https://doi.org/10.36375/prepare_u.iei.a222

Challenges in Design of Positive Isolation System for Large Diameter Gas Piping in Steel Plants

Anirban Datta[1] and Pranab Kumar Bhattacharya[2]

[1]Chief Technology Officer – MESCIA Engineers

[2]Founder – MESCIA Engineers

(FD-217/7, Sector-3, Salt Lake City, Kolkata, West Bengal, India, Pin Code – 700106)

ani_dat@yahoo.co.in

Abstract – In this era of heading to 5 trillion dollar economy, 'Safety' remains prime concern for any industrial establishment; steel plant is no exception. During reduction of iron ore, the blast furnace produces blast furnace gas, having considerable calorific value. The gas, however, is not only poisonous, but has potential to form explosive mixture. Apart from blast furnace gas, there are other hazardous gases such coke oven gas, mixed gas etc. which also run through piping system in steel plants. After utilizing optimum heat value of the gas in various shops/units inside the plant, it is often required to release unused/excess gas through flare system. While maintaining the line pressure, the process calls for extreme safety measures against any hazard. 'Water-seal' is a conventional requirement at the upstream of branch-out connections or flare stack, which avoids any accidental propagation of fire caused by ingress of air from top of the stack, or from any other source of leakage. In addition, 'positive isolation' during maintenance necessitates either U-seal (requiring considerable plant space) or a Goggle Valve (a costlier proposition), in lieu. Designing of the positive isolation for repair/maintenance in large diameter gas piping mains connected to different units/shops/equipment often possess a challenge to the consulting engineer.

This paper articulates on those challenges and focuses on a cost-effective, efficient and innovative safety device for flare stack, which can be called 'Water-Seal-cum-Lock'.

Keywords – *Steel; Gas; Flare; Water-seal; Positive-isolation; Safety.*

INTRODUCTION

Firstly, the recommended/normative basic safety requirements in handling fuel gases such as Blast Furnace Gas (BFG), Coke Oven gas (COG), and LD gas (LDG) & their mixtures (MG) and Liquid Petroleum Gas (LPG) are discussed in this paper. It focuses briefly the precautions to be taken, safety appliances to be available and their use in working with above gas lines to prevent from their main hazards of fire, explosion & gas poisoning, within and outside iron & steel making sector.[1]

HAZARDS OF BY-PRODUCT GASES

Following Table I indicates the hazardous properties of various by-product gases produced/used from/in various shops/units, shown in Safety Code for Iron & Steel Sector, published by Ministry of Steel, Govt. of India, Doc. No: SC/21: [1]

TABLE I

(TITLE: HAZARDS OF BY-PRODUCT GASES)

Limit	BFG	COG	LDG	MG
Toxicity	Highly toxic	Toxic	Extremely toxic	Highly toxic
Flammability	Inflammable	Inflammable	Inflammable	Inflammable
Carbon Monoxide percentage by volume	23 - 27	6 - 10	60 - 70	10 - 60
Explosiveness	Explosive	Explosive	Explosive	Explosive
Lower Explosive Limit (LEL)	35% in air	6% in air	15% in air	10 - 30% Depending on composition
Higher Explosive Limit (HEL)	73.5% in air	31% in air	72% in air	35 - 70% Depending on composition
Identification of gases (by smells)	Odourless	Burning tar Rotten egg or rotten fish	Odourless	Odourless

https://doi.org/10.36375/prepare_u.iei.a222

A. Effect of Carbon Monoxide (CO) on Respiratory System

Carbon monoxide when inhaled along with air is absorbed in blood and reduces the oxygen carrying capacity in blood, and forms carboxy-hemoglobin in place of oxy-hemoglobin, causing body tissues to suffer from anoximia (lack of oxygen), with symptoms such as Headache, Nausea, Vomiting, Feeling of giddiness, difficulty in breathing. [2]

B. Effect of Carbon Monoxide (CO) in Blood

Following Table II indicates the effect of different percentage levels of CO when absorbed in blood, shown in Safety Code for Iron & Steel Sector, published by Ministry of Steel, Govt. of India, Doc. No: SC/21:[1]

https://doi.org/10.36375/prepare_u.iei.a222

TABLE II
(TITLE: EFFECT OF VARIOUS PERCENTAGES OF CO IN BLOOD)

CO percentage in blood	Effects
0 – 10	Shortness of breath on exertion
10 – 20	Increase in shortness of breath and slight headache
20 – 30	Headache is more pronounced, irritable, judgment impaired, vomiting
30 – 40	Becomes confused, faint
40 – 50	Above symptoms are intensified with increased pulse rate respiration
50 – 60	Unconsciousness
60 – 70	Respiration may fail, death may occur

C. Fire and Explosion Hazards

1) Due to presence of leakage in gas piping and presence of ignition source in near vicinity: In case there is any ignition source such as gas cutting/ welding spatters, sparking due electrical short circuit as well as from tools and tackles, or thunder etc. in the vicinity of gas conveying piping/pipeline, and there is any event of leakage through flanged joint(s) of valve(s) or expansion/dismantling joint(s), severe fire and explosion can occur.

2) Spontaneous ignition of coke oven gas (COG):
Sometimes, in a steel plant, spontaneous ignition is experienced in coke oven gas (COG) deposits either on ground or inside piping running on overhead pipe-rack, in the form of white smoke or fire, particularly during shutdowns when COG piping/pipelines are opened for inspection or maintenance. Reason of this is the presence of pyrophoric iron sulfide (PIS), which is formed by the conversion of iron oxide (rust or corrosion deposits) into iron sulfide in an environment which is free from oxygen and/or where hydrogen sulfide gas is present with concentration more than oxygen. PIS, when exposed to the atmospheric air, oxidizes exothermically, resulting in the formation of excessive heat oxidation which can ignite nearby flammable material, substances or fuel-air mixtures.

PREVENTIVE MEASURES & POSITIVE ISOLATION OF GAS MAINS

Fire occurred due to PIS can be avoided by preventing PIS from contacting air, by maintaining a continuous layer of liquid or inert gas between the by-product gas and the air, through following precautionary measures:

a) Always purging the gas piping/pipeline, preferably with nitrogen or steam, before dismantling it for maintenance.
b) Covering the open ends thoroughly immediately after dismantling the pipes, to prevent air ingress inside the pipe.
c) Keeping the deposits inside the pipe submerged in water, if capping of end is not possible.
d) Maintaining a positive pressure inside the pipe, if possible, preferably with nitrogen supply.

Due to the hazardous characteristics/features of by-product gases indicated in Table I, it is an absolute ‘safety-necessity’ to provide a positive isolation in gas piping during shut-down/maintenance.

In steel plants, there are three conventional ways of achieving positive isolation of gas lines:

1. Water Seal (U Seal/ Quick Dump Seal
2. Blanking
3. Goggle Valve

Fig. 1 shows means of positive isolation of gas piping main with both U Seal and Goggle Valve.

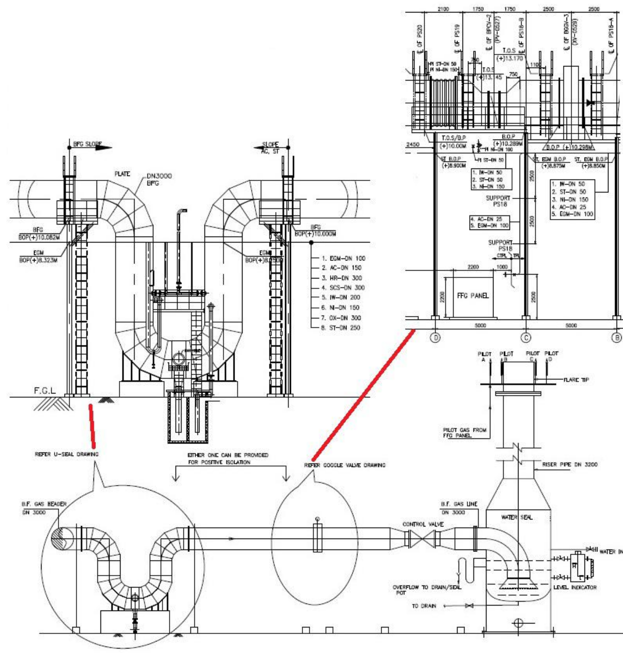

Fig. 1 Positive isolation of gas main with U-seal / Goggle Valve.

https://doi.org/10.36375/prepare_u.iei.a222

Fig. 2 Typical installation of Goggle Valve in gas piping main.

Fig. 3 Typical installation of U Seal in gas piping main.

Isolation with Water Seals

1) Water Sealing (Fig. 4):

a) First, the Gas isolating valve '1' is to be closed.
b) Next, the drain valves '4'& '5' are to be closed and a blank is to be put additionally below the valve '4'.
c) It is to be ensured that there is sufficient water pressure in the water inlet line.
d) Then, water inlet valves '2' and '3' are to be opened.
e) Next, water overflow valve '6' is to be opened.
f) As soon as water starts coming from overflow line, water inlet valve '2' is to be adjusted in order to ensure continuous trickling through water overflow line.
g) Now, water sealing of U Seal is done.
h) From time to time the flow of water trickling from overflow line is to be kept under watch.

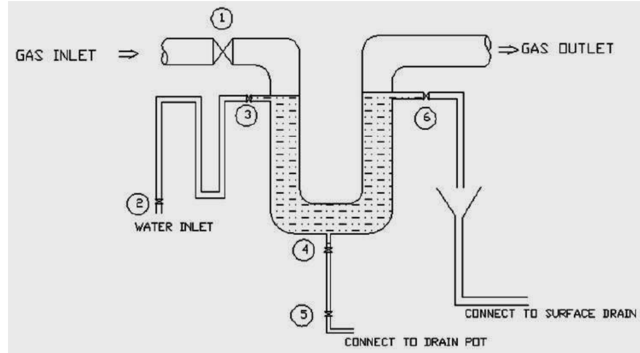

Fig. 4 Scheme of U Seal in gas piping main.[2]

2) Purging of gas line with inert gas (Fig. 5):

a) The gas incoming line valve, if provided, is to be closed.
b) The outlet gas line valve at consumer's side, if provided, is to be closed.
c) Water sealing in incoming line is to be done as per Fig. 4.
d) Water sealing in outlet line (consumer side) is to be done as per Fig. 4.
e) Bleeder/vent valve, just before first isolation device (valve or U seal) of downstream line of all consumers is to be opened, to depressurize the gas line and it is to be ensured that the line is completely depressurized before purging preferably with nitrogen.
f) During purging process, no personnel is to be allowed to stay near the vicinity of end bleeders due to presence of high concentrations of nitrogen.

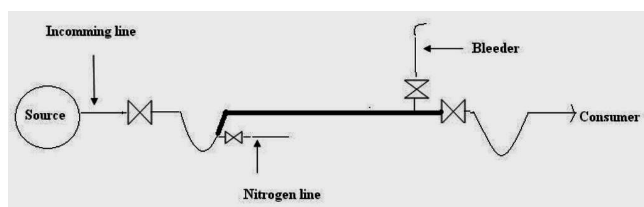

Fig. 5 Purging of gas main with nitrogen.[2]

g) Purging valve nearest to the isolation point is to be opened.
h) Line pressure is to be monitored and controlled by installing a manometer in one of the drip pots. This manometer should not be fixed very near to purge in and vent out point, in order to ensure accurate monitoring. Pressure in the gas line is to be controlled by throttling either purge-in or vent-out valves. Drip pot where manometer is placed must not be used as vent-out for controlling the line pressure.
i) For COG, purging is to be continued till carbon monoxide concentration at bleeder becomes less than 50 ppm. During checking of

https://doi.org/10.36375/prepare_u.iei.a222

carbon monoxide concentration at bleeder, suitable gas mask must be used.
j) When carbon monoxide concentration at bleeder becomes less than 50 ppm, nitrogen purging valve is to be closed. Purging is now over and gas line work to be carried out from outside; however, personnel entry inside gas line must be prohibited still.
k) If any work which require entry of personnel inside the gas line, gas line is to be purged out with air (with suitable mechanical equipment (e.g. portable compressor or exhaust fan) till oxygen level goes above 20%, especially for BFG & LDG lines, as per the stipulations of confined space safety standard.
l) In no case any personnel should enter inside COG line.

2) Water Seal Breaking (after necessary purging of gas line) (Fig. 4):

a) Water inlet valves '2' and '3' are to be closed.
b) As soon as water trickling from overflow line stops, overflow valve '6' is to be closed.
c) The blank below drain valve '4' is to be removed and the drain valves '4'& '5' are to be opened.
d) The gas isolating valve '1' is to be opened.
e) Water seal breaking is now done.

Isolation with Blanking

Following steps are to be followed for isolation of gas piping main with blanking:

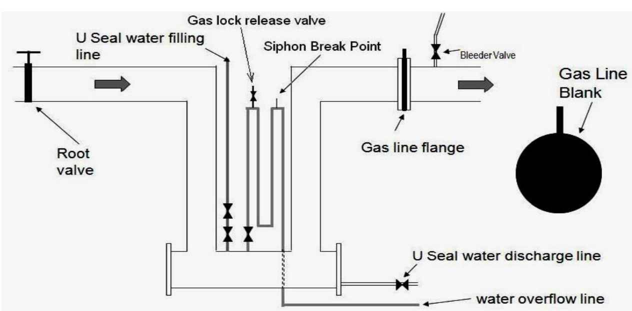

Fig. 6 Purging of gas main with nitrogen.[2]

a) Proper and safe location for inserting the blank in the gas line, preferably with nitrogen flooding arrangement, is to be selected/deigned.
b) Standard scaffolding with suitable platform, toe-guard, railing and proper approach is to be provided for overhead pipework.
c) Suitable gas mask/breathing apparatus (as required) are to be kept at site to meet any emergency situation, such as blower type gas mask. Carbon monoxide detector should be kept near the suction point of the blower during use to ensure that no carbon monoxide is sucked in the blower.
d) Fire tender is to be stationed near the blanking site.
e) Any possible presence of ignition source in the vicinity must be taken care off.
f) Blank of the right size to be kept ready along with gasket/ceramic rope/ring joint.
g) Gas line isolation valve is to be closed after getting clearance from consumer.
h) Water sealing of respective gas line is to be completed and the line is required to be depressurized by opening end bleeder at approachable and safe location.
i) Nitrogen/inert gas purging of gas line must be completed before doing blanking job in order to evacuate the toxic gas from the piping/pipeline.
j) Fasteners are to be opened, but without gas cutting or chiseling.
k) It must be ensured that isolation valves are fully shut-off; the amount of concentration of gas leakage, if any, must be under permissible limit (50 ppm). In case blanking is to done in the event/environment of gas leakage, it must be done by using appropriate gas mask.
l) All persons engaged for blanking/de-blanking job must wear fire-retardant cloth.
m) Non-ferrous tools such as hydraulic flange spreader are to be used for making gap between the flanges.
n) While inserting the blank in the gas main, personnel working in the vicinity must unfasten their safety belt and stand away from the flange joint(s) on the scaffolding platform. This is for ensuring that they can escape away in case of any unwarranted fire hazard.
o) While blanking/de-blanking, sufficient of water must be sprayed over the flange joints.
p) Gasket/rope should be put on both side of the blank.
q) Same precautions are to be followed during removing of blank from gas line.

Isolation with Goggle Valve

Goggle Valve is a positive isolation device, comprising of two components, a solid disc and an expansion joint. Operation of this valve requires that the faces of flanges are be separated by thermo-mechanical or hydraulic means, in order to allow the solid disc to be inserted into the gas stream flowing though conveying piping/pipeline, either manually or by a small electric motor. Once the solid disc

https://doi.org/10.36375/prepare_u.iei.a222

has been inserted into the gas path, the separation means is reversed, which in turn seals up the flange faces.[3]

Safety Arrangement in Flare Stack

Prevention of air ingress in flare system

Typically flare system operates at a low pressure close to atmospheric pressure. This pressure is actually the built-up back pressure due to continuous flared or purged gas flow in flare stack. Pressure at flare stack tip is atmospheric and back-pressure in the clean gas piping is atmospheric pressure plus frictional pressure drop from continuous venting/purging of gas. If flow of gas to flare stack stops for some reason, there is a possibility of air ingress into flare stack and subsequently into the clean gas piping. This can result in an explosive mixture of air and hydrocarbons in the flare network, which would perhaps be catastrophic.

Liquid (water) seal at base of flare stack

Water seal at flare stack base is a cylindrical volume of liquid into which the gas inlet to flare stack is dipped. The ‘seal-height’ is so maintained (depending on network gas pressure) that it just allows the flow of flared gas from inlet pipe to the stack (initially by bubbling through the water, and then by dispersing the water from the inlet pipe level). Water seal does not permit air ingress into the gas inlet pipe. Liquid (water) also helps in extinguishing any fire that would have accidentally travelled up to the bottom of flare stack. This is already a proven arrangement (Fig. 7).

However, in the subject case, this common arrangement has been improvised further with additional safety feature working in tandem, with significant reduction of cost and plant area.

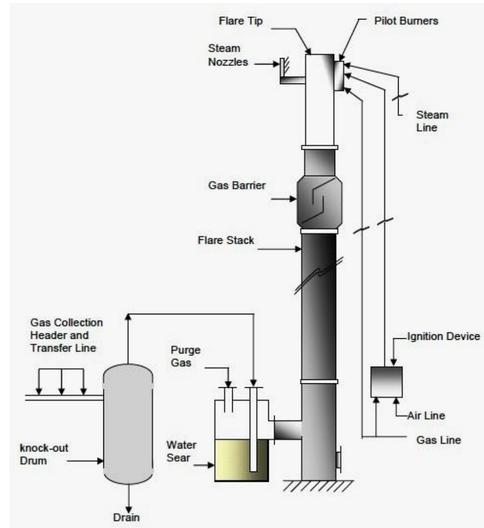

Fig. 7 Common liquid seal arrangement at base of flare stack.

Goggle valves (Fig. 2) are heavy in construction and involve considerable cost, both in procurement and installation, as well. It requires a robust supporting structure and considerably big maintenance platform, with stair/ladder. On the other hand, U seals (Fig. 3) are easier to design, install and operate, and ensuring 100% positive isolation. However, U seals require much larger space, in plant layout, compared to goggle valve.

Table III indicates a comparison between two options.

TABLE III
(Title: Comparison Between Goggle Valve and U-seal)

Sl. No.	Description		Features
1	Goggle Valve	Either of the two is a must technically	• Costly item • Heavy structure
2	U-seal (min seal height shall be ‘500 mm Water Col. plus actual gas pressure’ or ‘2000 mm Water Col.’, whichever is higher)		• Cost comparatively less than goggle valve • More space required

The ‘constraints’ gave rise to an ‘innovation in design’:

- To avoid Goggle Valve (high cost consideration)
- To avoid U-seal (space limitation)
- To offer an alternative ‘positive isolation’ for blast furnace gas
- To retain conventional water seal

https://doi.org/10.36375/prepare_u.iei.a222

To overcome the constraints and satisfy technical/functional requirements, an 'out-of-the-box' solution had been designed and implemented, i.e. to merge conventional 'water seal' (to prevent air ingress and propagation of back fire) with a device (hereafter referred as 'water lock') to provide positive isolation (substitute of goggle valve and/or U-seal).

In this route, following challenges had to be overcome:

1. **Pre-requisite of water seal:** Height of water must be less than 900 mm, so that forward gas can bubble through towards stack, but any possible fire cannot travel backward.
2. **Pre-requisite of water lock:** Height of water not to be less than 2000 mm, which is a technical requirement, in order to prevent/isolate any flow of gas, whenever required.

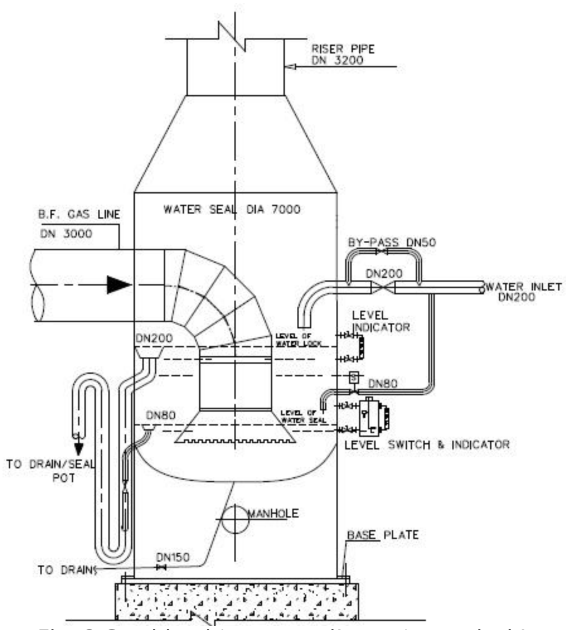

Fig. 8 Combined 'water seal' cum 'water lock' arrangement.

From the above, it is evident that the above requirements are contradictory to each other under normal condition. Hence, the real challenge was to satisfy/incorporate both requirements simultaneously, after incorporating 'extra-ordinary' modifications, as required, in the system.

Features of 'water seal' cum 'water lock'

It is a combined equipment with inner diameter of the order of 7000 mm at the base of flare stack, with provision to maintain either of the two pre-defined levels of water inside the equipment by means of piping and valves:

- Lower level providing 800 mm Water Column, for 'water seal'
- Upper level providing 2000 mm Water Column for 'water lock'

To supply water, there would be a DN 200 water header for the equipment, along with two branches:

- DN 200 supply line for higher level i.e. 'water lock' with a bypass line with isolation valve of DN 50 - to be operated during maintenance period only, to maintain continuous supply of water, yet avoid its wastage during that period.
- Inlet branch line DN 80 with solenoid valve, which will be kept open during normal operation, to maintain the level in 'water seal'

There would be a DN 200 overflow line for the equipment, discharging through drip pot (safety against possible gas leak). This overflow line would consist of isolation valve (manually operated). This valve is to remain open during normal operation of flare System, so that lower level of water is maintained inside the equipment, same functioning as normal 'water seal'. When isolation of the blast furnace gas line would be required, this valve has to be closed to stop the lower level overflow and allow the level to increase (up to the pre-defined level, by means of overflow line), creating and maintaining water level required for 'water lock'. Also, there would be a common drain valve of DN 150 at the bottom, for occasional cleaning of equipment. The material of construction of the seal is carbon steel as per IS 2062 Gr. B with Copper content of 0.25 - 0.35%.

Value Engineering

This proposition reduced the installation cost of the flare system significantly, along with occupying much less plant area. Table IV shows the comparison of costs for different options.

TABLE IV
(Title: Comparison Of Costs for Different Options)

Sl. No.	Description	Estimated Cost (INR Lakhs)	Remarks
1	Perforated gas inlet + base plate + shell with dished end	23.80	
2	Riser pipe and derrick structure	164.80	
3	BF Gas header with platform + 1 no. 4-	4.00	

https://doi.org/10.36375/prepare_u.iei.a222

	legged tower + 1 no. 2-legged trestle		
4	Control valve 1 no.	16.00	
5	Flare tip + Panel + utility piping with valves + cabling	50.00	
6	Civil foundation for flare stack, 4-legged tower & 2-legged trestle	92.16	
	SUB TOTAL	350.76	
7	Goggle valve	100.00	Option-A
	TOTAL – Option-A (Sum of 1 to 7)	450.76	
8	U-seal with pipes & valves	13.20	Option-B
	TOTAL – Option-B (Sum of 1 to 6 plus 8)	363.96	
9	'Water seal' cum 'water lock' with piping, valves, level gauge and extension of perforated gas inlet	2.28	Option-C
	TOTAL – Option-C (Sum of 1 to 6 plus 9)	353.04	

Therefore, proposed arrangement yielded a cost savings of INR 97.72 Lakhs (21.67%) when compared with installation of goggle valve, and INR 10.92 Lakhs (3%) when compared with installation of U-seal. Further, intangible effect of value engineering is even higher (in case of the innovative safety device), if the requirement of lesser plant area is taken into account. However, it is to be noted that cost comparison presented in Table IV above is as of the year 2015, and a 15% – 20% escalation may be considered, if this proposition is to be implemented in any project today.

CONCLUSION

In upcoming and future steel plants in India and abroad, this integrated 'water seal' cum 'water lock' arrangement can open a new horizon in plant and process safety.

ACKNOWLEDGMENT

The authors sincerely acknowledge the guidance and support provided by Mr. Subrata Chatterjee, Former Deputy General Manager, Fluid System & Piping Department, MECON Limited, and Mrs. Oindrila Dey Mukherjee, Lead Engineer – Inline Component & Piping, GE India.

REFERENCES

[1] Safety Code for Iron & Steel Sector, *Handling Fuel Gas, Doc. No: SC/21*, Ministry of Steel, Govt. of India, pp. 1

[2] Inter Plant Standard – Steel Industry, *Safety Standard for Working on Gas Lines in Steel Industry*, Steel Authority of India, pp. 1, 2, 3, 7, 8, 9, 10

[3] Safety and Industrial Hygiene Safety Standard Practices, *Isolation, Purging, and Re-Introduction of Gas Safety Standard Practices*, pp. 20