Detection of Interfaces And Voids in Pipelines Using Gamma Scanning

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Abstract: *Industrial activity involves plenty of technical problems to which solutions are sought at various levels, from trouble shooting to complete investigation and modeling of processes or plants, or development of new technologies. The purpose of this investigation is to apply the gamma scanning technique to detect the interface, voids present in pipe lines. The results of experiments performed in a leading petrochemical complex are presented. Gamma scanning of the pipeline carrying para xylene was carried out in three different orientations of the pipe line using Cesium-137 and the transmitted radiation intensity was recorded by using Scintillation detector NaI (Tl). Interface location and presence of voids in some of the bends were successfully identified using this technique. The interface locations observed were not found to be stable but oscillating up and down with some well-defined period of oscillation.*
Keywords: *Gamma scanning technique, Cesium-137, Scintillation detector, Interface, voids.*

I. Introduction

In any industry, good plant performance and avoiding a shutdown, especially in continuous process, are of special importance for healthy production, economy and safety. Gamma scanning can provide speedy solutions to many plant and process problems, starting from malfunctions in specific components to poor overall plant performance. Performance of an industrial process depends upon chemical process optimization and intended fluid transfer. Fluid transfer takes place through pipelines of different sizes, configuration and analogy. Any trouble in fluid flow through the pipeline may lead to reduction in production resulting in revenue loss. The application of gamma pipe scanning has developed appreciably over the last few years. Gamma pipe scanning offers information that cannot be obtained by means of conventional methods. This technique is safe if all necessary precautions are taken. Gamma scanning technique is a very useful on-line troubleshooting tool to identify presence of liquid, solid and void inside the pipeline without disturbing the process. Gamma scanning provides a non-destructive and cost effective way of analyzing problems related to solid deposition, presence of voids and presence of foreign objects in the pipeline.

II. Gamma Pipe Scanning

When two different materials of dissimilar densities are present in tanks or in vessels, the location of interface/level of liquid could be identified exactly using gamma ray attenuation technique. When gamma ray emitted by a collimated radiation source on one side of the vessel/tank/pipe passes though the material in the vessel/tank/pipe, its extent of stoppage (attenuation) is inversely and exponentially proportional to the density of material. A sudden change in transmitted intensity will be observed when gamma rays pass from material at

higher density to the material at lower density or vice a versa. This change in transmitted radiation intensity from a source on one side of the vessel/tank/pipe is accurately monitored using highly sensitive radiation detector moving on the opposite side of the vessel/tank/pipe. Radioisotope Cesium-137 has suitable radiation energy to get clear contrast, reasonably long half-life to be used for such several applications in the years to come and possibility of economic production at high specific activity. Therefore it was decided to use the same for this investigation.

III. Advantages And Disadvantages Of Pipe Scanning

Major advantage of the pipe scan is its utility without disturbing the process i.e. it is carried out online. Conventional methods like pressure drop studies, sampling etc. can provide rough idea about the problem in the pipeline but they cannot pinpoint the problem area. Whereas, gamma pipe scan provides detailed insight of the pipeline and visualization of what could be happening inside the pipeline.

Disadvantage of this method is, it requires trained manpower, additional training for handling of radioisotopes and knowledge of radiation safety.

IV. Safety Issues

Usually radioisotope used for gamma pipe scan is Cesium-137. This has half-life of 33 years and emits gamma energy of 0.66 MeV. Intensity of the source used was 100 mCi which is sufficient to scan the pipes of the diameters of about 36 inches. The source was collimated using tungsten collimator so as to get the concentrated beam of radiation of 2 mm width. However, this intensity will not be as hazardous as the intensity of a radiography source which is usually of the order of 10Ci. In case of radiography being carried out the area surrounding needs to be cordoned off.

In general, criteria of time distance and shielding was observed while handling radioisotopes. Time taken to handle the radioisotope or when in vicinity was critically least minimum (<30 seconds), the radioisotope was handled from the distance as far as possible. Care was taken to keep persons away from the source and the radioisotope was adequately shielded for handling i.e. surface dose rate on the container was less than 10 mR/hour at any given time.

All of these factors were strictly taken in to account while carrying out the gamma pipe scanning. The radioisotope was handled by the trained and experienced professionals, it was maneuvered in the lead shielded collimators in the pipe scanner along the pipeline and it was observed that general public / plant staff and workers do not go in the vicinity of the source except those involved in the direct scanning.

V. Experimental Procedure

1.1. Principle Of Gamma Pipe Scanning

A schematic representation of the experimental arrangement is given in the above figure (Fig1). The transmission of γ radiation through any material is governed by the exponential equation

$$I = I_0 e^{-\mu x}$$

Where:

I $\rightarrow$ Intensity of radiation transmitted through a material of thickness Xcm
Io $\rightarrow$ Intensity of radiation from the γ - ray source reaching the detector in
    the absence of the material.
μ $\rightarrow$ Linear absorption coefficient (cm $^{-1}$)

A collimated source and detector system is positioned diametrically opposite to the pipeline. The transmitted radiation, after traversing through the pipeline is detected by a collimated detector. The source and detector are moved along the length of the pipeline in the same horizontal plane. The transmitted radiation will be proportional to the density and thickness of material in the pipeline. After assessing the increase/decrease in the radiation intensity, the location of interface can be estimated.

5.2. Gamma Pipe Scanning In The Pipeline

The layout of the pipeline scanned is shown in Fig.2 The gamma scanning of the pipeline was carried out using radioactive source Cesium-137 (Cs-137), 100mCi. The energy of gamma rays of Cs-137 is 662 keV which is sufficient for scanning pipelines up to 36". The source was placed in a lead collimator.

Scintillation detector NaI (Tl), 1"x1", in conjunction with battery operated count rate meter was used to record the transmitted radiation intensity across the pipeline. The detector was placed in a lead collimator and placed diametrically opposite to the source. The schematic representation of the position of source and detector (Fig.3). Readings were obtained at 150mm intervals.

5.3 Describtion Of The Pipelines :

The description of the pipelines being scanned is tabulated in Table 1.

Exchanger	Line Size(inch)	Line ID(mm)	Pipe thickness (mm)	Insulation thickness (mm)	Density Kg/m³	Vertical length of leg (m)
E5-304	32 (top part) 36 (bottom part)	782.8 (top part) 880.4 (bottom part)	15 (top part) 17 (bottom part)	165	867.9	24.009
E5-305	20	488	10	115	902.5	18.423
E5-306	12	311.2	6.35 (SCH 20)	90(max)	928.8	18.23
E5-307	10	260.4	6.35 (SCH 20)	25(max)	942.2	18.843
E5-308	10	257.4	7.8 (SCH 30)	25(max)	994.1	14.415

Table 1: The description of the pipelines being scanned

VI. Results And Discussion

6.1. Interface Detection:

a) For HX 304: Interface location is at about 402" from the HX bottom. The variation in readings in the higher side (vapour phase) represent statistical fluctuations. After the interface location, the liquid phase co-exists with some vapour coming from the bottom i.e. 2 phase flow. However, grossly it could be considered that the interface is located at 402". (Fig.4)

b) For HX 305: Interface appears to be dynamic due to the flow of liquid from top to bottom and flow of vapour from bottom to top. This is evident from the appearance of interface at 2 locations. Within the time span of scanning the one portion the interface has travelled to the other location. Hence it could be considered at 240" from the bottom of the HX. (Fig.5)

c) For HX 306: Interface location is identified at 312" from the HX bottom. The interface in this particular pipe is clearly noticed. Vapour portion in the upper part has fluctuations within statistical limits. (Fig.6)

d) For HX 307: No clear cut interface could be observed in this pipe. Some fluctuations are observed which could be due to the presence of sparged vapours which slightly change the dynamic density of the liquid phase. Otherwise it appears that there could be only liquid phase in this pipe. If the count-rate readings for reference pipeline are compared with those in this pipeline, it corroborates the indication. (Fig.7)

e) For HX 308: Interface could not be observed in this pipe. Consistency in the readings shows that a single medium of uniform density is present between the source and detector. (Fig.8)

f) The change in position of the interface with respect to time was observed in few pipes. The period of oscillations of interfaces in these pipes were measured and shown in Fig.9 to Fig.16.

6.2. VOIDS:

In few of the bends, the voids are not observed which could be due to smooth liquid phase flow. However, in many of the bends few or multiple voids are detected which could have been due to presence of vapour pockets. Sometimes these pockets may be static or sometimes dynamic with very slow speed. Thus, in case of doubts, repetition performed has also concurred with the same readings. Dimensions of the larger voids which could grossly affect the flow are mentioned in the figures. (Fig.17 to Fig.23)

VII. Conclusions

In all the pipes mentioned above, starting from bottom of the heat exchangers stable interface could not be observed may be due to the existence of two dynamic phases together. It was suspected that the interface formed between vapour phase and liquid phase is not static and stationed at one location but it is oscillating up and down with some well-defined period of oscillation. This was monitored by placing source and detector stationed at suspected interface location for about 3 to 5 cycles i.e. between 9 to 15 minutes. The readings of count rate are plotted with respect to real time and the period of oscillation was monitored. Oscillations with specific period are observed in three pipelines viz. 304, 305 & 306. However, in 307 and 308 the readings remained almost constant and the variations are within the statistical fluctuations. The periodic oscillations could be due to the intermittent condensations in the heat exchangers and liquid formed is delivered through the headers towards the feed line. In these headers (307 & 308) liquid could be filled up to the monitoring level which is evident from the steady state count-rate observed in the Para xylene pipe compared with these pipes. There are voids present in some of the bends which could be due to vapour trapped and localized at a particular location which may be obstructing the smooth flow of fluid through the pipe.

Acknowledgements

References

[1]. Charlton, J.S., 1986.RadioisotopeTechniques for Problem Solving in Industrial
[2]. Process Plants.LeonardHill.
[3]. Guidebook on radioisotope tracers in industry, 1990.Technical report Series
[4]. No. 316.InternationalAtomicEnergyAgency (IAEA), Vienna.
[5]. Zitny, R., Thyn, J., 1996.Programs For Residence Time distribution analysis, RTD
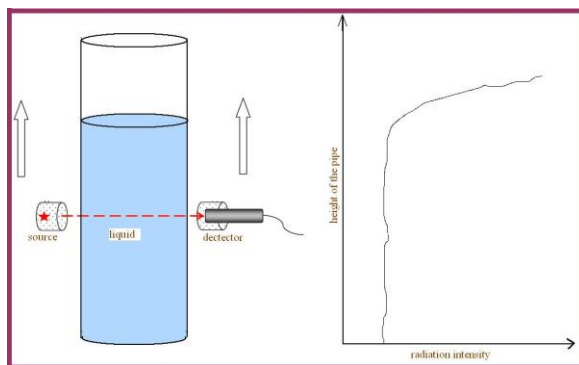[6]. Software manuals for data analysis of radiotracer experiments.

Figures

**Fig 1: Interface detection/level measurement using
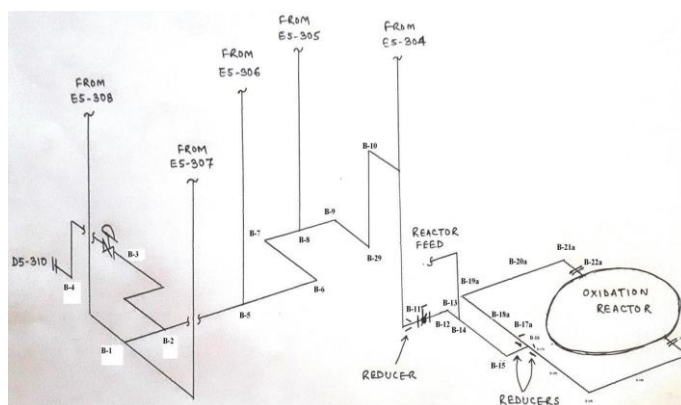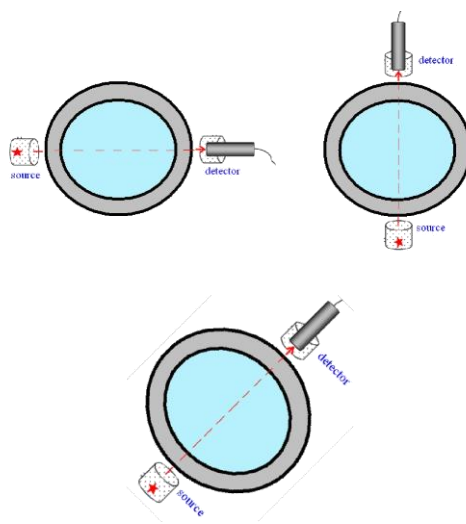gamma scanning**

**Fig 2: layout of the pipe line for gamma
scanning**

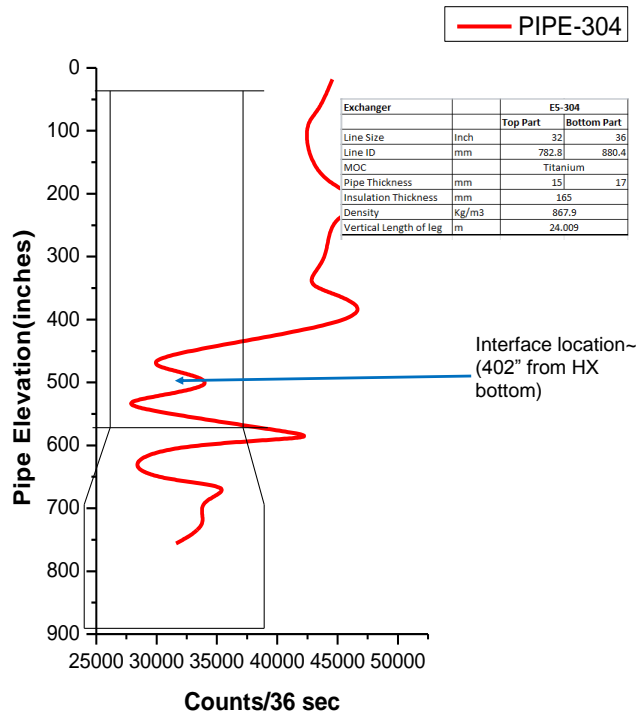**Fig 3: Orientations for gamma pipe scanning in x, y and
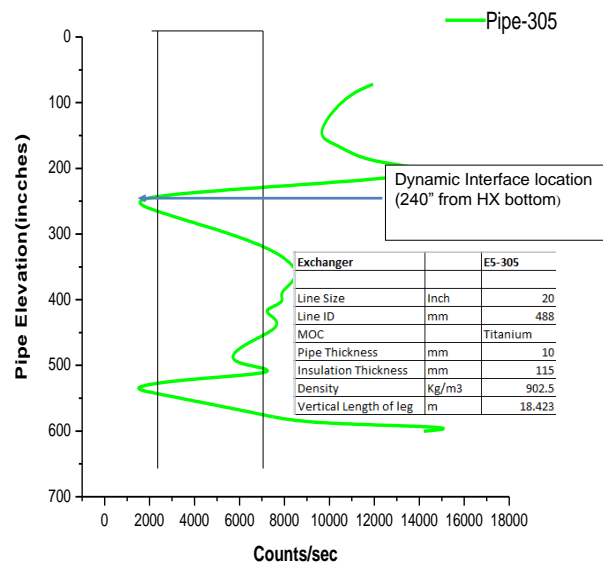z directions**

Fig 4: Interface in pipe 304

Fig 5:Interface in pipe 305

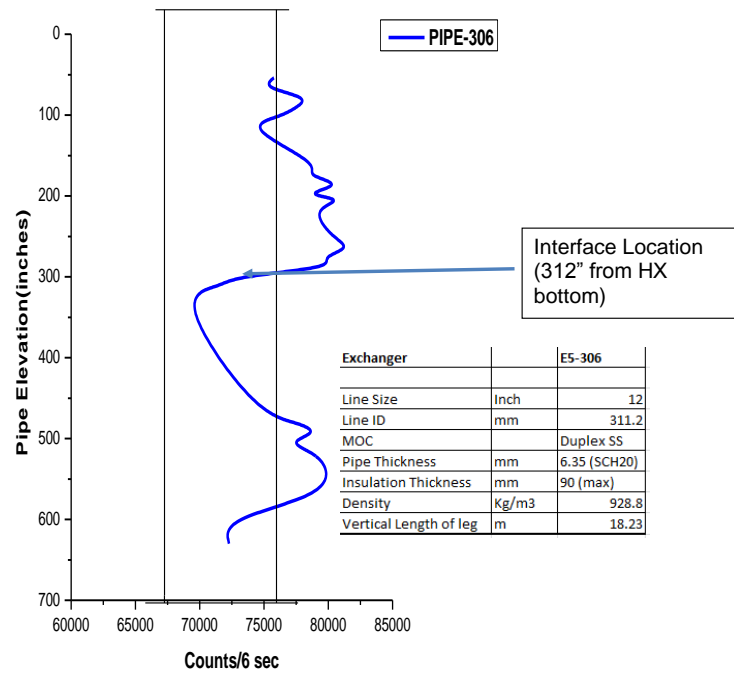| Exchanger		E5-306
Line Size	Inch	12
Line ID	mm	311.2
MOC		Duplex SS
Pipe Thickness	mm	6.35 (SCH20)
Insulation Thickness	mm	90 (max)
Density	Kg/m3	928.8
Vertical Length of leg	m	18.23

Fig 6: Interface in pipe 306

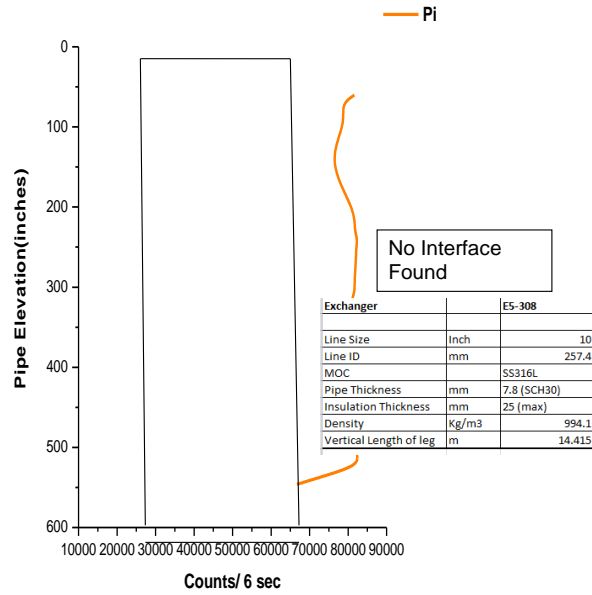| Exchanger		E5-307
Line Size	Inch	10
Line ID	mm	260.4
MOC		Duplex SS
Pipe Thickness	mm	6.35 (SCH20)
Insulation Thickness	mm	25 (max)
Density	Kg/m3	942.1
Vertical Length of leg	m	18.843
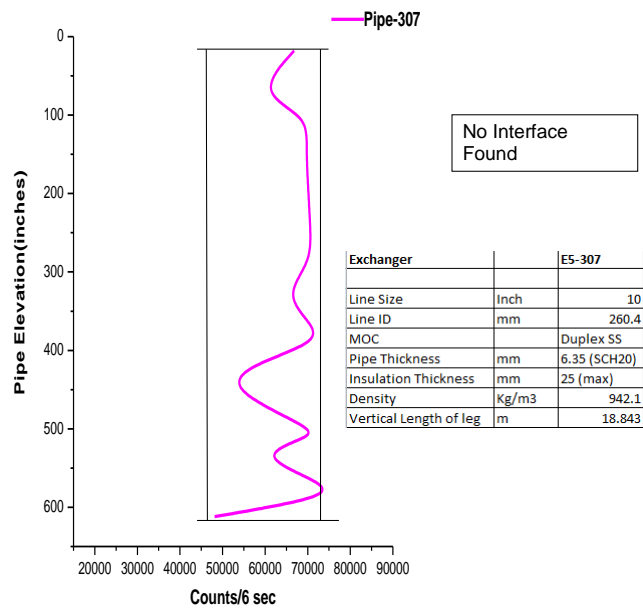
Fig 7: Interface in pipe 307
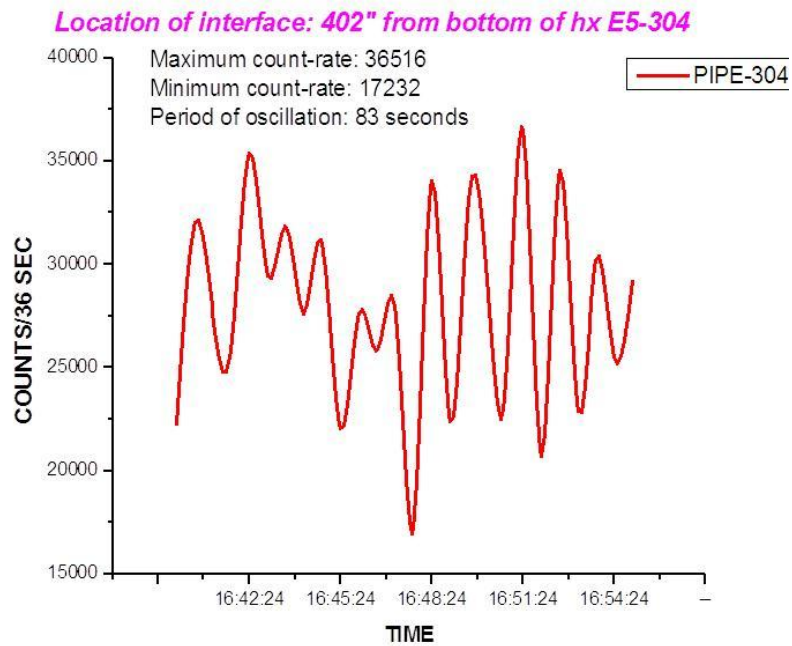
Fig 8: Interface in pipe 308

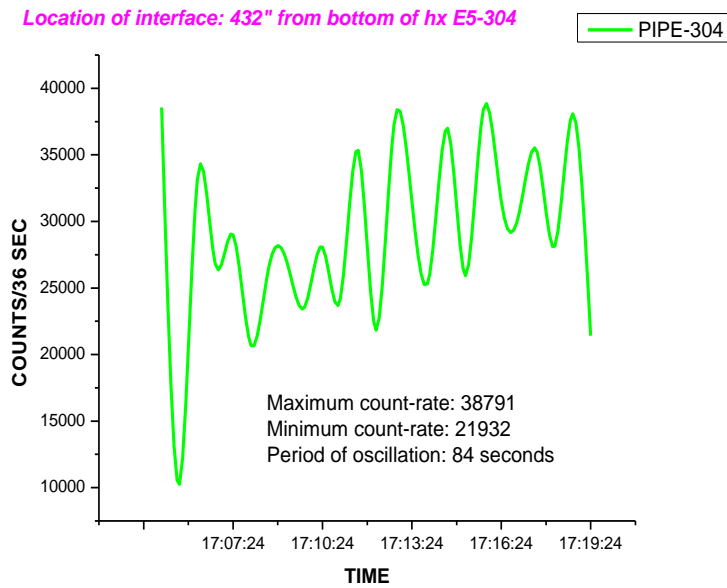Fig 9: Period of oscillation in pipe E5-304:402'' from bottom of HX

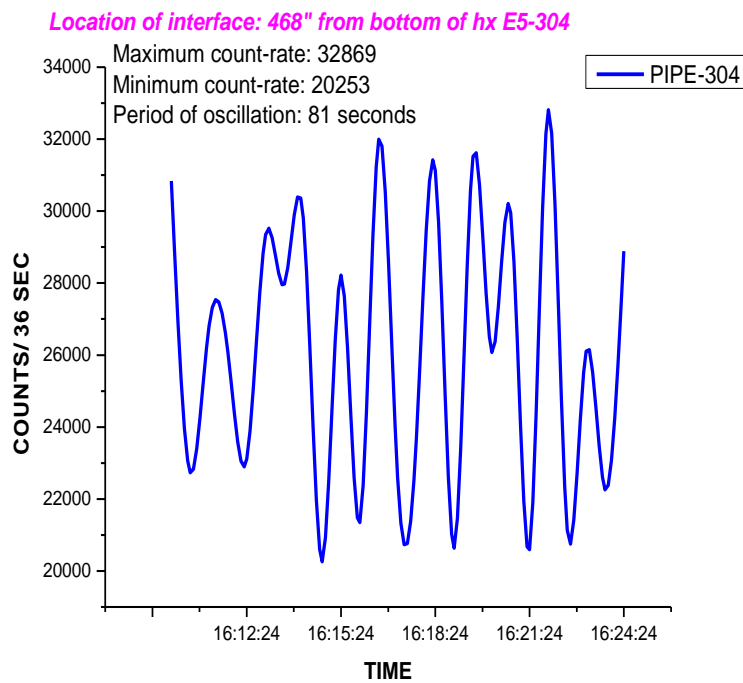**Fig 10: Period of oscillation in pipe E5-304:432'' from bottom of HX**

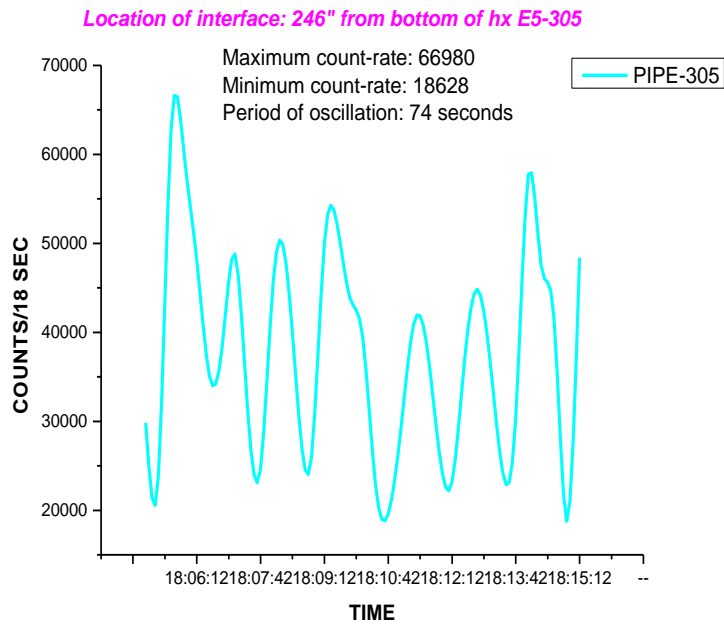**Fig 11: Period of oscillation in pipe E5-304:468'' from bottom of HX**

Location of interface: 246" from bottom of hx E5-305

Maximum count-rate: 66980
Minimum count-rate: 18628
Period of oscillation: 74 seconds

PIPE-305

COUNTS/18 SEC

TIME

18:06:12 18:07:42 18:09:12 18:10:42 18:12:12 18:13:42 18:15:12 --

Fig 12: Period of oscillation in pipe E5-305:246''   from bottom of HX

Location of interface: 258" from bottom of HX E5-306

PIPE-306

COUNTS/ 6 SEC

Maximum count-rate: 67957
Minimum count-rate: 55293
Period of oscillation: Regular oscillations
                        not observed

TIME

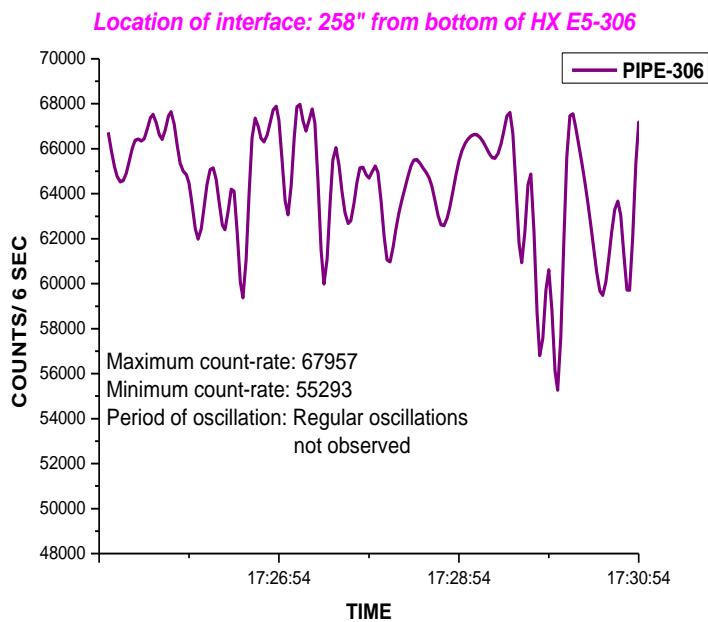17:26:54   17:28:54   17:30:54

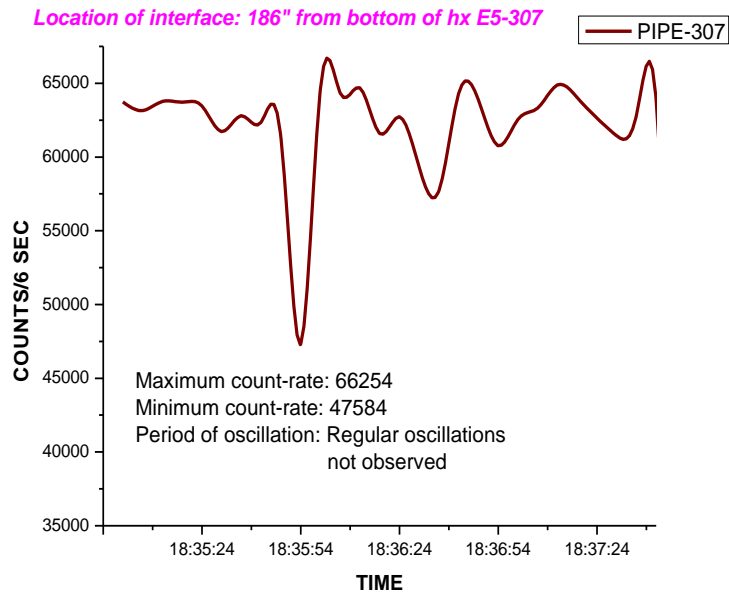**Fig 13: Period of oscillation in pipe E5-306:258'' from bottom of HX**

Fig 14: Period of oscillation in pipe E5-307:186'' from bottom of HX

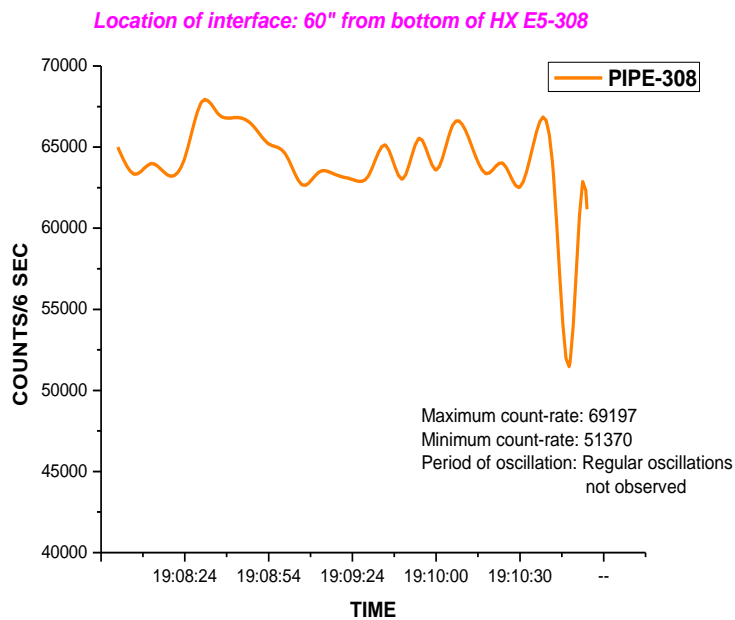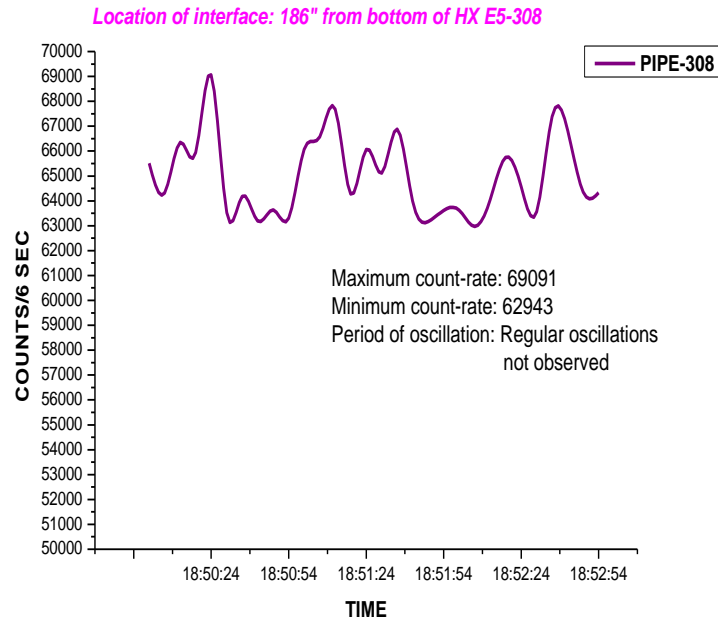**Fig 15: Period of oscillation in pipe E5-308:60'' from bottom of HX**

Location of interface: 186" from bottom of HX E5-308

Maximum count-rate: 69091
Minimum count-rate: 62943
Period of oscillation: Regular oscillations
not observed

Fig 16: Period of oscillation in pipe E5-308:186'' from bottom of HX

	B-2	
	T-JOINT	
	UNINSULATED	
	X	Y
1	10354	11365
2	9875	12079
3	9647	10441
4	9019	8762
5		6328
6		6470
7	7004	7058
8	9190	10948
9	9571	9932
10	9325	9523
11	8962	13250
12	18430	13898
13	12600	17822
14	14272	14423
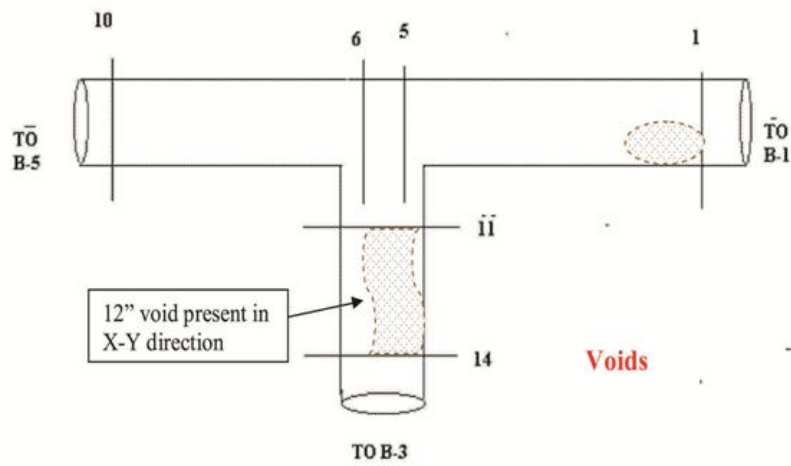
Fig 17: Voids in B-2 T-JOINT

	BEND B-7		
	X	Y	Z
1	31936	42306	54433
2	30758	30973	32500
3	35619	41206	32612
4	30114	43024	31291
5	42301	32283	34250
6	37631	30217	30775
7	35555	30467	23616
8	30215	43480	15808
9	28227	41319	15240
10	19253	20622	18193
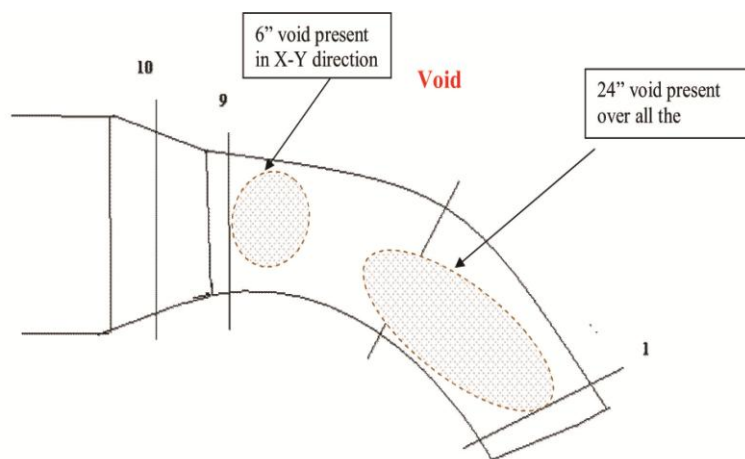
Fig 18: Voids in B-7 BEND

	B-10		
	INSULATED		
	X	Y	Z
1	18933	63052	26983
2	68766	68256	25524
3	29200	32798	66685
4	51798	15835	17674
5	59605	21860	64343
6	48585	UNACCESIBLE	52751
7	20782	UNACCESIBLE	21801
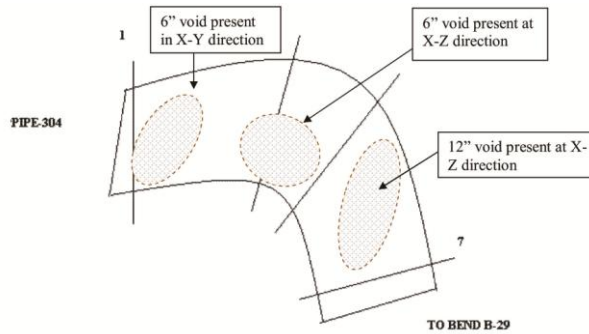
Fig 19: Voids in B-10 BEND

	B-13		
	INSULATED		
	X	Y	Z
1	2653	8136	1325
2	4220	5058	4813
3	1323	1971	1255
4	874	4509	904
5	2832	9927	2011
6	2774	4321	1722
7	6102	1880	1290
8	1733	2878	627
9	1415	4699	479
10	902	7570	989
11	1597	4423	2149
12	2001	1733	2977
13	5663	6180	2534
14	1845	4281	2843
15	1368	2426	1911
16	987	2163	3816
17	2755	3044	4487
18	5096	7181	4863
19	2556	3467	4892
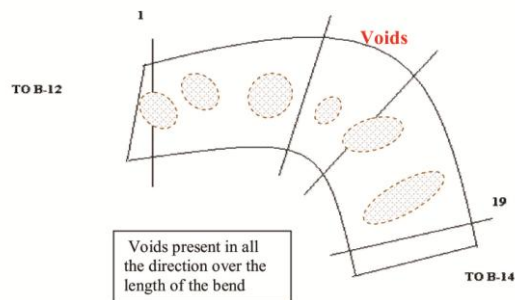
Fig 20: Voids in B-13 BEND

	B-14		
	T-JOINT		
	X	Y	Z
1	14309	3171	1370
2	1075	2203	1782
3	1521		973
4	1536		1355
5	3870	14106	2121
6	6051	10155	1810
7	7225	7416	1965
8	25830	10184	2044
9	27784	25384	28972
10	24368	29581	26499
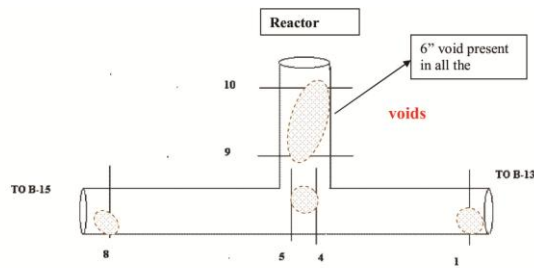
Fig 21: Voids in B-14 T-JOINT

	B-19B		
	BEND		
	X	Y	Z
1	3236	7760	4701
2	4153	6463	4859
3	4440	11653	5260
4	4154	7567	5908
5	4391	6002	6393
6	4830	5358	7790
7	4934	6218	12135
8	4095	11678	7863
9	4250	11013	5449
10	3864	7882	6513
12	4060	8435	4830
13	5411	7984	13343
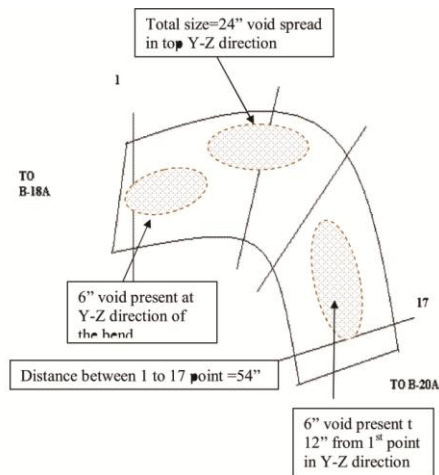
Fig 22: Voids in B-19 B BEND

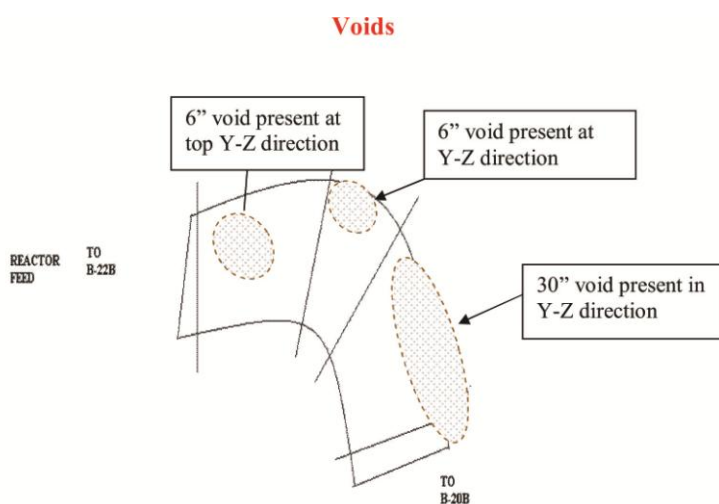|	B-21B		
	BEND(INSULATED)		
	X	Y	Z
1	4355	10928	8557
2	3722	8070	10193
3	4353	8533	6195
4	3661	5809	5764
5	4066	9059	15177
6	3528	5129	7530
7	3609	6836	10992
8	2822	7415	11183
9	1285	6092	11158
10	4168	9695	12433
11	2767	7136	10547
12	1350	6995	11604

Voids

Fig 23: Voids in B-21B BEND