ENGINEERING STANDARD

FOR

PIPING FLEXIBILITY ANALYSI

FIRST EDITION

DECEMBER 2014

FOREWORD

The Iranian Petroleum Standards (IPS) reflect the views of the Iranian Ministry of Petroleum and are intended for use in the oil and gas production facilities, oil refineries, chemical and petrochemical plants, gas handling and processing installations and other such facilities.

IPS is based on internationally acceptable standards and includes selections from the items stipulated in the referenced standards. They are also supplemented by additional requirements and/or modifications based on the experience acquired by the Iranian Petroleum Industry and the local market availability. The options which are not specified in the text of the standards are itemized in data sheet/s, so that, the user can select his appropriate preferences therein

The IPS standards are therefore expected to be sufficiently flexible so that the users can adapt these standards to their requirements. However, they may not cover every requirement of each project. For such cases, an addendum to IPS Standard shall be prepared by the user which elaborates the particular requirements of the user. This addendum together with the relevant IPS shall form the job specification for the specific project or work.

The IPS is reviewed and up-dated approximately every five years. Each standards are subject to amendment or withdrawal, if required, thus the latest edition of IPS shall be applicable

The users of IPS are therefore requested to send their views and comments, including any addendum prepared for particular cases to the following address. These comments and recommendations will be reviewed by the relevant technical committee and in case of approval will be incorporated in the next revision of the standard.

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GENERAL DEFINITIONS:

Throughout this Standard the following definitions shall apply.

COMPANY:

Refers to one of the related and/or affiliated companies of the Iranian Ministry of Petroleum such as National Iranian Oil Company, National Iranian Gas Company, National Petrochemical Company and National Iranian Oil Refinery And Distribution Company.

PURCHASER:

Means the “Company” where this standard is a part of direct purchaser order by the “Company”, and the “Contractor” where this Standard is a part of contract documents.

VENDOR AND SUPPLIER:

Refers to firm or person who will supply and/or fabricate the equipment or material.

CONTRACTOR:

Refers to the persons, firm or company whose tender has been accepted by the company.

EXECUTOR:

Executor is the party which carries out all or part of construction and/or commissioning for the project.

INSPECTOR:

The Inspector referred to in this Standard is a person/persons or a body appointed in writing by the company for the inspection of fabrication and installation work.

SHALL:

Is used where a provision is mandatory.

SHOULD:

Is used where a provision is advisory only.

WILL:

Is normally used in connection with the action by the “Company” rather than by a contractor, supplier or vendor.

MAY:

Is used where a provision is completely discretionary.

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APPENDICES:

1. SCOPE

This Standard specification covers the basic requirements for the flexibility analysis of piping systems in Oil, Gas and Petrochemical Industries.

The analysis shall consider the effects of Temperature, Pressure, Vibration, Loads, Fluid, Reactions and Environmental Factors.

Note 1:

This standard specification is reviewed and updated by the relevant technical committee on Jun. 2006. The approved modifications by T.C. were sent to IPS users as amendment No. 1 by circular No. 301 on Jun. 2006. These modifications are included in the present issue of IPS.

Note 2:

This is a revised version of this standard, which is issued as revision (1)-2014. Revision (0)-1997 of the said standard specification is withdrawn.

2. REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

ASME (AMERICAN SOCIETY OF MECHANICAL ENGINEERS)

ASME B16.5 "Pipe Flanges and Flanged Fittings"
ASME B16.47 "Large Diameter Steel Flanges"
ASME B.31.1 "Power Piping Design and Fabrication"

ASME B.31.3 "Process Piping"

ASME B.31.4 "Pipeline Transportation Systems for Liquids and Slurries"

ASME B.31.8 "Gas Transmission and Distribution Piping Systems"

ASME Section VIll Div. 1 "Boiler and Pressure Vessel Codes"

API (AMERICAN PETROLEUM INSTITUTE)

API 520 "Sizing, Selection, and Installation of Pressure Relieving Devices in Refineries"

API 560 "Fired Heaters for General Services"

API 610 "Centrifugal Pumps for Petroleum, Petrochemical and Natural gas Industries"

API 612 "Special Purpose Steam Turbines for Refinery Services"

API 617 "Axial and Centrifugal Compressors and Expander Compressors for Petroleum, Chemical and Gas industry Services"

API 650 "Welded Steel Tanks for Oil Storage"

API 661 "Air Cooled Heat Exchangers for General Refinery Services"

API 662 "Plate Heat Exchangers for General Refinery Services"

API 674	"Positive Displacement Pumps-Reciprocating"
API 676	"Positive Displacement Pumps-Rotary"

ASCE (AMERICAN SOCIETY OF CIVIL ENGINEERS)

ASCE 7	"Minimum Design Loads for Buildings and other Structures"

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-E-GN-100	"Engineering Standard for Units"
IPS-G-PI-280	"General Standard for Pipe Supports"

NEMA (NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION)

NEMA SM 23	"Steam Turbines for Mechanical Drive Service"

3. DEFINITIONS AND TERMINOLOGY

3.1 Creep

Plastic flow of metal, usually occurring at high temperatures, subject to stress appreciably less than its yield strength. Progresses through first, second, and third stage to fracture or results in stress relaxation.

3.2 Flexibility Factor

Flexibility factor is defined as the ratio of the rotation per unit length of the part in question produced by a moment, to the rotation per unit length of a straight pipe of the same nominal size and schedule or weight produced by the same moment.

3.3 Stress Intensification Factor

Will be defined as the ratio of the bending moment producing fatigue failure in a given number of cycles in a straight pipe of nominal dimensions, to that producing failure in the same number of cycles in the part under consideration.

3.4 Section Modulus

The ratio of the moment of inertia of the cross section of a pipe undergoing flexure to the greatest distance of an element of the pipe from the center line.

4. UNITS

This standard is based on international system of units (SI), as per IPS-E-GN-100 except where otherwise specified.

5. PIPING STRESS ANALYSIS

Piping systems shall be routed, supported, anchored or guided so that thermal expansion/contraction, weight effects including the pipe contents, insulation and any other superimposed loads, pressure effects, vibration or movements due to earthquakes and storms will not result in stresses in the piping or loads on the connected equipment in excess of those permitted by ASME B31.3 and the equipment design code, in order to prevent:

a) Failure of piping components due to overstress;

b) Leakage at joints;

c) Excessive loads and moments on connected equipment, anchor points, flanged connections, etc.

The following specifications shall be complied with:

a) Pipe support design based on IPS-G-PI-280

b) Special requirements of rotating equipment, civil, stationary pressure, storage equipment and heat transfer equipment specialists concerning allowable loads and moments on equipment under their responsibility and are required to be included in the equipment Manufacturing Data Book.

5.1 Design Conditions

Piping stress analysis SHALL be carried out for the following temperature conditions:

a) Design Temperature

b) Operating Temperature

c) Transient Temperature conditions possibly caused by, amongst others, the following load cases:

- Start-up and shut-down
- Steam cleaning (Steam-out) of lines and/or equipment
- Protective steam heating or electrical heating including winterizing
- Decoking
- Regeneration
- Compressor recycle
- Temperature drop by pressure relief, or depressurization effect

(**Note: If needed, the specific pressure - temperature envelope can be defined as a specific load case to take credit for pressure reduction at low temperatures.**)

- Solar radiation

Piping stress analysis shall be carried out for the following pressure conditions:

a) Design Pressure

b) Maximum Operating Pressure

c) Operating Pressure

d) Cyclic pressure conditions

6. LOAD AND STRESS CONSIDERATION IN PIPE STRESS ANALYSIS

Load and stress effects which should be considered in piping stress analysis are listed below:

6.1 Weight Effect

The following weight effects, combined with loads and forces from other causes, shall be taken into account in the design of piping.

6.1.1 Live loads:

These loads include the weight of the medium transported or the medium used for test. Snow and ice loads due to both environmental and operating conditions shall be considered.

6.1.2 Dead loads

These loads consist of the weight of piping components, insulation, and other superimposed permanent loads supported by the piping like valves, flanges, etc.

6.2 Hydro Test

Spring supports are considered as rigid support during hydro test case. On the field, these spring supports shall be locked to prevent excessive deflection and over-stressing of the system.

6.3. Thermal Expansion and Contraction Effects

6.3.1 Thermal loads due to restraints

These loads consist of thrusts and moments which arise when free thermal expansion and contraction of the piping are prevented by restraints or anchors.

6.3.2 Loads Due to Temperature Gradients

These loads arise from stresses in pipe walls resulting from large rapid temperature changes or from unequal temperature distribution as may result from a high heat flux through a comparatively thick pipe or stratified two phase flow causing bowing of the line.

6.3.3 Loads due to differences in expansion characteristics.

These loads result from differences in thermal expansion where materials with different thermal expansion coefficients are combined, as in bimetallic, lined, jacketed, or metallic–nonmetallic piping.

6.4 Friction Effect

The effect of frictional resistance to thermal movement of the pipe for all sizes.

Friction force shall be calculated based on the properties of the sliding surface and contact material.

Contact Surface	**Friction Coefficient**
Stainless Steel on PTFE	0.1
Steel on Steel	0.3
Steel on Concrete	0.5

6.5. Dynamic Effects

6.5.1 Impact

Impact forces caused by external or internal conditions (including changes in flow rate, hydraulic shock, liquid or solid slugging, flashing, surge and geysering) shall be taken into account in the design of piping.

6.5.2 Wind

Wind loading shall be considered in accordance with ASCE 7. Wind effects shall be analyzed by applying wind load in one of four horizontal, perpendicular directions which would cause the most severe condition of piping stress.

For the design of piping system for wind effects, the force drag coefficient, C_d=0.7 shall be used

In following conditions wind load calculation shall be applied:

BOP Elevation ≥ 10 m

OD + Insulation ≥ 400 mm

6.5.3 Earthquake

The effect of earthquake loading shall be taken into account in the design of piping. The method of analysis may be as described in ASCE 7.

6.5.4 Vibration

6.10.1 Piping system connected to reciprocating compressors hall receive analog study/ dynamic analysis by compressor vendor to avoid vibration problem. Vendor shall confirm type, location of pipe supports and resistance directions at each individual support.

6.10.2 Lines subjected to mixed phase flow must have provisions for addition of dampeners or shock absorbers in the event that the line vibrates.

6.5.5 Discharge reaction (Pressure Safety valve load effect and flare system)

PSV reaction forces shall only be considered for process PSVs in gas/vapor services with a Dynamic Load Factor (DLF)=2.0

Reaction force due to blow-off of safety valves shall be considered in stress calculation. Calculated stresses are compared with allowable stress as an occasional case which comprises the criteria mentioned in design code of B31.3.

Flare piping system shall be designed to take care of expansion, movement, or vibration caused by the most sever operating or emergency conditions, and is to be constrained against a tendency to move off its supports. Pipe shoes or saddles shall be furnished on the main flare header at all supports.

6.6 Effects of Supports and Structural Deflections

The effect of movements of piping supports, anchors, structure and connected equipment shall be taken into account in the design of the piping. These movements may result from the flexibility of equipment, supports, or anchors; and from settlement, tidal movements, or wind sway.

For new design or when adding new equipment in existing plan, differential settlement between two foundations shall be considered in the pipe stress calculation. As a guideline, settlement need not be included in the computer analysis when long-term settlement is less than ½”.

7. FLANGE LEAKAGE CRITERIA

a) ASME Flanges

Critical flange joints shall be assessed for leakage as per the equivalent pressure method.

Flange leakage calculation is required when flange joint is connected to equipment nozzle and flange joints located in lines carrying service fluids deemed as hazardous by Process Safety Department.

The flange leakage formula is as below:

The Total Pressure: $P_T = P_{eq} + P$

The Equivalent Pressure: $P_{eq} = \frac{4}{\pi G^2}\left(F + \frac{4M}{G}\right)$

Where: P_{eq} = equivalent pressure due to pipe loading only

F = tensile axial force acting at the flange

M = bending moment acting at the flange

G = effective gasket diameter (reactive load location)

P = operating pressure

P_T ≤ rating pressure of the flange as per ASME B16.5/ASME B16.47.

In cases where the total pressure exceed the allowable pressure, a second verification shall be performed at the maximum operating conditions or a detailed flange calculations shall be carried out as per requirements of Section Vlll Div. 1, Appendix 2 of ASME Boiler and Pressure Vessel Codes (using CAESAR II module).

b) Clamp Connectors/Compact Flanges

The piping loads at clamp connectors and compact flanges shall be limited to the Vendor allowable limits.

8. ALLOWABLE LOADS ON EQUIPMENT NOZZLES

Forces and moments induced by piping system on nozzles of major equipment shall not exceed the values stated in the various standards mentioned below.

For piping connected to strain sensitive/rotating equipments, the nozzle loads calculation shall be based on operating temperature. For all other nozzle loads, calculation shall be based on design temperature. Air-cooled heat exchangers shall be considered as strain sensitive equipment.

8.1 Vessels, Columns, and Heat Exchangers

Piping loads applied at the shell-nozzle junction shall be checked by WRC 107 to check the magnitude of local stresses due to piping loads. Subsequently, the loads shall be submitted to the Mechanical Department for onward transmission to the Vendor for approval.

For welded plate frame and plate heat exchangers, the allowable loads at nozzles shall be as per Table-I of API 662.

8.2 Air-Cooled Heat Exchangers

Piping loads on Air-Cooled Heat Exchangers nozzles shall satisfy requirements mentioned in API 661.

8.3 API Centrifugal Pumps

The allowable forces and moments for API Centrifugal Pumps shall meet the criteria explained in API 610.

8.4 Non-API Pumps/Manufacturer standards

Vendor/Design standards allowable loads shall be followed.

8.5 Centrifugal Compressors/Turbines

The allowable nozzle loads on centrifugal compressors/turbines for individual and combined loads shall be as per API 617/NEMA SM-23 equations respectively.

8.6 Rotary Type Positive Displacement Compressors

The loads on rotary type positive displacement compressors shall be in accordance with API 619.

8.7 Reciprocating Compressors

Supplier shall provide maximum individual and resultant allowable forces and moments of both inlet and outlet nozzles. API 618 and NEMA SM-23 are used for guidance only.

8.8 Fired Heaters

Fired Heater nozzle allowable loads shall be as mentioned in API 560.

8.9 Storage Tanks

Allowable loads for nozzle of storage tanks shall be as mentioned in API 650.

8.10 Unlisted Equipments

For equipments that are either not mentioned or governed by any of the codes stated in References, the equipment manufacturer's recommendation shall be considered.

9. DESIGN CONSIDERATION

9.1 Restraint Loads

Any piping loads in excess of 5 kN acting horizontally or 20 kN acting vertically and/or supports more than 2 meters in height shall be issued to Civil Department for support member design.

9.2 High Pipe Deflection

The pipe deflection of free span shall not exceed ½ inch or 12.7 mm. For sloping lines, maximum deflection shall be ¼ inch or 6.25 mm. Exceptions to this shall be approved by the stress engineer.

Pipe lateral deflections should not be excessive as to cause clashing with surrounding pipe work, structural or equipment. Stress engineer shall mark pipe horizontal displacements $\geq$ 75 mm on the stress isometrics for providing longer shoe lengths and checking of pipe spacing clearance by piping designer.

9.3 Spring Supports

Use of spring supports shall be minimized and considered only when the piping layout cannot be configured to add extra flexibility to mitigate vertical thermal displacements or relative movement e.g. tank settlement.

For the piping connected to rotating/strain sensitive equipment, the maximum load variation shall be 10%. The maximum load variation for piping connected to other equipment shall be 25%.

Constant spring supports shall be selected in either of the following cases:

- The load variation exceeds the above specified limits
- To reduce the transfer of load to nozzles on fragile equipment e.g. GRE material of construction

Spring support vertical displacements shall be calculated for the operating conditions i.e. at operating temperature. However, the working range of selected spring model shall also be suitable for vertical displacement at design temperature.

When used on liquid lines a WNC (Weight No Contents) checking shall be carried out to ensure that the equipment nozzles are not overloaded, or the pipe is not overstressed when the pipe is empty. Otherwise, spring shall be marked to be locked when the line is empty/under maintenance.

The selected size of spring support shall be suitable for hydro test loads with spring in locked position. Vendor shall confirm suitability of the selected size for hydro test loads during technical bid evaluation.

9.4 Expansion Joints

Expansion joints shall be avoided unless those are required as per Process requirements. In case piping layout constraints do not permit addition of flexibility by means of providing loops, etc., then expansion joints shall be utilized only after obtaining Company approval. For piping systems utilizing expansion joints, recommendations of EJMA standard shall be followed.

10. EXTENT OF ANALYSIS

Method of Analysis

The piping layout shall be analyzed by the individual consideration of each line affected by restraints (temperature, imposed displacements, etc.) to determine the reactions produced at anchors and terminal points and the stresses in the piping. The methods of analysis are classified into three Stress Analysis Levels.

The levels of requirements and the corresponding methods of analysis are defined as follows:

10.1 Level 1: Visual Inspection (or by analogy)

It is an approximate, visual inspection method. It shall be restricted to lines that are similar to other calculated lines, or lines having a clear and adequate flexibility.

If not, these lines shall be classified as level 2 or 3.

No actual values of forces and moments acting on supports are requested for a level 1 analysis.

10.2 Level 2: Simplified Analysis

This method includes the use of charts, nomographs and simplified formulae which may only be accepted if they are used in the range of configuration for which their accuracy is acceptable.

In case of doubt, the line shall be classified as level 3.

The result of a level 2 analysis may be shown only on the calculation isometric, or in a simplified report including isometric and a computer calculations output restrain summary.

10.3 Level 3: Comprehensive Analysis

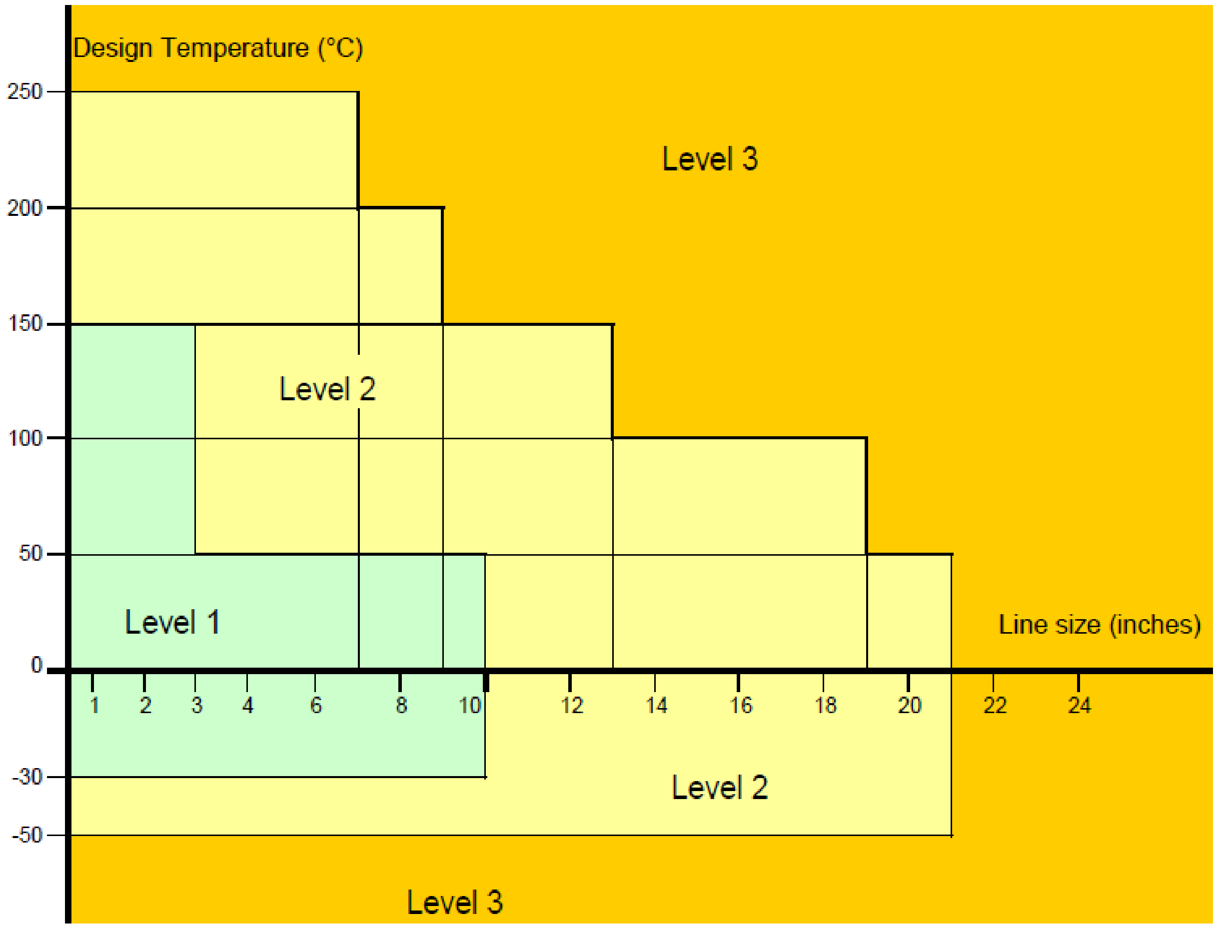
It is a comprehensive method by computer calculations exclusively that shall meet the requirements of the piping code.

The accuracy level selection shall be indicated in a document called "Critical Line List". This document shall include all the lines to be reviewed by the stress analyst and shall be submitted to the COMPANY for approval.

APPENDICES

APPENDIX A
STRESS ANALYSIS LEVEL REQUIREMENTS

GENERAL CHART



SPECIFIC CASES

Connection type		Line Maximum Pipe Size (Inches)	Design Temperature (°C) below -46	-46	Ambient	50	80	100	150	250	above
A	Rotating Machine or sensitive equipment	Ø ≤ 3"					Level 2				
		Ø > 3"			Level 2			Level 3			
B	Reciprocating machine (pumps and compressors)	All Ø					Level 3				
C	Expansion joint	All Ø					Level 3				
D	Heater-Transfer Line Compressor / Turbine	Ø ≤ 3"					Level 2				
		Ø > 3"					Level 3				
E	Cryogenic (1)	Ø ≤ 18"	Level 3	Level 2							
		Ø > 18"		Level 3							
F	High Pressure (Piping Class ≥ 600 Lbs	3" < Ø ≤ 12"					Level 2			Level 3	
		Ø > 12"					Level 3				
G	HP relief lines to and from PSV (or bursting disc-expansion joint lines)	Ø > 3"					Level 3				
H	Non-ferrous materials	All Ø		Level 2				Level 3			
I	Non-metallic materials (2)	All Ø			Level 2				Level 3		
J	GRP (3)	Ø ≤ 8"				Level 2			N.A.		
		Ø > 8"				Level 3			N.A.		
K	Buried Lines	Ø ≤ 12"					Level 2				
		Ø > 12"					Level 3				

Notes:

(1) Above ambient temperature, the General Chart or the Specific Cases shall be applied

(2) GRP excluded

(3) Size to be confirmed for each project

APPENDIX B
STRESS ANALYSIS REPORTS

CONTENTS

1. COVER SHEET
2. COMPUTER INPUT LISTING
3. COMPUTER OUTPUT (RESTRAINT LOAD SUMMARY REPORT)
4. COMPUTER OUTPUT (STRESS COMPLIANCE REPORT)
5. COMPUTER OUTPUT (SPRING DATA - IF ANY)
6. EQUIPMENT CHECK REPORT (IF ANY)
7. FLANGE VERIFICATION LEAKAGE REPORT
8. COMPUTER ISOMETRIC PLOT

LINES COVERED IN THIS CALCULATION NOTE:

LINE NO (s)	**REV. NO.**
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REFERENCES:

CODE	PROCESS PIPING ASME B31.3
JOB SPEC	------------------------------------
AMBIENT TEMPERATURE	------ (MIN)/----- (MAX) (FOR STRESS RANGE PURPOSE) ------- (FOR NOZZLE LOAD PURPOSE)
CAESAR INPUT FILE	------------------------------------

Design Data

LINE NO.	PIPING CLASS	PIPE OD. (inch)	WALL TICK./SCH. (mm)	C.A. (mm)	FLANGE RATING	TEMP. (°C)		PRESSURE (PSIG)		DENSITY (KG/MM^3)		INSUL. THK. (MM)
						OP.	DES.	OP.	DES.	OP.	TEST	

EQUIPMENT NOZZLE LOAD CHECK:

EQUIPMENT TAG NO.	NOZZLE		NOZZLE LOADS	CASE	ALLOWABLE LOAD BASIS	FORCES (N)			MOMENTS (N.m)		
	NO.	SIZE				F_X	F_Y	F_Z	M_X	M_Y	M_Z
			CALCULATED								
			ALLOWED								
			CALCULATED								
			ALLOWED								