PI-81-0105

May 1, 1981

Mr. Leo Effenberger
Nibco Inc.
500 Simpson Avenue
P.O. Box 1167
Elkhart, IN 46515

Dear Mr. Effenberger:

In regard to your letter of April 14, 1981, it is the policy of this office not to sanction vendors of pipeline materials. We will be happy, however, to answer any remaining questions you or your clients may have regarding compliance with §§192.147 and 195.126.

Sincerely,
SIGNED
Melvin A. Judah
Acting Associate Director for
Pipeline safety Regulation
Materials Transportation Bureau

NIBICO INC.
500 SIMPSON AVENUE
P.O. BOX 1167
ELKHART, IN 46515

April 14, 1981

Mr. Melvin Jadan
Acting Assoc. Director of Pipeline Regulations
Department of Transportation
Materials Transportation Bureau
Washington, DC 20590

Dear Mr. Jadah:

Your office in September, 1977 issued an opinion to our representative that stress analysis and proof testing to VG-101 would be sufficient to qualify our convoluted flange for use under Section 192.147 and 195.126. I am enclosing that required documentation and requesting correspondence from your office that we are a qualified vendor for flanges under that section. We have several gas companies that will use our product only with this qualification letter from your office.

Sincerely,
Leo Effenberger, P.E.
National Sales Manager
Industrial Division

DEPARTMENT OF TRANSPORTATION
MATERIALS TRANSPORTATION
BUREAU WASMNGTON, D.C. 20590

September 21, 1977

Mr. Gunter Schlicht
Pipetech, Inc.
One Northwood Drive #5
Orinda, California 94563

Dear Mr. Schlicht:

Your letter of July 7, 1977, requests an interpretation of the applicable requirements of Parts 192 and 195 relating to the design and testing of pipeline flanges. Your specific question is: are the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, *Division 1* (Boiler Code) considered as an equivalent as intended in Section 192.147 to the referenced specifications for flanges in Part 192? Also, does the Boiler Code meet the requirements for flanges of Section 195.126 in Part 195?

The Boiler Code, which is referenced in both Parts 192 and 195, and the ANSI B16.5 and MSS-SP-44 specifications that are referenced in Part 192 are intended for the conventional design flanges that would be manufactured by casting or forging rather than the convoluted design that would be folded into shape.

In Appendix II, Paragraphs UA-45 thru UA-59, inclusive, of the Boiler Code, the procedure for designing flanges for manufacture by casting or forging is set forth. It is suggested in this Appendix that if the procedure set forth is not appropriate for the design, then in order to establish allowable working pressures, the flange should be proof tested under the provisions of the Boiler Code, Section UG-101, Proof Tests, to establish maximum allowable working pressure. The testing required by UG-101, that is applicable to all pressure vessels, is more severe and thorough than that required by any of the other referenced specifications for flanges.

It is our opinion that a detailed design and stress analysis supported by a proof test under the provisions of UG-101 of the Boiler Code provides the equivalent level of safety intended by Section 192.147.

Section 195.126 states, with respect to a flange connection, that the "connection as a unit must be suitable for the service in which it *is* to be used." It does not provide *any* standard or test method to be used to determine the suitability.

It is our opinion that the stress analysis and Boiler Code testing under the provision of UG-101 would be sufficient to determine whether flange connections are suitable under Section 195.126.

Sincerely
Cesar DeLeon Acting
Director Office of Pipeline
Safety Operations

THOMAS A. SHORT CO.
3430 Wood Street
Oakland, California 94608

November 8, 1978

NIBCO Inc.
500 Simpson Avenue
Elkhart, Indiana
46514

Attention: Mr. Bob Russell

Dear Mr. Russell:

This letter verifies that the below listed convoluted NIBCO flanges, Class 150, were hydrostatically tested in our facility on September 20, 21, 22 and October 27, 1978.

TEST PURPOSE To establish working pressure ratings for NIBCO convoluted Class 150 flanges in sizes and types indicated in the tables below in order to satisfy Section VIII, Div. I UG-101 proof test, and Section 1, Div. 1 PG-100 Proof Test (ASME Pressure Vessel Code).

TEST SPECIMENS NIBCO convoluted flanges, Class 150, were mounted to conventional ANSI B16.5 blind flanges, class 150, raised face with standard serration. Bolting material consisted of A-193 B16 studs with grade 4 nuts, lubricated with anti-seeze lubricant. Gasketing material consisted of 1/16" thick standard compressed asbestos sheets and/or line backers.

The conventional ANSI B16.5 blind flanges were center drilled and tapped with 3/4" NPT in order to fill the specimen with water through this opening and remove the entrapped air and to connect the hydrostatic pressure test system. All flanges were identified per MSS-SP25.

GENERAL STATEMENT Each pressure test was terminated at point of gasket leakage or gasket blowout and not at the metallic burst pressure level of the component (flange) under evaluation. Three types of flanges were tested. Specific descriptions relating to the flange type preceeds the associated table.

A) NIBCO Convoluted Weld Neck Flange, Class 150, ASTM A316-60

The weld neck flanges were welded to standard wall, black steel pipe on one end while a standard wall B16.9 weld end cap was welded to the other end. The pipe length represented a minimum length of two times the diameter of the nominal flange connection size.

Test Results:	Size	Max hydrostatic Pressure PSI	Leak	Torque Ft.-lb.
	2”	3500	no	100
	2-1/2”	3500	no	110
	3”	2200	yes	125
	1”	2400	yes	150
	5”	2600	yes	190
	6”	1900	yes	200
	8”	2000	yes	270
	10”	2200	yes	500

B) Convoluted Blind Flanges, Class 150, ASTM A-516-60 The convoluted blind flanges were mounted directly to convoluted ANSI B16.5 raised face blind flanges.

Test Results:	Size	Max hydrostatic Pressure PSI	Leak	Torque Ft.-lb.
	2”	4200	yes	100
	2-1/2”	3800	yes	110
	3”	2600	yes	125
	4”	2800	yes	150
	5”	2700	yes	190
	6”	2000	yes	200
	8”	2000	yes	330
	12”	1900	yes	600

C) Convoluted Lap-Joint Flanges, Class 150, ASTM A-36 The convoluted lap-joint flanges were slipped over a conventional standard wall stub end type "A" to which a piece of standard wall black steel pipe was welded, plus a standard wall B16.7 weld end cap. This entire assembly was mounted to an ANSI 816.5 raised face standard serration blind flange.

Test Results:	Size	Max hydrostatic Pressure PSI	Leak	Torque Ft.-lb.
	1”	4000	no	.35
	1-1/2”	3700	yes	45
	2”	4100	yes	120
	2-1/2”	3950	yes	125
	3”	3500	yes	140
	4”	3000	yes	150
	5”	2800	no	190
	6”	2550	yes	200

All welding of the test specimen were performed by Scott Company of Oakland, California. The tests were assembled and performed by the THOMAS A. SHORT CO. under the personal supervision of Bill Sutliffe. The tests were witnessed by:

Bill Sutliffe

Gerald Horn, Safety Engineer D.I.5 838, N.B. 4663
Pressure Vessel Section
Division of Industrial Safety
Department of Industrial Relations
State of California

and:
Gunter Schlicht, President
Pipetech, Inc.
Orinda, California

Very truly yours,
R.M. Johnson, Manager Contracting and Repairs

STRESS ANALYSIS OF PIPETECH FLANGE
PROFILE #14

R.C. Murray
May 1976

INTRODUCTION

The purpose of this analysis was to determine stresses and displacements of profile #14 Pipetech flange when subjected to both bolt load and hydrostatic pressure.

The flange was modeled as a body of revolution with loads applied to simulate the bolt and hydrostatic pressure. A linear elastic static analysis was conducted.

The analysis was conducted with the computer program MARC-CDC. MARC-CDC is a finite element computer program used for structural analysis. The program is widely used for structural analysis and design of nuclear facilities. Westinghouse, General Electric, and Bechtel Corporation are some of the many firms that have used the program. The program is available at all Control data Corporation data centers throughout the United States. All analysis was conducted on the CDC-6600 computer at the Western Cybernet Center at Sunnyvale, California.

DESCRIPTION OF ANALYSIS TECHNIQUE

The Finite Element Technique is a numerical procedure which can be used to compute displacements and stresses in structures of arbitrary geometry subjected to various loading conditions. Solution is obtained by the following steps:

- Break the structure up into individual elements interconnected by nodal points.
- Describe the location of the nodal points by specifying the coordinates of each point.
- Describe the elements by indicating the nodal points connected to them and the material properties (E,v) associated with them.
- Specify the applied loads and indicate which nodal points are not free to move.

The finite element program then takes the input geometry, material properties, and load description and calculates displacements at the nodal points and stresses at the center of each element. The mathematical techniques employed in the solution are based on the principles of solid mechanics. Details of the calculations can be found in O.C. Zienkiewicz, The Finite Element Method in Engineering Science.

MODEL DESCRIPTION

The flange was modeled as showing in fig. 1. Four elements were used through the thickness.

Node and element numbers are shown on the mesh. R and Z components of displacement are calculated at each nodal point in the model, while stresses are calculated at the center of each element. Radial, axial, hoop, shear, and von Mises stress are calculated for each element.

Rollers which prevent axial motion (z-direction) were placed at the free end, node 5, and at the gasket, nodes 145, 150, and 155. Nodes 226-230 were not constrained. This was felt to be a worst case condition for the flange pipe connection.

Pressures were applied to simulate the bolt load over elements 45, 46, 47, 48, and 49. Pressures were applied over elements 116, 117, 133, 134, 135, 136, 137, 153, 154, 155, 156, 157, 158, and 159 to simulate hydrostatic pressure. The input load description is shown in Table 1.

TABLE 1

Input Loading

Bolt Load	=	11,300 lbs/bolt
Total Bolts	=	12
Contact Area	=	$\pi(9.94^2 - 8.815^2) = 66.286$ in^2

$$\text{Bolt Pressure} = \frac{(\text{number of bolts})(\text{bolt load})}{\text{Contact area}}$$

$$= \frac{(12)(11{,}300)}{66.286} = 2045 \text{ psi}$$

Also subjected to a hydrostatic pressure of 285 psi.

Material Properties

Steel: $E = 30 \times 10^6$ psi

$v=0.3$

RESULTS

The contour plot of the von Mises stress is shown in Figure 2. The von Mises stress was calculated by the following formula:

$$\sigma_{von\ Mises} = \sqrt{\tfrac{1}{2}\left(\sigma_{zz} - \sigma_{RR}\right)^2 + \left(\sigma_{RR} - \sigma_{hoop}\right)^2 + \left(\sigma_{hoop} - \sigma_{zz}\right)^2 + 3\sigma^2_{RZ}}$$

For a ductile material such as steel, the von Mises stress can be compared directly with the allowable stress specified for the material. For this loading a maximum von Mises stress of 12, 770 psi occurs in Element 47. Note that stresses are calculated at the center of the elements and must be extrapolated to get maximum values at the surface.

I have also included the stresses computed for each element and the calculated nodal point displacements.

METALLURGICAL AND MECHANICAL EVALUATION OF 3", 4", AND 6” FLANGES

HASKELL D. WEISS, P.E.
MT431

INTRODUCTION

This report presents and evaluation of three flange parts (3", 4", and 6") and a portion of a plate typical of starting material prior to cold forming.

Sections were removed from parts by sawing and/or flame cutting and then prepared for study by polishing and etching.

The analysis was made with the aid of a metallurgical microscope and a microhardness tester.

The report sections cover in detail the following:

1) Metallurgical examination of starting material.
2) Metallurgical examination of 3”, 4", and 6” diameter flanges.
3) Deficiencies that should be corrected.
4) The effect of welding on flange material.
5) Product reliability and heat treatment.

DISCUSSION

1. The starting material is cross-rolled and has a reported chemical content by weight of:

C	-	.18%
M_n	-	.74%
P	-	.006%
S	-	.015%
S_i	-	.22%
F_e	-	balance

To obtain a fine grain it is rare earth treated. It has not as yet been determined if production parts will be pickled, grit blasted or surface treated in some fashion prior to forming. To prevent inbedding of foreign materials during drawing it is suggested that starting plate be cleaned prior to working.

A sample was removed from the starting stock as per Fig. 1. Fig. 2 and Fig. 3 show the microstructure in both longitudinal and transverse directions. The grain size and elongation show that rolling was about equal in each direction. The dark regions are pearlite and the light regions are ferrite. Reported tensile data:

Yield Strength ------- 45,000 psi
Tensile Strength ----- 66,000 — 72,000 psi
Elongation in 8" ----- 26.5 — 28.2%

Microhardness tests were made on both center and edges of the plate as shown in Fig. 4. The hardness numbers in DPH were converted to Brinell and tensile strength.

	DPH	BH	Tensile Strength (psi)
Edge	171	162	79,000
Center	150	143	71,000

This agrees quite well with the reported data, also it indicated the strength is uniform throughout the thickness.

It is important that in future purchases of starting stock that this uniformity of microstructure be maintained. Lack of uniformity could lead to differences in springback from one lot of material to another. Additionally lack of uniform texture could cause failure in forming.

2. There were three flanges examined; a 3", 4" and 6" diameter type. These are formed in multiple draw operations. The tooling concepts may be different between sizes. However, each type is treated as a single population and die design differences are not relevant to the conclusions drawn.

The drawing sequences are done at ambient temperature conditions with no anneal, stress relief or heat treatment of any type performed on the final formed parts. Thus, the microstructures are representative of production parts.

Fig. 5 shows a 3" blind flange in section and location of microhardness readings and orientation of grain structure examination. Fig. 6 and Fig. 7 shows the variation in cold work areas "k" verses "n". Areas "a" and "c" are shown in Fig. 8 and Fig. 9. These show laps and heavy deformation resulting from the forming operations. Note that in heavily deformed regions the identity of the grain structure is almost lost. Also note the depth of heavy deformation appears to be approximately .010" to ,015".

From reference (1) it is noted that steel typical of this composition has a true strain at fracture of between .9"/" to 1.0"/". This can be transformed into the cold work capacity which amounts to between 50-60%. (Reference 1)

The microhardness in the various areas are tabulated and converted into tensile strength and cold work percentage, Table 1. From these numbers and the microstructure and assessment of the part can be made.

Fig. 10 shows a 4" flange in cross section and location of areas of investigation. Fig. 11 and Fig. 12 of areas "c" and "i" are typical of the microstructure. Note the diamond penetrator mark in Fig. 11, indicating measurements of cold worked areas within .005" of the surface. See Table 2 for hardness, cold work and tensile strength. The microstructural examination shows no evidence of laps, seams or tears.

Fig. 13 and Fig. 14 shows a 6" blind flange and the section removed for examination. Fig. 15 and Fig. 16 shows areas "a" and "c" where a lap and tear are evident. The hardnesses and cold work are listed by area in Table 3.

Comparison of the three flanges by microstructure and cold work would indicate the 4" to have the least amount of surface deformation. The areas of maximum work, 3" and 6", show where metal has been cold worked as high as 57%. This heavy amount of cold work however, measures less than .015".

3. If the 4” flange were to serve as a standard, then the surface of all parts should be continuous without tears or laps. From a cosmetic standpoint this would be desirable, however from a reliability standpoint it is not necessary, as will be discussed in section 5. What is needed is reproducibility and quality control.

4. In the upper portion of Fig. 14 is shown an almost straight section. The right edge at the arrow indicates a region where the part was flame cut to separate from the balance of the flange. Note the shade difference at the right. This indicates the recrystallized zone due to oxy-acetylene flame cutting. This region also appears during a welding operation. Fig 17 shows two different structures in the heat affected zone (HAZ), note Fig. 18 which shows a microstructure typical of the starting material. Working through the regions of melt zone and HAZ, the distance involved amounts to .180". This would indicate that the heat generated by an electric arc would not affect the parent material beyond a distance, conservatively with multipass welding, of .30" from the molten edge. Note that the hardnesses are higher in region "u", Fig. 17, then in the starting material, (Table 3). This results from the rapid cooling of the HAZ allowing for a finer grain structure. Generally, strength increases with decreasing grain size.

The above would suggest that welding will not degrade the strength of the worked parent material. Generally, the weld metal is the weakest link in any structure, since it has a cast, course grained microstructure. This, as a rule, is compensated for by increasing the cross sectional area of the weld metal.

5. In the absence of long term test data on fully stressed flanges, assumptions and conservative estimates are necessary in order to present a credible reliability statement. A review of the stages in the drawing of a 3" diameter flange indicates that there are three stages involved. The state of stress varies not only throughout the part but through the thickness as well. As indicated earlier the heavy deformation is

limited to approximately .015”. Biaxial stresses exist throughout the part and are generally in tension radially and in compression circumferentially. A feel for the magnitude of these stresses are indicated by the hardness readings when converted to percentage cold work. The presence of biaxial stresses can be noted by Fig. 19 which is taken in the area between "a" and "c". Note the elongation of grains perpendicular to the surface, as opposed to the grains in Fig. 12 which are parallel to the surface. This would tend to indicate compression at the surface in many locations would inhibit the tendency for fatigue cracking.

In my opinion 40% cold work is a tolerable level for parts so long as this amount is kept within .010-.020" of the edge. However, in the 3" and 6" flange this is exceeded not in depth but in magnitude. To assess the significance of region "c" in Fig. 9, I assumed that a part had a fatigue crack .015" and cyclic stresses of 10 KSI (Appendix). This calculates to a part life of 5.5 x 10^6 cycles. Other stresses, fatigue crack lengths and cyclic life are tabulated in the Appendix. These results show fatigue is not a problem at the selected design loads and defects limited to .015". I have arbitrarily selected 5.4 x 10^6 cycles as infinite life. This calculation assumes an infinite thickness of plate. Obviously, this is not true, also the effect of corrosion products on fatigue cracks has not been taken account of in the calculation. For this reason, I have been conservative in my estimates and believe the above crack limitation and stresses are realistic.

It should also be pointed out that high hardness on the surface has a somewhat similar effect relative to fatigue resistance as that of shot peening. While, the material below the heavy deformation has an extremely high toughness, or fatigue resistance. Therefore, I do not believe it is either necessary to anneal or shot peen the flange surfaces. Quality control should be exercised to limit sharp tears to a maximum of .015” or approximately 5-10% of the part thickness. Dents as a result of handling are not a problem so long as they do not result in sharp cracks. This is a materials handling problem faced by all users of any structural piece of hardware.

The inspection techniques can be a combination of "Magnaflux" and dye penetrant. The latter can, with experience, be developed to provide a quanitative estimate of the depth of surface flaws. Starting material should be randomly (1) mechanically tested; (2) grain size checked; (3) chemically analyzed; (4) and hardness tested. All of the above is directed toward the use of a controlled starting material. A lowering of reduction of area; increase of grain size; differences between longitudinal and transverse grain structure could cause the manufacturing process to become out of control and parts not meet specification.

REFERENCES

1. "Material Properties and Manufacturing Processes", J. Datsko, John Wiley and Sons, 1967.
2. "Linear Elastic Fracture Mechanics and Its Application to Fatigue", R.I. Stephens, Society of Automotive Engineers, 740220, 1974.

Table 1

Region	Hardness(DPH)	Hardness (BH)	T.S. (KSI)	Cold Work (%)
a (edge)	353	334	168	56
a (edge)	348	329	164	
c (lap Area)	366	347	173	57
c (edge)	305	289	143	49
d (edge)	252	240	117	37.5
d (edge)	255	243	119	39
a x d (center)	241	228	112	35
e (edge)	263	250	123	41
e (edge)	272	258	127	42
e (center)	245	233	114	36
f (edge)	266	252	124	41
f(edge)	252	240	117	37.5
f (center)	243	231	113	35
g (edge)	285	270	134	46
h (edge)	322	306	152	52
g x h (center)	255	243	119	39
g x h (center)	256	244	120	39
I (edge)	287	273	134	46
I (edge)	290	275	136	46
j (center)	223	212	102	28
j (center)	237	225	109	33
j (outside edge)	226	215	104	30
k (inside edge)	323	306	153	52
n (outside)	228	217	105	30
n(center)	241	228	112	35
n (inside)	258	245	120	39
n (inside)	250	238	116	37

Table 2

Region	Hardness (DPH)	Hardness (BH)	T.S. (KSI)	Cold Work (%)
a	221	210	101	28
c	225	214	103	29
d	252	240	117	37.5
e	232	221	107	32
f	223	212	102	28
g	254	242	119	38
h	250	238	116	37
i	277	262	130	44
j	247	235	115	36
j	255	243	119	39
k	265	252	124	41
m	263	250	123	41

TABLE 3

Region	Hardness (DPH)	(Hardness (BH)	T.S.	Cold Work (%)
a (HD)*	284	270	134 (KSI)	46
a (LHD)*	287	273	135	46.6
a (NHD)*	261	247	121	40
a (HD)*	377	357	178	59.5
c (HD)*	394	373	187	61
c (LHD)*	348	329	164	56
c (LHD)*	322	306	153	52
c (NHD)*	287	273	134	46
cf	277	262	130	44
f	232	221	107	32
cf	232	221	107	32
e	214	204	98	26.5
e	261	247	121	40
ee	254	242	119	38
o	270	256	126	43
n	322	306	152	52
n	256	243	119	39
n	290	275	136	46
nn	239	228	110	36
i	277	262	130	44
h	277	262	130	44
g	259	245	120	39
gh	276	262	130	44
p	285	270	134	46
k	287	273	135	46
j	259	247	121	40
d	280	265	131	45
q	248	237	115	37
q	217	207	95	24
q	212	202	93	22
r	217	207	95	24
s	204	194	90	20
t	169.5	162	76	5
u	187	178	82	12
u	197	188	87	17
n	206	196	90	20

HD - Heavily deformed
LHD - Less heavily deformed
NHD - Not heavily deformed

Weld Zone + HAZ = 1.3 mm + 3.3mm = 4.6 mm
=.184