Flotek-g :- “Emission Control in valves and pumps”

Fugitive Emission in Hydrocarbon Processing Units – Limiting at Source for enhanced Safety

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ABSTRACT

The control and reduction of fugitive emission is gaining importance in oil and gas industries as this raises major concerns on health, safety, well being of environment and operation of process plants itself. Being major contributor to the fugitive emission, Process Line Valves -automated or manual ones, need special attention in mitigating the emission to a considerable level.

This paper discusses the fugitive emission through valves based on type, application and operation and its impact on plant environment and safety. This paper brings in a methodology to assess the fugitive emission through published figures of manufactures and standards etc. The methodology to be adopted in applying the right valve technology for process plants in terms of types of valves, construction features like special packing , sealing etc to reduce the emission levels without compromising on the process performance are also discussed.

A study report on reduction in fugitive emission for a typical refinery complex by adopting above mentioned methods is also presented along with Capex involved. The regulations & acts, which are in place in various countries, are analysed and the need for bringing the regulatory measures to the Indian Oil and Gas Sector are also discussed

INTRODUCTION

Fugitive emission is defined as the chemical or mixture of chemicals in any physical form which is emitted from various sources in industrial sites[1] .Emissions of volatile organic compounds such as benzene from oil refineries and chemical plants pose a long term health risk to workers and local communities. In situations where large amounts of flammable liquids and gases are contained under pressure, leaks also increase the risk of fire and explosion.

FUGITVE EMISSION QUANTIFICATION

The U.S. Environmental Protection Agency has devised the Average Emission Factor[3] for emission quantification which is widely applied across the industry. This approach takes into account the physical quantities of equipment/items therefore, the contributions of fugitive emission of each of the items is evaluated from the average emission factor and number of such items. This way the overall fugitive emission quantity is established in any industrial set-up.

Following charts indicate the default emission factor in lbs per source per year for various source types prevalent in Oil & Gas installation sites[3].

The % contribution of valves to emission is 6.3% when compared individually w.r.t. other major emission causing sources. Further, study indicates the emission factors for various valves vis-à-vis the service as under.

Though the average emission of valves as a source is only 6.3%, but when taken into consideration the total number of automated and manual valves, the fugitive emission is a substantial figure. The variation of emission rate is due the constructional feature of valve actuator stem and its movement primarily. Rotary valves like ball and butterfly are having less emission rate compared to linear movement valves like globe.

CASE STUDY

A case study was carried out in one of the recent grass root refinery with multiple process units to find out the extent of contribution of valves to fugitive emission in the refinery complex. The study takes into account all types of valves, viz. mechanical valves, motor operated valves and automated valves.

Automated valve :The following are the counts of automated valves (Control & On Off).

SOURCE TYPE	ORGANIC GASES Emission Factor lbs/source/yr [Kg/Source/Year]
Valves HC gas/vapour	72 [32]
Valves fuel & natural gas	12 [5.5]
Valves light liquid	57 [25]
Valves heavy liquid	4.4 [2]
Inaccessible valves HC gas/vapor	120 [55]
Inaccessible valves light liquid	74 [34]
Pumps light liquid	520 [235]
Pumps heavy liquid	402 [182]
Compressors	2570 [1165]
Others (fittings, hatches, sight-glasses, meters, etc.)	5 [2.25]
PRVs (no rupture disc)	1135 [514]
Process drains	400 [180]

Table 1 **Source EPA 1988**

Type of valve	Factor	Emission Rate (MG/S)
Ball	0.003	0.000015
Butterfly	0.3	0.009
Gate	1	0.03
Globe	1	0.03
Plug	0.3	0.009

Table 2 **Source :- Jalil A et Al, fugitive emission reduction, Elsevier**

Unit	Total valves(approx)	Valves in Gas and Hydrocarbon service(approx)
Crude Distillation block	340	250
Mild Hydrocracker block	220	200
Residual Fluid Catalytic Block	500	300
Gasoline block	125	75
Hydrogen Block	300	230
Motor Spirit block	350	300
Sulfuric Acid/ Alkylation block	200	175
Sulfur block	180	125
Polypropylene block	510	425
Captive power plant	100	25
Offsites and other utilities	325	275
Total	**3158**	**2383**

Table 3

Thus we see that, valves in gas and hydrocarbon service comprises of about 3/4th of the total valves. In the above table majority of the on off valves are ball type, while the majority of control valves are globe type and a few butterfly valves. These automated valves(on off and control) in hydrocarbon services were further subdivided as per the process service-ref Table 4

Process Unit	Valves in Gas and Hydrocarbon service							
	Valves in HC gas/vapor	Emission [ef=72 lbs/source/ year]	Valves in fuel & natural gas	Emission [ef=12 lbs/source/year]	Valves in light liquid	Emission [ef=57 lbs/source/year]	Valves in heavy liquid	Emission [ef=4.4 lbs/source/year]r
Crude Distillation block	39	2808	36	432	146	8332	21	92.4
Mild Hydrocracker block	67	4824	26	312	108	6156		
Residual Fluid Catalytic Block	234	16848	5	60	69	3933		
Gasoline block	44	3168	8	96	17	969		
Hydrogen Block	43	3096	40	480	130	8493		
Sulfuric Acid/ Alkylation block	1	72	1	12	273	15561		
Sulfur block	12	864	6	72	102	5814		
Polypropylene block	40	2880	112	1344	270	14250		
Captive power plant		0	7	84	16	912		

Offsites and other utilities	30	2160	45	540	201	11457	
Total emission		36720		3432		75877	92.4
Grand total emission	**1,16,121.4lbs/year [52672 Kg/year]**						

Table 4 , ef=emission factor

The emission is calculated using *the emission factor method* as outline before. The formula is therefore: Emissions (pounds) = (Number of Sources) x (Average Emission Factor) as defined in Table-4. ***Therefore, from Table-4, the total emission caused by automated valves is 1,16,121.4lbs/year [52672 Kg/year].***

Mechanical (Non automated valve): For the same grass root refinery and petrochemical project, the quantification and classification is done as under

Total mechanical valve (non automated)	60400 Nos.
Total mechanical valves (non automated) in hydrocarbon/process services	50882 Nos.

Table 5

Thus, about 85% comprises of mechanical valves (non automated) in hydrocarbon services. We have categorized these mechanical valves count as per the types and services as under

valve size in inch->	**0.25**	**0.5**	**0.75**	**1**	**1.5**	**2**	**3**	**4**
Gate valve		1066	12456	6201	1959	4316	2028	1617
Globe valve	2	542	2874	1891	663	1080	325	310
Check valve		702	936	952	315	557	380	339
Ball valve		102	250	546	18	440	236	257
Plug Valve		2	47	38	28	140	103	97
Butterfly Valve								2

valve size in inch->	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**24**	**26**	**28**	**30**	**32**
Gate valve	1453	924	638	717	8	439	186	181	119	20	2	16	5
Globe valve	188	136	99	67	2	46	19	14	8	2			
Check valve	462	226	144	166		126	32	28	48	4		7	
Ball valve	130	94	38	39		20	21	0	5				
Plug Valve	17	2	13	12		3	3	5	5				
Butterfly Valve	7	9	14	2		2	2	3	9		2	4	20

valve size in inch->	**38**	**40**	**42**	**48**	**56**	**66**	**72**	**76**
Gate valve	4							
Globe valve								
Check valve		2	2					
Ball valve			2	2	2			
Plug Valve								
Butterfly Valve	19	4	2	6	2	2	2	1

Table 6

From the above table it can be inferred that there are about 85% mechanical valves reside up to 4" size, while a substantial number does exist within the size range of 6"to 12" range.

Barring the check valves, total valves count is 45454. For globe and gate valves the emission factor is same while for butterfly and other types the emission factor is lower as discussed. Since other valve types –ball, plug and butterfly are quantitatively small in number, for estimation purpose it was considered emission factor for these type of valves to be same as globe/ gate valves. The average emission factor for the valves was calculated by taking the average weighted factor of the emission caused by a valve in a particular type of service.

i.e. if N1, N2, N3 ... are the number of valves in Service S1 , S2 , S3 (light hydrocarbon, heavy hydrocarbon etc.).

with emission factor E1, E2, E3 etc., then

Average emission factor for valves = (S1*N1 + S2*N2 + S3*N3 ...) / (N1+ N2+ N3...)

Data from Table-1 is considered for Average emission caused by a valve in a particular service and number of automated valves in the respective service is considered from Table 4. With this information, the average emission factor for automated valves is evaluated as ***54.05 lb/source/year [24.5 kg/source/year]***.

It is considered that the ratio of manual to automated valves remains approximately same irrespective of the service, and therefore, the emission factor for the manual valves shall also be considered to be the same (i.e. 54.05 lb/source/year).

With this information, the average emission caused by the manual valves is estimated to be ***2457102* lbs/year [1114523 Kg/year].**

Motor operated valve: There are about 1090 MOVs there in the grass root refinery and petrochemical project under consideration out of which there are 1048 Nos. in hydrocarbon service. The valve sizes vary from 6" to 56". MOV are normally globe or gate type mechanical valves with motor operated actuator. With an average emission factor of 54.05 lbs/source/year as considered above, these 1048 nos. of MOV can contribute an estimated emission of ***56651* lbs/*year [25696 kg/year]*** of hydrocarbon to the atmosphere.

Total combined emission for automated valve, mechanical valves and MOVs in hydrocarbon service is therefore ***2630000 lbs/year [1192950 Kg/year]*** . Figure 1 below shows the percentage wise contribution of fugitive emission for these three categories of valve.

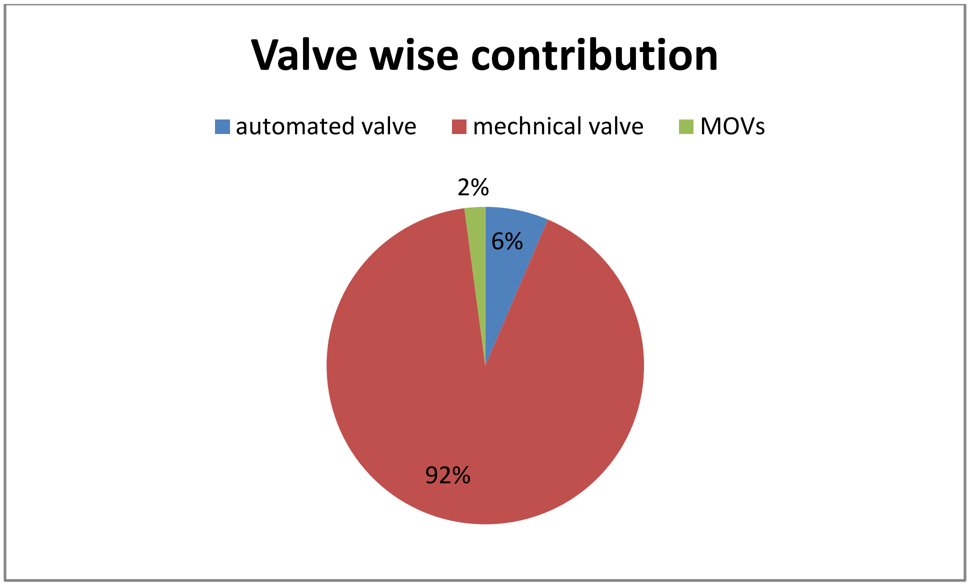

Figure 1

The estimated emission figures as calculated above is a substantial amount going unnoticed almost. Itclearly indicates that there is a need for fugitive emission regulation for Refinery and petrochemical set up.

Valves & Other emission causing sources:

As observed from table-1, there are other major emission causing sources like compressors, pumps, Pressure safety valves etc. present in the refinery complex, the total contribution of such major sources of emission is tabulated as per Table-6.

FUGITIVE EMISSION STANDARDS AND VALVES

For fugitive emission of valves, there are various standard &regulations already in place in the USA and Germany. In the European Union the regulation development is in progress. The major standards are:-

SNO	SOURCE OF EMISSION	QTY.	TOTAL EMISSION Lb/year [Kg/year]	% CONTRIBUTION
1	Safety valve	1350	1206000[547032]	30
2	Pumps (excluding standby)	350	170000[77110]	4
3	Compressors (excluding standby)	35	87000[39462]	2
4	Valves	50000	2630000[1192950]	64

Table 6

1. Clean Air Act -1990 USA
2. FCI 91-1-1997
3. TA LuftVDI 2440-2000
4. EN13555
5. ISO 15848-1-2006 & 15848-2
6. API 622 & API 624.

All of them describes measurement, test and qualification procedures for fugitive emissions at industrial valves. However ISO 15848 is considered as a basis since it is widely followed by valve manufacturers in India and abroad. It defines tightness classes for the fugitive emission type testing of valves Part-1 describes classification system and qualification procedures for type testing of valves. Part 2 is for production test of valves. According to this emission standard, the emission rates for fugitive emission compliant valves are further categorised under 3 classes:-

Class A :- Max. allowable Emission of 10^{-6} mg $s^{-1}m^{-1}$

Class B :- Max. allowable Emission of 10^{-4} mg $s^{-1}m^{-1}$

Class C:- Max. allowable Emission of 10^{-2} mg $s^{-1}m^{-1}$

APPLYING FUGITIVE EMISSION STANDARD

In this case study , it is established that the estimated emission is from valves is ***2.63 million lbs/year[1.2million kg/year].*** However, when the valves are fugitive emission compliant, complying with emission class C as per ISO 15848, which is least stringent , a tremendous reduction in emission quantum of valves to a figure of ***4500 lbs/year[2040 kg/year]*** is observed***.*** This causes a dramatic ***64%*** fall in the overall fugitive emission from the refinery overall complex. In case fugitive emission packing is selected for valves of size 2" and above, we end up with 30% reduction in emission

TECHNOLOGY TO ACHIEVE THE FUGITIVE EMISSION STANDARDS REQUIREMENT

Òver the years, the valve manufacture need to develop/use bellows seal, low emission packing design, including live loaded construction for globe style valve and simple o-ring seals for rotary type valves, specialized flange gaskets such as reinforced expanded graphite gaskets to achieve the leakage rate within the permissible limit. For a quarter turn ball valve, live loaded packing is used alongwith very smooth shaft surface. Further, the valves need to undergo type test as per the one of the adopted standard for certification as low-emission valve.

CAPEX CONSIDERATION

Valves with fugitive emission compliance may have higher expenditure due to type test requirement and technology, use of special packing and design. This may very manufacturer wise. But the cost implication must be justified in terms of the environment and HSE benefits. Emission itself is a substantial amount of material lost by the owner as already established through the case study. ***In terms of cost, application of fugitive emission packing for manual and automated valves leads to 5 to 8 % increase in valve cost*****. If its implication is studied relative to Overall project cost, in a typical refinery complex, the overall valve cost is generally 3% of overall project cost. Therefore, introduction of fugitive emission packing causes an increment of order of 0.2% considering the overall advantages of emission, this will be a viable investment.**

RECOMMENDATION FOR INDIAN REFINERY AND PETROCHEMICAL COMPLEXES

As established in the study, it is prudent to consider all valves with fugitive emission compliance., which will reduce the overall emission to over 60%. However, till industry is tuned to the same, the following recommendations can be adopted, which will reduce the emission by 30%.

1. Automated valves & automated : valve size above 2" shall be fugitive emission compliant
2. MOVs valve size above 6" shall be fugitive emission compliant.

The above consideration is based on the population of valves in these size range, combined with high potentiality of emission as per our case study. Owner can also broaden the range for low emission valve requirement. ISO 15848 standard can be considered due to its increased popularity amongst the valve manufacturers.

CONCLUSION

There are several existing Refineries and Petrochemical complexes in India. More such complexes are being set up newly. A substantial amount of fugitive emission happens through the valves used in such complex which has impacts on the environment, health and safety in the absence of implementation of any Fugitive standard regulation or standard. This can be brought to an acceptable level by a careful consideration for compliance through established international standards. Its time for the Indian oil and gas industry to make conscious strides in checking fugitive emission, thereby reaping benefits of better HSE levels as well as lower hydrocarbon wastage. Since the quantum of valves run in to several thousands in a complex, its time for Indian environment regulators to include emission norms to be applied for valves in India.

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Number of Papers Published in Journals: 1 nos.

1. "Commissioning of package equipment-". *Harbingers of Technological Excellence*, 2016, EIL in-house Journal

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2. "Predictive emission monitoring system (PEMS) for Indian Industry" in ISA Power & Automation meet 2017.
3. "Synthesis of Nano-crystalline NTC-Thermistors through organic and inorganic routes" in ISA Meet, 2014.