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DESIGN OF GAS PIPES AND ANALYSIS OF FLOW INDUCED VIBRATION

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Abstract

Flow Induced Vibration is a critical failure in pipes. In this project work Flow Induced Vibration based design of gas pipes is propose, this method integrates modal, flow induced vibration analysis within the design. This technique allows a designer to play with design parameter and to increase resonance frequency level to ensure better and safer design. Every structure has the tendency to vibrate at certain frequencies, named natural or resonant frequencies. Every accepted frequency is associated with a definite shape, named mode shape, which the replica tends to assume when vibrating at the frequency. When a structure is properly excited by a dynamic load with a frequency that coincides with one of its ordinary frequencies, the structure undergoes great displacements and stresses. This phenomenon is known as resonance and cause failure to the design. It is important to understand and find the resonance frequency for every design to alter the design from failure.

1.1 Introduction

Fluid flow in circular and rectangular pipes is commonly came upon in practice. The hot and cold water to facilitate we use in our homes is pumped all the way through pipes. Water in a city is distributed by extensive piping networks. Oil and natural gas are elated hundreds of miles by large pipelines. Blood is carried all over our bodies by arteries and veins. The cooling water in an engine is elated by hoses to the pipes in the radiator where it is cooled as it flows.

Fluid flow is classified as external and internal, depending on whether the fluid is strained to flow over a surface or in a conduit. Internal and external flows reveal very different characteristics. In this chapter we believe internal flow where the conduit is completely filled with the fluid, and flow is motivated primarily by a pressure divergence. This should not be puzzled with open-channel flow where the conduit is partially filled and thus the flow is partially bounded by solid surfaces ,as in an irrigation ditch, and flow is driven by gravity alone.

Liquid or gas flow through pipes or duct is commonly used in heating and cooling applications and fluid distribution networks. The fluid in those applications is regularly forced to flow by a fan or pump through a flow section. We pay particular awareness to friction, which is directly associated to the pressure drop and head loss during flow through pipes and ducts. The pressure is then used to determine the pumping power requirement. A classic piping system involves pipes of different diameters connected to each other by various fittings or elbows to route the fluid, valves to manage the flow rate, and pumps to pressurize the fluid.

The terms pipe, duct, and conduit are usually interchangeably for flow sections. In common, flow sections of circular cross section are referred to as pipes (especially when the fluid is a liquid), and flow sections of rectangular ducts (especially when the fluid is a gas). Small diameter pipes are frequently referred to as tubes. Given this insecurity, we will use more descriptive phrases (such as a circular pipe or a rectangular duct) whenever necessary to avoid any misinterpretations. We have
Probably noticed that most fluids, especially liquids, are elated in circular pipes. This pipes with a circular cross section can withstand large pressure differences between the inside and outside without undergoing significant distortion. Noncircular pipes are usually used in application such as the heating and cooling systems of buildings where the pressure difference is relatively small manufacturing and installation costs are inferior, and the available space is inadequate for ductwork.

Although the theory of fluid flow is reasonably well understood, solutions are obtained only for a few simple cases such as fully developed laminar flow in a circular pipe. Thus, we must rely on tentative results and empirical relations for most fluid flow problems rather than closed-form analytical solutions. Nothing that the experimental results are obtained under carefully controlled laboratory conditions and that no two systems are exactly alike, we must not be so inexperienced as to view the results obtained as “exact”. An error percent (or more) in friction factors calculated using the relations in this chapter is the “norm” rather the “expectation”.

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The fluid velocity in a pipe changes from zero at the surface because of the no-slip condition to a maximum at the pipe centre. In fluid flow, it is convenient to work with an average velocity Vive, which remains constant in compressible flow when the cross-sectional area of the pipe is constant. The usual velocity in heating and cooling applications may change somewhat because of changes in density with temperature and treat them as constants. The convenience of functioning with constant. Properties habitually more than justifies the slight loss in accuracy.

Also, the friction between the fluid particles in a pipe does cause a slight rise in fluid temperature as a result of the mechanical energy being converted to sensible thermal energy. But this temperature ascend due to frictional heating is usually too small to warrant any consideration in calculations and thus is disregarded. For example, in the nonexistence of any heat transfer, no evident difference can be detected between the inlet outlet temperatures of water flowing pipe. The primary consequence of friction in fluid flow is pressure drop, and therefore any significant temperature change in the fluid is due to heat transfer.

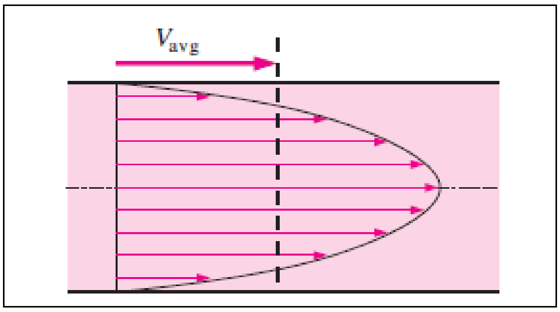


Fig1.1Average velocity through a cross-section

2. Flow Induced Vibration

The roughness of the pipe causes the friction between the fluid particle and inside pipe wall. Due to the friction criteria the flow velocity is significantly decreases or increases pressure drop. If the inside wall of the pipe is not smooth the friction exist. Let us consider the inside wall of the pipe which has a measureable roughness. The flowing fluid will reduces its velocity because of the ridges and valley present in the tube or pipe. This Ridges and valley oppose the motion of the fluid particle. Therefore the fluid particles which are flowing near the wall surface were affected. A fluid consist of infinite number of fluid particle have kinematic energy (K.E) during the motion. When any one of the fluid particle kinematic energy is distributed, it kinematic energy increased or decreased.

If the valley and ridges are exposed during the motion is kinematic energy is converted into sudden pressure energy normally called impact force. If the length of the pipe is long enough, with valley and ridges are also high. Therefore each and every ridge and valley oppose the fluid particle motion resulting in the vibration of the pipe.

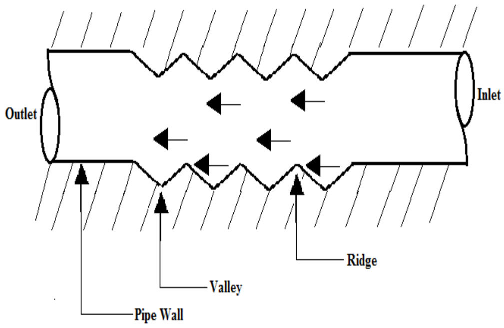


Fig 2.1. Enlarged view of the pipe

At ridge and valley K.E of fluid is converted into impact force.

2.1 Flow of Vibration

Flow of vibration is classified into two types. That is following as :

a). Vibration in Laminar

b). Vibration in Turbulent

a).Vibration in Laminar:

As the fluid flow through the conduit with stream line the velocity of the fluid particle is considerably low. Therefore, they particle have less amount of K.E at ridge and valley it experiences a small impact resulting in low vibration.

b).Vibration in Turbulent flow

When the flow is turbulent flow the fluid particle have higher rate of velocity and therefore it collide with ridge and valley with high K.E resulting in high vibration as compared to laminar flow vibration. so as the result of vibration in laminar is less than vibration in turbulent.

That is,

Vibration in Laminar < Vibration in Turbulent.

Due to the friction between fluid particles and surface of the wall a small amount of heat is developed but its too small and can be neglected. This heat is stored as a latent heat of the fluid.

3.Pressure drop

The friction causes the reduction in flow rate through the pipe (i.e., due to dale and crumple it oppose the flow and they act as the exposed area perpendicular to the direction of the flow) as the the fluid flow continuously through the pipe. The amount of fluid increases inside the conduit(pipe). This resulting in the increased pressure inside the pipe.

For the compensation to withstand higher rate of pressure the pipe expands within its elastic limits

It should be noted that in order to maintain the flow velocity at a prescribed level. The pressure at the inlet is increased. Resulting in the pressure drop inside the pipe. For the compensation of increased pressure the pipe. The stresses are developed in two directions namely

1. Longitudinally
2. Transversely

The transverse developed stress is also know circumferential (or) hoop stress.

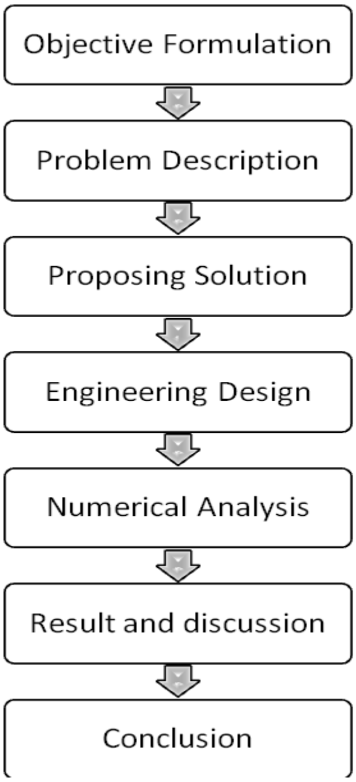


Fig 3.1 Methodology

3.1 Problem Description

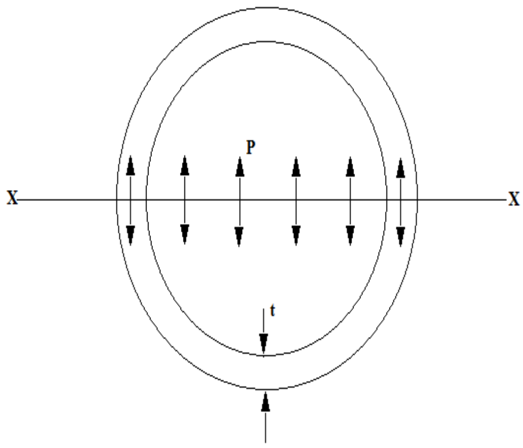
There are so many problems associated with natural gas piping such as structural, thermal and vibration problems. Here, vibration due to flow is taken for study. If flow induced vibration frequency is matched with pipe's natural frequency that will lead to resonance and get broken. To overcome this problem, this project is carried out.

3.2 Proposing solution

Flow induced vibration leads to structural damage of the pipe. In this project, natural gas pipe is designed and its natural frequency is found out. Forced vibration due to flow induced vibration is found out using numerical simulation by using results of flow analysis in computational fluid dynamic software.

3.3 Pipe Structural Design

Pipe design will be done on following factors. It is an unburied pipe to transport natural gas. The natural gas transportation and distribution lines convey natural gas from the source and storage tank forms to points of deployment, such as power plants, industrial amenities, and profitable and suburban communities.



Cross-section of pipe

$$\sigma_c = Pd / 2t$$

Where:

P=Internal Pressure in N/m^2

d=Internal Diameter in m

t=Thickness in m

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σ_c=Hoop Stress in N/m^2

An alternative to hoop stress in describing circumferential stress is wall stress or wall tension (T), which usually is defined as the total circumferential force exerted along the entire radial thickness.

P=1000 psi to 3000 psi (Normal Design Values)

Modular D

P=2500 psi

=17.23 Mpa (N/mm^2)

Volume flow rate required=0.8 m^3/sec (800 Lps)

V=10 m/s

D=1 m (From Mass Flow Rate)

t=0.05m

σ_c=(17.23 * 1) / (2 * 0.05)

=172.3 Mpa

Material =MS

Yield Strength (σ_t)=250 Mpa

$\sigma_t \quad > \quad \sigma_{c*}$

So the design is safe.

3.4 Longitudinal Stress

$$\sigma_l = Pd / 4t$$

=(17.23 * 1) / (4 * 0.05)

=86.15 Mpa (<σ_t)

Design is safe

3.5Max. Shear Stress

$$\sigma_{ss} = Pd / 8t$$

=(17.23 * 1) / (8 * 0.05)

=43.08 Mpa (<0.5σ_t)

Design is safe

4. Numerical Analysis

Tool used: ANSYS 14.0

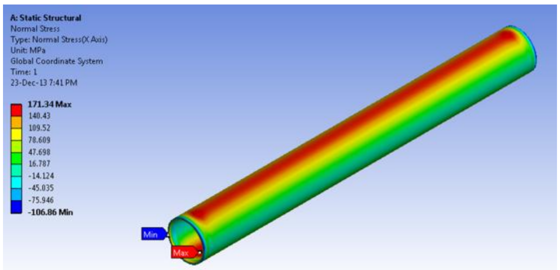

Fig4.1Hoop Stress

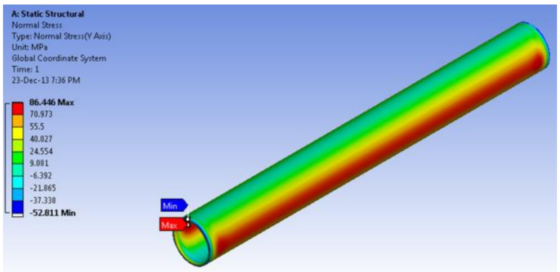

Fig 4.2Longitudinal stress

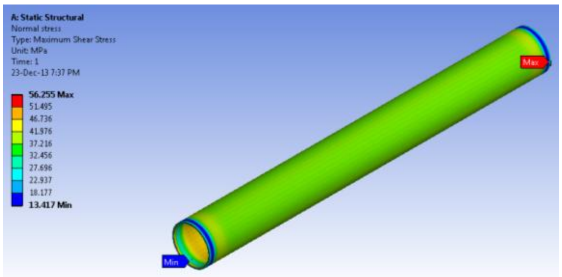

Fig 4.3Max.Shear stress

This results shows the design of pipe is safe.

5. Simulation procedure

- Modal analysis will be done for designed pipe to find its natural frequency.
- Calculation fluid dynamic analysis will be done for gas flow through designed pipe under suitable boundary conditions.
- CFD results will be used to conduct Forced vibration analysis to optimize the design for safe operation.

6. Result and discussion

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6.1 Modal Analysis

The following section details the modal analysis of the pipe. The pipe is made of structural steel with 10m length and 1m diameter, the thickness of the pipe is 0.1m. The modal analysis is vital in any design to find out the critical frequency, which will be used for any further dynamic, flow and relevant analysis and to ensure the safety of the pipe under static and dynamic working conditions.

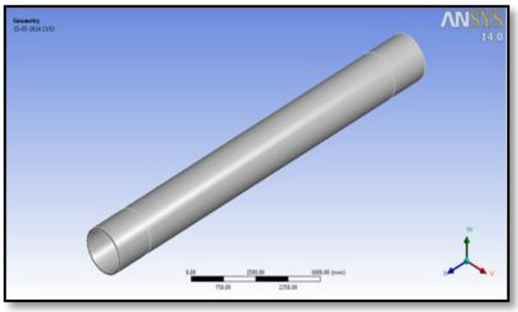

Figure 6.1 – Pipe Model

The following figure shows the meshed model of pipe, the model contains 3465 quad elements with 23234 nodes.

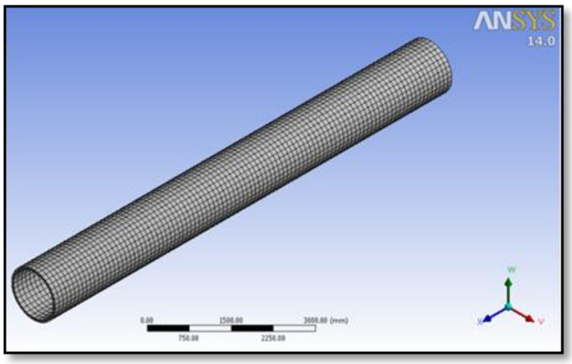

Fig 6.2 Meshed Model

The following figures show the boundary condition and Mode Shapes. This analysis takes material density, elastic modulus and Poisson ratio for computation and doesn't require any load configuration.

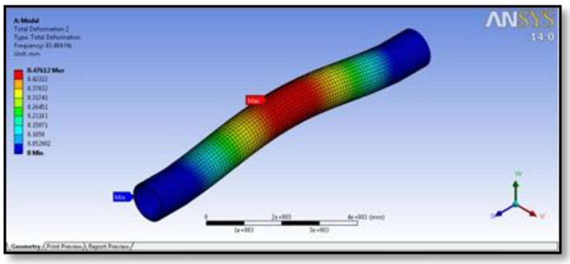

Fig6.3 Mode Shape1at 83.494 Hz

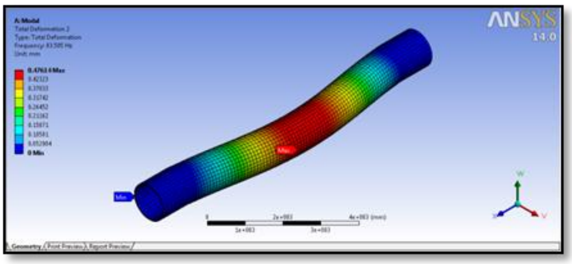

Fig6.4ModeShape2at83.505Hz

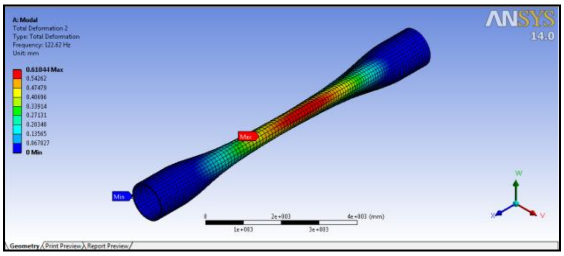

Fig 6.5 ModelShape3at 122.62Hz

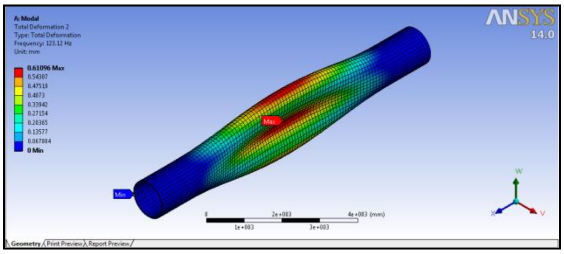

Fig 6.6 Mode shape 4at 123.12Hz

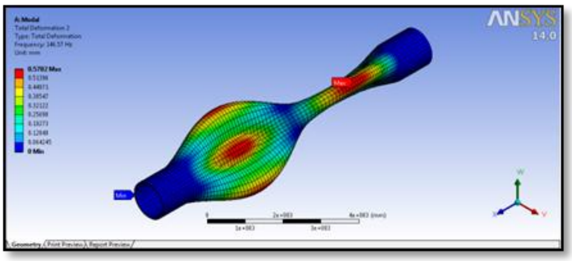

Fig6.7 Mode shape 5 at 146.57

The following table and chart shows the mode shape Vs frequency result of the pipe model, it is evident that the first two modes are critical (pipe failure due to bulging under pressure) and those are taken for fluid structure interaction based verification

Mode	Frequency
1	83.494
2	83.504
3	122.62
4	123.12
5	146.57
6	146.97

Table6.1 mode vs frequency

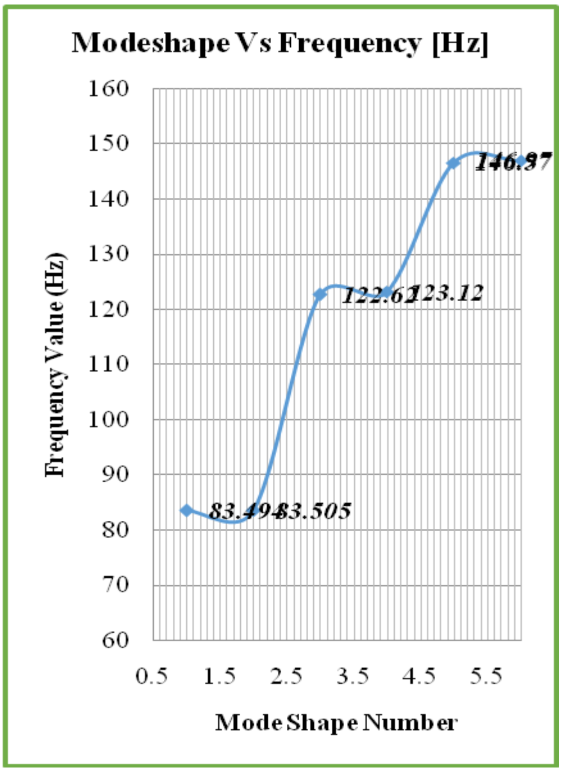

Fig 6.8 Mode vs frequency

7.Flow analysis

The following section provides details of flow simulation. The pipe carries natural gas under a specified pressure and velocity, the section is 10m long and designed to hold high pressure, in the flow there will be fluctuations and this creates flow induced vibration. It is vital to understand and find out this pressure variation to ensure design safety and modify the design if failure occurs.

7.1Analysis Details

The following section shows the flow analysis and its details. The inlet and outlet pressure are maintained to generate 10m/s velocity inside the pipe

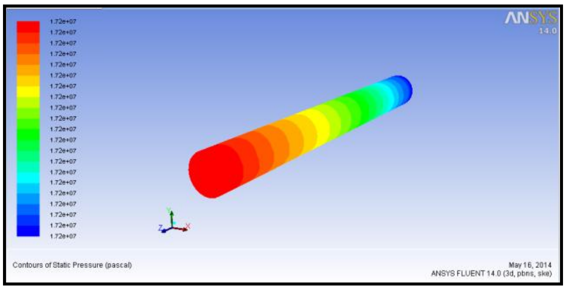

Fig7.1 Pressure due to flow inside the pipe

7.2 Forced Vibration Analysis

The following section details the forced vibration analysis due to flow inside the pipe. The pipe experience a maximum pressure of 17.23 N/m^2, in its flow and this flow pressure will create forced vibration, which must be found to ensure the safety of the pipe design. The excitation frequency of the pipe is found with modal analysis early and tabulated in the modal analysis section, the first two frequencies are critical for pipe flow. This is evaluated through forced vibration simulation

Mode	Modal(Hz)	Forced(Hz)
1	83.494	83.338

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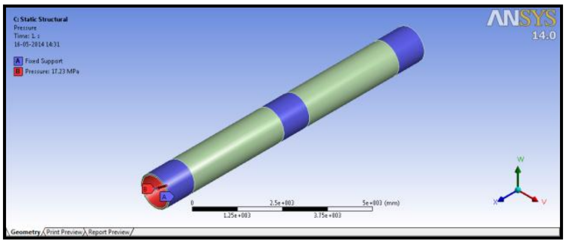
2	83.504	83.339
3	122.62	142.12
4	123.12	142.19
5	146.57	163.2

Fig 7.1 Modal vs forced

Since the flow induced vibration frequencies are nearer to the critical values the design must be revised to get a higher frequency than critical. Since the dimensions of the pipe are well established, it is must to play with pipe support only and it is done by adding mid way support, and simulate to evaluate the result.

The following provide the new design verification results.



8.Conclusion

Flow induced vibration is a major concern in piping design, it is vital to ensure that the pipe operation or flow parameters doesn't produce critical frequencies. The present work produced simulation integrated pipe design which provides comprehensive guide for pipe designing system.The importance of design is safety with optimization; the first design experienced near resonance frequency in its operation, to modify that there are two ways, one is to increase the diameter of the pipe, which in turn increase the weight and cost of the whole system. The second one is intelligent support; this will not produce any change in the design parameters of the pipe.Existing support system (Two Support) is changed to three support system and the same is verified with simulation and succeeded. The flow induced vibrations are well above the resonance frequency and hence design is safe.

REFERENCES

[1]MohinderL.NayyarP.E.,"Piping Handbook", 6th edition, pp.1-25, 2000.

[2]G.Bendor,"The role of vortex wake dynamics in the flow-induced vibration of tube arrays",pp-69-86,1999.

[3]A.Yakhot,M.Arad and G.Ben-Dor,"Numerical investigation of a laminar pulsating flow in a rectangular duct",fluids 29:935-950(1999)

[4]S.Meniconi,B.Brumone,M.Ferrante,and C.Massan,"Numerical and experimental investigation of leaks in viscoelastic pressurized pipe flow",8 feb 2013.

[4]Dr.Mauwafake A.Tawfik,Dr.Zene k.Kadhim & kuaa Y.Hammoudi,"vibration analysis of sudden enlargement pipe conveying fluid with presence of heat flux,"vol 27,no:3,2009

[5]N.K-R.kevelahan,"The role of vortex wake dynamics in the flow-inced vibration of tube arrays",27(2011),pp-829-857

[6]Andreas Brummer,Roland Edlerherr,Johann lenz,"Experimental and theoretical and theoretical investigation of thermoacoustic osilations in natural gas metering stations",oct 13-15,2012

[7]M.R.Acton,T.R Baldwin and R.P cleaver,"Development and implementation of risk assessment methods for onshore natural gas terminals", storage sites and pipelines.

[8]BeiLiu,Qingyuan.ke-Hua Su,Xin.Yang,Ben-cheng Wu,Chang-Yu sun and Guang-Jin chen",Experimental simulation of the exploition of natural gas hydrate",Energies 2012,5,pp466-493

[9]Ming Wu,shemiao Wang,Hongbo liu,"A study of on inhibitors for the prevention of hydrate formation in gas transmission pipelines",16(2007)81-85.