Standardization of Hpx Spool for Lead Time Reduction of String Test

S.Venkatesh/Assistant Professor,
Department of Mechanical Engineering,
Sri Eshwar College of Engineering,
Coimbatore.
venkatesme2014@gmail.com
S.Balasubramani/Assistant professor
Department of Mechanical Engineering,
Sri Eshwar College of Engineering,
Coimbatore.
S.Venkataramanan,
Department of Mechanical Engineering,
Sri Eshwar College of Engineering,
Coimbatore.
L.Gokulraj,
Department of Mechanical Engineering,
Sri Eshwar College of Engineering,
Coimbatore.
P.Ganesh kumar/ Senior Engineer
Flow serve controls India Ltd, Coimbatore.

Abstract — Time is the most precious thing. In today's competitive business world, companies require small lead times, low costs and high customer service levels to survive. Because of this companies have become more customers focussed. The result is that companies have been putting in significant effort to reduce lead times. Engineers are not only meant for design and manufacturing, they must know how to work with time, cost and quality of product effectively and efficiently. So, engineers are also responsible for time management. Time management can be carried out in any section of the industry and can also be carried out in testing section of pump industry. The main objective of our project is to reduce the lead time taken for carrying out the string test, which is being currently carried out in centrifugal pump testing section of industry.

Standardization of HPX spools is the best way to reduce lead time of pump testing. Hence a flexible bellow is introduced in between spool connected to pump and discharge pipe of test bed. Currently the process is carried out by using rigid spool to perform the string test, which makes adjustment of length impossible. This will eventually increase the lead time and incurs loss to the industry. We are introducing a flexible bellow between spool and discharge pipe of test bed which reduces the setting time of string test. This advancement helps to adjust the length of the spool between discharge pipe of test bed and the discharge pipe of pump. So that variety of pumps can be tested without replacing a new spool every time. This is an improvement when compared to traditional process. Lead time has been reduced from 5 hours to 1 hour by implementing the above suggested method.

Keywords* — *pump, string test, bellows, testing procedure, pressure

1.INTRODUCTION

The main objective of this research is to reduce the lead time taken for string test by standardizing the HPX spools. Time management in a testing section is possible only when standard components are available to facilitate easy assembly. Easy assembling and dismantling of test setup helps to test more number of pumps than usual. Flexible bellows are the equipment's that are used as expansion joints (i.e., to adjust the length between two joints). Flexible bellows are implemented in our project so that lead time for testing gets reduced and more number of pumps can be tested. Abdul Rahman Th. Mohammad, et al [1] International Journal of Mechanical Engineering and Applications in February 2, 2015 published that "Prediction of cycle life of flexible pipe bellows". This paper aims to investigate the relationship between maximum stresses produced and cycle life of different shaped bellows expansion joints. Flexible pipe bellows which have been selected in the present study are made of stainless (STS 304) and (STS 316) material based on two types of (axial, and axial with control ring) with three shapes of bellow section (U-shape, Ω-shape and disc-shape). Our calculation is done using simulation model written by MATLAB. The simulation results show that, U-shaped bellow has smaller internal pressure-induced stress, longer fatigue life, and is more suited for higher internal pressure situations.. Brijeshkumar, M.Patel, V.A. Patel [2] International Journal of Engineering Science and Innovative Technology (IJESIT) May 2013 published that "Design, Manufacturing and Analysis of Metal Expansion Bellows". Bellows have a function to absorb regular or irregular expansion and contraction in piping system, it is widely used as the element of expansion joint in various piping system, aerospace, micro electromechanical and industrial system. The failure of bellows expansion joints made of SS 304 has been analyzed. Over pressure, Vibration of steam in piping are responsible for the failure. Based on these design data we have improve the design and its re-design the metal expansion bellows by using EJMA code adding with inner liner. To prevent the bellows failure chances we have provide internal liner in the bellows which has many advantages such as to ensure smooth flow of media, minimize friction losses, minimize resonant vibration caused by high flow velocity, reduce the effect of turbulent flow upstream of the expansion joint, prevent erosion of the bellows wall from chemical and abrasive attack, reduce the temperature of the bellows in high temperature application. In this work a finite element analysis (FEA) of bellows proposed in this paper to for the validation of the software results and EJMA design calculated results bellows with the inner liner. Finally the validation of results of EJMA design calculated value and FEA value shows a very good agreement. Here by adding the inner liner in the bellows gives the better results and performance achieved then the conventional bellows.Jayesh .B Khunt ,et al [3] International Journal for Innovative Research in Science &Technology IJIRST

November 2014 Published paper on "Design And Thermal Analysis Of Thermal Expansion Joint In Industrial Application" in this paper they discussed the present study covers different types of expansion joints used in industry. The expansion joints are used to dissipate the energy during contraction or expansion in pipes. This covers detailed calculation from EJMA (Expansion Joint Manufacturers association), Design, Modelling, and Thermal and Structural analysis of axial type expansion joint. All design process will be performed with aid of FE analysis using ANSYS software. Gaurav R. Mohite1, A. P. Edlabadkar [4] International journal of pure and applied research in engineering and technology IJPRET, May2014 Published paper on "Analysis of Expansion Joint in Heat Exchanger Using Finite Element Analysis Method". This paper mainly focuses on Finite Element Analysis of Expansion Joint in heat Exchangers using ANSYS. The main Purpose of Expansion joint is to withstand axial deformation (thermal Expansion) & loads inside a High Pressure heat Exchanger. Hence the design of Expansion joint becomes critical. Heat Exchanger with Expansion bellows are widely used in Oil & gas industries today. Brijesh M. Patel, et al [5] International Journal of Engineering Science and Innovative Technology (IJESIT) March 2013 Published paper on "A Critical Review on Metal Expansion Bellows". The flexible element of an expansion joints consisting of one or more convolutions with no more than five plies and the end tangent with length to diameter ratio not more than three. Any device containing one or more bellows used to absorb dimensional changes such as caused by thermal expansion or contraction of pipe line, duct or vessel or heat exchangers. Tubular bellows are one of the most efficient energy-absorbing elements for engineering system. Flowserve tests variety of HPX pump in the test bed (9 models, 60 series). Whenever the pump to be tested changes, the diameter and the length of the suction and discharge spool changes. The length of the spools to be fixed is identified only after the pump is mounted on the test bed. If the required spools are not available in the inventory, it has to be manufactured and it takes nearly 5 hours to produce a new spool (by cutting and welding the pipe, reducer, flanges).It eventually increases the lead time of the string test. This costs loss to the industry .It is the problem prevailing in the industry. The 1st, 2nd and 4th process are standard and hence time required for it cannot be altered and so time reduction is only possible in 3rd process.

2. METHODOLOGY

2.1 PRINCIPLE OF BELLOW DESIGN:

The following table represents the design parameters of bellow design. The main purpose of this bellows is to adjust the spool position in the pump testing places. It reduces the number of different sizes of spool manufacturing processes.

S.NO	REQUIREMENTS	VALUES
1.	Bellows material.	SS304
2.	Nominal diameter.	10 inch
3.	Overall length of bellow	1 metre
4.	End types (i.e. flanges, weld ends, etc.).	Flanges #300 class
5.	Maximum Operating pressure of HPX pumps	30 bar
6.	Pressure withstanding capability of bellow	33 bar
7.	Bursting Pressure.	88 bar
8.	Hydrostatic pressure of HPX pump	63 bar
9.	Design temperature.	65 deg C
10.	Design Movements	Axial (±50mm)

TABLE:1(Design Requirements)

2.2. DEFINE:

HPX pump is one of the major products of Flowserve. The pump undergoes various testing procedure as per the customer specifications. String test or complete unit test is a type of test carried out on HPX pumps. The testing dates of pump get postponed due to inadequate spools in the inventory. This eventually increases the lead time. In this project, it was decided to reduce the lead time taken for carrying out the complete unit test by making special arrangements in spool.

2.3. PROJECT SELECTION:

HPX model pump is one type of pump that is assembled in flowserve Coimbatore**.** There are various test conducted for HPX pumps. In that, for string test lead time get increased from 20 to 24 hours. In order to reduce lead time a new concept is to be implemented. So we have collected data for string test from March-14 to August-14.

IMPACT	**HIGH**		⇧		⇧
	MEDIUM				⇧
	LOW				⇧
		LOW	**MEDIUM**	**HIGH**	
		EFFORT			**PROBABILITY OF SUCESS**

TABLE:2. (Impact diagram)

The above matrix shows that medium effort is required to get efficiency of achieving results.

2.4. DATA COLLECTION:

Average Lead Time Taken / Order				
S.NO	**Month**	**No Of Order**	**Average Lead Time Taken In Days / Order**	**Total Average Lead Time In Days / Order**
1	March-14	2	1	

2	April-14	2	0	**1**
3	May-14	13	2	
4	July-14	4	1	
5	Aug-14	4	1	

TABLE:3 (Data collection and sorting)

There are various series in HPX model pumps. We have chosen 6HPX series as a sample for this project and collected the data relevant to this series

2.5. ANALYZE:

Identify causes:

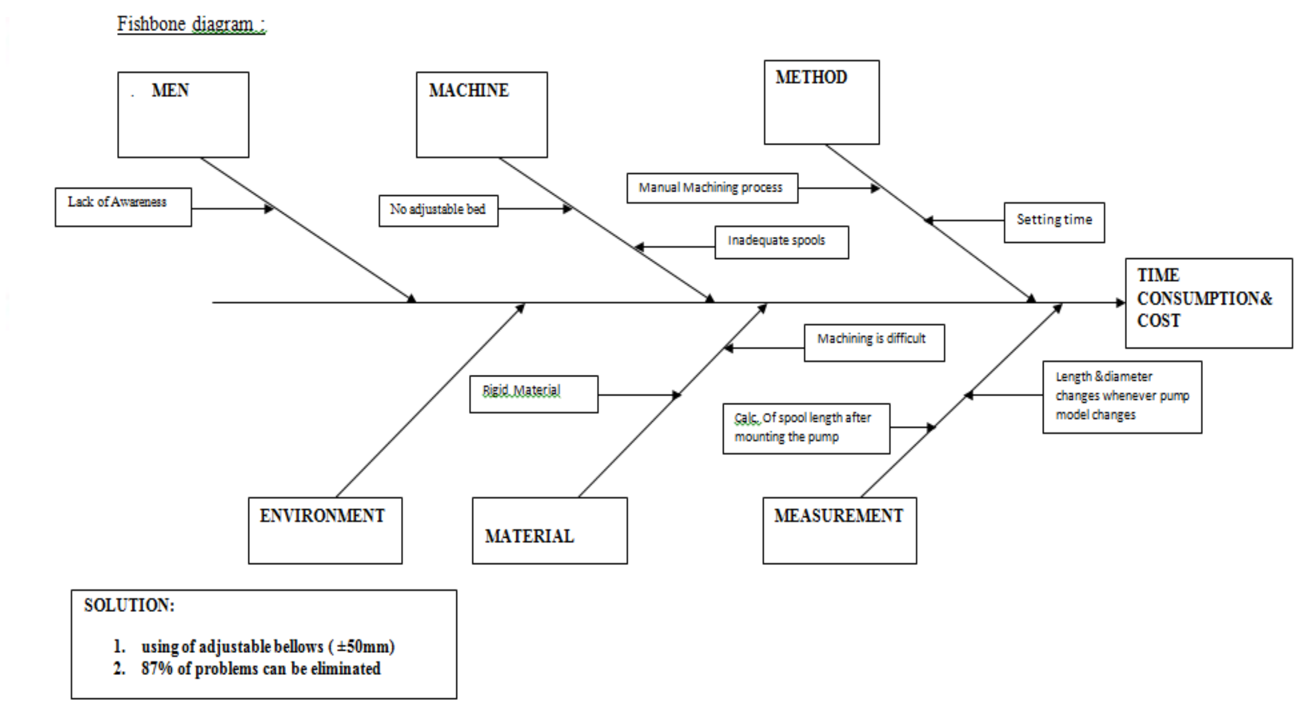

Fig1. Fishbone diagram

BRAINSTORMING:

CAUSES:

1. Change in Specification of pumps and its spools.

2. Shortage of spools.

3. No data regarding spools available for corresponding pumps.

4. Lack of awareness among employees.

5. Supplier issues.

6. Improper routing.

7. Delay in manufacturing of spool.

8. Change in specification of pump by customer.

2.6. GROUPING

S.no	**Grouping-** Manual machining process
1.	Supplier issues
	Improper routing
	Grouping-Rigid material
2.	Rigid material of spool
	Grouping- Inadequate spools
3.	Shortage of spools
	No data regarding spools available for corresponding pumps
	Grouping- Lack of awareness about spool by workers
4.	Lack of awareness among employees
	Improper routing
	Grouping-Calculation of spool length
5.	Change in Specification of pumps and its spools
	Change in specification of pump by customer

TABLE: 4(Grouping of causes)

2.7. SELECT CAUSES:

Standard / Noise / Controllable

S.no	Causes	SCN
1.	Manual machining process	C

2.	Rigid material	S
3.	Inadequate spools	C
4.	Lack of awareness about spool by workers	C
5.	Calc.of spool length	N

TABLE:5(Identification of SCN causes)

2.8. QUANTIFY AND VERIFY CAUSES:

XY MATRIX:

Input variables (X's)	Output variables (Y's)	Setting time	Space utilization	inventory	Labour		
	Weightage	9	6	5	5	Total value	Total value %
Manual machining process		9 / 81	5 / 30	5 / 25	3 / 15	151	23.19
Rigid material		8 / 72	5 / 30	5 / 25	4 / 20	147	22.58
Inadequate spools		9 / 81	2 / 12	3 / 15	5 / 25	133	20.43
Lack of awareness about spool by workers		7 / 63	5 / 30	4 / 20	3 / 15	128	19.66
Calc.of spool length (specification of pumps and customer)		8 / 72	0 / 0	0 / 0	4 / 20	92	14.13

TABLE:6 (XY matrix)

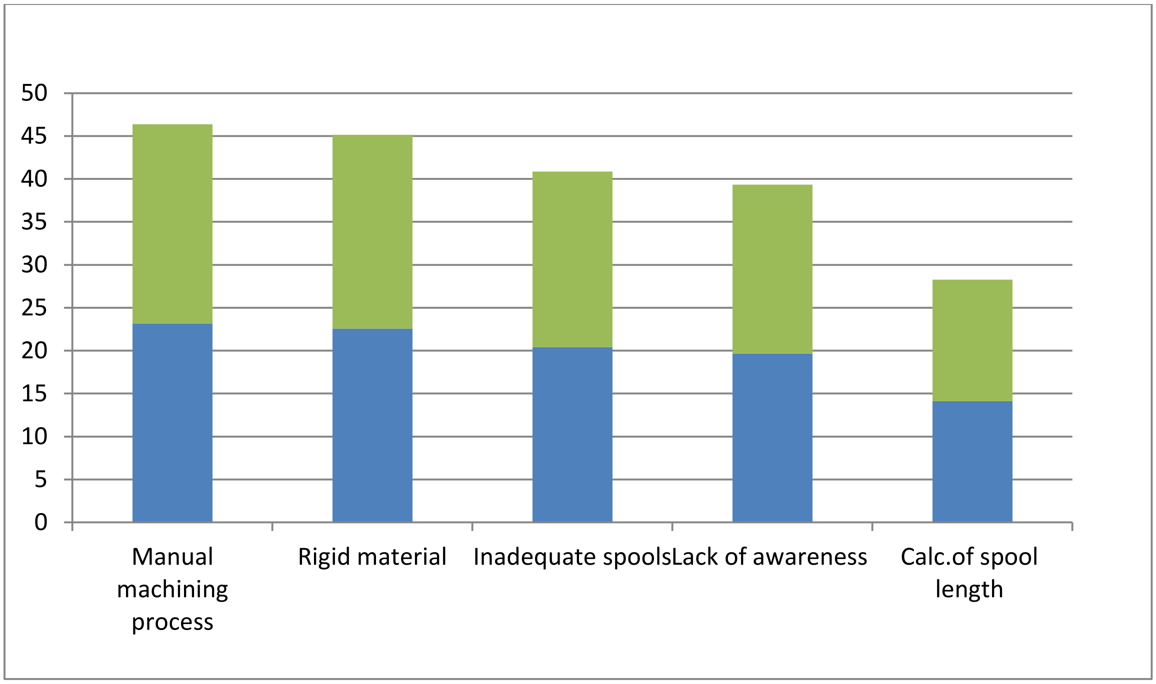

Fig2.Variation of Causes

2.9. QUANTIFY OPPORTUNITIES:

The Quantified Causes are categorized into the following:

Standard / Noise / Controllable:

S.no	Causes	Total value	Total value %	SCN
1.	Manual machining process	151	23.19	C
2.	Rigid material	147	22.58	S
3.	Inadequate spools	133	20.43	C
4.	Lack of awareness about spool by workers	128	19.66	C
5.	Calc.of spool length	92	14.13	N

TABLE:8. (Ranking for causes)

2.10 IMPROVE:

SOLUTION:

S.no	CAUSES	PROPOSED SOLUTIONS
1.	**Grouping- Manual machining process**	
	Supplier issues	Proper supply of materials
	Delay in manufacturing of spool.	Standardized spools are to be made.
2.	**Grouping-Rigid material**	
	Rigid material of spool	Flexible material has to be implemented.
3.	**Grouping- Inadequate spools**	
	Shortage of spools	Standardized spools are to be made.
	No data regarding spools available for corresponding pumps.	Maintaining record of spools corresponding to the pumps.
4.	**Grouping- Lack of awareness about spool by workers**	
	Lack of awareness among employees	To educate employees the standardization process.
	Improper routing	Proper sequence to be followed.
5.	**Grouping- Calculation of spool length**	
	Change in Specification of pumps and its spools	A record of lengths has to be maintained.
	Change in specification of pump by customer	

TABLE: 9(Solutions)

2.11. DESIGN CALCULATION:

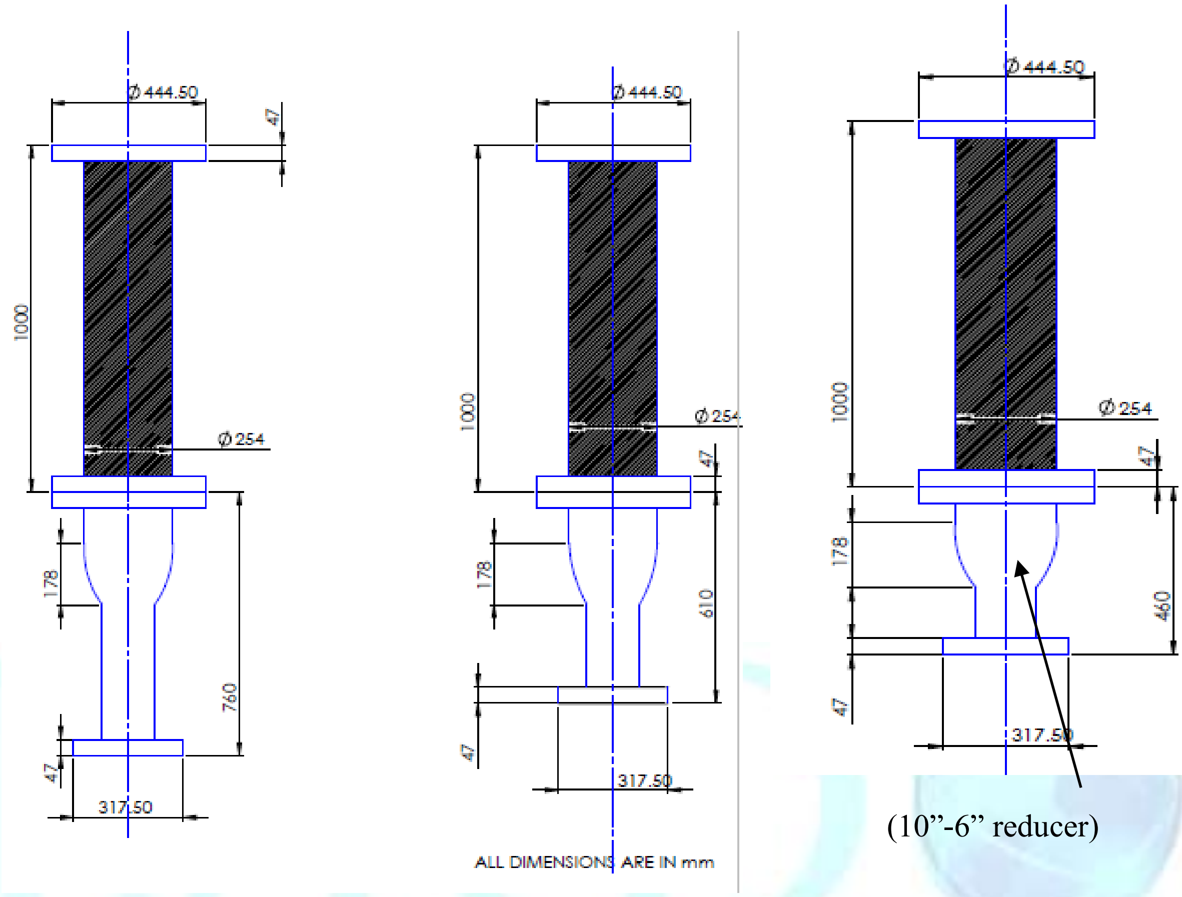

Fig 3. Bellows connected with spools

The standard parameters of a bellow for this project requirement is as follows

Length	1m
Inner diameter	10”
Pitch	20mm
2R	4mm
No of convolutions	38

TABLE:10. (parameter for project requirement)

2.12. CALCULATION FOR SPOOL LENGTH:

(For 6HPX series)

FIXED HEIGHT OF DISCHARGE FLANGE FROM FLOOR(TEST BED) (mm)	**DISCHARGE FLANGE HEIGHT RANGE FROM FLOOR(PUMP) (mm)**	**SPOOL LENGTH CALCULATION (mm)**	**STANDARD SPOOL LENGTH (mm)**	**SETTING PLATE HEIGHT**
2710	900	2710-(1000+900)	810	No setting plate required for heights between 810mm to 710mm
	900-950	2710-(1000+950)	760	
	950-1000	2710-(1000+1000)	710	Insert **SETTING PLATE** of 50 mm when height is between 660 mm to 710mm
	1000-1050	2710-(1000+1050)	660	
	1050-1100	2710-(1000+1100)	610	No setting plate required for heights between 660 mm to 560mm
	1100-1150	2710-(1000+1150)	560	Insert **SETTING PLATE** of 50 mm when height is between 510 mm to 560mm
	1150-1200	2710-(1000+1200)	510	
	1200-1250	2710-(1000+1250)	460	No setting plate required for heights between 510 mmto 410mm
	1250-1300	2710-(1000+1300)	410	

TABLE : 11 calculation for spool length.

From table shows the calculation for spool lengths from this table the Three spools of length 760, 610, 410 mm has to be manufactured which is mentioned in table.

2.13. CALCULATION FOR LOSSES IN PIPES:

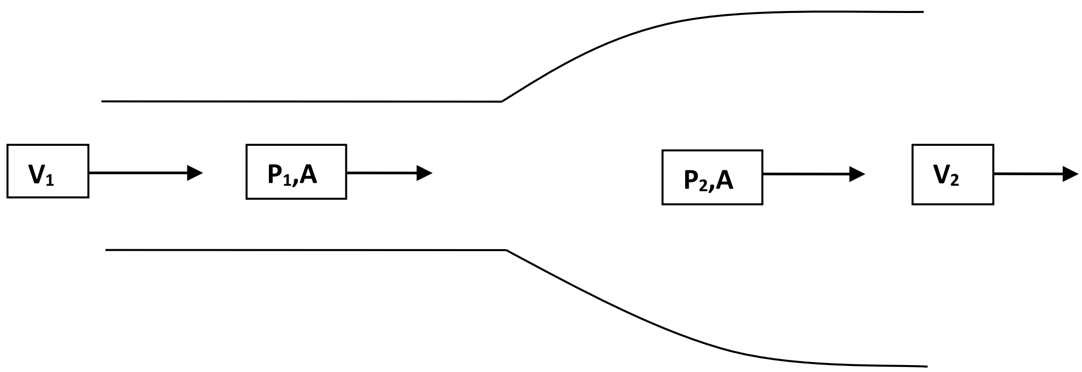

Fig4. Flow through spool

We know that,
For pump discharge,
The diameter of pipe is enlarged from 6” to 10”
Diameter of smaller pipe (d_1) = 152.4mm =0.152m
Diameter of larger pipe (d_2) = 254mm =0.254m
We know that,
For 6HPX12A, the rated flow is 210 m^3/hr
So,

$$Q = 210/3600$$
$$= 0.0583\ m^3/s$$

Area of smaller pipe $A_1 = \pi/4*(d_1)^2$
$$= \pi/4*(0.152)^2$$
$$= 0.0181 m^2 \quad \text{------------------------ (1)}$$

Area of larger pipe $A_2 = \pi/4*(d_2)^2$
$$= \pi/4*(0.254)^2$$
$$= 0.0506 m^2 \quad \text{------------------------ (2)}$$

Velocity $V_1 = Q/A_1$
$$= 0.0583/0.0181$$
$$= 3.220 m/s \quad \text{------------------------ (3)}$$

Velocity $V_2 = Q/A_2$
$$= 0.0583/0.0506$$
$$= 1.152 m/s \quad \text{------------------------ (4)}$$

Loss of head due to enlargement of pipe is given by

$$H = (V_1 - V_2)^2/2g \quad \text{------------------------- (5)}$$

Apply (1),(2),(3),(4) in (5)

$$= (3.220-1.152)^2/2*9.81 = 0.217 \text{ m of water}$$

3. RESULT AND DISCUSSION

3.1 IMPLEMENTATION OF BELLOW:

A metal bellow made of stainless steel material of 1m length which has a axial compression of ±50mm has been implemented between discharge pipe of test bed and spool connected to the discharge pipe of the pump. This has reduced the time taken for connecting the pump and the discharge pipe of test bed.

3.2 BILL OF MATERIALS:

S.NO	COMPONENTS	MATERIAL	QUANTITY
1.	**SPOOL**		
	a)Cast iron pipe(1m)	CI	1
	b)Reducer(10”-6”)	CI	2
	c)Flange for 10”(upper)	CI	2
	d)Flange for 6” (lower)	CI	2
	e)Nipple	CI	2
2.	**BELLOW**		
	a)Flexible bellow ss304	SS 304	1
	b)Bellow flanges	SS 304	2
3.	**BOLTS AND NUTS**	SS	24pairs

TABLE:12.(Bill Of Material)

3.3 COST ANALYSIS:

Method followed in the company:

They manufacture **19 spools** and its requirements are as follows

S.NO	COMPONENTS	DIMEN SIONS	QUANTITY
1	Cast iron pipe	28m	1

2	Reducer	10”-6”	19
3	Flange (upper)	10”	19
4	Flange (lower)	6”	19
5	Nipple	ID (5mm)	19

TABLE:13 (Bill Of Materials for current method)

REQUIREMENT PER ITEM	COST PER ITEM	QUANTITY	COST FOR REQUIRED QTY
Cost of a 1m pipe	Rs.3000	for 28m	Rs.84,000
Cost of a 10”-6” reducer	Rs.2000	for 19 reducers	Rs.38,000
Cost of a 10” flange	Rs.4500	for 19 flanges	Rs.85,500
Cost of a 6” flange	Rs.3000	for 19 flanges	Rs.57,000
Cost of a nipple	Rs.50	for 19 nipple	Rs.950
Cost for welding 10” section	Rs.1700	for 38 welding	Rs.64,600
Cost for welding a 6” section	Rs.720	for 38 welding	Rs.27,360
	Total cost	**Rs. 3,57,410.**	

TABLE:14 (cost incurred for current method)

After the implementation of bellow:

It is enough to manufacture **3 spools** and to implement a flexible bellow

Requirements:

S.NO	COMPONENTS	DIMENSIONS	QUANTITY
1	Flexible metal bellow	ID=10”, length =1m	1
2	Cast iron pipe	2m	1
3	Reducer	10”-6”	3

4	Flange (upper)	10”	3
5	Flange (lower)	6”	3
6	Nipple	ID (5mm)	3

TABLE: 14. (Bill of Materials for proposed solution)

REQUIREMENT PER ITEM	COST PER ITEM	QUANTITY	COST FOR REQUIRED QTY
Cost of flexible bellow	Rs.26,000		
Cost of a 1m pipe	Rs.3000	For 2m pipe	=Rs.6,000)
Cost of a 10"-6" reducer	Rs.2000	For 3 reducer	=Rs.6,000)
Cost of a 10" flange	Rs.4500	For 3 flange	= Rs.13,500)
Cost of a 6" flange	Rs.3000	For 3 flange	= Rs.9,000)
Cost of a nipple	Rs.50	For 3 nipple	= Rs.150)
Cost for welding 10" section	Rs.1700	For 6 welding	=Rs.10,200)
Cost for welding 6" section	Rs.720	For 6 welding	=Rs.4,320)
Total cost		Rs. 75,170.	

TOTAL SAVINGS= 3,57, 410 – 75,170 = Rs. 2, 82, 240.

TABLE: 15 (cost incurred for proposed solution)

4. CONCLUSION:

Flexible bellows are the best solution for this project. A bellow of 1 metre along with three spools has been manufactured. Thus the spools have been standardized from 19 to 3 spools. The lead time has been reduced from 5 hours to 1 hour. Cost savings of Rs.2, 82,240 is achieved.

5. REFERENCES

[1] Abdulrahman,Th. Mohammad, JasimAbdulateef, ZaidHammoudi **“Prediction of cycle life of flexible pipe bellows”,IJMEA ,** February 2, 2015,Vol. 3No. 1 pp. 6-15.

[2] Brijeshkumar , M. Patel, V.A. Patel "**Design, Manufacturing and Analysis of Metal Expansion Bellows",IJESIT** May 2013**,**Volume 2, Issue 3.

[3] JayeshB Khunt , Rakesh ,P Prajapati "**DesignAnd Ther AnalysisOfThermal Expansion Joint In Industrial Application",** Nover 2014,Volume 1,Issue 6.

[4] Gaurav R. Mohite, A. P. Edlabadkar "**Analysis Of Expansion Joint In Heat Exchanger Using Finite Element Analysis Method",IJPRET,** May2014 Volume2.

[5] Brijesh M. Patel, B.D.Patel, V.M.Prajapati,"**A Critical Review on Metal Expansion Bellows" IJESIT,** March 2013,Volume 2, Issue 2.