DETAIL

FIG. 2

During the course of the Engineering study other potential deficiencies and design questions arose. These additional items involved crack-like indications (tears) on the edges of some of the straps, and questions of ASME code material compliance. ITT/Grinnell issued a detailed report (Ref. 4) on all identified deficiencies and items of concern. Copies of that report are available at the WNP-3/5 Project site. This report summarized each of these items and their resolution.

Subsequent to the issuance of the report on September 15, 1981, the following additional items of concerns were raised by the Supply System (the Owner) and the NRC (Ref. 25).

A. Effects of Differential Thermal Expansion and Pre-Load on the Stiffness of Figure 215 Stiff Clamp

B. Toughness Properties of SA564, TP630 Material at Elevated Temperatures

C. Localized Pipe Wall Stresses

D. Probabilistic/Reliability Analysis

E. Code Cases Applicability

A detailed Engineering assessment was made of the materials, design, fabrication, inspection, qualification testing and installation procedures. As a result of this assessment, modifications to the design were implemented, revised installation procedures were developed and code cases initiated to allay concerns for code applicability and acceptance of the rivet and strap materials application.

These additional items of concern were addressed by a supplement and revision to the September 15, 1981 report issued on December 8, 1981 (Ref. 5).

4) MODIFIED DESIGN

As a result of the concerns identified with the original Figure 215 Stiff Clamp design, it was subsequently determined by ITT/Grinnell that a modification to the original stiff clamp design was required. (Fig. 3)

STIFF CLAMP CONFIGURATION
MODIFIED DESIGN

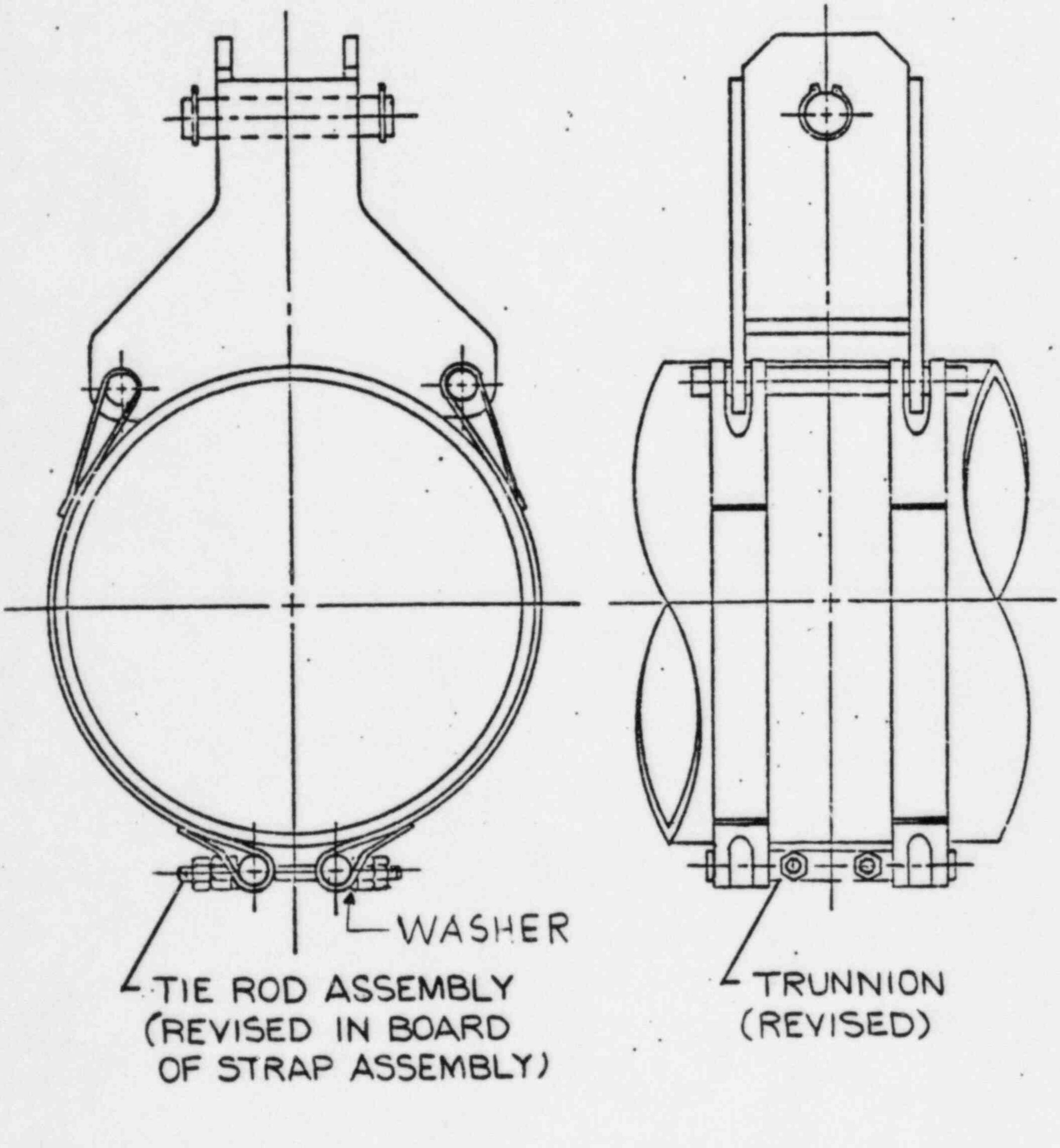


FIG. 3

The design modification proposed was as follows:

1. The rocker washer assembly was removed.

2. The trunnion design was modified so that the two (2) straps on each side of the clamp assembly utilized a single trunnion rather than two (2) separate trunnions.

3. The trunnion material was changed from SA-36 to SA-193 Gr. B7.

4. The location of the tie rods was changed so that pre-torque is applied in-board of the straps.

5. Hardened steel washers were added under the tie-rod hex nuts.

Because of this proposed modification to the original design, ITT/Grinnell performed requalification testing on the new design to insure that the changes made to eliminate the identified problems would also maintain the integrity of the overall design and stiffness characteristics required by the Project Design Specification. In addition, because of the modified method of applying the pre-load to the straps in the new design, new torque levels had to be established which would achieve the necessary pre-load and stiffness requirements.

5) REMAINING CONCERNS

As a result of the modifications to the clamp and further clarifications to the report (Ref. 5) all open items relating to the 10CFR 50.55(e)-Construction Deficiencies Pipe Hanger Stiff Clamps, were closed with the exception of the following two: 1) NRC acceptance of code cases N-249-2 and 2) NRC Office of Nuclear Reactor Regulation (NRR) review of the Stiff Clamp design. The clarifications to the report covered items such as the use of rivets in ASME III-NF components, actual clamp materials, design methods, clamp controls and the effects of changing the heat treating sequence on the strap material.

On June 18, 1982 representatives of the Supply System, Ebasco and ITT/Grinnell met with NRC Staff to review the ITT/Grinnell FIGURE 215 pipe clamps. As a result of this meeting, the NRC Staff raised (13) questions concerning the application of the stiff clamp (Ref. 7). On April 4th, 1983 the NRC Staff issued (7) additional follow-up questions (Ref. 8). Extensive correspondence has been exchanged between the Supply System and the NRC regarding these questions (Ref. 18 through 22).

The concerns expressed by the NRC as reflected by the open items of the 10 CFR 50.55(e) and by the (20) questions can be divided into three general areas:

1) Materials of construction

2) Pipe wall induced stresses

3) Installation requirements and control

These (3) areas will be addressed in the following chapters.

IV - MATERIALS OF CONSTRUCTION

1) ORIGINAL CONCERNS

During the investigations of the originally identified deficiencies, concerns arose over the materials and the code acceptability of the straps and rivets specified in the stiff clamp design.

a) The strap material was purchased to ASTM A-693 GR 630 (a sheet and strip specification) in the annealed condition (condition A). ITT/Grinnell performed operations (age hardening) that altered the mechanical properties and recertified the material to SA 564 GR 630 H 1075. However, SA-564 is a bar specification. ITT/Grinnell used the option provided in NF 2124 which allows the use of "materials outside the limits of size or thickness given in any specification in Section II..." for recertification of the material. The possible deviation from ASME Code material specification and the acceptability of this approach of recertification was of concern.

In addition, tensile test results of three (3) randomly selected straps and one (1) broken strap indicated an average ultimate tensile strength of 173 ksi which exceeded the maximum measured ultimate tensile strength (UTS) limit of 170 ksi as described in Code Case N-249. This led to a concern regarding the susceptibility of the component to brittleness and stress corrosion.

b) The rivet material was specified in the ITT/Grinnell stiff clamp design document as SA 453 Grade 660. This bolting specification material requires that the product be annealed at 1650 F for 2 hours (minimum) and hardened at 1325 F for 16 hours. The material received had been annealed and heat treated in accordance with National Aerospace Specification NAS-1199 which deviates from the requirements of SA 453. This deviation from code product acceptibility was also a concern. R1

2) RESOLUTION

The above concerns have been investigated and actions taken to insure compliance to code requirements. Proposal for code/code cases modifications to clear up the ambiguity in code interpretation has been discussed and presented to the responsible Code Committee/Working Group.

a) The ASTM-A693 Gr 630 strap material in the H1075 condition has been included in the Code Case No. N-249-2. ITT/Grinnell was an authorized material manufacturer at the time of fabrication of the stiff clamps. ITT/Grinnell, as a material manufacturer may perform or supervise one or more operations to achieve the material properties required by the material specification.

Both Tables I-7-1 and I-13-1 of the code indicate that the subject generic material regardless of product form has a reduction in toughness at room temperature after exposure at 600 F for about 5,000 hours and after shorter exposure above 650 F. In 98%

of the WNP-3 applications the operating temperature is less than 500 °F. The Supply System has committed to have the remaining 2% of the clamp applications reviewed on a case by case basis. In those instances where the operating temperatures exceed 500 °F and the reduction of toughness is unacceptable the design of the support will be changed.

Code Case N-249 also includes cautionary notes on the use of materials where the UTS exceeds 170 ksi. It requires impact testing of such materials as a condition of use. In the application of the strap material, however the impact test is not required because of its thinness. Code Paragraph NF-2311, Component Supports for Which Impact Testing of Material is Required, specifically excludes the impact testing of materials with a nominal section thickness of 5/8 inch or less.

The high strength stainless steel, ASTM A693 GR. 630, commercially known as 17-4PH, is representative of a class of alloys that derives its strength and hardness through a combination of martensitic transformation and precipitation hardening. The stress corrosion cracking (SCC) properties of 17-4PH steel are very dependent on strength and electrochemical potential and thus follows the general trend experienced for most other high strength steels. Numerous studies (Refs. 9,10) have shown that increasing strength (achieved through decreased aging temperature) increases the susceptibility to stress corrosion cracking. This material is moderately sensitive to SCC at high strength levels, less sensitive to SCC at intermediate strength levels, and relatively insensitive to SCC in the average low strength condition. (Ref. 10) The stiff clamps installed at WNP-3 exhibit a level of tensile strength that would be classified as intermediate.

Stress corrosion cracking (SCC) requires the presence of a specific corrosive agent. Generally, high strength steels are subject to SCC in chloride solutions, marine atmospheres, solutions containing Hydrogen Sulfide(H_2S)and acetic acid, and in some cases in solutions containing negative ions of Sulfate ($So_4^=$), Phosphate ($Po_4^{\equiv}$) or Nitrate (No_3^-). Precipitation hardening stainless steels are among the most resistant of this class of materials, but have been known to crack in aqueous chlorides and sulfides. Even in the event the stiff clamps were exposed to a moderate levels of chlorides, available data indicates cracking would not occur, as the highest strength levels and concentrations of corrosive agent are required to induce SCC. Exposure to this type of environment is not postulated, under any circumstances for the stiff clamp application.

The resistance of 17-4PH steel to SCC has been demonstrated in long term exposure tests conducted in the marine atmosphere at Kure Beach, N.C. These tests showed no failure in 17-4PH steels heat treated at temperatures above 900 F (resulting in yield strengths of 173 ksi max.) and loaded to 100% of yield strength. Other work indicates no cracking in U-bend samples of 17-4PH heat treated to maximum strength level (210 ksi yield strength) and exposed to seawater. (Ref. 11) The environment in the WNP-3 containment during a LOCA will have a boron concentration below 4,400 ppm buffered with sodium hydroxide to a pH of 8.5 to 11. (FSAR Sections 6.2.2.2, 6.5.2.1,6.5.2.2) These design basis accident concentrations will not affect the strap material. Chlorides or similar corrosive agents will not be present in appreciable concentrations (except as noted above) in the long term operating environment. R1

In the absence of a corrosive environment, stress corrosion induced cracking cannot, by definition, occur. The data cited herein, obtained from a variety of sources, provides the basis for the position that 17-4 PH steel is immune to SCC in the relatively benign environment at the WNP-3 Site and would, in fact, resist SCC under considerably more severe conditions. R1

b) The ASTM-A453 Gr. 660, type A or B rivet material, solution heat treated at 1650 F for 30 minutes and oil quenched and aged at 1325 F for 1/2 to 1 1/2 hours and air cooled, is used in the ITT/Grinnell stiff clamp design and fabrication. This rivet material with the above aging treatment has been included in the Code Case N-249 as revision 2, note #31.

c) The material used in fabricating the clamp frames was SA515 Gr. 65 or SA-36 which are code acceptable materials for Class 1, 2 and 3 components.

d) As was discussed previously in Paragraph IV-1-a, only specific combinations of alloys and chemical environment lead to stress corrosion cracking. Stress corrosion cracking is not possible without all the detrimental factors, including a suitably corrosive environment present during construction, test, startup and operation regardless of the ultimate tensile strength of the material.

Code Case N-249 as presently written (Rev.5), is ambiguous in its requirement for demonstrating that the material is not subject to stress corrosion cracking. The ASME Working Group on Component Supports - Subgroup on Design - Section III is currently in the process of revising Code Case N-249. In requirement(5) of the present Code Case version, the word

"and" will be replaced by "or" to read as follows:

"....For these cases, it should be demonstrated by the Owner that (1) the impact test results for the material meet Code requirements and (2) the material is not subject to stress corrosion cracking by virtue of the fact that (a) a corrosive environment is not present <u>or</u> (b) the component that contains the material has essentially no residual stresses or assembly stresses, and it does not experience frequent sustained loads in service."

Requirement (5) as revised will either be kept as an integral part of the Code Case or it will be deleted from it and included into the main body of the ASME Section III Code - Appendix NF Subarticle 1-2300 - Physical Requirements.

V - PIPE WALL INDUCED STRESSES

1) ORIGINAL CONCERNS

As indicated in Section III-3, one of the original concerns regarding the application of the Stiff Clamp was that the interaction between pipe and clamp had the potential to induce significant stresses in the pipe wall. This concern was later raised generically for all specialized "Stiff" clamps by the USNRC IE-Information Notice 83-80 (Ref. 1).

The potential for the stiff clamp to induce significant localized stresses in the pipe wall was recognized and considered in the WPPSS Technical Specification 3240-4 for Piping and Piping Supports by requiring that "the localized stresses induced by the external forces into the pipe wall shall be analyzed by the Engineer in combination with all existing stresses in the piping." (Par. 4.11.bb) R1

In the initial design development the pipe stress induced by the clamp was thought to be minimal. As the design was developing, the Supply System and Ebasco requested verification of the magnitude of the induced stresses from ITT/Grinnell. However, since there were many different combinations of pipe size, pipe material and thickness and clamp size, the means of enveloping all these combinations and determining a representative stress value for clamp/pipe interaction were not well established.

In regards to the subject clamp, its geometry was not amenable to a simple analytical treatment. It was evident in 1981, that in order to obtain meaningful stress data a test program supplemented by analysis would be required.

2) TEST PROGRAM

The test program to determine experimentally the magnitude of induced stresses on the pipe wall evolved over a period of 4 years (1981-1985). Engineering evaluations and assessments of the on-going test results provided a better understanding of the interaction effects between pipe and clamp and therefore provided a basis for new tests. R1

The source of the local pipe stresses induced by the stiff clamp can be caused by one or a combination of the following conditions:

1) PRELOAD - The clamps are installed with a certain preload obtained by torquing the Tie-Rods to a specified torque.

2) PRESSURE RADIAL EXPANSION - The radial expansion of the pipe due to the internal fluid pressure is locally restrained by the clamp, thus causing additional stresses.

3) THERMAL RADIAL EXPANSION - This is a similar effect to 2) above, except that the radial expansion is due to the thermal expansion effects. This effect is more significant in the case of stainless steel pipe, due to the higher coefficient of thermal expansion of the pipe relative to the clamp (carbon steel yoke, high alloy steel straps). The radial growth of the stainless steel pipe is therefore restricted more than in the case where pipe and clamp are of similar materials.

4) APPLIED LOAD - During the operational life of the piping system, various loads will be transferred between the pipe and the supporting structures, through the clamps. These applied loads will cause additional localized pipe stresses. The applied loads can

be "compressive" or "compression" if they cause the yoke to bear against the pipe or "tensile" if they cause the yoke to separate from the pipe.

5) THERMAL TRANSIENTS - For piping subject to thermal transients, the contact of the clamp against the outside surface of the pipe provides an additional heat sink which has an affect on the piping through wall temperature distribution.

Since the induced stresses due to thermal transients were considered to be negligible and the stresses due to the pressure radial expansion can be calculated from the thermal radial expansion stresses, the test program covered only the local stresses due to preload, applied load, and thermal expansion. (More detailed discussion on the thermal transient stresses and pressure radial expansion is presented in Sections V-6-B and C.)

The first series of tests to determine the local pipe wall induced stresses were completed by ITT/Grinnell in March 1982. These tests addressed only the stresses due to the pretorque and were done for the following combination of pipe and frame sizes (for relationship between frame size and pipe size see Appendix I).

FRAME SIZE	PIPE SIZE	LOAD
1 C	6" Sch. 40	120 ft-lbs
1 C	6" Sch. 160	120 ft-lbs
3 C	24" Sch. 20	180 ft-lbs

R1

The results of these tests showed induced hoop stresses in the magnitude of 35,000 psi for the case of 6" Sch. 40 pipe. These stresses were located on the top of the pipe (yoke area) in the region between the 2 straps. The tests although showing potential for significant induced stresses were inconclusive due to the fact that there was no assurance that the strain gages had been located at or close to the highest stressed region.

Therefore a second set of tests were performed in 1983. The first part of these tests included the determination of the highest stress points through

the use of "STRESSCOAT" technique. Once these points were identified, strain gages (three gage 45 rosettes) were placed at these points and stresses were measured for two load conditions: a) Pretorque alone b) Pretorque + Max. Applied Load (compressive). The following combinations of pipe/clamp and load were tested:

FRAME SIZE	PIPE SIZE(Std.Sch.)	LOAD CONDITION
1 C	6"	a) 25 ft-lbs b) 25 ft-lbs + 11,520#
2 C	8"	a) 35 ft-lbs b) 35 ft-lbs + 11,520#
2 C	14"	a) 35 ft-lbs b) 35 ft-lbs + 11,520#
3 C	24"	a) 40 ft-lbs b) 40 ft-lbs + 11,520#
4 C	6"	a) 120 ft-lbs b) 120 ft-lbs+ 26,700#
5 B	14"	a) 130 ft-lbs b) 130 ft-lbs+ 26,700#
6 B	24"	a) 170 ft-lbs b) 170 ft-lbs+ 26,700#

R1

The results of these tests indicated that the maximum stresses occurred in the area of contact between pipe and yoke and that their magnitude could be significant, especially for the cases of thin wall pipe (standard schedule) subject to maximum torque and maximum rated load. (For example, for the 8" pipe with frame 2C the stresses calculated on an elastic basis were 62,700 psi). It became evident then that for some combinations of pipe/clamp size subject to the full torque and maximum rated load the local induced stresses would approach or exceed those allowed by the Code. R1

These series of tests also indicated that the induced stresses could vary greatly when using different clamps of the same frame size. An evaluation of the causes of this variation indicated that the amount of contact between pipe and yoke was an important factor on the magnitude of induced stresses. Since the amount of contact is largely dependent on physical conditions such as yoke radius, pipe and clamp fabrication tolerances which vary from application to application, it became clear that in order to obtain meaningful test data the contact between pipe and yoke would have to be controlled and quantified. All these events lead to the third series of tests performed by ITT/Grinnell in 1984. R1

As a result of the knowledge acquired from the previous tests it was recognized that in order to be able to accurately predict the magnitude of the local pipe stresses induced by the stiff clamp, a comprehensive plan which would include both analytical and test methods had to be established.

Such a plan was then formulated with the following objectives:

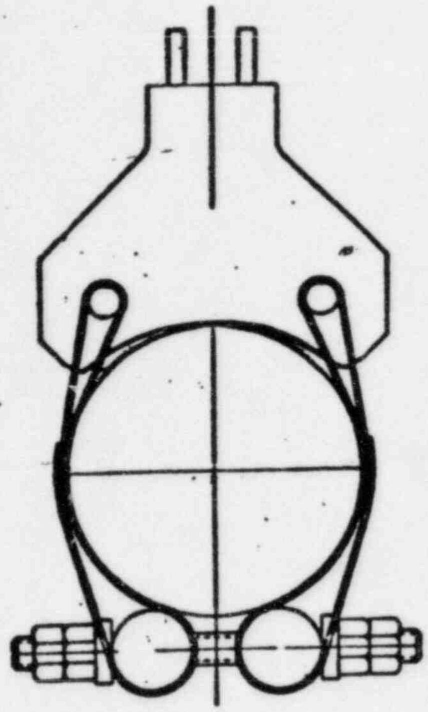
1) Develop an analytical relationship between pretorque and lift-off load. (lift-off load being defined as the tensile load which causes the initiation of lift-off or separation of pipe and yoke resulting in at least a .002" gap).

2) Perform limited tests to validate analysis described above.

3) Establish the worst condition of contact between yoke and pipe. This "Point" load or "Line" load condition occurs when the contact between yoke and pipe is at a minimum (see Fig. 4).

4) Develop an analytical model using finite element methods, simulate "Point" load conditions and run analyses for all combinations of pipe/pipe schedule/clamp frame sizes.

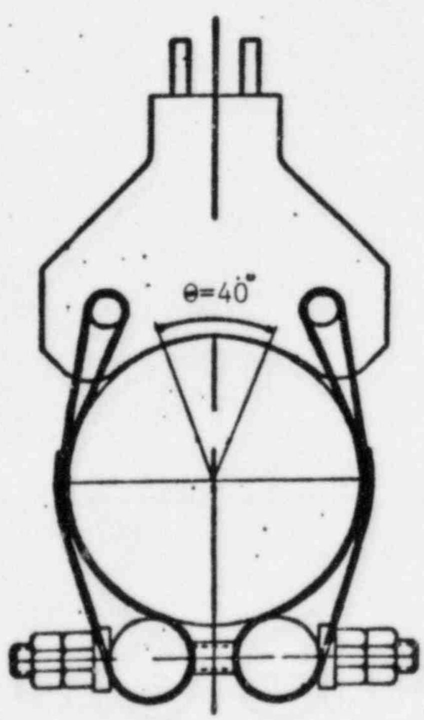
5) Perform tests for several combinations of pipe/clamp. Compare results of the testing with analytical methods.



"POINT LOAD"

CONTACT

FIG. 4



"DISTRIBUTED"

CONTACT

FIG. 5

6) Develop correction factors for conditions where the contact between yoke and pipe is other than point load. Perform tests to validate this approach.

7) Use the analytical results to determine the maximum magnitude of the induced stresses, as a function of pipe diameter, pipe wall thickness, clamp frame size, pre-torque, applied load, and pipe temperature.

3) TEST DESCRIPTION

In this section the tests performed at the facilities of the Research, Development and Engineering Departments of ITT/Grinnell in Providence, R.I., as part of the plan mentioned above will be briefly described:

A. Tests To Determine Lift-Off Loads

The purpose of these tests was to determine the relationship between pretorque and lift-off load. The following combination of pipe/pipe wall/clamp size were used:

Pipe Size		Material	Spool Length	Clamp Frame Size
2 1/2"	std.	Carbon Steel	24"	1 C
6"	std.	Carbon Steel	24"	1 C
6"	std.	Stainless Steel	24"	1 C
8"	std.	Carbon Steel	24"	2 C,5 B
8" sch	160.	Carbon Steel	24"	2 C
14"	std.	Carbon Steel	24"	2 C,5 B
14"	std.	Stainless Steel	24"	2 C
24"	std.	Carbon Steel	36"	3 C,6 B
30"	std.	Carbon Steel	36"	9 C

Each clamp was attached to the corresponding spool piece, placed in a Rhiele Test Machine and the tie rods were torqued in incremental steps of 5 or 10 ft-lbs. At each interval of pretorque a tensile force of increasing magnitude was applied until lift-off occurred. This lift-off was identified when a gap of .002", as measured by a feeler gage, first appeared between the yoke and pipe. The magnitude of this force was recorded. The assembly was then unloaded, the next torque was applied and a new lift-off was determined.

A picture of a typical tensile test is shown in Fig. 6. Samples of data obtained are presented in Appendix IV.

B. Tests To Determine Stress vs. Torque

The purpose of these tests was to determine the maximum induced stresses in the pipe wall as a function of the pretorque applied to the tie-rods. These tests were done for the same combinations of pipe/clamp as described above, and were done in conjunction with the tests previously described.

To simulate the worst condition of contact between yoke and pipe, a hardened wire was placed between the yoke centerline and the pipe. Strain gages (three gage rectangular 45° rosettes) were placed on the pipe as close as possible to the yoke at the hardened wire location. The strain gages were connected to appropriate signal conditioning and read out devices. The clamp was installed on the piping, the tie rods hand tightened and the strain gages were zeroed. The tie rods were then tightened in incremental steps and the strains at each step were recorded. These strains were later on corrected for transverse sensitivity and converted to principal stresses (and stress intensities) using elastic stress-strain relationships. Samples of data obtained are presented in Appendix IV.

C. Tests To Determine Stresses Due to Pretorque + Applied Load (Compression)

The purpose of these tests was to determine the magnitude of pipe induced stresses by the stiff clamp under the loads consisting of pretorque + applied load (compression). Since the highest stresses due to the pretorque condition occurred at the contact between yoke and pipe, it was evident that these stresses would increase for those cases where the support load transmitted through the clamp would be in the direction that would make the yoke bear further against the pipe (compressive load).

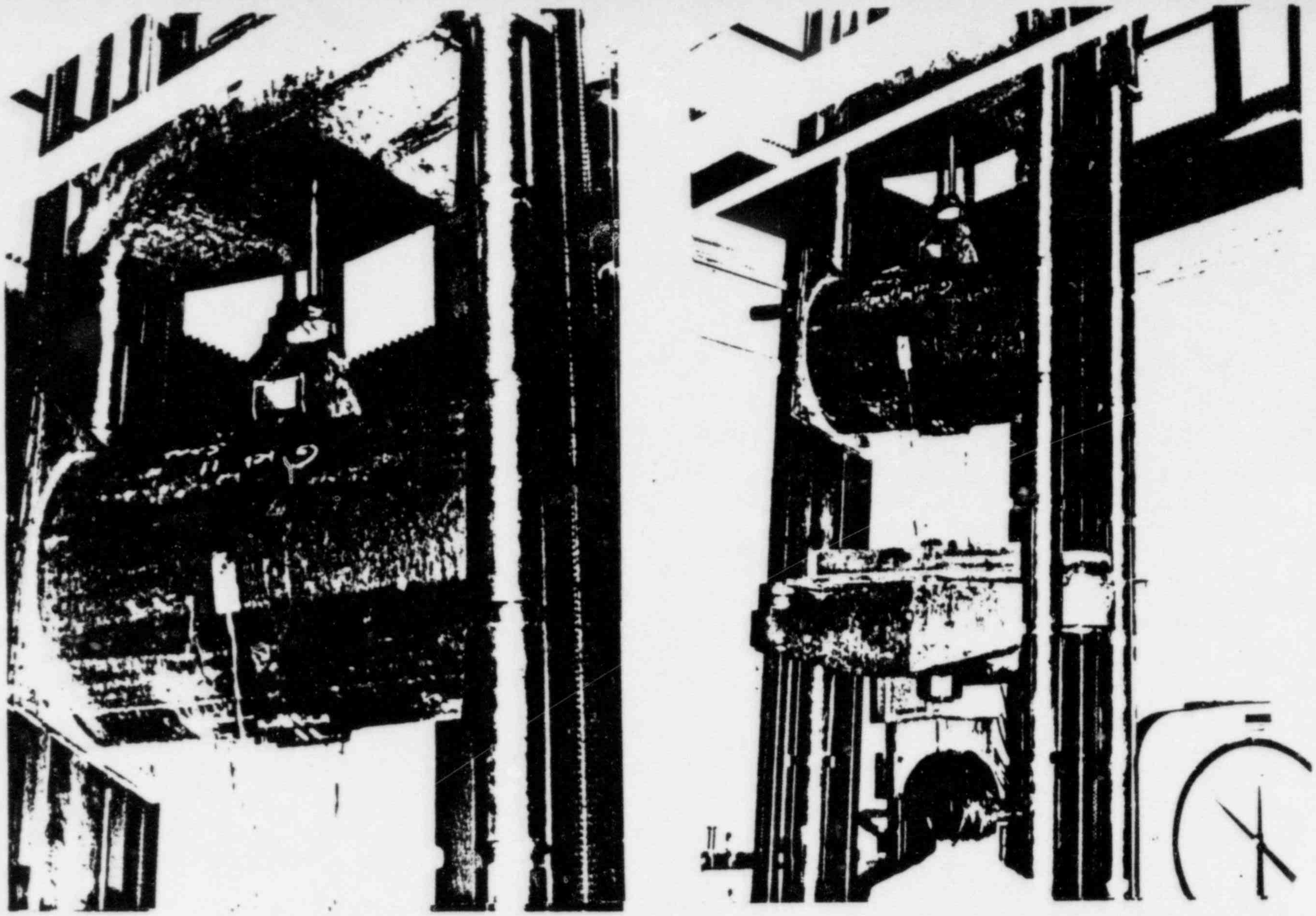


FIG. 6

TYPICAL TENSILE TEST SETUP

These tests were performed in a similar fashion as described in A) and B) above except that the load was applied in the opposite direction.

At each pretorque incremental step, the strains were measured for the pretorque condition alone. A compressive load was then applied in incremental steps (generally 1,000 or 2,000 lbs) and strains were measured at each step. The strains were then corrected for transverse sensitivity, and for the "Beam Bending" effect and converted into stresses. Data relating the increase in stresses with the magnitude of applied load was then obtained. Typical results obtained from these tests are shown in Appendix IV (Table A), and a typical "compression" test set-up is shown in Fig. 7.

D. Tests To Determine Correction Factors

As indicated previously the above described tests were performed under simulation of "Point Load" or "Line Load" contact between yoke and pipe. A series of tests were performed to determine the stress reduction factors for the situations where the contact between the yoke and pipe was done through "2 Point Contact" or distributed through a circumferential arc (Fig. 5).

The "2 Point Contact" tests were done with a 14" standard wall pipe, frame 5B, using 2 hardened wires located at various angles θ (see FIG. 13). Strains were measured at the contact points for the conditions of torque alone and torque + applied load (compressive). R1

To simulate various arcs of circumferential contact, 1/8" thick aluminum curved shim plates were placed between the pipe and yoke in 1/2" or 1" increments. These tests were performed for the following specimens: 6" standard wall pipe with frame 1C, 14" standard wall pipe with frame 5B, and 24" standard wall pipe with frame 3C and frame 6B. Loading conditions consisted of torque alone and torque + applied load (compression). R1

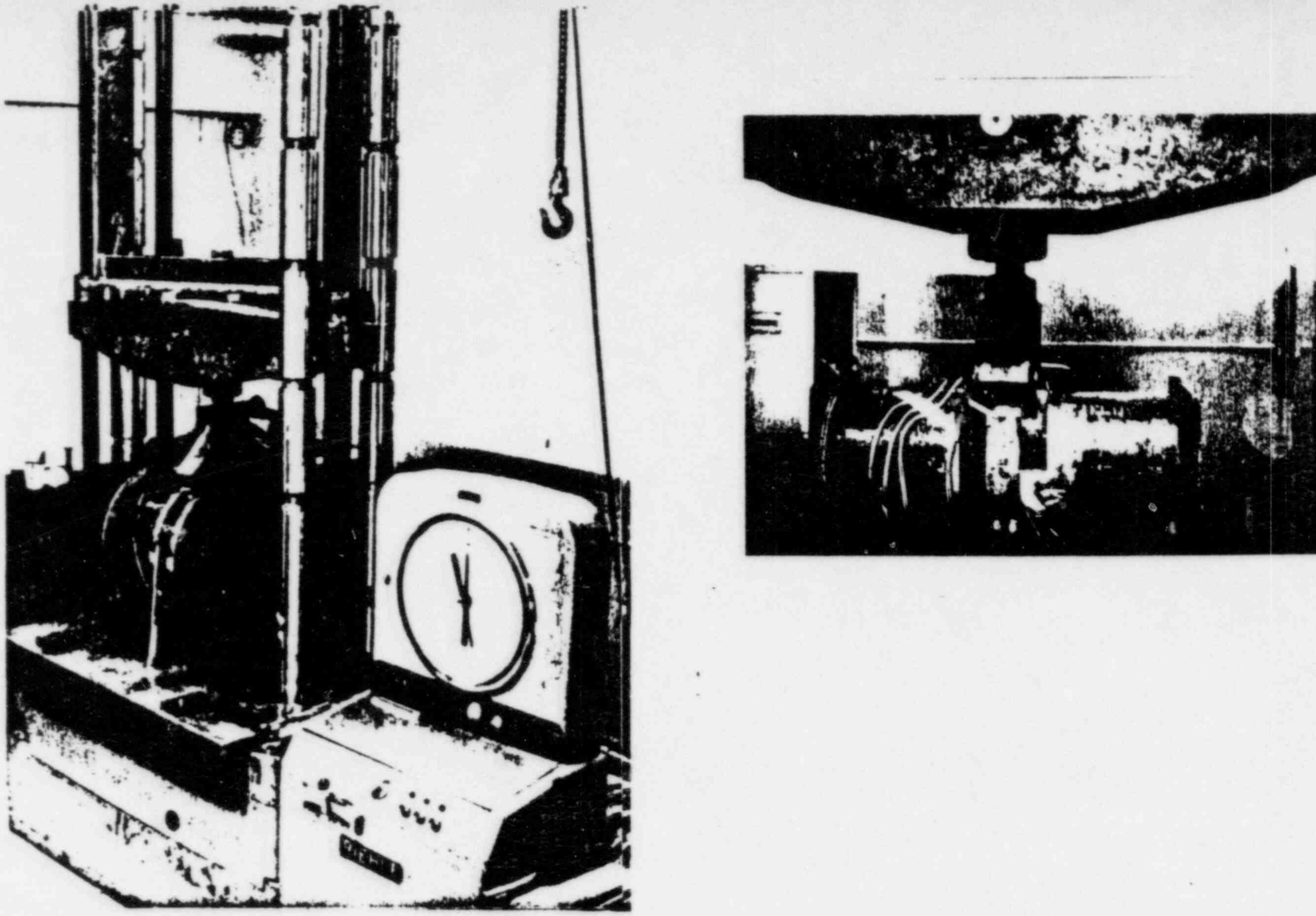


FIG. 7

TYPICAL COMPRESSION TEST
SETUP

E. Tests To Determine Thermal Stresses

The purpose of these tests was to determine the maximum induced stresses in the pipe wall due to the restraining effects imposed by the stiff clamp to the free thermal radial expansion of the pipe.

The tests were performed for the following specimens under simulation of "Point Load: 6" standard wall stainless steel pipe with frame 1C, 14" standard wall stainless steel pipe with frame 2C, and 14" standard wall carbon steel pipe with frame 2C. R1

A single 3-gage rectangular (45°) rosette was installed on each pipe specimen located near the "Point Load" contact between yoke and pipe. One thermocouple was welded to the pipe and another on the yoke. The testing was performed in two steps. In the first step the pipe together with the thermocouple and strain gage were placed in a "Blue M" oven at ambient temperature ($\simeq$ 70 °F) and the instrumentation was then zeroed. The pipe specimen was heated in increments of 25 °F. After each increment, the resultant strains were recorded. These readings (referred to as "apparent strains")reflected the effects of the temperature on the gage and the effects of the free thermal expansion of the pipe.

In the second step, the clamp was attached to the pipe and an initial preload was applied to the tie-rods to ensure a snug fit between clamp and pipe. The instrumentation was again zeroed. Insulation was placed around the clamp in order to obtain a differential of temperature between yoke and clamp to simulate the field conditions. The temperature was then raised in the same steps as in the first step and resulting strains were recorded ("test strains"). By subtracting the "apparent strain", the strains due to the local effects of the stiff clamp were obtained. These strains were then corrected and converted to stresses. A typical set-up for this test is shown in Fig. 8.

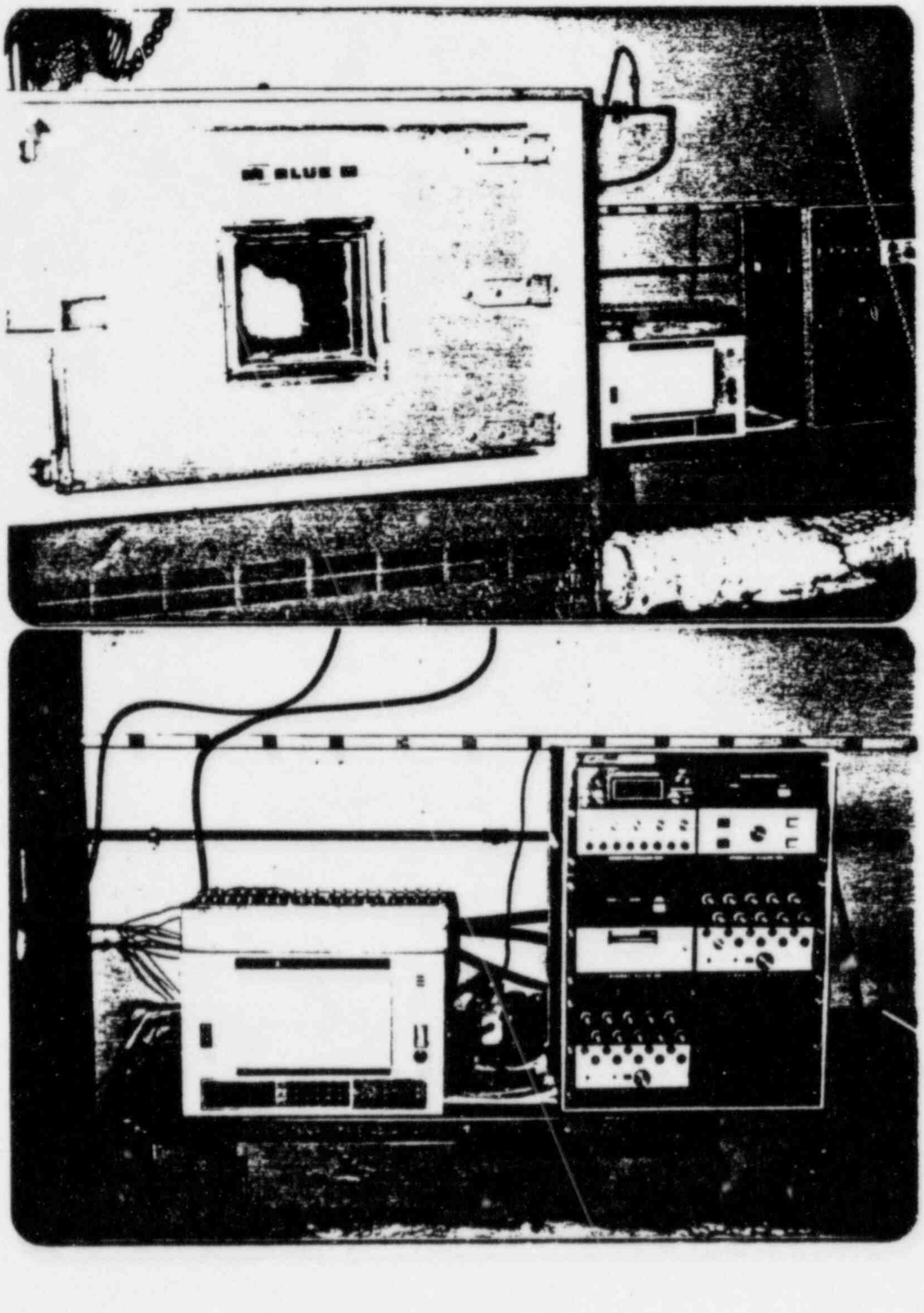


FIG. 8

THERMAL TEST SETUP

4) ANALYTICAL APPROACH

The following analytical models were established to analytically determine the local pipe wall stresses induced by the stiff clamp:

1. First, a simplified model of forces acting on the pipe due to torque was established taking into account the geometric characteristics of each clamp/pipe application. This force distribution is shown in FIG. 9 . A linear relationship between F3 and torque(T) was derived.

2. The set of forces derived above was applied to a finite element model representing the piping. The general purpose finite element program McAuto Strudl Release 4.6 was used, with the "SIPQ" quadrilateral curved shell isoparametric elements with four corners and four nodes chosen for the elements. This element is ideally suited for the analysis of thin to moderately thick plates and shells. The application of the forces into the piping can be seen in Fig. 10.

   A structural analysis was performed for each combination of pipe size/pipe wall thickness/clamp size (a total of 85 different combinations exist at WNP-3). The maximum stresses obtained in the region near the application of force F3 represents the stresses calculated analytically at the point of contact between yoke and pipe under the "point load" assumption. Since the Strudl results are linear and elastic a linear relationship was established between stresses and torque for each clamp application.

3. From the distribution of forces shown in FIG. 9, and assuming that pipe and clamp interact as 2 springs as shown in FIG. 11, the following analytical relationship can be established between lift-off load, F3, stiffness of pipe (kp), and stiffness of straps (ks):

   $F_{lift-off} = 2F3 \; (1 + 2\; ks/kp) = 2\; F3\; (k)$ where $k \geqslant 1$.

FORCE DISTRIBUTION IN PRELOADED STIFF CLAMP

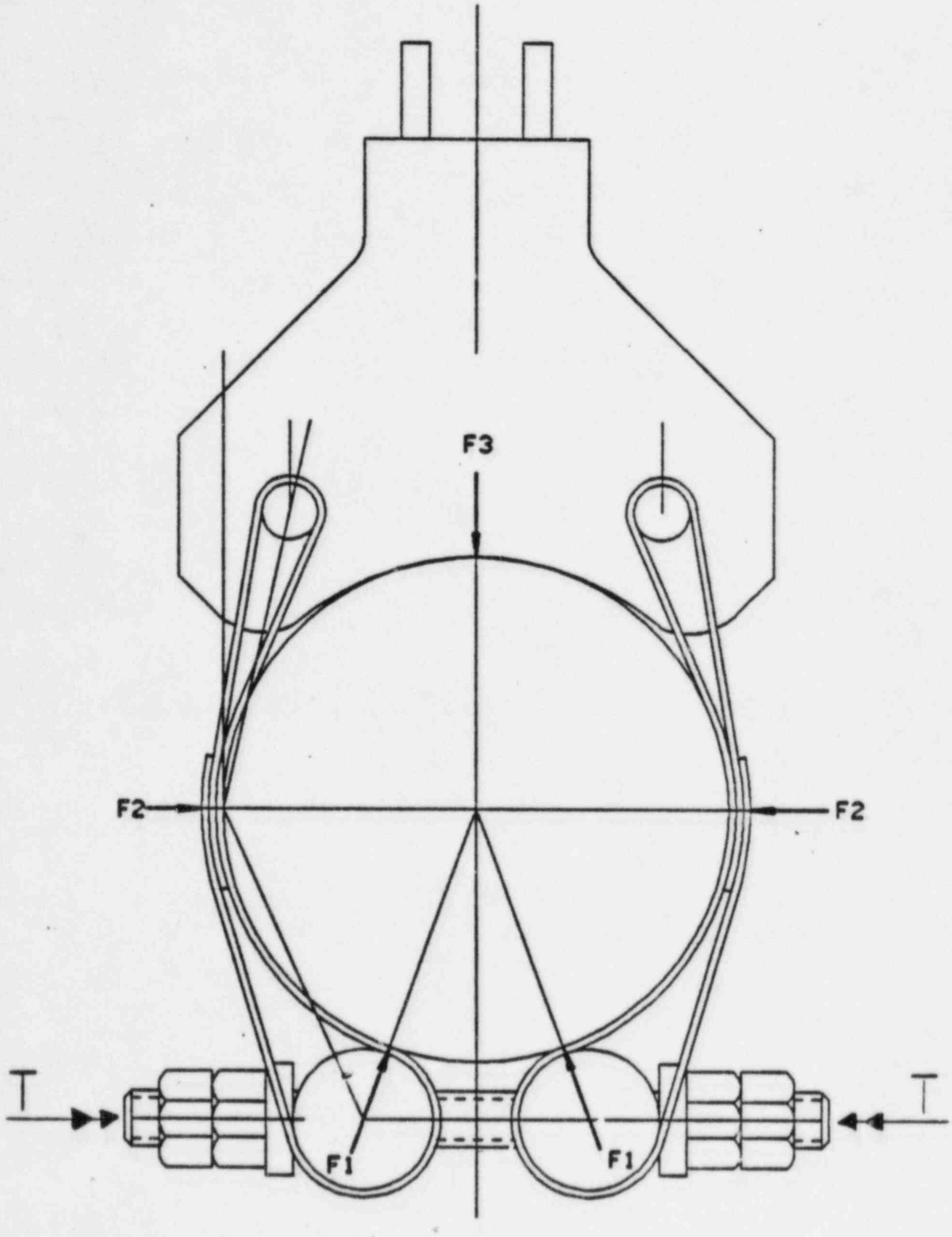


FIGURE 9

FINITE-ELEMENT MODEL
PRELOAD ONLY

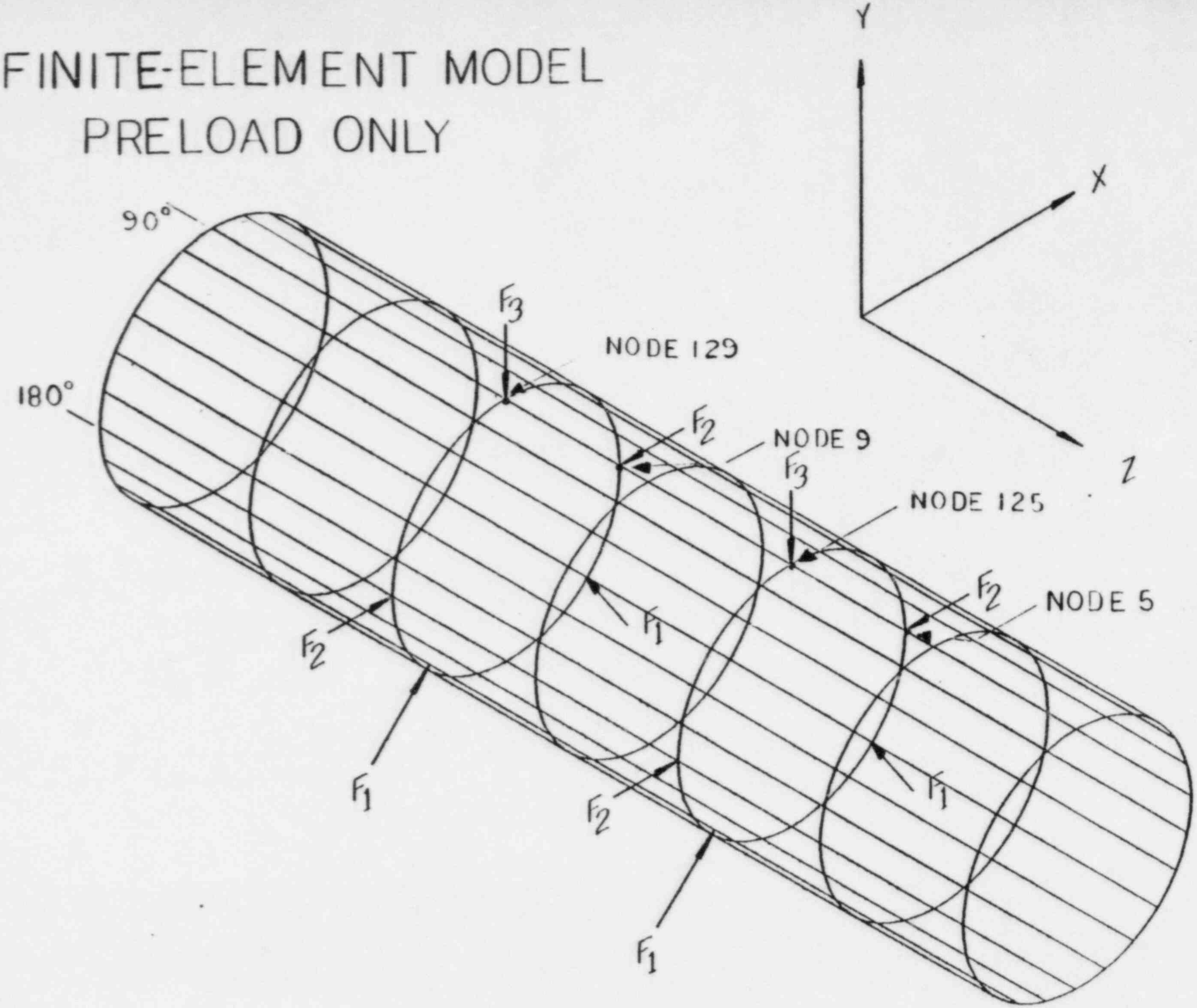
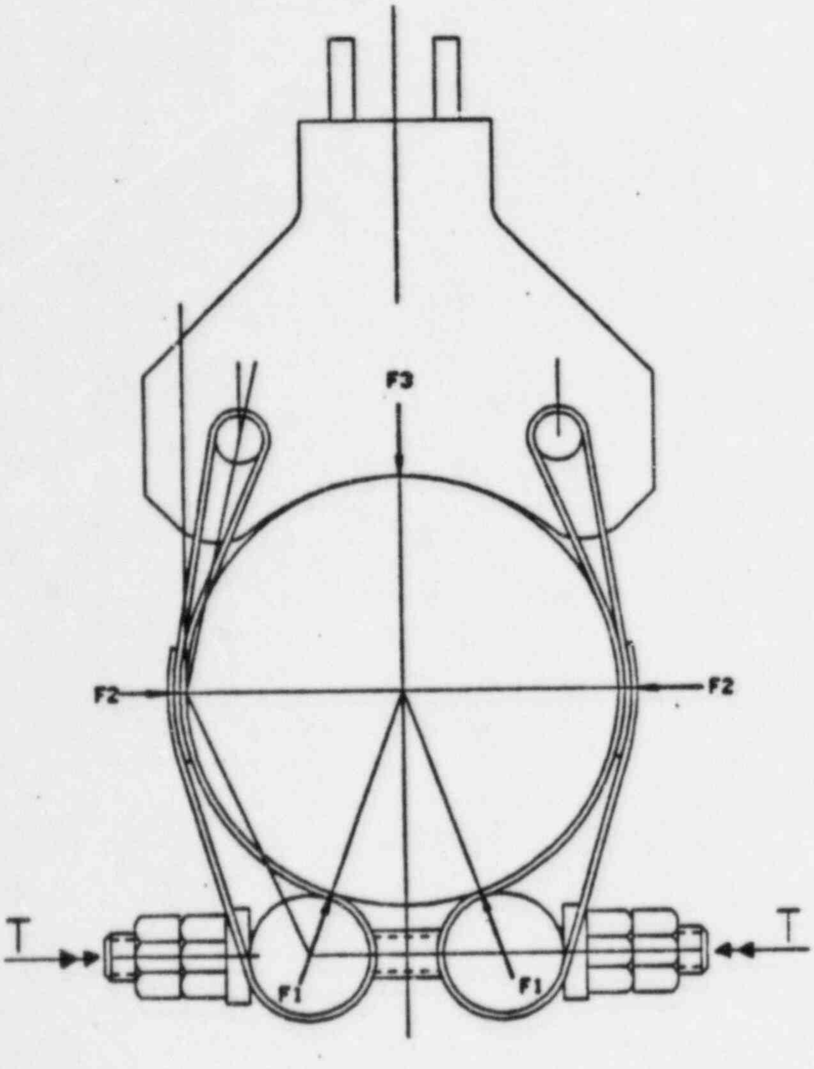
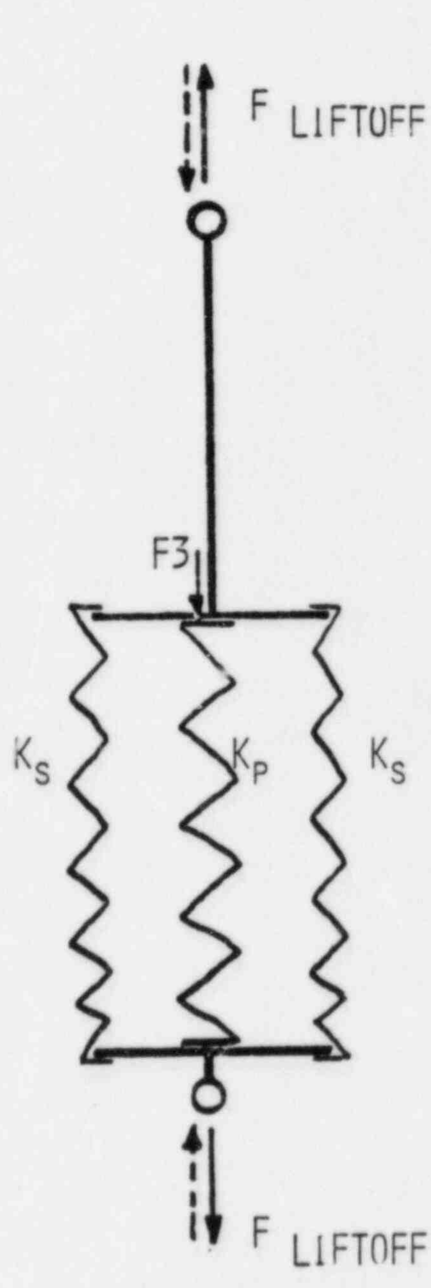


FIGURE 10



ACTUAL CLAMP



SIMPLIFIED SPRING MODEL

FIG. 11

Since the lower the value of lift-off load the more conservative the analysis is the value of $k = 1$ was chosen, so that F(Lift-Off) = 2F3. Since a relationship between F3 and torque had been established in item 1 above, a linear relationship was then established between lift-off and torque for each pipe/clamp application.

4. The lift-off load is the maximum load that can be applied to the clamp (for a certain pretorque). If this load is applied in the "compression" direction, and using the simplified model shown in FIG. 11, then the contact load F3 (due to pretorque) will double, i.e., the analytical stresses double under the condition of torque + applied load. Using the data obtained from analysis described in 2 above, the stresses due to torque applied load (compression) can be derived.

5. For the analytical determination of the pipe induced stresses caused by the restriction of the stiff clamp to the free thermal radial expansion of the pipe a thermal finite element model using finite element program McAuto Strudl, Release 4.6 was used. The "Hybrid" plane stress/plate bending element "PBSQ2" was chosen for the pipe model. Beam elements were used to model the strap which was then attached to the piping using "rigid axial only" beam elements. Because of symmetry only a quarter model was used with appropriate boundary and symmetry conditions. A typical model can be seen in FIG. 12. Point 89 represents the contact between pipe and yoke under the assumption of "Point Load". This model was run for all combinations of stainless steel pipe/pipe wall thickness/ clamp frame size (total of 43 models).

6. The analytical model used to calculate the stress reduction factors for "2-Point" contact between yoke and pipe was a ring subject to a combination of concentrated and distributed loading, as shown in FIG. 13. Formulas for stresses were taken from "Formulas For Stress And Strain" by Roark and Young, 5th Edition.

THERMAL FINITE ELEMENT MODEL
(6" PIPE AND LARGER)

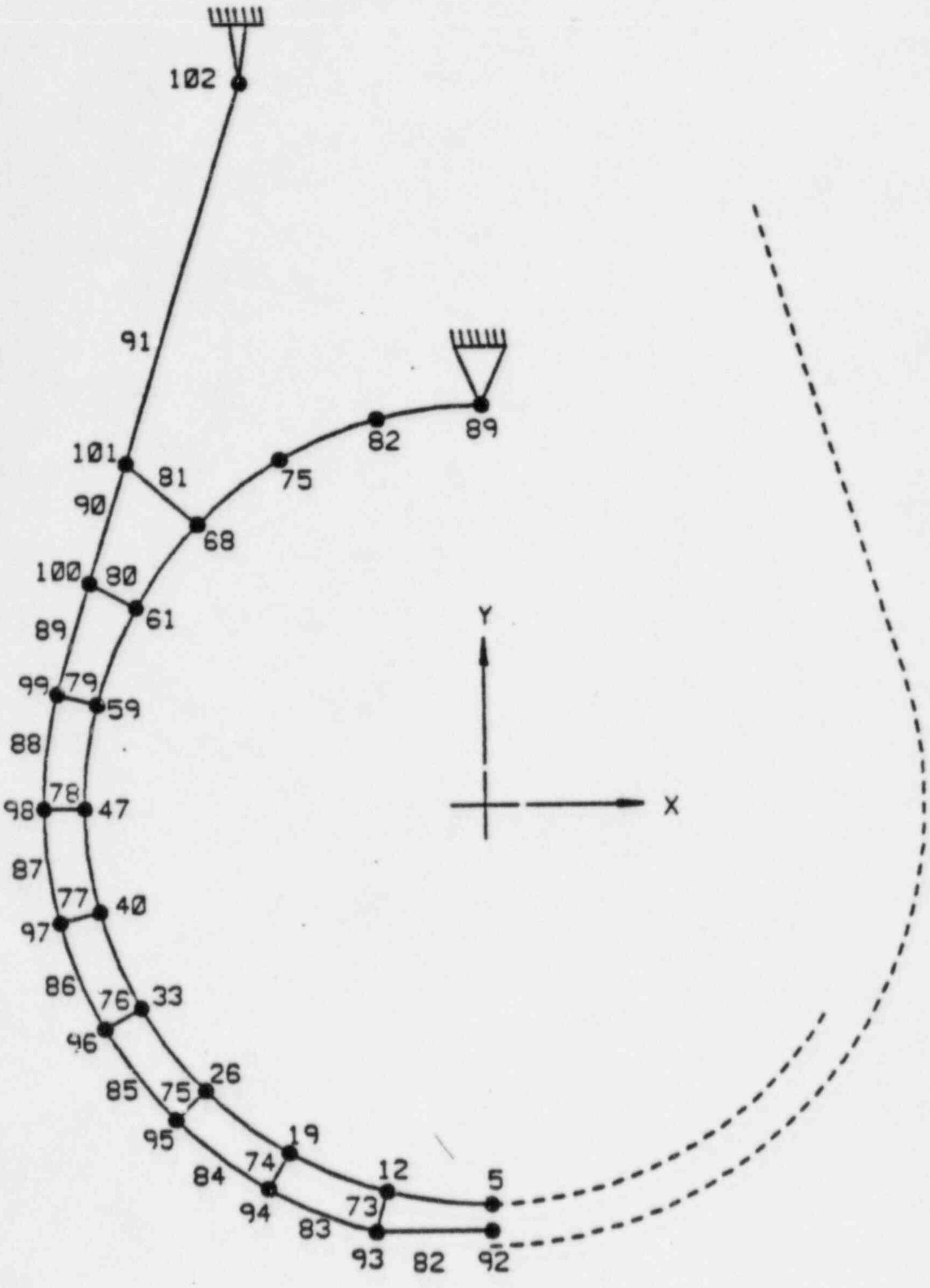


FIGURE 12

"TWO POINT" LOAD CONFIGURATION

(ANALYSIS MODEL)

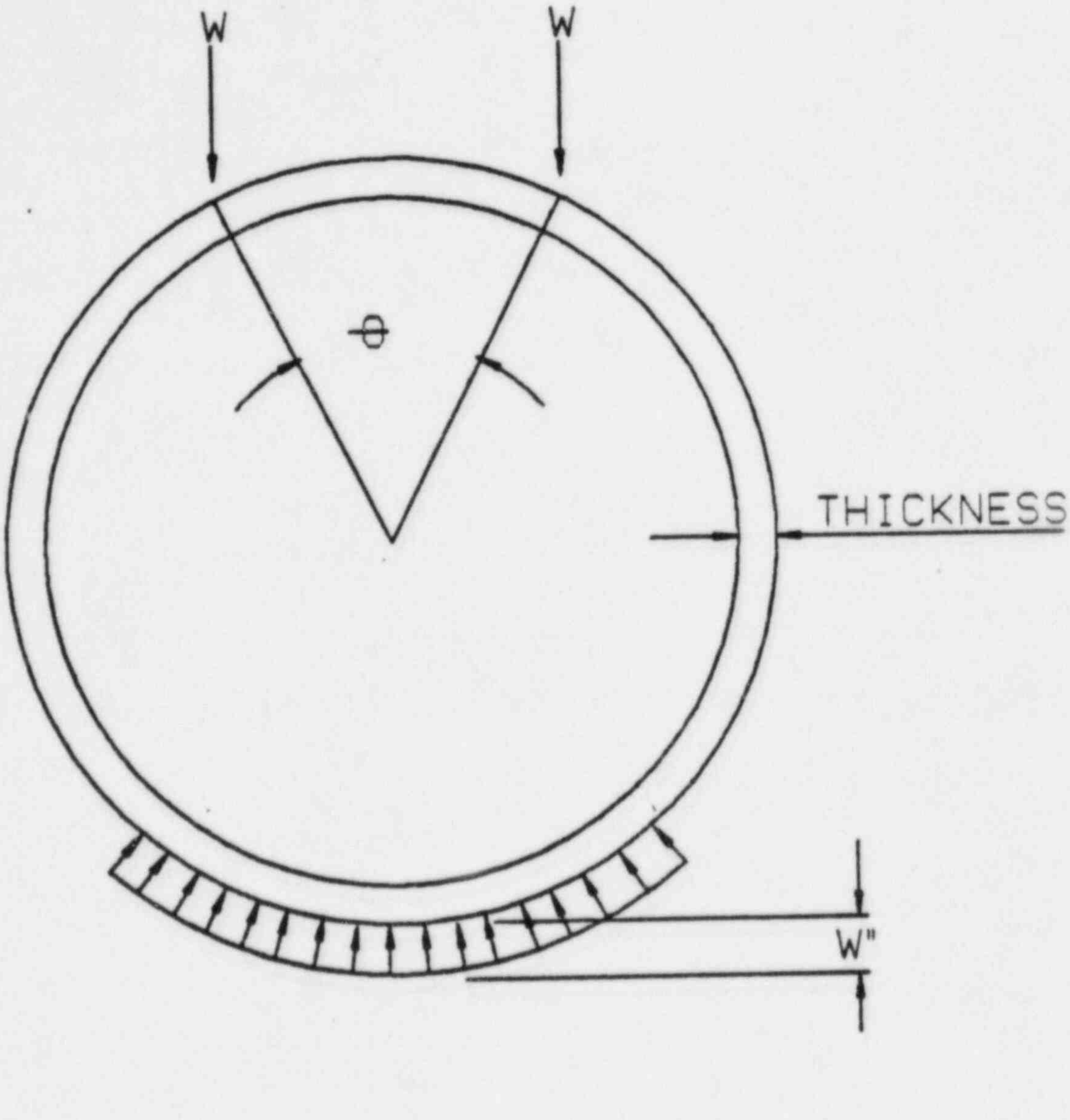


FIGURE 13

5) RESULTS

A) Analytical Results

The results of the analyses described in Section 4 are shown in Appendix III. All the stresses shown in the Appendix are for the "Point Load" condition. In column (4) the values of lift-off load resulting from applying a 10 ft-lbs pretorque are shown. Column (5) shows the maximum stresses induced in the pipe wall by the application of a pretorque equal to 10 ft-lbs. Column (6) shows the stresses induced in the pipe wall by an application of an applied load equal to 1000# in compression. And in column (7) the induced stresses in a stainless steel pipe due to an increase of pipe temperature of 1°F are shown. Thermal stresses for carbon steel pipe are considered to be very small and therefore negligible.

B) Test Results

The results obtained from the test program described are presented graphically in Appendix IV.

Pages IV-2 through IV-9 present the results obtained for the lift-off vs. preload tests described in Section V-3A . Also shown for comparison purposes are the results of the analysis as described in Section V-4.3.

The following considerations should be noted in reference to these particular results presented: 1) For the 2 1/2 pipe test, due to the bending stiffness of the strap, some of initial preload applied to the tie-rods was used into bending the straps around the pipe circumference. Since the analytical method did not take this effect into account, the results of the analysis became somewhat unconservative. Because the strap becomes more flexible as the pipe size increases, the analytical unconservatism will decrease as the pipe size increases. For 2 1/2, 3 and 4" pipe sizes the analytical results for lift-off vs. torque have therefore been adjusted (reduced by 17% based on the largest unconservatism found for the 2 1/2" pipe). The analytical values presented on page III-2, for pipes 2 1/2 through 4" already reflect that adjustment. 2) The lift-off load measured during

the tests was the applied load value at which separation at any of the two yoke plates was first observed. Because an absolutely equal distribution of tensile load between the two pairs of straps cannot physically be achieved, during the test, a more realistic test value could have been obtained by determining the value of the applied load when the first yoke plate shows separation, another value when both yoke plates show separation and obtain an average of those two values. The test values presented in Appendix IV represent however a lower bound and therefore a conservative value.

Based on the considerations above and by comparing the test versus the analysis results, it can be concluded that the analytical results are generally conservative and in good agreement with the test results.

Pages IV-10 through IV-18 present the results obtained through tests and analysis for the maximum stress induced in the pipe as a function of the pretorque for the "Point Load" condition. An observation of the data presented demonstrates that the analytical results are conservative when compared with the test results.

Page IV-19 (Table A) presents a comparison between test and analysis for the increase in pipe wall stresses due to application of an applied compressive load of 1000#. The test values shown on the table represent an average of all values obtained in each test. Except for one case (24" pipe, frame 3) all the analytical results are conservative when compared with test values. The results for the 24" pipe are unconservative by a factor of 2% which can be considered insignificant.

Page IV-20 presents the "normalized" stress values for the case of distributed contact between yoke and pipe as a function of the contact angle (θ). These "normalized" stress values represent, in fact, a stress reduction factor (≤ 1) that can be applied to the stresses obtained by the "point load" condition. The curve shown was obtained from

test .. .a as follows: "linefitting" methods were applied to the raw test data by the "least squares methods" to linearize the "pipewall stress" versus the load distribution angle (θ). The values of pipewall stress were then "normalized" with respect to "Point Load" condition (Table B , pages IV-21, 22). These normalized values were then grouped according to the angle θ, regardless of any other parameter, such as frame size, preload, etc, (Table C , page IV-23); and linearized again to produce the line shown in page IV-20. Because test data was available only to angles up to 26° (25.9°), no additional reduction is considered for angles higher than 26°.

Page IV-24 presents a similar Normalized Stress value for the case of "2-Point Contact" between yoke and pipe. This curve was based on tests performed on a 14" pipe, where two hardened wires were used to simulate the two point contact. "Linefitting" methods were applied to the raw test data to linearize the test results. The pipe wall stress was then "normalized" with respect to the "pipe load" stress. Since the test data was limited, additional normalized data was generated via the analytical model described in Section V.4.6. A good agreement was found between the analytical and test data. Similarly to the case of distributed load, normalized stress values are provided for angles up to 26°.

Page IV-25 (Table D) presents a summary of the stresses induced in the pipe wall due to the thermal effects, i.e., restriction to the free radial expansion of the pipes, for the "Point Load" condition. The test values snown represent an average of all test values obtained. As can be seen, the analytical results are very conservative in comparison with the test results.

6) COMBINATION OF STRESS METHODS

A) Acceptance criteria

Since there is no industry-wide established acceptance criteria for clamp induced stresses, the following criteria has been established to evaluate the acceptability of local pipe stresses induced by the Stiff Clamp. This criteria is based on the same philosophy that has been used by the ASME Code for the treatment of the local stresses due to welded attachments and that is included in the Code Cases N-318, N-392, N-122 and N-391 (Refs.12 through 15). This philosophy has been recently summarized in an ASME paper entitled "Review of Analysis Methods for Rectangular Lug Attachments" (Ref. 16) and can be summarized as follows: maximum stress intensities induced on the pipe walls by the welded attachments and calculated on an elastic basis are added directly to the other pipe stresses and compared with the code allowables by means of the standard Code Equations. This approach is conservative because maximum stresses from various loads are added directly without regard of location.

For the case of the stiff clamp, the clamp induced stresses are also calculated on an elastic basis, appropriately classified under different groups such as Local Primary, Secondary, and Peak, added to the other piping system stresses at the stiff clamp locations and compared with the ASME allowables, also using the standard Code Equations. The ASME allowables are the same as the ones used in Code Cases N-391 and N-392,

It should be noted that the Piping Stress Analysis for WNP-3 is done in accordance with the requirements of the ASME Code, 1974 Edition, Summer 76 Addenda, while Code Cases N-391 and N-392 are based on the 1983 Edition. The pertinent differences between the two Code Editions are elaborated below:

a) For Class 1 piping analysis, equation (10) of NB-3650 in the 1983 Edition does not

include the term $\frac{E \cdot |\Delta T_1| \alpha}{2(1-\nu)}$. For conservatism the evaluation of local stresses @ stiff clamp locations is done including the term $\frac{E |\Delta T_1| \alpha}{2(1-\nu)}$.

b) For Class 2, 3 piping analysis, equations (8) and (9) of NC-3650 are slightly different in the two Code Editions. The 1983 Edition uses "B" indices while the 1974 Edition uses "i" indices. However, for straight portions of pipe, i=1, B_1 =0.5 and B_2 =1.0 and the equations become identical.

In addition to the limits imposed by the modified code equations a special limit has been imposed on the magnitude of the stresses induced by the pretorque condition. To prevent the possibility of mechanical ratchetting, those stresses shall be limited by the yield strength of the pipe material at room temperature (S_y)

The total stresses obtained from combining the local pipe stresses with the other piping stresses and expressed in modified code equations will also be used to postulate pipe break locations in accordance with the established criteria for break postulation in Section 3.6.3 of WNP-3 FSAR.

B) Consideration of Thermal Transient Stresses

A scoping evaluation of the effect of a stiff clamp on the piping through wall temperature distribution provided by reference (17) concludes that "based on published results of conventional clamps and engineering judgment, it appears that thermal gradient stresses in pipe at stiff clamps are not significant". This evaluation was done for a type of stiff clamp which was assumed to "represent a larger heat sink than a conventional pipe clamp". In the case of the ITT/Grinnell FIG. 215 Stiff Clamp the contact between pipe and clamp is through the straps, which are thin and in intimate contact with the pipe, and through the

yoke that has limited contact with the pipe. This constitutes a very small heat sink therefore causing a much smaller influence in the pipe wall temperature distribution. Therefore, in the evaluation of the stiff clamp effects, the additional thermal stresses due to temperature gradients as results of the pipe/clamp interface will be considered insignificant and therefore negligible.

Thermal gradient stresses for the pipe (assuming no clamp) will be done in accordance with the ASME Code requirements.

C) Consideration of Pressure Stresses

The localized piping stresses due to the restriction that the stiff clamp imposes to the radial expansion of the pipe under internal pressure are calculated on the basis of the stresses induced by the clamp to the free radial expansion of the pipe when subject to an increase in temperature. The magnitude of these thermal induced stresses have been determined analytically as indicated in Section V-4. The maximum hoop pressure stresses at WNP-3 do not exceed 13,200 psi. Therefore the maximum local stresses induced in the pipe wall due to the restriction of the stiff clamp can be calculated based on the stresses induced on a stainless steel pipe subject to a ΔT = 110 °F. The derivation of this value is presented in Appendix V.

VI- INSTALLATION REQUIREMENTS AND CONTROL

1) TORQUE RELAXATION

As the clamp preload is required to achieve adequate clamp stiffness to prevent the clamp from lifting off the piping, a concern regarding the possibility of torque relaxation and its effect on the clamp stiffness needed to be addressed. In response to this concern, ITT/Grinnell conducted three separate tests as described in the Grinnell test reports PE-452 (Ref. 23) and PE-473-1 (Ref. 24).

In the first test, a torqued ITT/Grinnell size 2A Figure 215 stiff clamp, secured around an 8" stainless steel sch 160 pipe spool, were oven heated up to a maximum temperature of 650°F and then cooled down to 200 °F for ten(10) full cycles. A check afterward did not indicate any reduction in torque.

During the second test, a preloaded ITT/Grinnell size 2C, Figure 215N, stiff clamp, secured around a 14" standard wall stainless steel pipe was oven-heated to 350°F and cooled down to 70°F for a total of five cycles. A reduction of the bolt torque was found after the cycle loading. A similar loss of torque in tie rods also occurred after application and removal of a compressive load in the "Preload plus Compressive Load Test".

Consequently, a third test was performed to determine whether the reduction in the tie rod torque would adversely affect the stiffness of the clamp. A tensile load was first applied to a preloaded frame size 2C, Figure 215N, stiff clamp secured on a 14" standard wall pipe to determine the lift-off force. Then a compressive load was applied to cause the anticipated reduction of tie rod torque. Finally, a tensile force was again applied to determine the lift-off force after the loss of torque had occurred. The result of this test indicated an even greater lift-off force after the loss of torque had occurred.

This phenomenon can be attributed to the redistribution of the tension forces along the straps. When the straps are initially torqued there is an unequal tension along their respective lengths due to the friction encountered between the strap and the pipe as it is being stretched. As the bolts are initially pretorqued the tension in the strap is greater at the bottom (near the tie-rods) than at the top (near the yoke pins).

After application of a cyclic or compressive load, the distribution of tension in the straps tends to become more uniform, the result being that the tension at the bottom of the strap decreases (resulting in a loss of torque at the tie-rods) while the tension at the top of the strap increases. As the lift-off load depends heavily on the strap tension at the top, it is expected that the lift-off would increase with the redistribution of tension in the straps and the corresponding loss of torque at the tie-rods. This has been confirmed by the above mentioned tests.

Therefore, it is evident that the torque relaxation which is caused by the redistribution of tension in the straps (not the material relaxation) will not have an adverse effect on the stiffness of the clamp and the lift-off load corresponding to the preload of the tie-rod will not be diminished. R1

It should be noted that the connections at the tie-rods are double nutted (see Fig. 3). This will preclude any loosening or backing off of the nuts due to any reduced load at the tie-rod end.

2) INSTALLATION, MARKING & CONTROL

Application of the appropriate preload on the clamp during the initial installation is important. As described in the previous section, torque relaxation due to loading redistribution along the strap may occur after certain loading cycles. Since the overall stiffness of the clamp is not affected, no adjustment of torque load on the tie-rod is required after installation.

The installation program to be implemented at the site assures that all field work during and after installation is controlled so that no physical modifications are allowed without an Engineering approved work package. This program includes procedures listing the appropriate torque settings by Stiff Clamp frame and pipe size. The Stiff Clamp itself is provided with a metal tag which denotes the following:

...Frame Size

...Figure Number and size of the attached Strut or Snubber.

...Pipe Size

...Support Mark Number

In addition, following the final torque setting the stiff clamp studs and nuts will be marked. This measure will allow a quick visual inspection to determine if the position of the nuts and studs have been altered.

The control provided during installation, and the marking of the studs and nuts after torquing, provides the necessary measures to assure continuing control of stiff clamp installation at WNP-3.

VII- OTHER SUBJECTS

1) TORQUE SELECTION

The selection of the pretorque to be applied to each stiff clamp will be based on the maximum load acting on the stiff clamp derived from the appropriate design load combinations for piping support design as specified in the WPPS Technical Specification 3240-4, Section 4.02.c (Design Requirements - ASME Piping Supports).

The required torque is then determined by dividing the maximum load by the lift-off vs. pretorque factors derived analytically as shown in column (4) of Appendix III. This result will then be increased by 10% to provide an extra margin of safety. This latter value represents the minimum torque required. It may be increased

to maintain uniformity in the installation process. Torque required will be shown on each support design package. In no case will the torque required exceed the values indicated by the ITT/Grinnell Load Capacity Data Sheet (Appendix VII).

2) CONTACT AREA CONTROL

The analyses and tests performed have shown that the amount of contact between pipe and yoke is an important factor on the magnitude of stresses induced in the pipe wall.

In order to quantify this parameter, the following approach will be taken: A contact area factor (CAF) will be introduced. This factor provides the reduction in stresses caused by different contact areas relative to the stresses caused by point loading (worst condition). When combining the stresses induced by the clamp with the other piping stresses, the initial evaluation will be done assuming CAF = 1. If the acceptance criteria is met under these conditions, the contact requirements will be identified as CAF = 1 (point load acceptable). Otherwise, the minimum value of CAF (CAF > 1.0) will be calculated, identified as a design requirement and translated into the support design package and installing contractor's work package.

3) APPLICATION OF STIFF CLAMP

The Fig. 215 Stiff Clamp will be applied on safety related piping systems with maximum operating conditions as follows:

PIPE MATERIAL	PRESSURE (psig)	TEMPERATURE (°F)
Stainless	2310*	350*
Carbon Steel	1800	110
	1170	454
	1143	563

(*Note: Ref (18) transmitted to the NRC similar information in response to Question(6). However, the maximum pressure for stainless steel pipe was reported as 550 psig instead of 2310 psig. This is therefore a correction to the previously transmitted information.

There are approximately (1400) Stiff Clamps that will be used in piping systems analyzed to the ASME requirements (Class 1,2,3). Of those (1400) only five(5) are presently installed and torqued to the original Load Capacity Data Sheet (LCD) torques.

Using the data obtained from the analytical approach as presented in Appendix III, a preliminary evaluation has been made to assess the impact that the pipe wall induced stresses might have in the application of the stiff clamp. The results of the evaluation show that: a) Approximately 65% of the clamps are acceptable even if the contact between pipe and yoke is a minimum (point load). This group includes the majority of pipe thicker than standard wall and the majority of standard wall pipe 6" and below. b) Approximately 25% of the clamps require some degree of limited contact between yoke and pipe. It is expected that this contact already exists or can be easily obtained by minor grinding of the yoke. This group includes most of the standard wall piping between 8" and 16" subject to loads of "average" magnitude. c) Approximately 10% of the remaining clamps either require extensive contact between pipe or yoke or an alternate means of load distribution. This group includes most of the standard wall pipe between 8" and 16" size subject to high loads and standard wall pipe larger than 16" subject to average or high loads.

The final assessment will be available when the combination of stresses in accordance with the rules explained in Section V-6 is complete.

A review of the (5) Stiff Clamps installed and torqued to the original LCD values indicated the following: (3) clamps determined to be acceptable with point loading. (2) clamps were found acceptable after a field examination indicated that sufficient contact exists between pipe and yoke.

4) CLAMP/PIPE DATA

The stiff clamp is a component standard support load rated in accordance with subsection NF. A copy of the load capacity data sheet is provided in Appendix VII.

A discussion of the effect of load rating the clamp at maximum pressure and temperature is presented below.

Load rating of the stiff clamp at operating pressure will have no effect on ultimate failure load. This is based on having performed tests on clamps that were purposely overtorqued and found that there was no change in failure load. The additional torque would provide additional strain to the straps simulating any radial expansion of the piping due to pressure. The reason there was no change in the failure load is that the additional strain simply increases the force required to lift off the pipe, and until this load is exceeded, the straps see practically no further increase in stress and the ultimate load capacity of the clamp will be attained at essentially the same load. R1

The difference in testing at operating temperature would only be that the ultimate test load achieved would be lower by an amount proportional to the ultimate tensile strength at room temperature and operating temperature. This is not a code requirement and the clamp would still yield the required stiffness.

A question has been raised regarding the effect of the local pipe wall stiffness on the Clamp assembly. Using the simplified spring model of Fig. 11 it can be seen that due to the preload condition between pipe (k_p in compression) and strap (k_s in tension), the effect of the pipe wall stiffness is to add to the stiffness of the straps. This is true for applied loads that do not exceed the lift off values.

5) NRC QUESTIONS

As indicated in Section III-5, the NRC Staff has raised a total of (20) questions concerning the application of the ITT/Grinnell Fig. 215 Stiff Clamp. These questions have been the subject of extensive correspondence between the Supply System and the NRC. The concerns raised by the NRC Staff have also been addressed in this report. A convenient cross-reference between the (20) NRC questions and the location in this report where the concerns are addressed is provided in Attachment VI.

VIII- SUMMARY AND CONCLUSION

From the data and discussions presented in this report it can be concluded that:

1) The stiff clamp is made of appropriate materials which will withstand the loadings and environmental conditions stipulated for the plant without degradation.

2) The pipewall induced stresses by the stiff clamp can be conservatively determined. By adding the local pipe stresses with the other piping stresses and limiting the total stresses to specified allowables, the structural integrity of the pipe will be assured.

3) The installation and control program will assure that the pretorque is properly applied and that the straps will be loaded to an appropriate value that will assure no lift-off up to the maximum design load of each clamp.

In conclusion, it can be stated that the ITT/Grinnell Fig. 215 Stiff Clamp meets the intent of the applicable codes and engineering design specifications and complies with NRC guidance as presented in SRP Section 3.9.3 and therefore is acceptable for use at WNP-3.

IX - REFERENCES

1) U.S. Nuclear Regulatory Commission IE Information Notice No. 83-80: Use of specialized "Stiff" Clamps - November 23, 1983.

2) U.S. Nuclear Regulatory Commission - Standard Review Plan - 3.9.3 - II-3-b(2) - Rev. 1, July 1981 (NUREG - 0800).

3) Stiff Clamp NCR No. 14020

4) Engineering Final Report. ITT/Grinnell Stiff Clamps Deviation/Non Compliance 031 - September 15, 1981.

5) Same as above, Revision 1, Dated December 8, 1981.

6) USNRC - IE - Inspection Report No. 50-508/82-10 Dated June 4, 1982.

7) Letter F. J. Miraglia To R. L. Ferguson Dated June 25, 1982.

8) Letter G. W. Knighton To R. L. Ferguson Dated April 4, 1983 (GO-3-83-129).

9) Fujii, C.T., "Stress Corrosion Cracking Properties of 17-4PH Steel", Stress Corrosion - New Approach, ASTM STP 610, ASTM, 1976.

10) Gaugh, R.R., "Sulfide Stress Cracking of Precipitation Hardening Stainless Steel", Materials Performance, V.16, No. 9, Sept. 1977, Page 24.

11) Sandoz, G. "High Strength Steels", Stress Corrosion Cracking in High Strength Steels, and in Titanium and Aluminum Alloys" Naval Research Laboratory, Washington, D.C., 1972.

12) ASME B&PV Code Cases, Nuclear Components, Case N-318 "Procedure for Evaluation of the Design of Rectangular Cross Section Attachments on Class 2 or 3 Piping Section III, Division I".

13) Same as above, Code Case N-392 "Procedure for Evaluation of the Design of Hollow Circular Cross-Section Welded Attachments on Class 2, 3, Piping, Section III, Division I".

14) Same as above, Code Case N-122 "Procedure for Evaluation of the Design of Rectangular Cross Section Attachments on Class 1 Piping, Section III, Division 1".

IX - REFERENCES

15) Same as above, Code Case N-391 "Procedure for Evaluation of the Design of Hollow Circular Cross-Section Welded Attachments on Class 1 Piping, Section III, Division 1".

16) F.Y. Jeung and G.C. Slagis, "Review of Analysis Methods for Rectangular Lug Attachments ASME Paper 83-PVP-14".

17) G.C. Slagis, "The Effect of Stiff Clamps on Pipe Stresses", ASME Paper 84-PVP-83.

18) Letter G.D. Bouchey To F.J. Miraglia Dated July 30, 1982 (GO-3-82-766).

19) Letter G.D. Bouchey To F.J. Miraglia Dated September 14, 1982 (GO-3-82-924).

20) Letter G.D. Bouchey To G.W. Knighton Dated November 11, 1982 (GO-3-82-1135).

21) Letter G.D. Bouchey To G.W. Knighton Dated June 15, 1983 (GO-3-83-476).

22) Letter G.D. Bouchey To G.W. Knighton Dated July 19, 1983 (GO-3-83-567).

23) ITT/Grinnell Corporation - Providence, R.I. Testing of Size 2A Figure 215 Stiff Clamp Oven-Heated To 650 F - October 28, 1982 Report No. PE-452.

24) ITT/Grinnell Corporation - Providence, R.I. Investigation of Temperature on Torque Relaxation - Report No. PE-473-1.

25) Letter O.E. Trapp to J.P. Sluka Dated October 14, 1981, Subject: ITT/Grinnell Stiff Clamps (QA-35-81-488).

APPENDIX I

RELATIONSHIP BETWEEN PIPE AND CLAMP SIZE

APPENDIX I

Relationship Between Pipe Size, Clamp Size And Level D Load

FIGURE 215 CLAMP SIZE	NOMINAL PIPE SIZE (IN)	MAXIMUM LEVEL D LOAD (LBS)
1A		1,200
1B	2½, 3, 4, 6	2,300
1C		11,520
2A		1,200
2B	8, 10, 12, 14	2,300
2C		11,520
3A		1,200
3B	16, 18, 20, 24	2,300
3C		11,520
4A		23,600
4B	3, 4, 6	26,700
5A		23,600
5B	8, 10, 12, 14	26,700
6A		23,600
6B	16, 18, 20, 24	26,700
7A		35,081
7B	10, 12, 14, 16	43,220
7C		91,000
8A		35,081
8B	20	43,220
8C		91,000
9A		35,081
9B	24, 30	43,220
9C		91,000
10	16	86,500
11	30	86,500

R1

APPENDIX II

LIST OF TESTS PERFORMED

DESCRIPTION OF TEST

TEST NO.	PIPE SIZE		FRAME SIZE	TEST	LOADING
1	2 1/2"	STD	Frame 1C	Liftoff	Point Load
2	2 1/2"	STD	"	Compression	" "
3	2 1/2"	STD	"	Liftoff	" "
4	2 1/2"	STD	"	Compression	" "
5	6"	STD	"	Liftoff	" "
6	6"	STD	"	Compression	" "
7	6"	STD	"	Liftoff	" "
8	6"	STD	"	Compression	" "
9	8"	STD	Frame 2C	Liftoff	" "
10	8"	STD	"	Compression	" "
11	8" Sch.	160	"	Liftoff	" "
12	8" Sch.	160	"	Compression	" "
13	8"	STD	Frame 5B	Liftoff	" "
14	8"	STD	"	Compression	" "
15	14"	STD	Frame 2C	Compression	" "
16	14"	STD	"	Liftoff	" "
17	14"	STD	"	Compression	" "
18	14"	STD	"	Compression	Machined *
19	24"	STD	Frame 3C	Liftoff	Point Load
20	24"	STD	"	Liftoff	" ****
21	24"	STD	"	Compression	Point Load
22	24"	STD	"	Compression	" "
23	24"	STD	"	Liftoff	" "
24	24"	STD	"	Liftoff	" "
25	24"	STD	Frame 6B	Liftoff	" "
26	24"	STD	"	Liftoff	" "
27	24"	STD	"	Compression	" "
28	24"	STD	"	Compression	" "
29	24"	STD	"	Liftoff	" "
30	6"	STD	Frame 1C	Compression	Machined *
31	8"	STD	Frame 2C	"	"
32	8"	STD	"	"	"
33	14"	STD	"	"	"
34	14"	STD	Frame 5B	"	Shipped **
35	14"	STD	"	"	Point Load
36	14"	STD	"	"	2 Point Load ***
37	14"	STD	"	"	"
38	14"	STD	"	"	"
39	14"	STD	"	"	"
40	14"	STD	"	"	1/2" Arc
41	14"	STD	"	"	1" Arc
42	14"	STD	"	"	1 1/2" Arc
43	24"	STD	Frame 3C	"	Machined *
44	6"	STD	Frame 1C	"	1/2" Arc
45	6"	STD	"	"	1" Arc
46	6"	STD	"	"	1 1/2" Arc
47	24"	STD	Frame 3C	"	1/2" Arc

DESCRIPTION OF TEST

TEST NO.	PIPE SIZE	FRAME SIZE	TEST	LOADING
48	24" STD	Frame 3C	Compression	1" Arc
49	24" STD	"	"	1 1/2" Arc
50	24" STD	"	"	2 1/2" Arc
51	24" STD	"	"	3 1/2" Arc
52	24" STD	"	"	4 3/8" Arc
53	24" STD	"	"	5 1/4" Arc
54	24" STD	"	"	(2) 1/2" Arc
55	24" STD	Frame 6B	"	1" Arc
56	24" STD	"	"	2" Arc
57	24" STD	"	"	3" Arc
58	24" STD	"	"	4" Arc
59	24" STD	"	"	4 3/4" Arc
60	24" STD	"	"	(2) 1/2" Arc
61	24" STD	"	"	(2) 1" Arc
62	30" STD	Frame 9C	Liftoff	Point Load
63	30" STD	Frame 9C	Compression	Point Load
64	6" STD(C.S.)	Frame 1C	Thermal	" " ****
65	6" STD(S.S.)	"	"	" " ****
66	14" STD(S.S.)	Frame 2C	"	" " ****
67	6" STD	Fig. 214 Size 3	Compression	As Is ***
68	6" STD(S.S.)	Frame 1C	Thermal	Point Load
69	This test does not exist			
70	14" STD(S.S.)	Frame 2C	"	" "
71	This test does not exist			
72	14" STD(C.S.)	Frame 2C	"	" "
73	14" STD(C.S.)	Frame 2C	"	" "
74	6" STD(S.S.)	Frame 1C	"	" "
75	6" STD(S.S.)	Frame 1C	"	" "
76	14" STD(S.S.)	Frame 2C	"	" "
77	14" STD(S.S.)	Frame 2C	"	" "
78	14" STD(S.S.)	Frame 2C	"	" "
79	6" STD(S.S.)	Frame 2C	"	" "
80	14" STD(S.S.)	Frame 2C	Thermal Cycling	" "
81	6" STD(S.S.)	Frame 1C	Compression/ Thermal Cycling	" "
82	14" STD(S.S.)	Frame 2C	"	" "

* Yoke machined to radius of pipe; For Information Only

** Yoke used as shipped from Warren; For Information Only

*** For Information Only

**** Test Voided

APPENDIX III

SUMMARY OF ANALYTICAL DATA

SUMMARY OF ANALYTICAL RESULTS FOR
"POINT" LOAD CONDITION

(1) PIPE SIZE	(2) SCHEDULE/ THICKNESS	(3) FRAME SIZE	(4) LIFT-OFF (#/10 FT-LBS)	(5) STRESS DUE TO TORQUE (psi/10 FT-LBS)	(6) STRESS DUE TO APPLIED LOAD (psi/1000#)	(7) STRESS DUE TO THERMAL EXP (psi/°F)	COMMENTS
2½"	STD/.203	1	2755	24872	7491	-	
3"	STD(40)/.216	1	2666	23258	7241	39.4	
	160/.437	1	2666	6266	1951	17.3	
	STD(40)/.216	4	1776	13518	6316	49.8	
	160/.437	4	1776	3688	1723	35.8	
4"	STD(40)/.237	1	2500	19940	6620	46.0	
	X-STG(80)/.337	1	2500	10144	3368	34.9	
	120/437	1	2500	6104	2026	25.5	
	STD(40)/.237	4	1666	11700	5827	56.3	
	X-STG/.337	4	1666	6004	2990	57.7	
	120/.437	4	1666	3640	1819	47.6	
6"	STD(40)/.28	1	2648	14846	5607	49.8	
	X-STG(80)/.432	1	2648	6198	2341		
	120/.562	1	2648	3554	1342		
	STD(40)/.28	4	1764	8842	5013		
	X-STG(80)/.432	4	1764	3706	2101		
	120/.562	4	1764	2132	1209		
	160/.718	4	1764	1274	722		
8"	STD(40)/.322	2	3084	14366	4658	37.0	
	X-STG(80)/.5	2	3084	6212	2014		
	STD(40)/.322	5	2056	8710	4236	44.0	
	X-STG(80)/.5	5	2056	3764	1831		

NOTE: When a frame is identified by a number only, it indicates that the data is applicable to all frame designations that start with that number. Example: Data for Frame 1 is applicable to Frames 1A, 1B and 1C. R1

SUMMARY OF ANALYTICAL RESULTS FOR
"POINT" LOAD CONDITION

PIPE SIZE	SCHEDULE/ THICKNESS	FRAME SIZE	LIFT-OFF (#/10 FT-LBS)	STRESS DUE TO TORQUE (psi/10 FT-LBS)	STRESS DUE TO APPLIED LOAD (psi/1000#)	STRESS DUE TO THERMAL EXP. (psi/°F)	COMMENTS
10"	STD(40)/.365	2	2824	11064	3918	37.2	
	STD(40)/.365	5	1884	6770	3594	43.9	
	STD(40)/.365	7AB	1576	4772	3028	49.8	
	80/.593	7AB	1576	1880	1193		
	STD(40)/.365	7C	2336	7158	3064		
	80/.593	7C	2336	2820	1207		
12"	STD/.375	2	2636	10156	3853		
	40/.406	2	2636	8842	3355	43.2	
	STD/.375	5	1756	6248	3558	56.4	
	140/1.125	5	1756	700	397	15.7	
	30/.33	7AB	1492	5644	3783	40.2	
	40/.406	7AB	1492	3938	2640	37.6	
	140/1.125	7AB	1492	500	335	8.1	
	160/1.312	7AB	1492	360	242		
	30/.33	7C	2212	8466	3828	60.3	
	40/.406	7C	2212	5908	2671	56.4	
	140/1.125	7C	2212	750	339	12.2	
	160/1.312	7C	2212	540	244		
14"	STD(30)/.375	2	2536	9856	3887	46.9	
	40/.437	2	2536	7594	2995	41.7	
	140/1.25	2	2536	946	373	7.1	
	STD(30)/.375	5	1692	6098	3604	61.1	

SUMMARY OF ANALYTICAL RESULTS FOR
"POINT" LOAD CONDITION

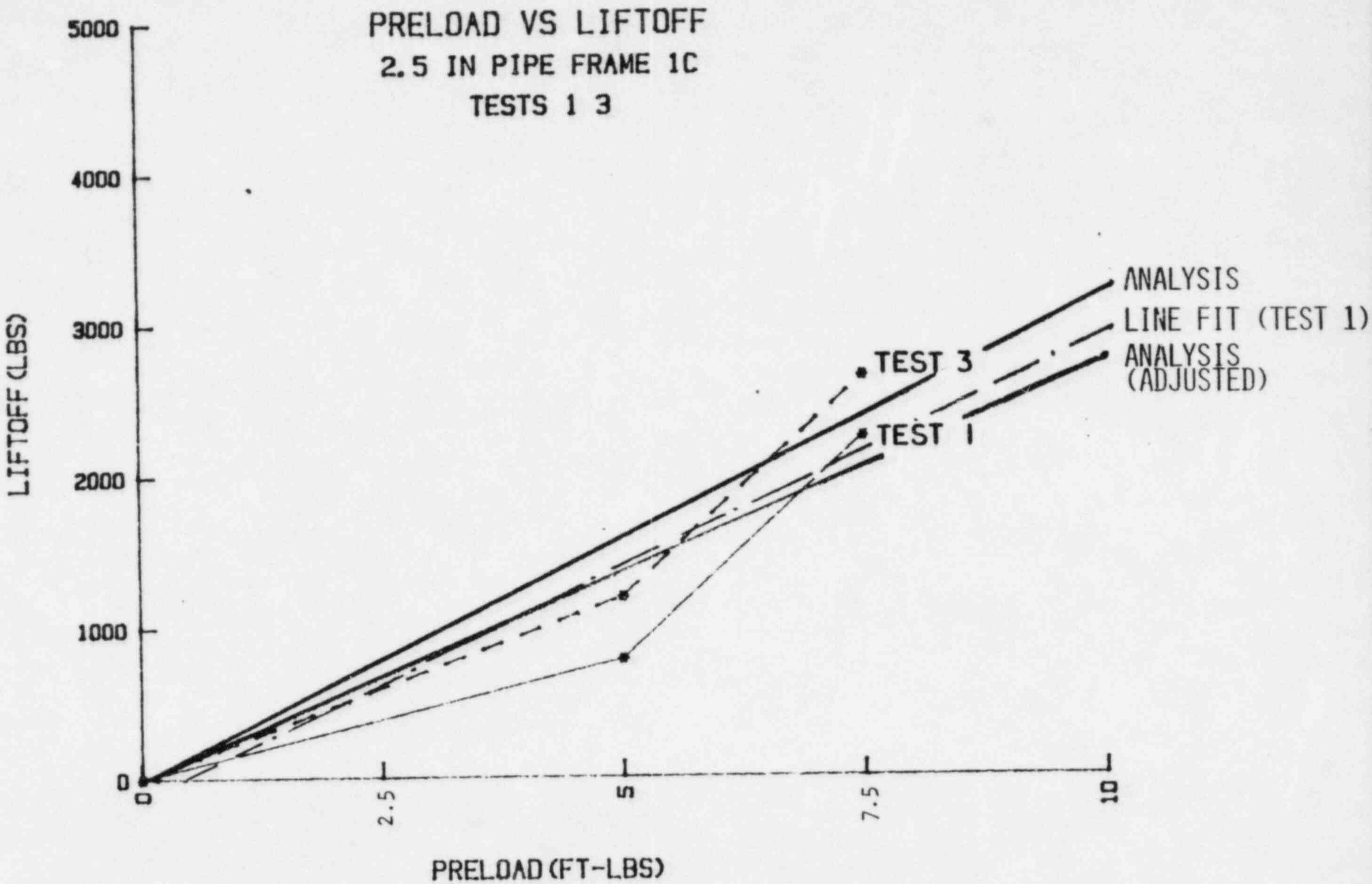
PIPE SIZE	SCHEDULE/ THICKNESS	FRAME SIZE	LIFT-OFF (#/10 FT-LBS)	STRESS DUE TO TORQUE (psi/10 FT-LBS)	STRESS DUE TO APPLIED LOAD (psi/1000#)	STRESS DUE TO THERMAL EXP. (psi/^{o}F)	COMMENTS
14"	40/.437	5	1692	4680	2766		
	80/.75	5	1692	1668	986		
	140/1.25	5	1692	562	332	12.3	
	STD(30)/.375	7AB	1436	4508	3140	56.7	
	40/.437	7AB	1436	3450	2403	58.0	
	80/.75	7AB	1436	1212	844		
	140/1.25	7AB	1436	402	280	13.3	
	STD(30)/.375	7C	2140	6762	3160	85.1	
	40/.437	7C	2140	5176	2419	87.0	
	80/.750	7C	2140	1818	850		
	140/1.250	7C	2140	604	283	20.0	
16"	STD(30)/.375	3	2936	16222	5526	37.9	
	80/.843	3	2936	3566	1215		
	140/1.437	3	2936	1194	408	7.8	
	STD(30)/.375	6	1956	10396	5315		
	X-STG/.5	6	1956	6182	3161		
	80/.843	6	1956	2246	1149		
	140/1.437	6	1956	744	381		
	STD(30)/.375	7AB	1384	6858	4956	60.6	
	80/.843	7AB	1384	1440	1041		
	140/1.437	7AB	1384	450	325	9.7	
	STD(30)/.375	7C	2064	10288	4985	90.9	

SUMMARY OF ANALYTICAL RESULTS FOR
"POINT" LOAD CONDITION

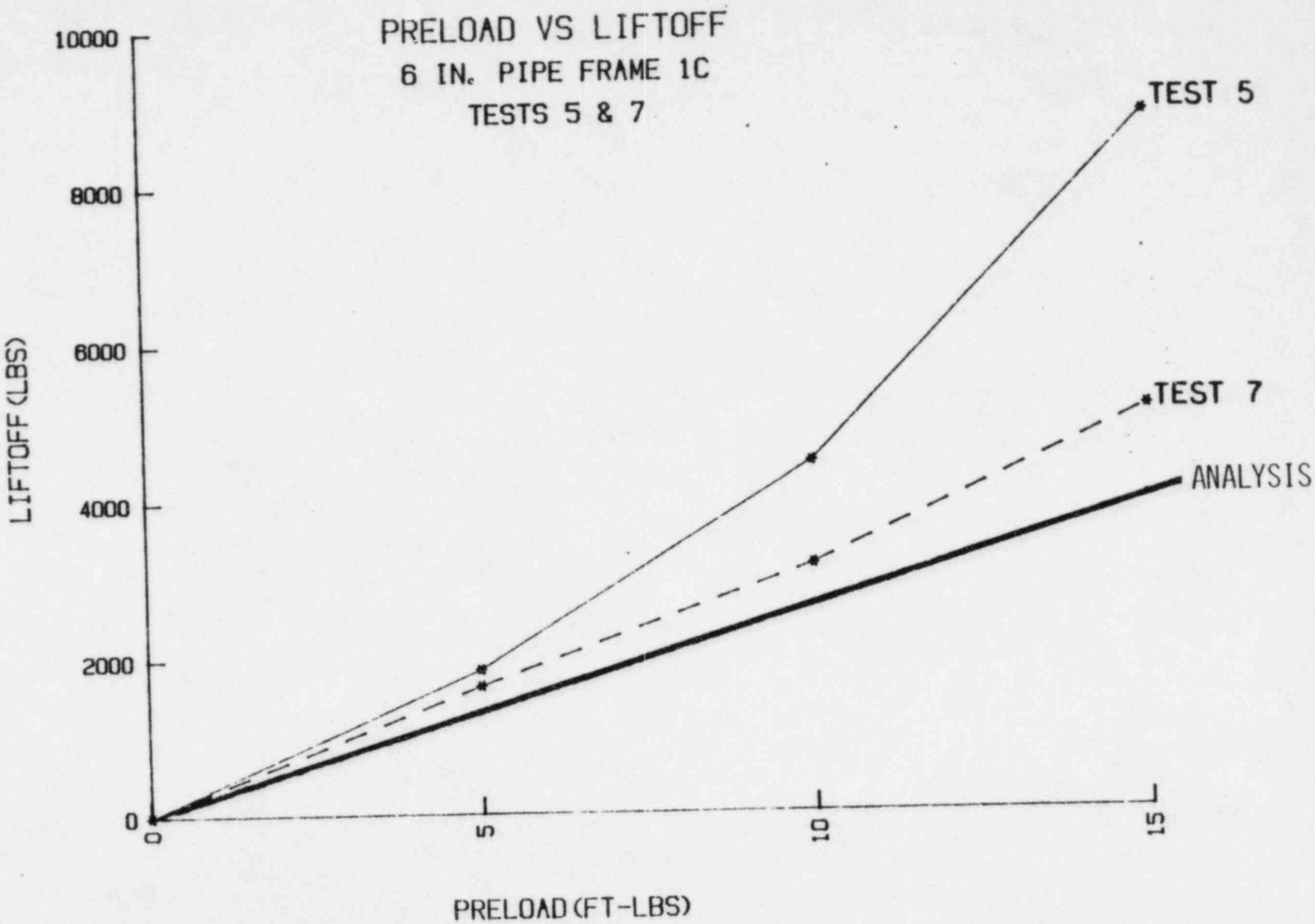
PIPE SIZE	SCHEDULE/ THICKNESS	FRAME SIZE	LIFT-OFF (#/10 FT-LBS)	STRESS DUE TO TORQUE (psi/10 FT-LBS)	STRESS DUE TO APPLIED LOAD (psi/1000#)	STRESS DUE TO THERMAL EXP. (psi/°F)	COMMENTS
16"	80/.843	7C	2064	2160	1047		
	140/1.437	7C	2064	676	328	14.6	
	140/1.437	10	3120	980	314	18.8	
18"	STD(40)/.375	3	2788	15258	5473		
	STD(40)/.375	6	1860	9828	5284		
20"	STD(20)/.375	3	2652	14290	5389	40.8	
	STD(20)/.375	6	1768	9222	5216	49.0	
	30/.5	6	1768	5644	3193		
	STD(20)/.375	8AB	1464	7470	5102	55.7	
	X-STG(30)/.5	8AB	1464	4546	3105	55.7	
	STD(20)/.375	8C	2184	11206	5131	83.6	
	X-STG(30)/.5	8C	2184	6820	3123	83.6	
24"	STD(20)/.375	3	2436	12646	5192		
	STD(20)/.375	6	1624	8170	5031		
	STD(20)/.375	9AB	1676	7968	4754		
	STD(20)/.375	9C	2512	11952	4758		
30"	/.375	9AB	1508	6858	4547	36.8	
	/.375	9C	2256	10288	4561	55.2	
30"	/.375	11	3000	12964	4322	57.6	

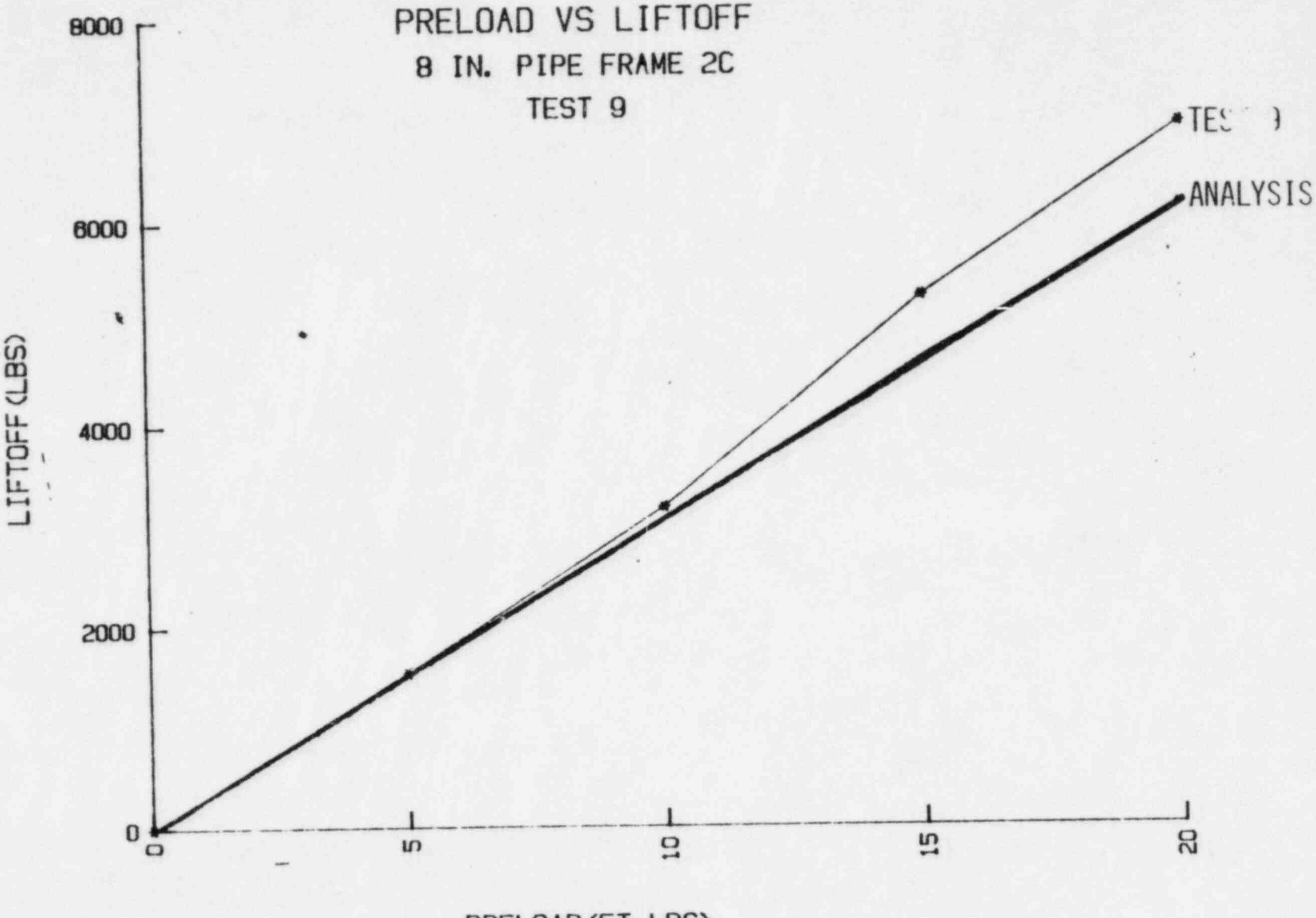
APPENDIX IV

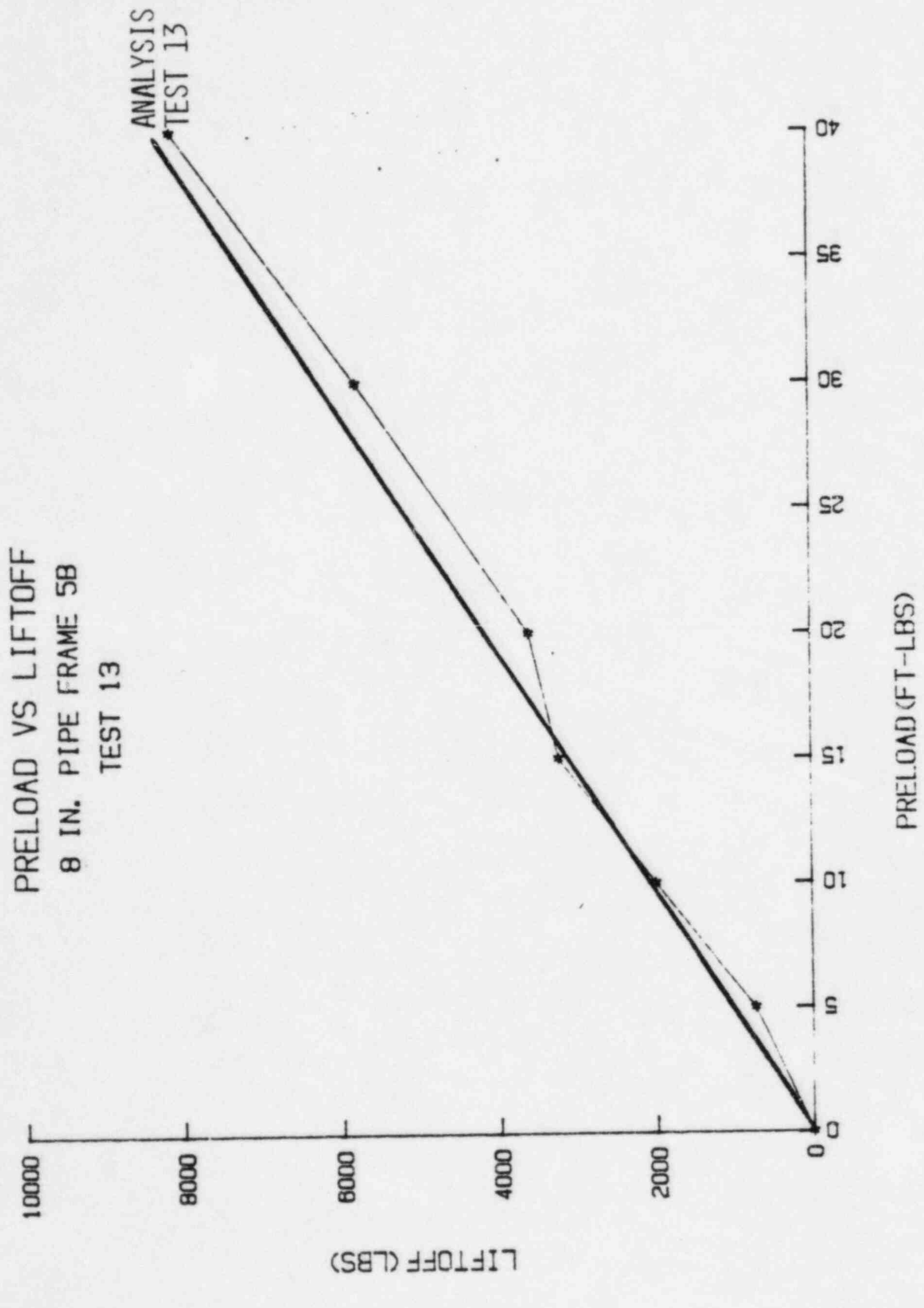
SUMMARY OF TEST RESULTS

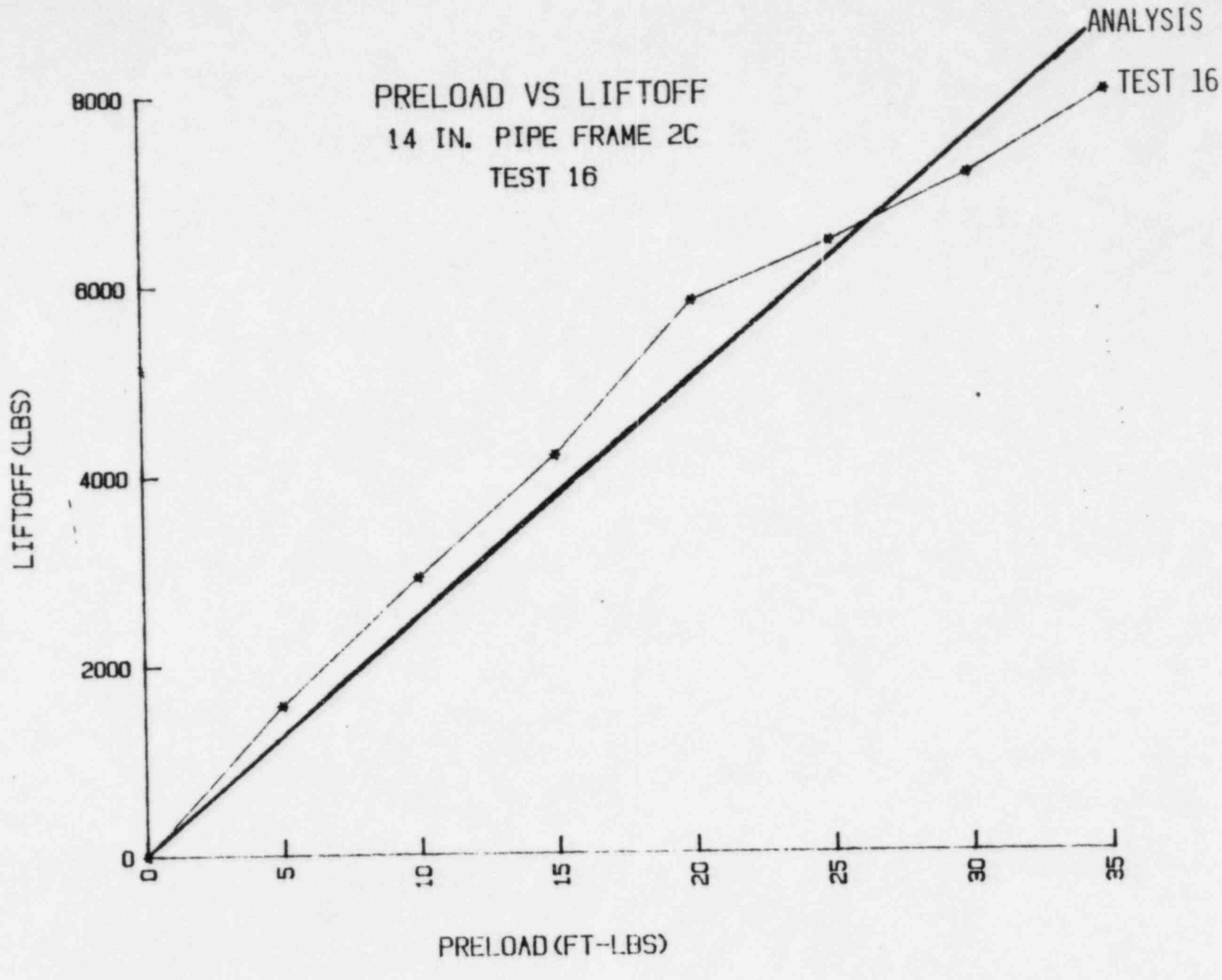


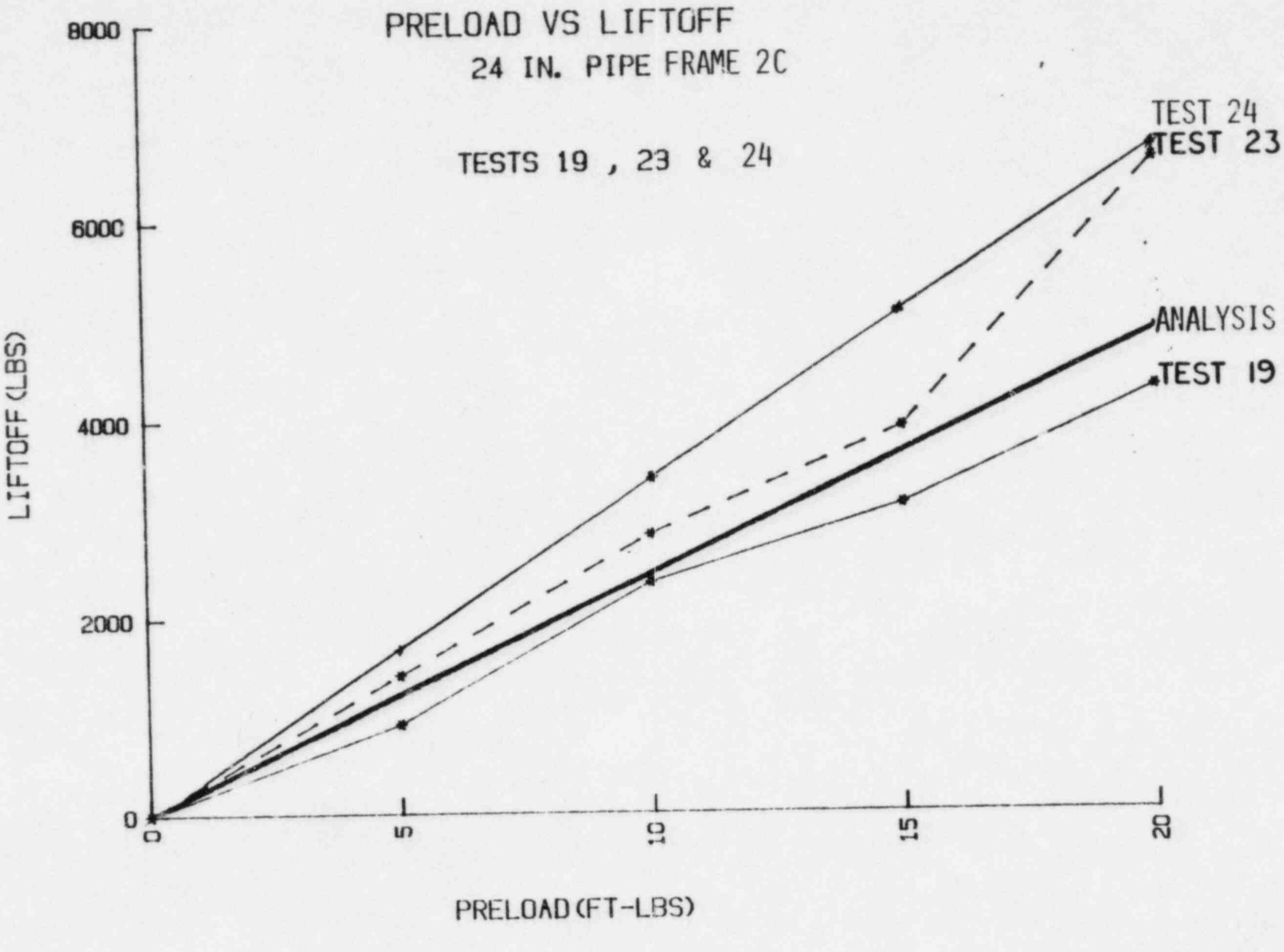
PRELOAD VS LIFTOFF
2.5 IN PIPE FRAME 1C
TESTS 1 3
5000
4000
3000
2000
1000
0
LIFTOFF (LBS)
ANALYSIS
LINE FIT (TEST 1)
ANALYSIS (ADJUSTED)
TEST 3
TEST 1
0
2.5
5
7.5
10
PRELOAD (FT-LBS)

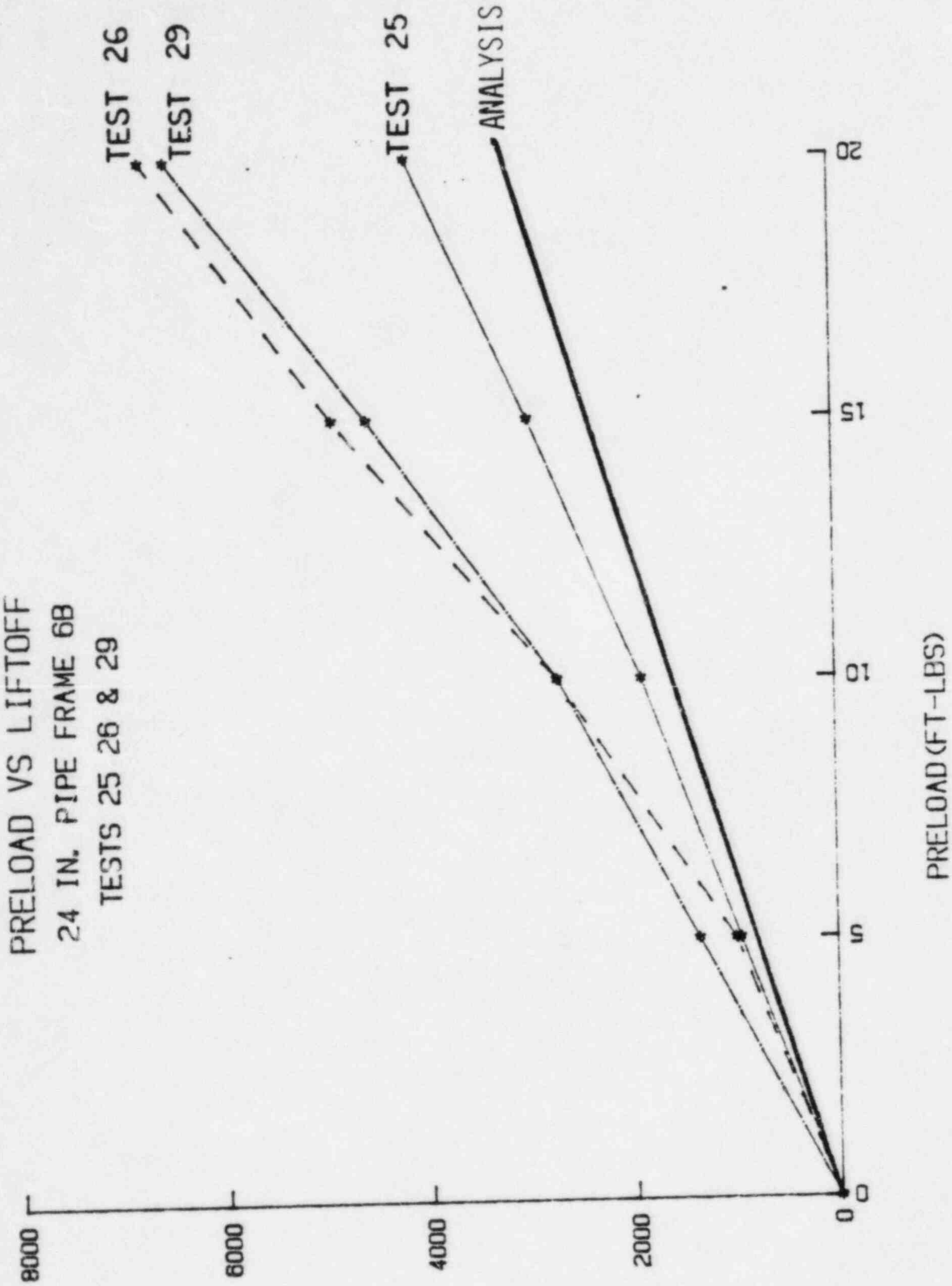

PRELOAD VS LIFTOFF
6 IN. PIPE FRAME 1C
TESTS 5 & 7
TEST 5
TEST 7
ANALYSIS
LIFTOFF (LBS)
PRELOAD (FT-LBS)
10000
8000
6000
4000
2000
0
0
5
10
15


PRELOAD VS LIFTOFF
8 IN. PIPE FRAME 2C
TEST 9
TES
ANALYSIS
LIFTOFF (LBS)
8000
6000
4000
2000
0
0
5
10
15
20
PRELOAD (FT-LBS)

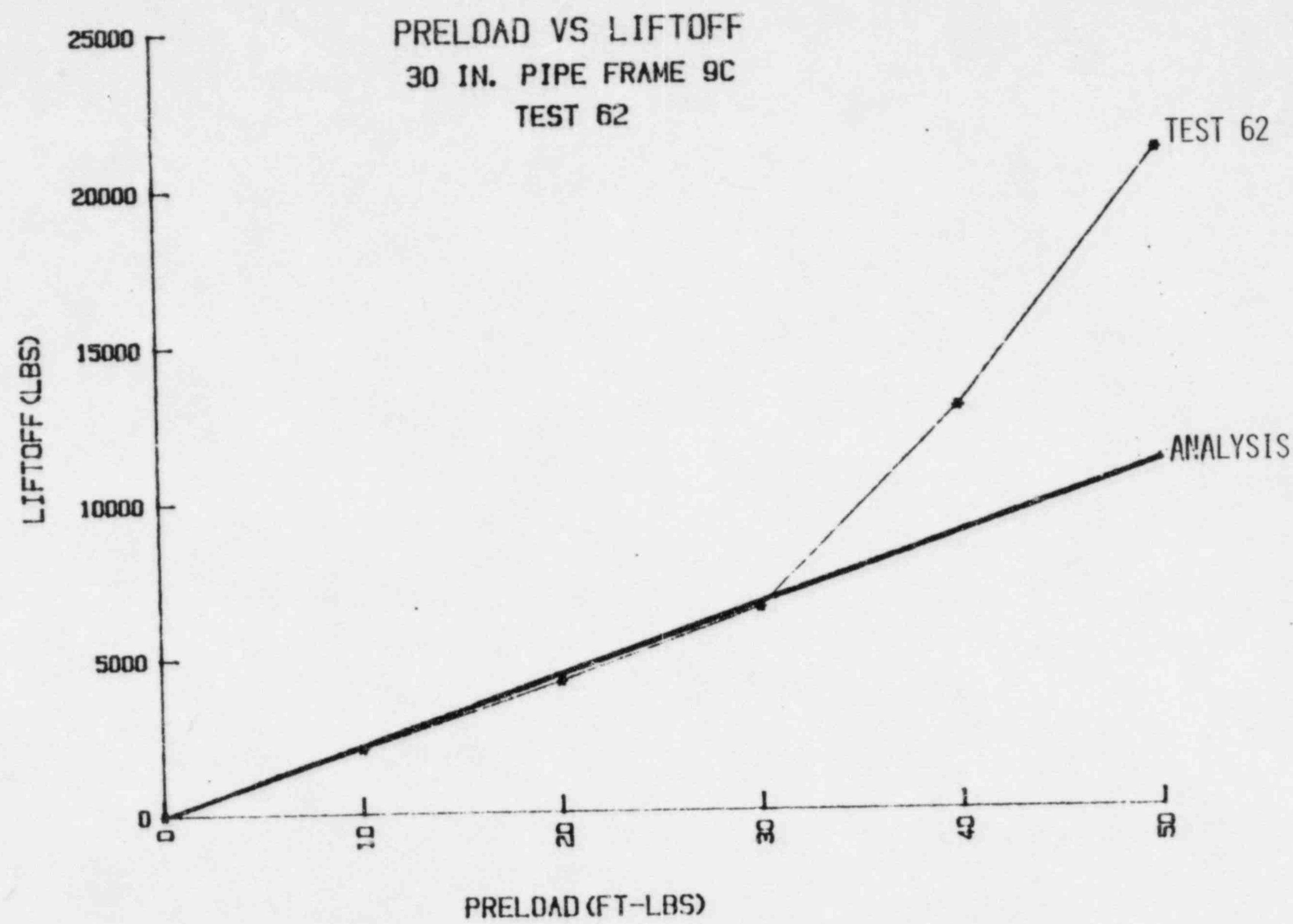

PRELOAD VS LIFTOFF
8 IN. PIPE FRAME 5B
TEST 13
ANALYSIS
TEST 13
LIFTOFF (LBS)
0
2000
4000
6000
8000
10000
PRELOAD (FT-LBS)
0
5
10
15
20
25
30
35
40

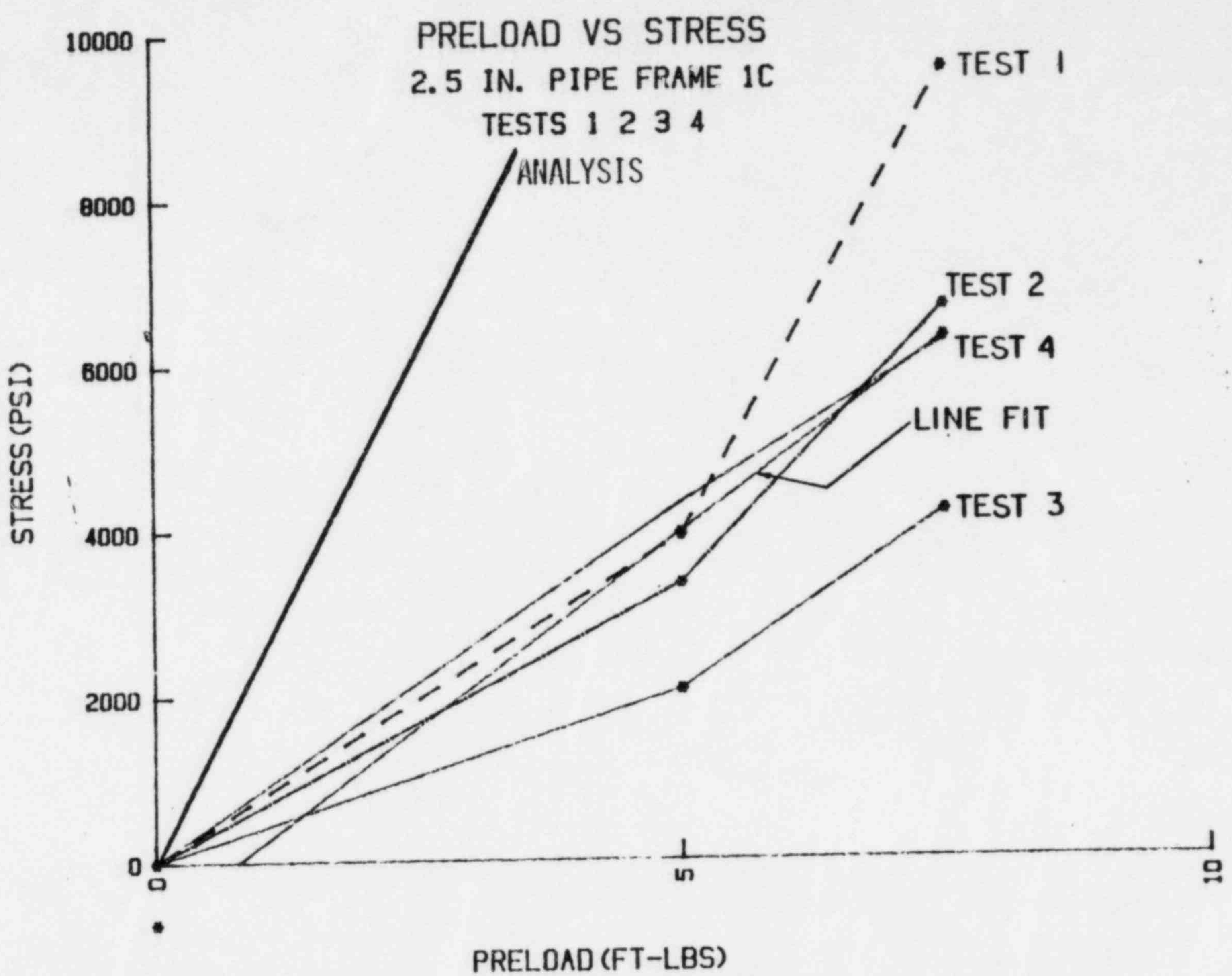

PRELOAD VS LIFTOFF
14 IN. PIPE FRAME 2C
TEST 16
ANALYSIS
TEST 16
LIFTOFF (LBS)
8000
6000
4000
2000
0
0
5
10
15
20
25
30
35
PRELOAD (FT-LBS)

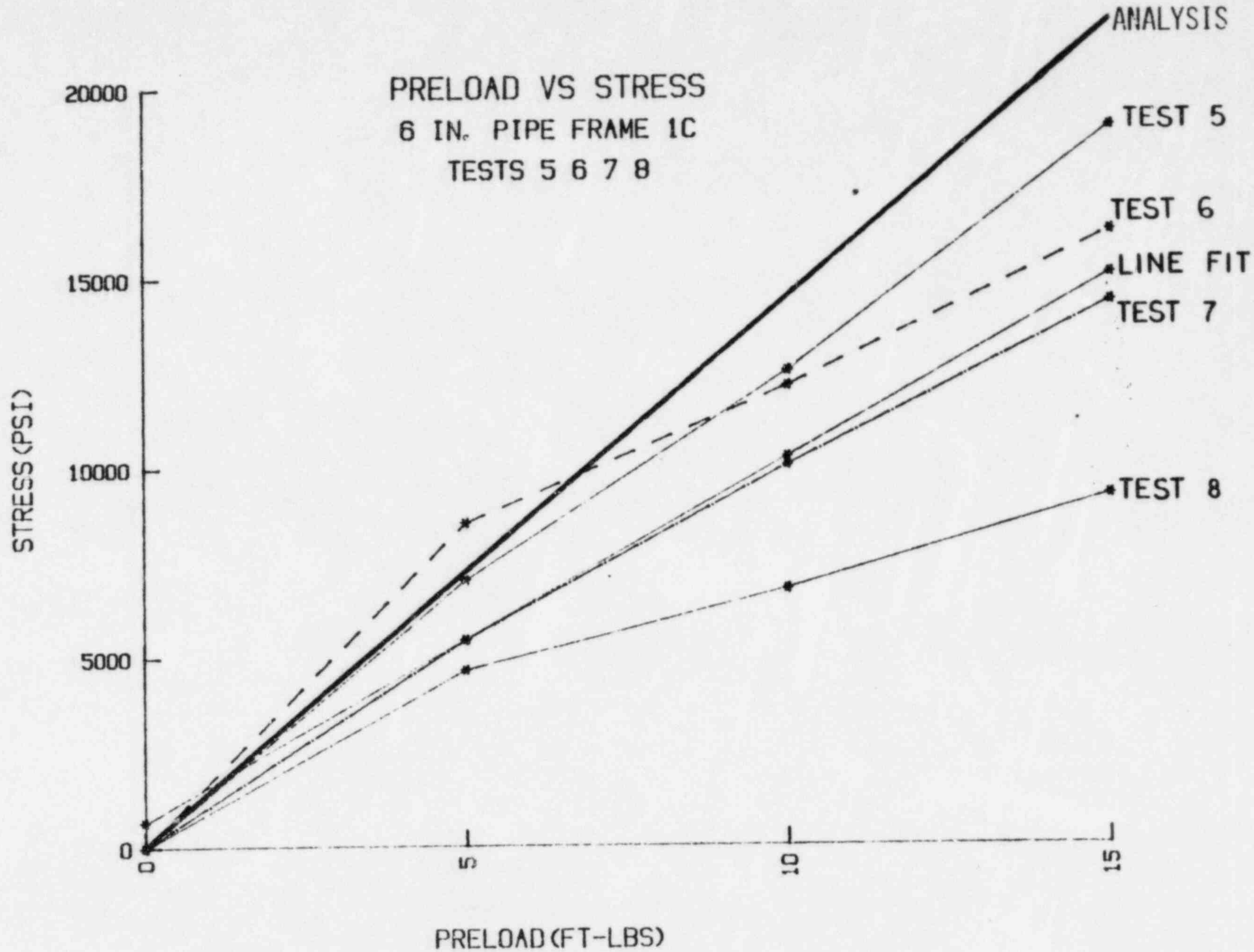

PRELOAD VS LIFTOFF
24 IN. PIPE FRAME 2C
TESTS 19 , 23 & 24
TEST 24
TEST 23
ANALYSIS
TEST 19
LIFTOFF (LBS)
8000
6000
4000
2000
0
0
5
10
15
20
PRELOAD (FT-LBS)

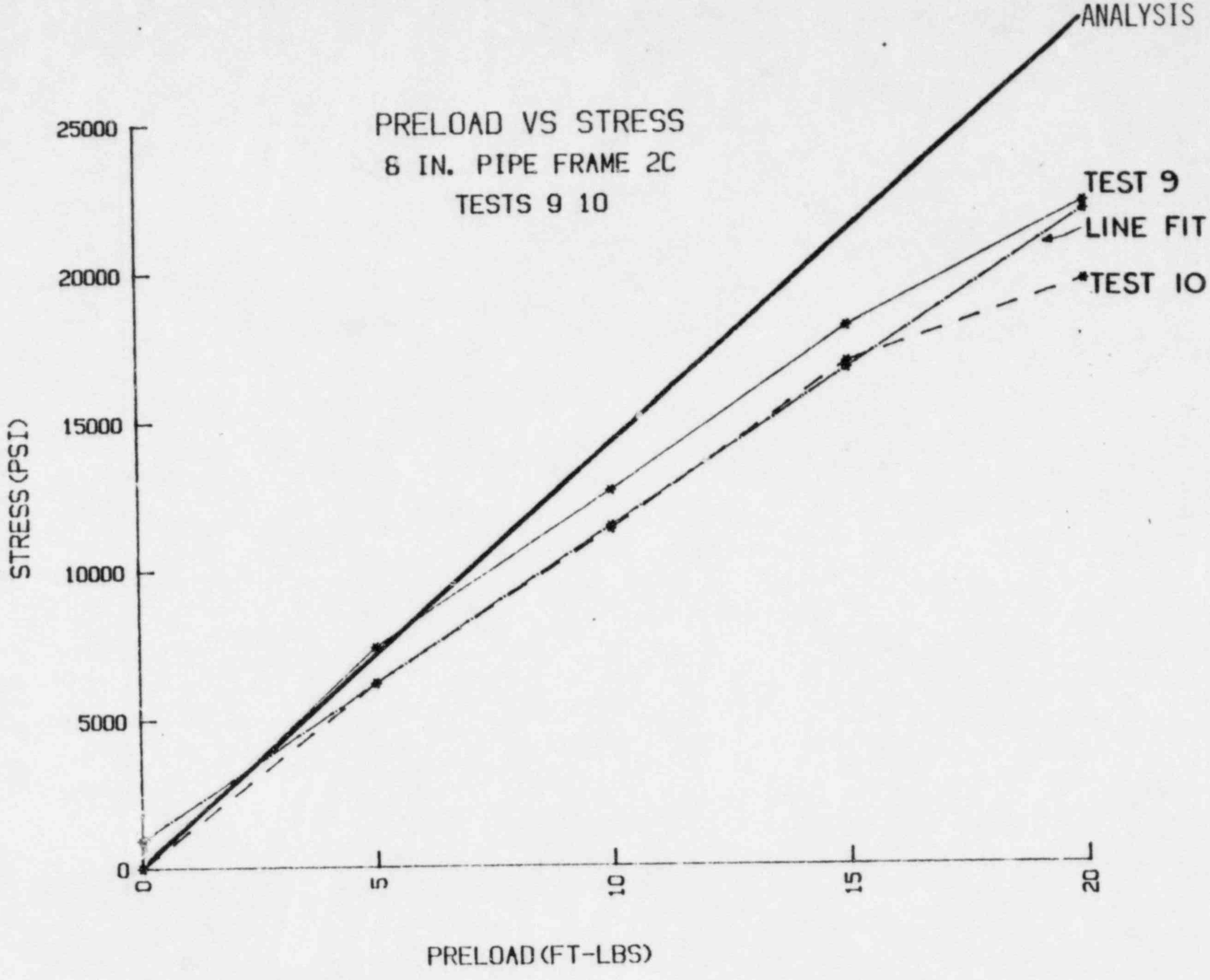


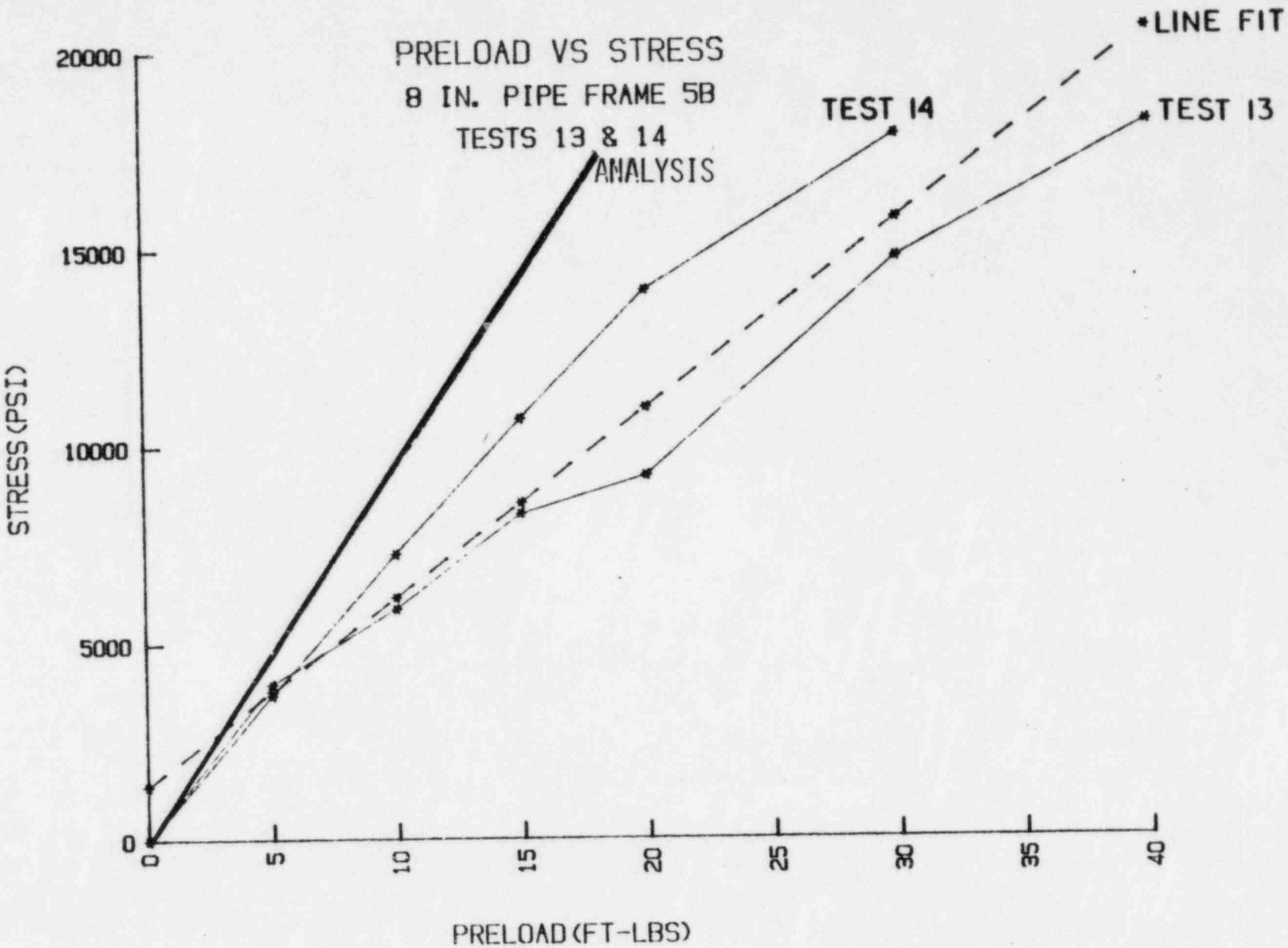
PRELOAD VS LIFTOFF
24 IN. PIPE FRAME 6B
TESTS 25 26 & 29
TEST 26
TEST 29
TEST 25
ANALYSIS
LIFTOFF (LBS)
8000
6000
4000
2000
0
PRELOAD (FT-LBS)
0
5
10
15
20

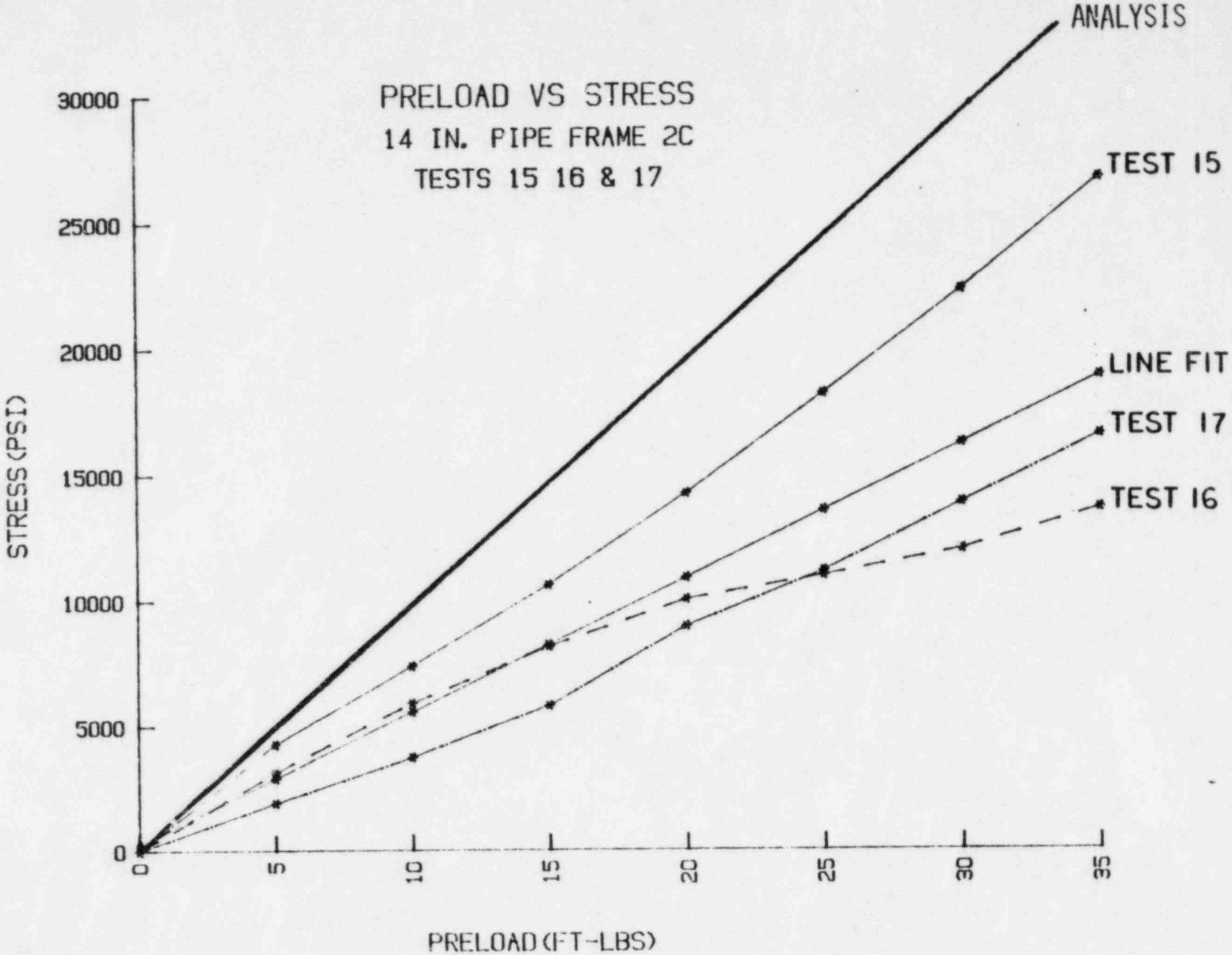

PRELOAD VS LIFTOFF
30 IN. PIPE FRAME 9C
TEST 62
TEST 62
ANALYSIS
LIFTOFF (LBS)
25000
20000
15000
10000
5000
0
0
10
20
30
40
50
PRELOAD (FT-LBS)

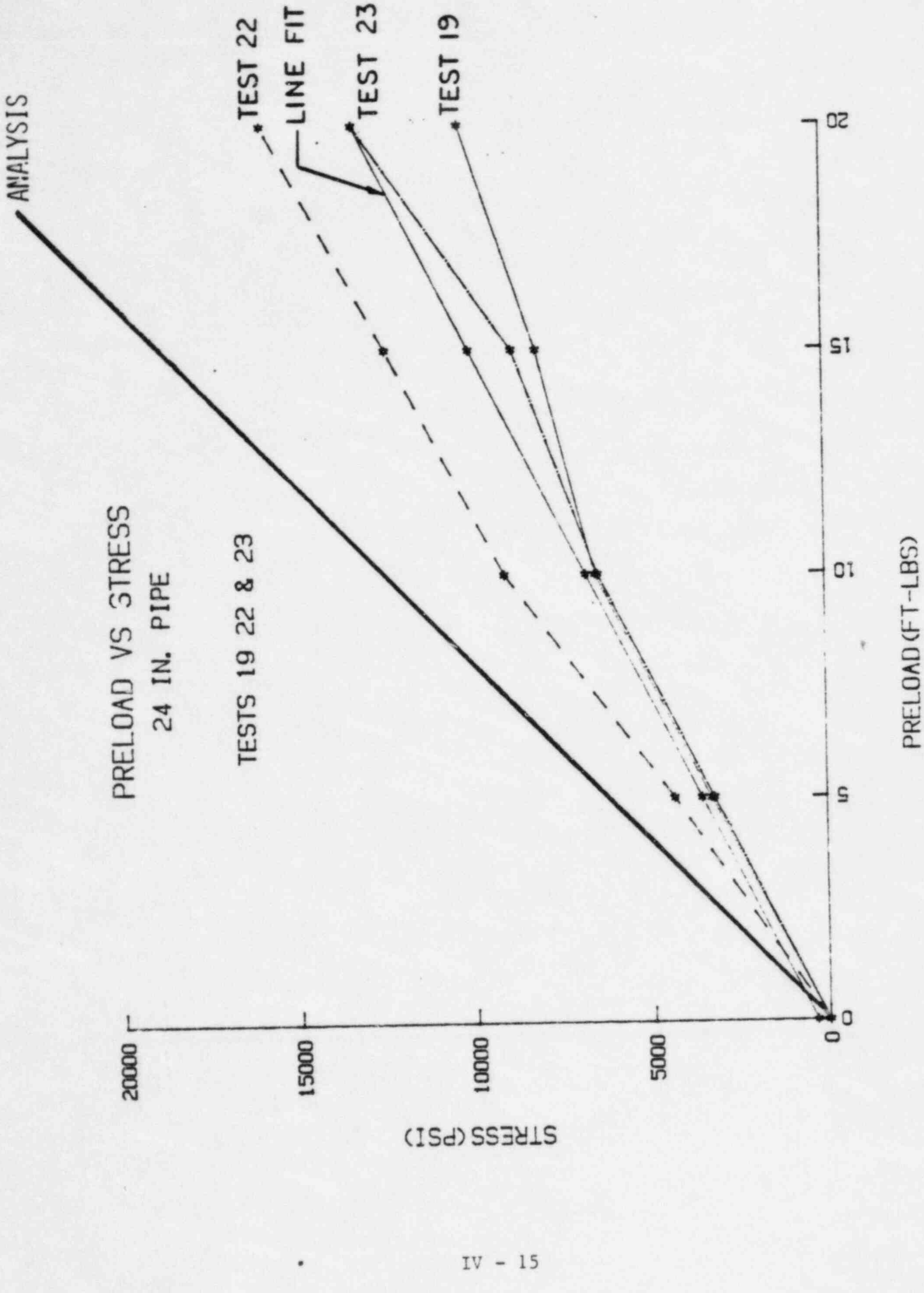

PRELOAD VS STRESS
2.5 IN. PIPE FRAME 1C
TESTS 1 2 3 4
ANALYSIS
TEST 1
TEST 2
TEST 4
LINE FIT
TEST 3
10000
8000
6000
4000
2000
0
STRESS (PSI)
0
5
10
PRELOAD (FT-LBS)

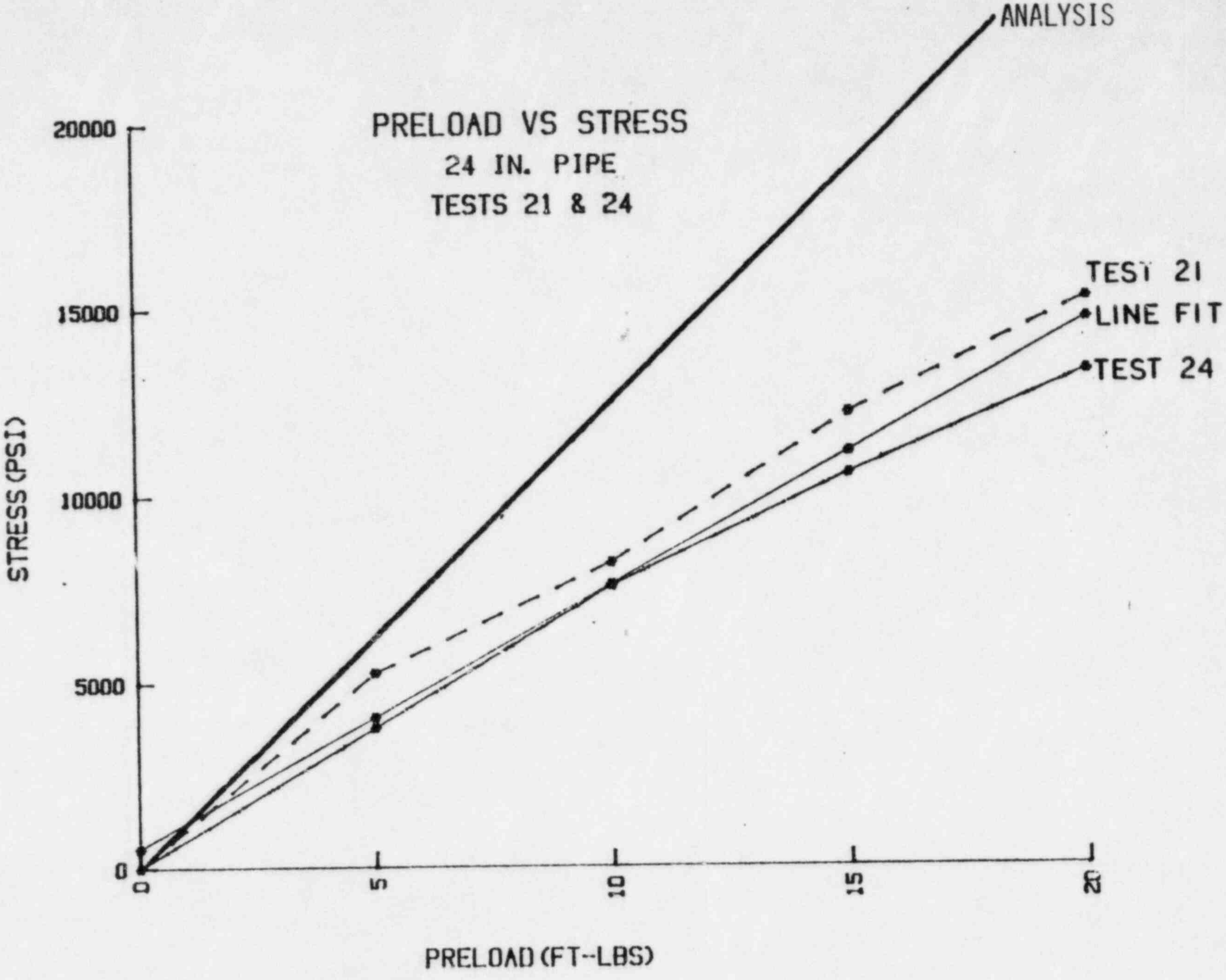

PRELOAD VS STRESS
6 IN. PIPE FRAME 1C
TESTS 5 6 7 8
ANALYSIS
TEST 5
TEST 6
LINE FIT
TEST 7
TEST 8
STRESS (PSI)
20000
15000
10000
5000
0
0
5
10
15
PRELOAD (FT-LBS)

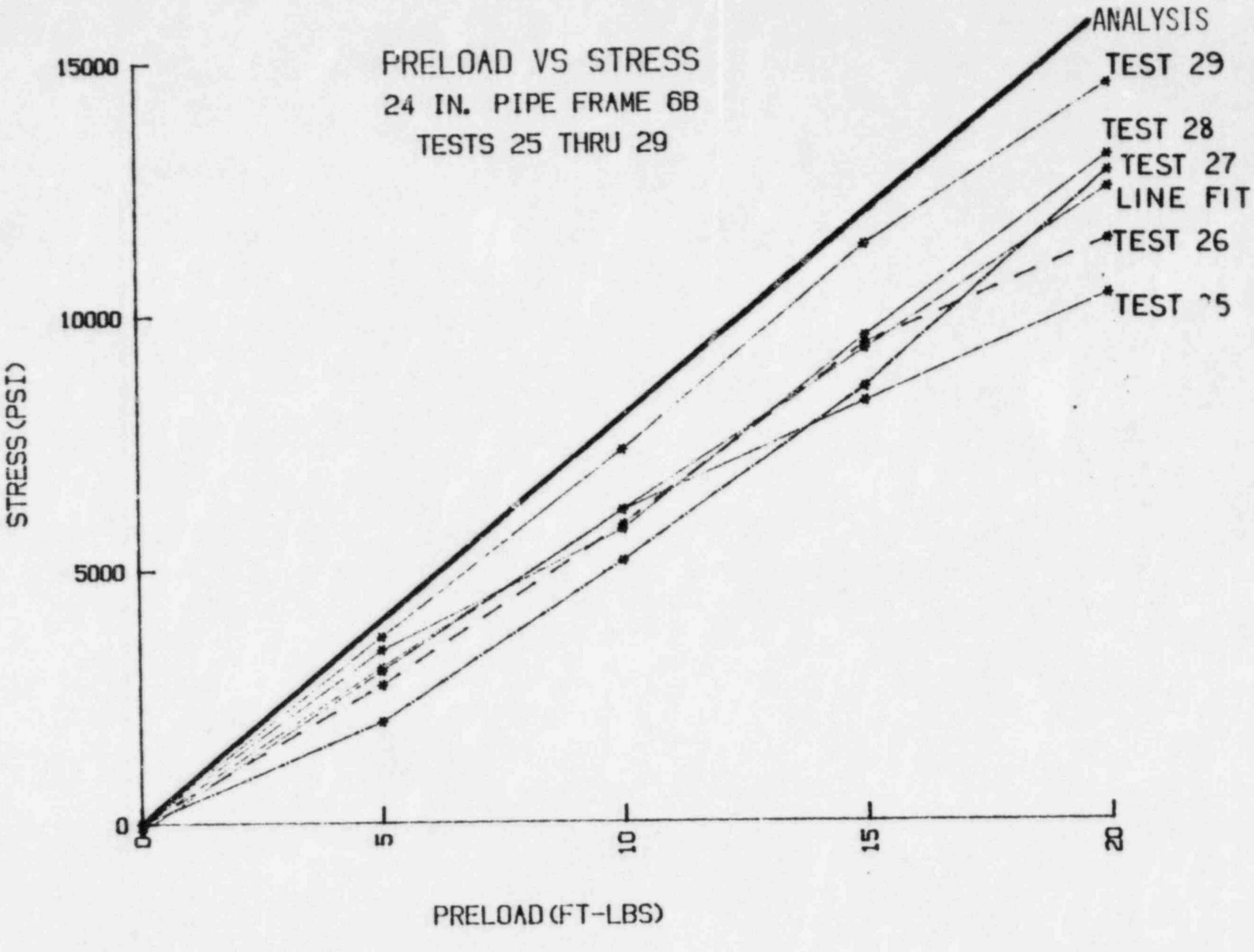

PRELOAD VS STRESS
6 IN. PIPE FRAME 2C
TESTS 9 10
ANALYSIS
TEST 9
LINE FIT
TEST 10
STRESS (PSI)
25000
20000
15000
10000
5000
0
0
5
10
15
20
PRELOAD (FT-LBS)


PRELOAD VS STRESS
8 IN. PIPE FRAME 5B
TESTS 13 & 14
ANALYSIS
TEST 14
TEST 13
*LINE FIT
STRESS (PSI)
20000
15000
10000
5000
0
0
5
10
15
20
25
30
35
40
PRELOAD (FT-LBS)


PRELOAD VS STRESS
14 IN. PIPE FRAME 2C
TESTS 15 16 & 17
ANALYSIS
TEST 15
LINE FIT
TEST 17
TEST 16
STRESS (PSI)
30000
25000
20000
15000
10000
5000
0
PRELOAD (FT-LBS)
0
5
10
15
20
25
30
35


PRELOAD VS STRESS
24 IN. PIPE
TESTS 19 22 & 23
ANALYSIS
TEST 22
LINE FIT
TEST 23
TEST 19
STRESS (PSI)
20000
15000
10000
5000
0
0
5
10
15
20
PRELOAD (FT-LBS)


PRELOAD VS STRESS
24 IN. PIPE
TESTS 21 & 24
ANALYSIS
TEST 21
LINE FIT
TEST 24
STRESS (PSI)
20000
15000
10000
5000
0
0
5
10
15
20
PRELOAD (FT--LBS)


PRELOAD VS STRESS
24 IN. PIPE FRAME 6B
TESTS 25 THRU 29
ANALYSIS
TEST 29
TEST 28
TEST 27
LINE FIT
TEST 26
TEST 25
15000
10000
5000
0
STRESS (PSI)
0
5
10
15
20
PRELOAD (FT-LBS)

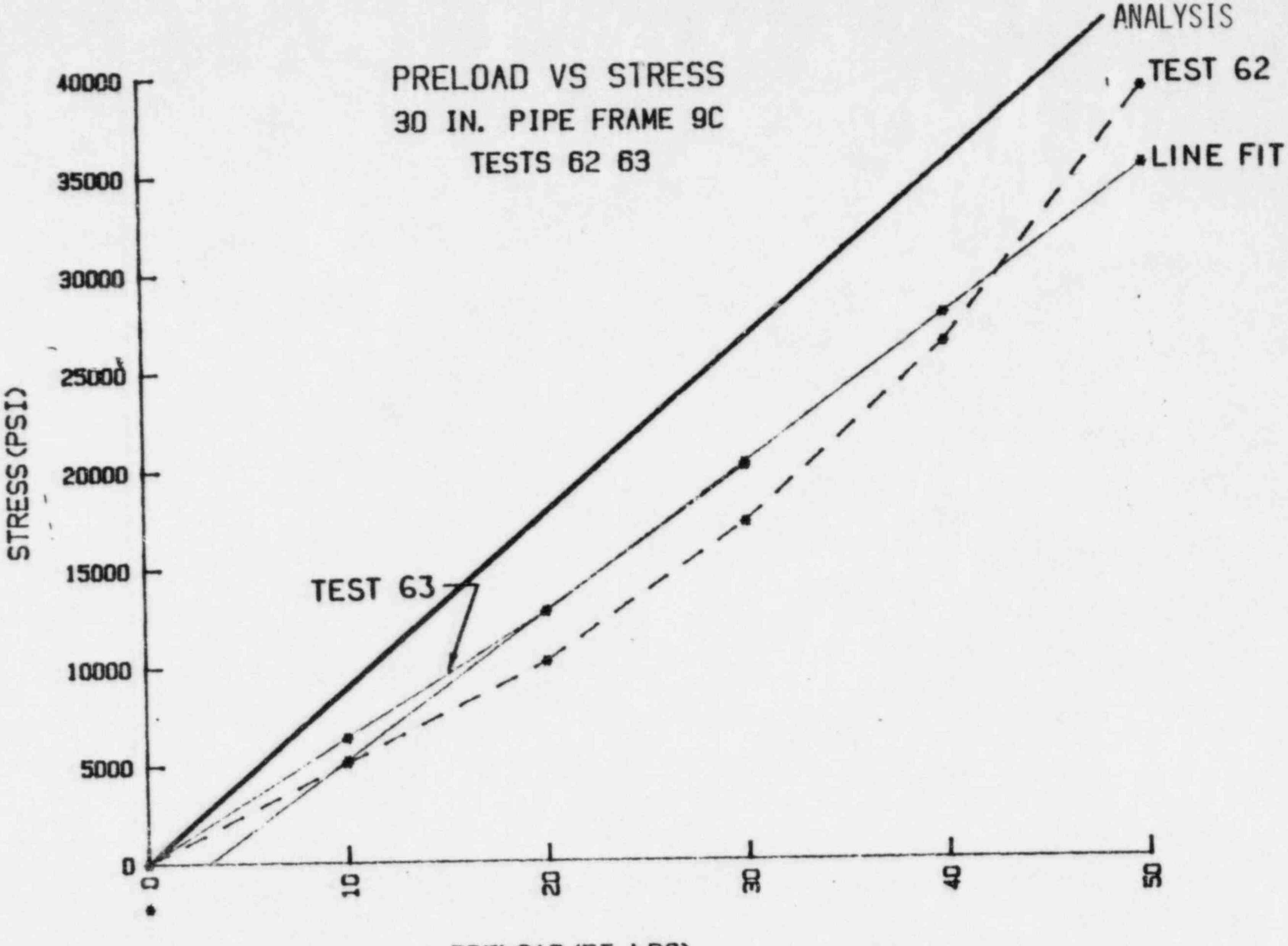

PRELOAD VS STRESS
30 IN. PIPE FRAME 9C
TESTS 62 63
ANALYSIS
TEST 62
LINE FIT
TEST 63
STRESS (PSI)
40000
35000
30000
25000
20000
15000
10000
5000
0
0
10
20
30
40
50
PRELOAD (FT-LBS)

TABLE A

INCREASE IN PIPEWALL STRESS DUE TO A 1000# COMPRESSIVE LOAD (POINT LOAD)

NOMINAL PIPE SIZE	CLAMP FRAME SIZE	TEST	ANALYSIS
2½	1	4796	7492
6	1	4892	5606
8	2	4282	4658
8	5	4037	4236
14	2	2455	3886
24	3	5287	5191
24	6	4822	5031
30	9	3798	4560

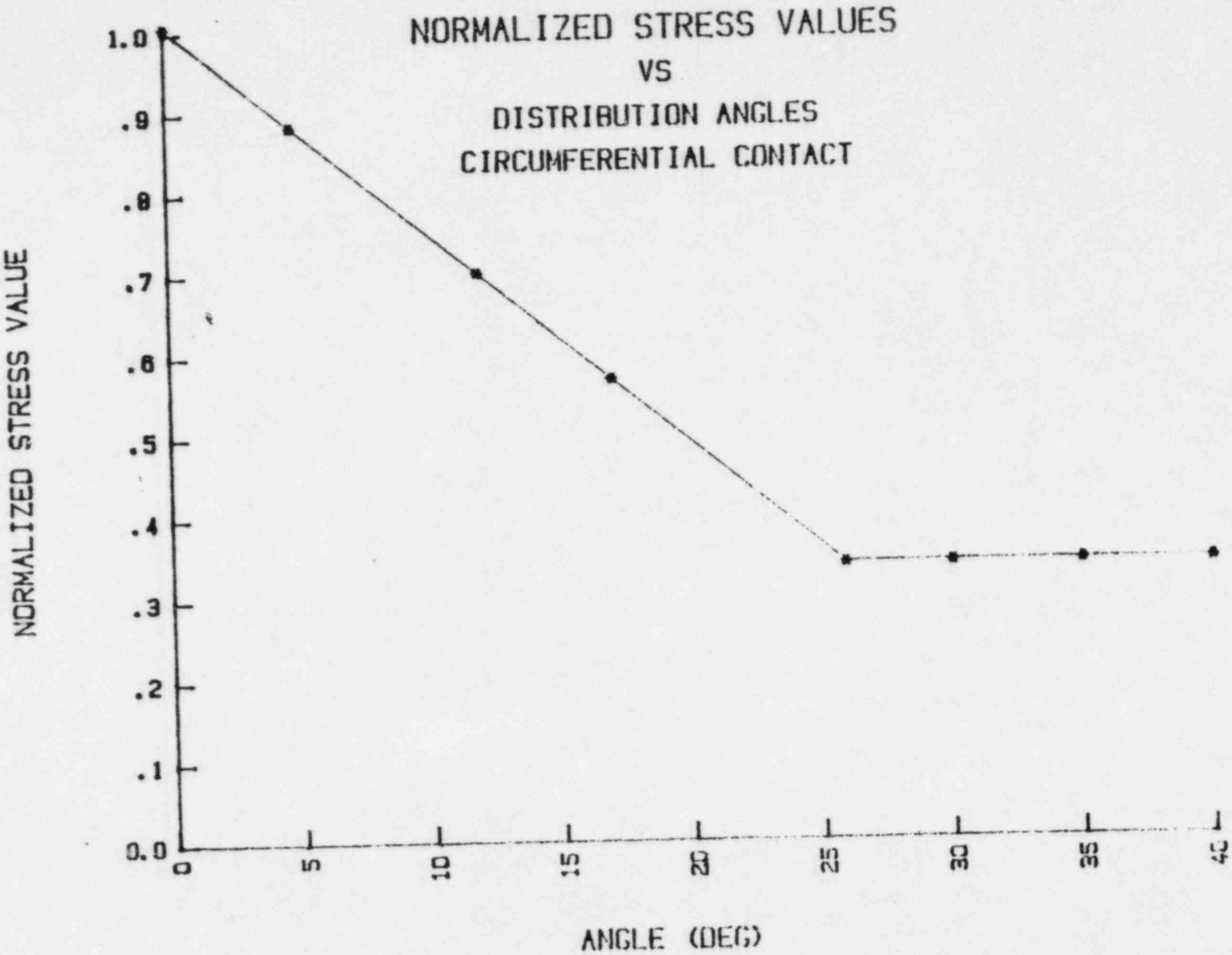

NORMALIZED STRESS VALUES
VS
DISTRIBUTION ANGLES
CIRCUMFERENTIAL CONTACT
NORMALIZED STRESS VALUE
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0.0
0
5
10
15
20
25
30
35
40
ANGLE (DEG)

TABLE B

NORMALIZED TEST STRESS VALUES AS A FUNCTION OF PIPE/FRAME SIZE
(ALL PIPE SIZES TESTED)

6.625/1 (pipe size/frame size)

Contact Arc (Deg) ↓	Preload/load (ft-lbs/lbs) → 10/0	10/1000	10/2000	15/0	15/2000
0°	1.0	1.0	1.0	1.0	1.0
8.6°	.7765	.793	.812	.778	.804
17.3°	.5527	.585	.623	.5572	.608
25.9°	.3289	.3785	.435	.335	.413

14/5 (pipe size/frame size)

Contact Arc (Deg)	10/1000	10/2000	20/4000	20/6000
0°	1.0	1.0	1.0	1.0
4.1°	.917	.903	.889	.882
8.2°	.834	.806	.779	.764
12.3°	.752	.709	.669	.646

Contact Arc (Deg)	30/0	30/3000	30/6000	30/8000
0°	1.0	1.0	1.0	1.0
4.1°	.896	.895	.885	.877
8.2°	.793	.791	.771	.754
12.3°	.689	.687	.657	.632

24/3 (pipe size/frame size)

Contact Arc (Deg)	10/0	10/1000	10/2000	15/0	15/2000
0°	1.0	1.0	1.0	1.0	1.0
2.4°	.931	.934	.931	.94	.931
4.8°	.863	.869	.863	.884	.862
7.2°	.794	.803	.795	.826	.794
11.9°	.658	.672	.658	.710	.656
16.9°	.521	.541	.521	.594	.519
20.9°	.401	.426	.401	.493	.398
25.1°	.282	.312	.282	.392	.278

TABLE B (cont'd.)
NORMALIZED TEST STRESS VALUES

24/3 (pipe size/frame size)				
Contact Arc (Deg)	Preload/load (ft-lbs/lbs) →			
	15/3000	20/0	20/3000	20/4000
0°	1.0	1.0	1.0	1.0
2.4°	.930	.939	.929	.916
4.8°	.862	.878	.859	.834
7.2°	.791	.818	.789	.751
11.9°	.652	.697	.649	.585
16.7°	.514	.575	.509	
20.9°	.392	.468	.386	
25.1°	.271	.362	.263	

24/6 (pipe size/frame size)							
	10/0	10/1000	10/2000	20/0	20/2000	20/3000	20/5000
0°	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4.8°	.859	.865	.842	.860	.856	.854	.848
9.6°	.719	.729	.684	.820	.7135	.708	.697
14.3°	.578	.594	.5269	.581	.570	.562	.546
19.1°	.438	.459	.3689	.4411	.427	.416	.394
22.7°	.332	.358	.2507	.336	.319	.307	.281

TABLE C

NORMALIZED STRESS VALUES AS A FUNCTION OF DISTRIBUTION ANGLE ONLY

Pipe size/Frame size								
4.8° (Contact Arc)								
6.625/1	.875	.884	.895	.876	.890			
14/5	.917	.903	.889	.882	.896	.895	.885	.877
24/3	.863	.869	.863	.884	.862	.862	.878	.859
	.834							
24/6	.859	.865	.842	.860	.856	.854	.848	
11.9° (Contact Arc)								
6.625/1	.6917	.714	.740	.694	.729			
14/5	.752	.709	.669	.646	.689	.687	.657	.632
24/3	.658	.672	.658	.710	.656	.652	.697	.649
	.585							
24/6	.65	.662	.607	.651	.643			
17° (Contact Arc)								
6.625/1	.5527	.585	.623	.5572	.608			
24/3	.521	.541	.521	.594	.519	.514	.575	.509
24/6	.497	.516	.436	.500	.487	.478	.4[illegible]2	
25.9° (Contact Arc)								
6.625/1	.3829	.3785	.335	.413				
24/3	.282	.312	.282	.392	.278	.271	.362	.263
24/6	.332	.358	.2507	.336	.319	.307	.281	

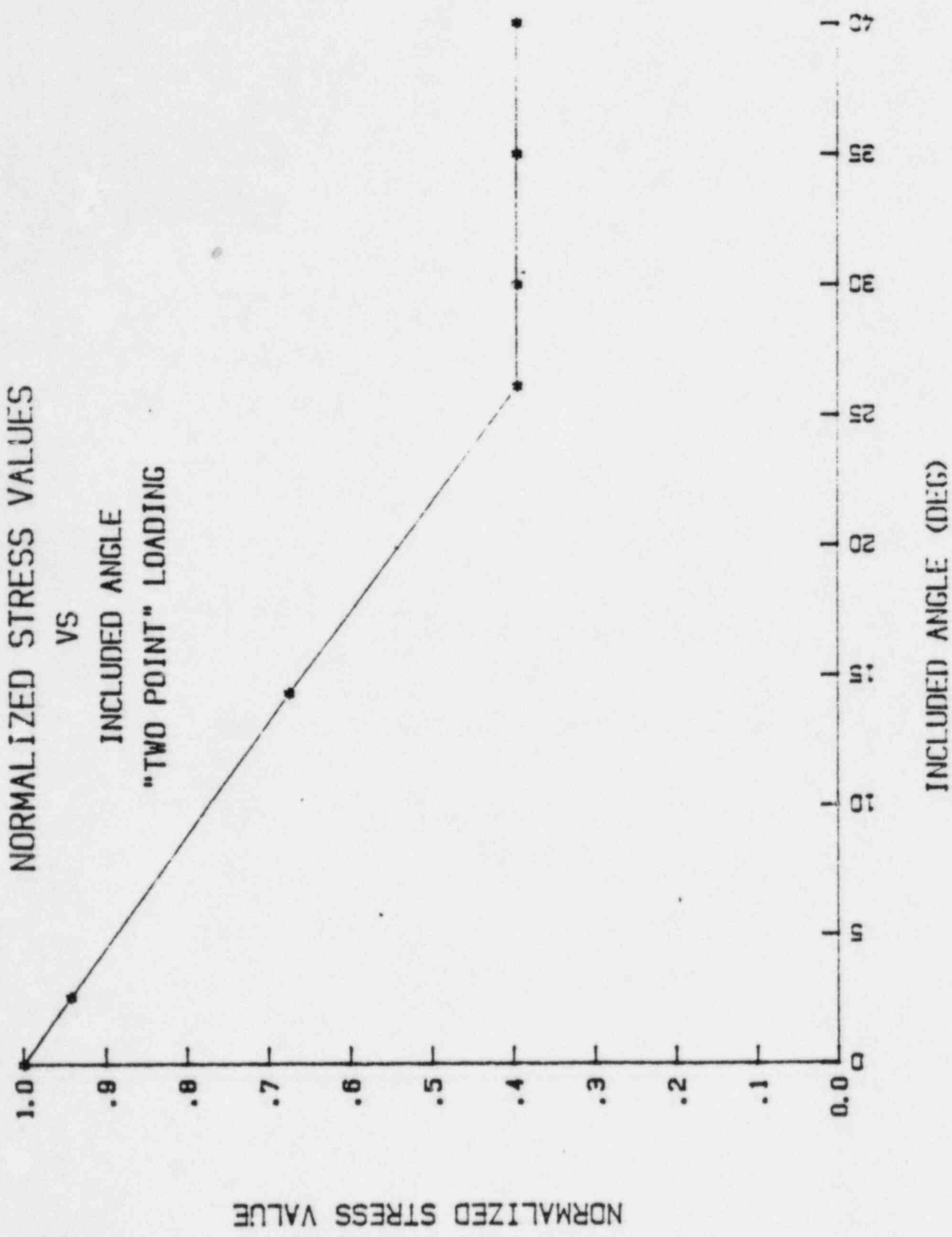

NORMALIZED STRESS VALUES
VS
INCLUDED ANGLE
"TWO POINT" LOADING
NORMALIZED STRESS VALUE
INCLUDED ANGLE (DEG)
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0.0
0
5
10
15
20
25
30
35
40

TABLE D

MAXIMUM INDUCED PIPEWALL STRESSES
DUE TO TEMPERATURE EFFECTS

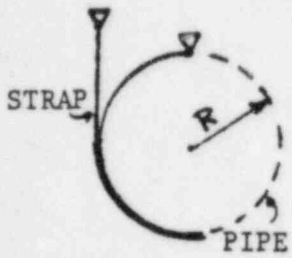
PIPE SIZE	FRAME SIZE	PIPE TEMPERATURE (°F)	PIPEWALL STRESS (psi)	
			TEST	ANALYSIS
6"	1	150	1680	3983
14"	2	175	3384	4385

APPENDIX V

EQUIVALENCE BETWEEN PRESSURE AND THERMAL INDUCED STRESSES

APPENDIX V

EQUIVALENCE BETWEEN PRESSURE AND THERMAL INDUCED STRESSES



Model used by ITT/Grinnell to determine the thermal induced stresses. The thermal stresses are proportional to the amount of restriction that the strap imposes the free thermal expansion of the pipe. This restriction is approximately given by

$$\Delta_t = 2xRx\,(\alpha_{pipe} - \alpha_{strap})\,\Delta T$$

$$\Delta_t = 2xRx\,(9.53^* - 5.74^*)\,10^{-6}\,\Delta T = 7.58x10^{-6}\,R\,\Delta T \quad (1)$$

The restriction imposed by the strap to the free pressure expansion of the pipe is:

$$\Delta_p = 2x\,\frac{(.85)pR^{2\,**}}{Et} = 2x0.85\,\frac{pR}{t}\,\frac{R}{E}$$

A review done for all the piping systems indicated that the hoop pressure stresses $\frac{(pR)}{t}$ for the WNP-3 project do not exceed 13,200 psi

$$\Delta_p = \frac{2x0.85\,(13,200)}{{}^*26.85x10^6}\,R = 835.7\,10^{-6}R \quad (2)$$

Equaling (1) and (2)

$$7.58 \times 10^{-6}\,R\Delta T = 835.7 \times 10^{-6}\,R$$

$$\Delta T = 110^{o}F$$

CONCLUSION: The maximum pressure induced stresses can be estimated from the thermal induced stresses calculated by ITT for the SS pipes using a value of $\Delta T = 110^{o}F$.

* Values used by ITT/Grinnell in their analysis for SS pipes at $350^{o}F$

** Ref. "Formulas for Stress and Strain" D J Roark, WC Young, 5th Edition

APPENDIX VI

CROSS REFERENCE BETWEEN NRC QUESTIONS AND SUBJECTS COVERED IN THIS REPORT

NRC QUESTIONS (REF.7 &8)

QUESTION #	SUBJECTS	SECTION**
1	MATERIALS, CODE CASE N-249	IV-2)*
2	PIPE INDUCED STRESSES	V-5),6)*
3	EVALUATION OF PIPE INDUCED STRESSES	V-6)*
4	TORQUE TOLERANCE	VII-1)*
5	MARGIN FOR LIFT-OFF	VII-1)*
6	STIFF CLAMP APPLICATION	VII-3)*
7	CLAMP LOAD RATING	VII-4)
8	TORQUE RELAXATION	VI-1)*
9	MATERIALS	IV-2)
10	CLAMP DATA	VII-4)*
11	POSTULATION OF BREAKS	V-6)A)*
12	LOCAL WALL PIPE STIFFNESS	VII-4)*
13	MATERIALS	IV-2)
14	MATERIALS, CODE CASE N-249	IV-2)*
15	PRESSURE STRESSES	V-6)C)*
16	TEST RESULTS, IMPACT	V-5);VII-3)*
17	PRETORQUE	VII-1),2)*
18	TORQUE RELAXATION, INSTALLATION	VI-1),2)*
19	TORQUE RELAXATION	VI-1)*
20	PIPE INDUCED STRESSES	V-6)

R

* Information provided in this Section updates or revises information previously transmitted to NRC by Refs. 18 through 22.

** Refers To Sections Of This Report Where This Subject Is Covered.

APPENDIX VII

ITT-GRINNELL

FIG. 215 STIFF CLAMP - LCD PE-41

PIPE HANGER DIVISION
ASME SECTION III
SUBSECTION NF
LOAD CAPACITY DATA SHEET

1. GENERAL INFORMATION

SUPPORT NAME: PE-41 Pipe Clamp Size 1-11 WPPSS Units 3 & 5	ENGINEERING PARTS LIST(S): 215-00000
SUPPORT TYPE: Component Standard	CODE CLASSIFICATION: Class 1,2,3&MC
DESIGN PROCEDURE: Load Rating	DESIGN TEMPERATURE: 650° See Note Page 3
SERVICE LIMITS: Levels A,B,C,D & Design Loading	

2. CERTIFICATION

ENGINEER: Richard C. Sherman DATE: 1-30-81	THE LOAD CAPACITY OF THIS COMPONENT SUPPORT IS RATED IN ACCORDANCE WITH SUBSECTION NF
CHECKED: James A. Williams DATE: 1-30-81	ROBERT B. MULDANEY NO. 34[illegible] REGISTERED PROFESSIONAL ENGINEER
LOCATION OF SUBSTANTIATION DATA Research, Development & Engineering Pipe Hanger Division, Prov., R.I.	REGISTERED PROFESSIONAL ENGINEER

3. REVISION AND RECERTIFICATION

LCDS REV. NO.	DATE	EPL LOG SH REV. NO.	DATE	RECERTIFICATION
2	1/30/81	--	1/30/81	[signature]
3	8/1/81	--	9/4/81	[signature]
4	10/29/81		10/29/81	[signature]
5	4/7/82	--	4/7/82	[signature]
6	6/15/82	--	6/17/82	[signature]
7	12/6/82	--	12/6/82	Frank Birch
8	3/26/85	--	3/26/85	Frank Birch

4. COMPONENT SUPPORT INFORMATION

ITEM	MATERIAL SPECIFICATION	ITEM TYPE
Frame	SA-515 Gr.65-70 or SA-36	Load Rating
Load Pin (Except Sz.35 Fig.306/307)	SA-193 Gr.B7 or SA-564 Type 630 Age Hardened @ 1075°F	Load Rating
Load Pin (Sz. 35 Fig. 306/307)	SA-564 Type 630 Age Hardened @1075°F	Load Rating
Spacer	SA-36 or AISI 1010 Exempt per NF 2121 (b)	Secondary Member
Retaining Ring	Truarc R Exempt per NF-2121 (b)	Load Rating
Strap Pins	SA-193 Gr. B7	Load Rating
Straps	ASTM A 693 Type 630 Condition H 1075*	Load Rating
Trunnion	SA-193 Gr. B7	Load Rating
Tie Rod Washer	SA-36 or C1018 Case Hardened to Rockwell C-35-38 Exempt per NF2121 (b)	Load Rating
Nuts	SA-307 Gr.B or ASTM A307 Gr.A*	Load Rating
Tie Rods	SA-193 Gr. B7	Load Rating
Rivets	AMS 5737* or SA-453 Gr.660 COND. A or B	Load Rating
Cotter Pins	ANSI B 18.8.1 Exempt Per NF2121 (b)	Secondary Member
*N-249		

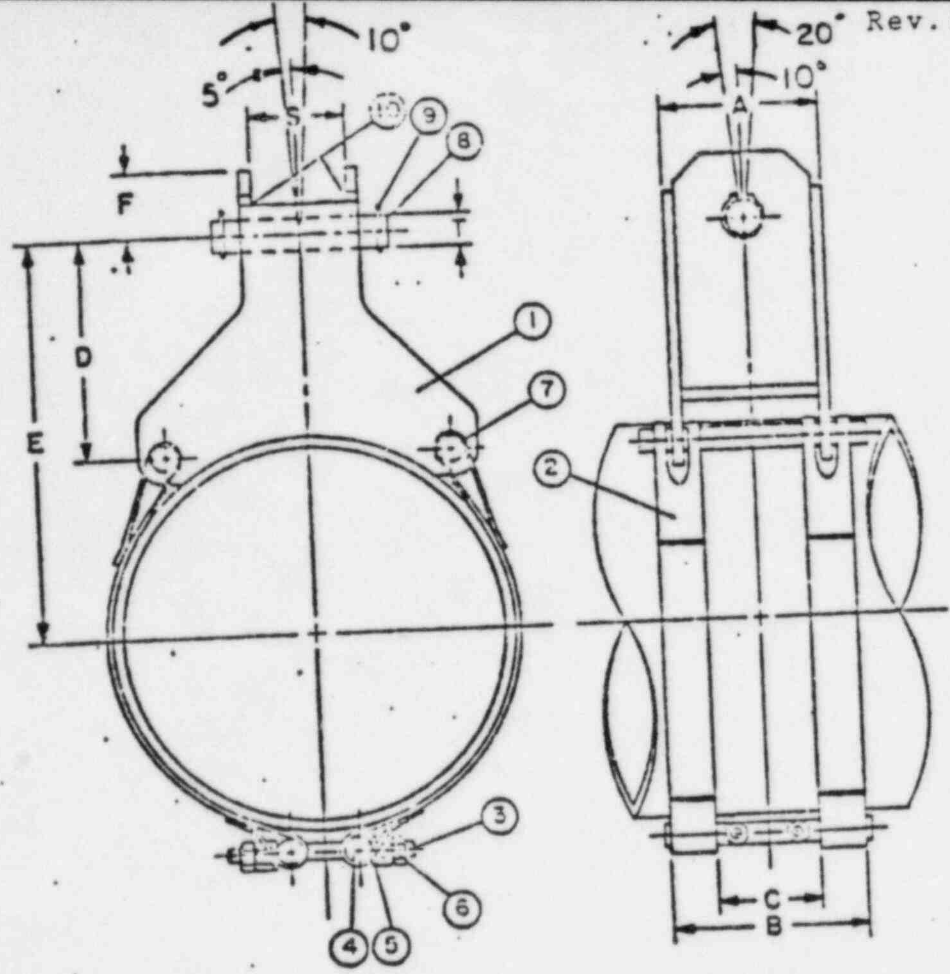
ITT GRINNELL PIPE HANGER DIVISION
FIG. 215 STIFF CLAMP
LOAD RATING
PE-41

Frame	Level A,B	Level C	Level D	Minimum Spring Rate Kips/In.
1A	650	870	1200	325
1B	1500	2067	2300	325
1C	6000	8610	11520	325
2A	650	870	1200	325
2B	1500	2067	2300	325
2C	6000	8610	11520	325
3A	650	870	1200	325
3B	1500	2067	2300	325
3C	6000	8610	11520	325
4A	15000	20100	23600	1000
4B	20700	24840	26700	1000
5A	15000	20100	23600	1000
5B	20700	24840	26700	1000
6A	15000	20100	23600	1000
*6B	20700	24840	26700	1000
7A	28000	32640	35081	2500
7B	33500	40200	43220	2500
7C	50000	70350	91000	2500
8A	28000	32640	35081	2500
8B	33500	40200	43220	2500
8C	50000	70350	91000	2500
9A	28000	32640	35081	2500
9B	33500	40200	43220	2500
9C	50000	70350	91000	2500
10	58734	78312	86500	2500
11	58734	78312	86500	2500

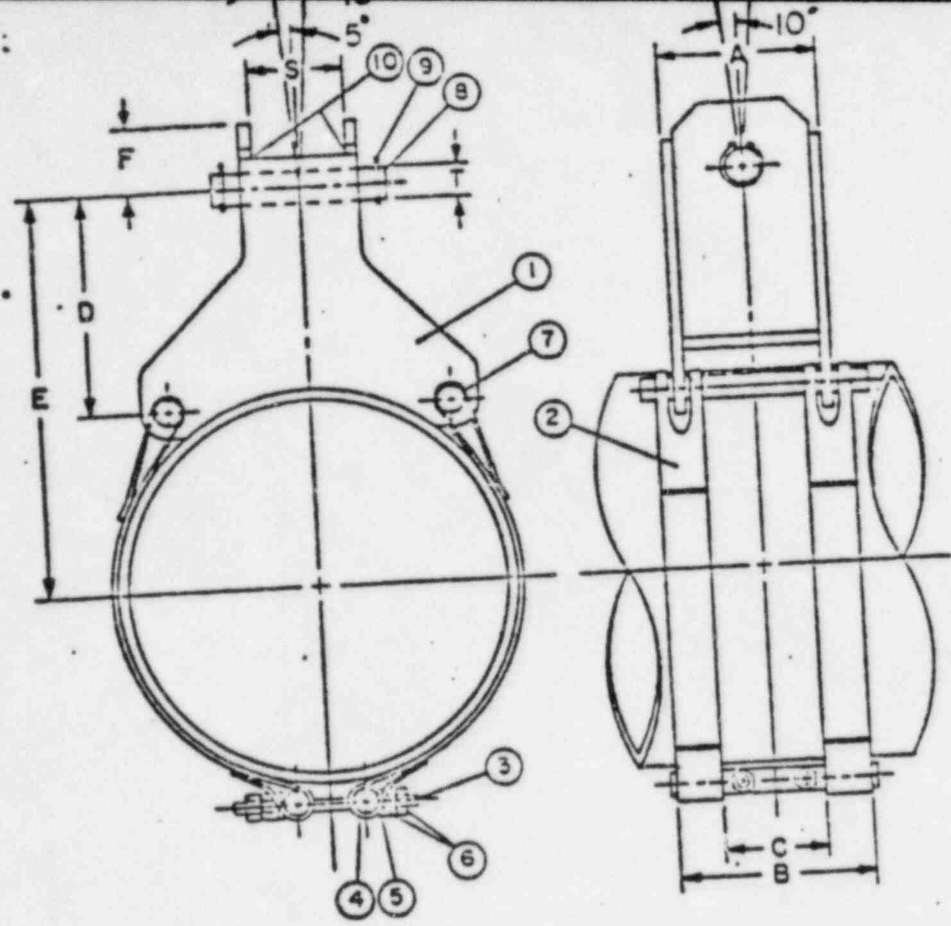
NOTES: 1. Use on stainless steel pipes operating above 350°F must be reviewed by ITT Grinnell Research, Development and Engineering.

2. For required torque values, see page 9 of 9.

* See Load Deration on Page 6.



FRAME SIZE	PIPE SIZE	T LOAD PIN DIA	FOR USE WITH FIG. 306	FOR USE WITH FIG. 660	FOR USE WITH FIG. 211	A	B	C	D	E	F	S
1A	2½ 3 3½ 4 6	.374 .372	½ & ½	--	A	4½	5 3/4	2½	3 11/16	5 9/16 5 7/9 6 3/8 6 7/16 6 15/16 7½	½	1
1B	2½ 3 3½ 4 6	.499 .497	1	--	--	4½	5 3/4	2½	3 7/16	5 13/16 6 1/8 6 5/8 6 11/16 7 3/16 7 3/4	3/4	1
1C	2½ 3 3½ 4 6	.749 .747	3	1	B & C	4½	5 3/4	2½	3 3/16	6 1/16 6 3/8 6 7/8 6 15/16 7 7/16 8	1	1
2A	8 10 12 14	.374 .372	½ & ½	--	A	4½	5 3/4	2½	6 3/16	10 13/16 11 15/16 [illegible] 13 9/16	½	[illegible]
2B	8 10 12 14	.499 .497	1	--	--	4½	5 3/4	2½	5 15/16	11 1/16 [illegible] [illegible] 13 15/16	3/4	1
2C	8 10 12 14	.749 .747	3	1	B & C	4½	5 3/4	2½	5 11/16	11 5/16 [illegible] [illegible] [illegible]	1	1



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<tr><th rowspan="2">FRAME SIZE</th><th rowspan="2">PIPE SIZE</th><th rowspan="2">T LOAD PIN DIA</th><th colspan="3">FOR USE WITH</th><th rowspan="2">A</th><th rowspan="2">B</th><th rowspan="2">C</th><th rowspan="2">D</th><th rowspan="2">E</th><th rowspan="2">F</th><th rowspan="2">S</th></tr>
<tr><th>FIG. 306</th><th>FIG. 660</th><th>FIG. 211</th></tr>
<tr><td>3A</td><td>16
18
20

24</td><td>.374
.372</td><td>½ & ½</td><td>--</td><td>A</td><td>4½</td><td>5 3/4</td><td>2½</td><td>10 3/16</td><td>17 7/8
18 7/8
19 7/8
20 15/16
21 15/16</td><td>½</td><td>1</td></tr>
<tr><td>3B</td><td>16
18
20

24</td><td>.499
.497</td><td>1</td><td>--</td><td>--</td><td>4½</td><td>5 3/4</td><td>2½</td><td>9 15/16</td><td>18 1/8
19 1/8
20 1/8
21 3/16
22 3/16</td><td>3/4</td><td>1</td></tr>
<tr><td>3C</td><td>16
18
20

24</td><td>.749
.747</td><td>3</td><td>1</td><td>B & C</td><td>4½</td><td>5 3/4</td><td>2½</td><td>9 11/16</td><td>18 3/8
19 3/8
20 3/8
21 7/16
22 7/16</td><td>1</td><td>1</td></tr>
<tr><td>4A</td><td>3

4
5
6</td><td>.999
.997</td><td>10</td><td>2+3</td><td>1+2</td><td>5½</td><td>6 3/4</td><td>3½</td><td>3½</td><td>5 11/16
6
6½
6 3/4
7 5/16</td><td>1½</td><td>1½</td></tr>
<tr><td>4B</td><td>3

4
5
6</td><td>1.249
1.247</td><td>--</td><td>4+5</td><td>3+4</td><td>5½</td><td>6 3/4</td><td>3½</td><td>3½</td><td>5 11/16
6
6½
6 3/4
7 5/16</td><td>1½</td><td>1½</td></tr>
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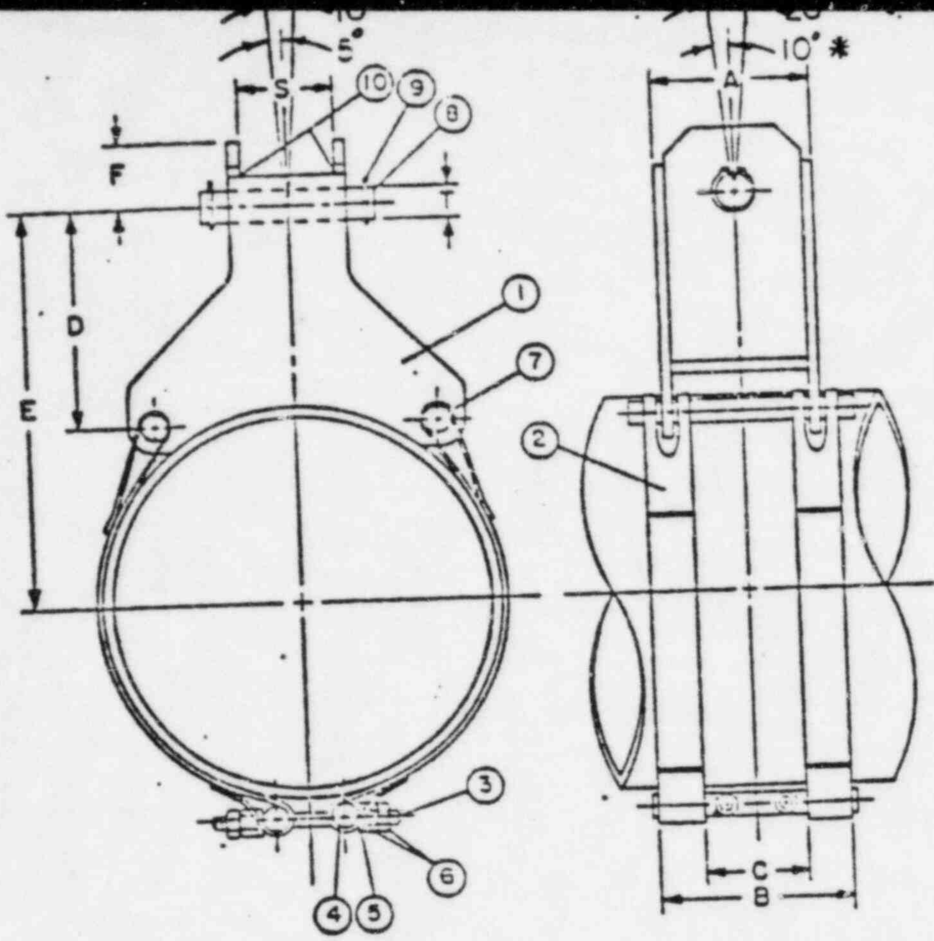
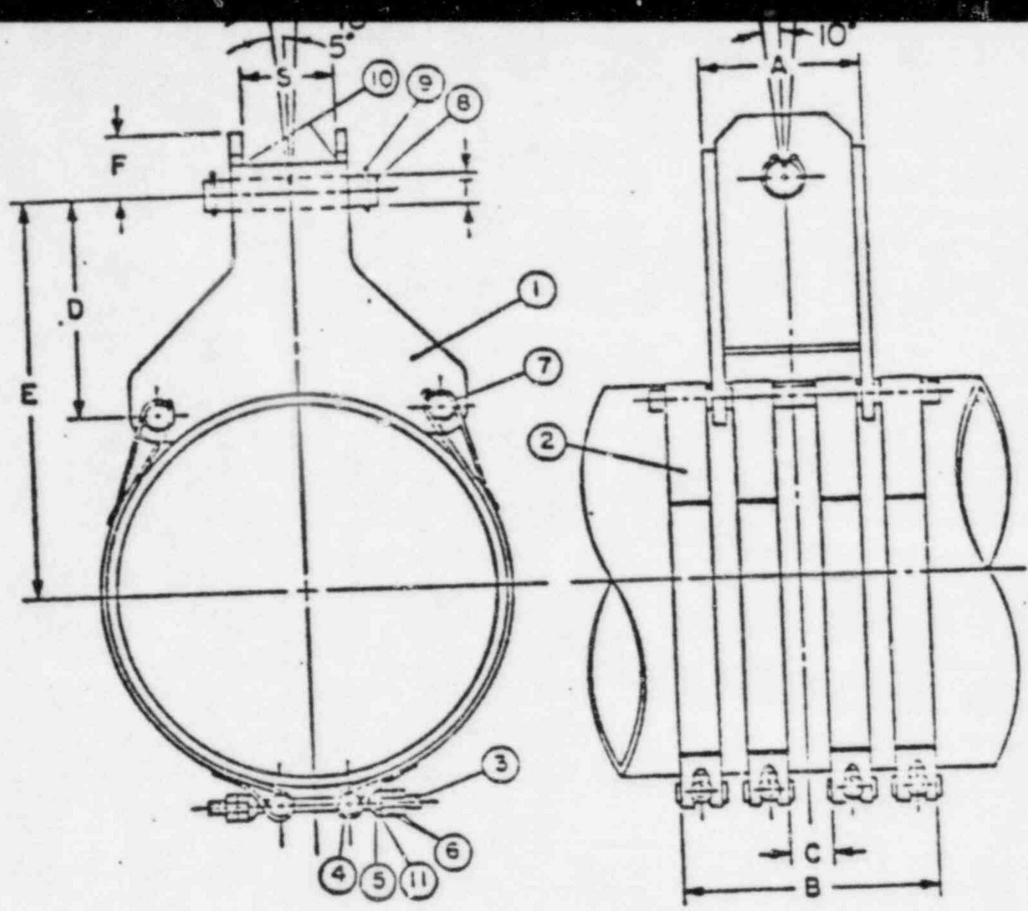


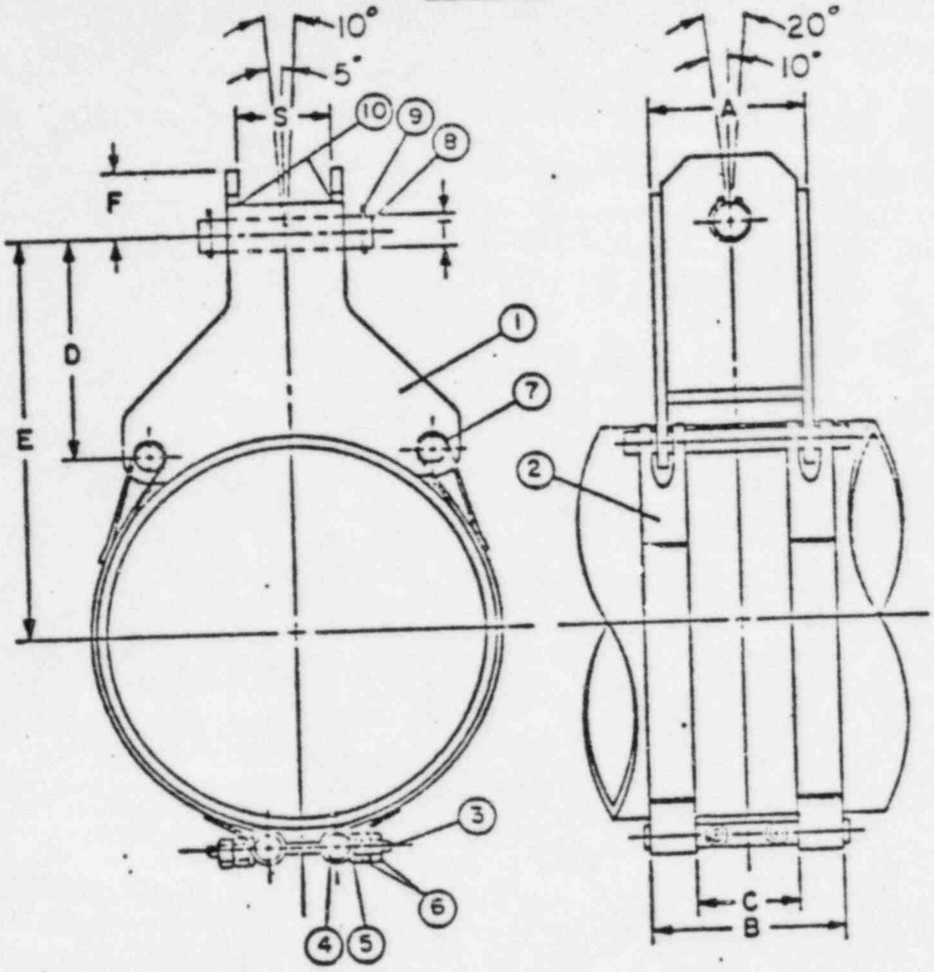
FRAME SIZE	PIPE SIZE	T LOAD PIN DIA	FOR USE WITH FIG. 306	FIG. 660	FIG. 211	A	B	C	D	E	F	S
5A	8 10 12 14	.999 .997	10	2&3	1&2	5½	6 3/4	3½	6½	11 1/8 12 1/4 13 1/4 13 7/8	1½	1½
5B	8 10 12 14	1.249 1.247	--	4&5	3&4	5½	6 3/4	3½	6½	11 1/8 12 1/4 13 1/4 13 7/8	1½	1½
6A	16 18 20 24	.999 .997	10	2&3	1&2	5½	6 3/4	3½	9 15/16	17 5/8 18 5/8 19 5/8 20 5/8 21 5/8	1½	1½
6B	16 18 20 24	1.249 1.247	--	4&5	3&4	5½	6 3/4	3½	9 15/16	17 5/8 18 5/8 19 5/8 20 5/8 21 5/8	1½	1½
7A	10 12 14 16	1.499 1.497	--	6	5	7 5/8	8 5/8	5 3/8	7 5/8	13 1/8 14 3/16 15 3/16 15 13/16 16 13/16	2½	2
7B	10 12 14 16	1.749 1.747	--	7	6	7 5/8	8 5/8	5 3/8	7 5/8	13 1/8 14 3/16 15 3/16 15 13/16 16 13/16	2½	2

* The load rating of size 6B <u>must</u> be decreased by 20% for a longitudinal alignment angle greater than 5°.



FRAME SIZE	PIPE SIZE	T LOAD PIN DIA	FOR USE WITH FIG. 306	FOR USE WITH FIG. 650	FOR USE WITH FIG. 211	A	B	C	D	E	F	S
7C	10 12 14 16	1.499 / 1.497	35	--	--	7 5/8	11 1/8	3 1/8	7 5/8	13 1/8 14 3/16 [illegible] 15 13/16 16 13/16	2½	2
8C	20	1.499 / 1.497	35	--	--	7 5/8	11 1/8	3 1/8	10 1/2	20 21½ 22½	2½	2
9C	24 30	1.499 / 1.497	35	--	--	7 5/8	11 1/8	3 1/8	15 9/16	27 1/16 28 1/16 29 1/16 [illegible] 31 1/16 32 1/16 33 1/8	2½	2
10	16	1.999 / 1.997	--	8	7	10½	14½	5	8½	17 7/16 18 7/16 19 7/16 20 1/2	2 5/8	2½
11	30	1.999 / 1.997	--	8	7	10½	14½	5	13 3/16	25 5/16 26 5/16 [illegible] [illegible] [illegible] [illegible] 31 7/16	2 5/8	2½

FIG. 215N



FRAME SIZE	PIPE SIZE	T LOAD PIN DIA	FOR USE WITH FIG. 306	FIG. 660	FIG. 211	A	B	C	D	E	F	S
8A	20	1.499 / 1.497	--	6	5	7 5/8	8 5/8	5 3/8	10 1/2	20 21 1/4 22 1/4	2½	2
8B	20	1.749 / 1.747	--	7	6	7 5/8	8 5/8	5 3/8	10 1/2	20 21 1/4 22 1/4	2½	2
9A	24 30	1.499 / 1.497	--	6	5	7 5/8	8 5/8	5 3/8	15 9/16	27 1/16 28 1/16 29 1/16 30 1/16 31 1/16 32 1/16 33 1/8	2½	2
9B	30	1.749 / 1.747	--	7	6	7 5/8	8 5/8	5 3/8	15 9/16	27 1/16 28 1/16 29 1/16 30 1/16 31 1/16 32 1/16 33 1/8	2½	2

REQUIRED TORQUE VALUES (FT-LBS)

Frame Size	Pipe Size 2 1/2	3	4	6	8	10	12	14	16	18	20	24	30
1A	5	5	5	5									
1B	9	9	10	9									
1C	42	44	46	45									
2A					5	5	5	5					
2B					8	9	9	10					
2C					38	41	44	46					
3A									5	5	5	5	
3B									8	9	9	10	
3C									40	42	44	48	
4A		133	142	134									
4B		151	161	152									
5A					115	126	135	140					
5B					130	142	152	158					
6A									121	127	134	146	
6B									137	144	151	165	
7A						223	236	245	254				
7B						275	289	301	313				
7C						390	412	426	441				
8A											240		
8B											297		
8C											417		
9A												210	233
9B												258	287
9C												363	404
10									278				
11													288