Industrial Human Error Analysis for Safely Handling the Oxygen Pipeline

Habis K. Siddiqui1, T. Karthikeyan2, B. Surender3, Dr. S.P. Venkatesan4, J. Senthil kumar5

PG Scholar1, Assistant Professor2,3,5, Professor4

Department Mechanical Engineering (M.E Industrial Safety Engineering)
Excel College of Engineering and Technology, Komarapalayam, Tamil Nadu, India

Abstract:
Oxygen is the only gas which can be ignited instantly than any other gases and chemicals. In steel using Industries, pressurized Oxygen gas plays a dominant role in heating and carburization processes. The gas is supplied through pipeline and the gas production unit is located outside the firm. Commonly in industries, safety measures provided to oxygen handling is less when compared to LPG pipeline and the same condition prevails in this firm. But oxygen is highly flammable (than any other chemicals) and may trigger huge explosion if catches fire. In this case, human error contributes a huge part in the probability of occurrence of accident and so this project deals with the human errors which may trigger a catastrophic incident/accident. Human Error Analysis technique has been used in this project in which each and every procedure during oxygen handling is taken into consideration to identify every deviations involved. Improvement has been done in the Safe Operating Procedure (SOP) in this project using the results of HEA with the current SOP.

1. INTRODUCTION
The safe design and operation of an oxygen transmission pipeline or piping system depends on various factors that can influence each other. The oxygen hazard can be effectively illustrated through the fire triangle, which shows that three main elements are required for a fire to occur an oxidizer, a fuel, and an ignition source. In an oxygen system, oxygen itself is the oxidizer and the system fire hazard increases with increasing concentration, pressure, temperature, and flow rate. The fuels in an oxygen system are the materials of construction (metals, non-metals, and lubricants) or potential contaminants like particulates, oils or greases. The ignition sources common to oxygen systems include particle impact, compression heating, frictional heating etc.

1.1 SAFE OPERATING PROCEDURE
Safe Operating Procedure (SOP) are generally written methods outlining how to perform a task with minimum risk to people, equipment, materials, environment, and processes. SOP are a series of specific steps that guide a worker through a task from start to finish in a chronological order. SOP are designed to reduce the risk by minimizing potential exposure. SOP should be developed as a result of completing a Hazard Assessment and should closely reflect the activities most common in the company’s type or sector of construction. All safe work practices should be kept in a location central to the work being performed and readily available to the workforce. Some safe work practices will require specific job procedures, which clearly set out in a chronological order each step in a process.

1.2 APPLICATIONS OF OXYGEN USAGE IN STEEL
Basically, in steel production industries Oxygen is consumed in vast amount for two processes and are as follows

ELECTRIC ARC FURNACE
In EAF, Oxygen is used for two processes (melting and refining)

MELTING
The melting period is the heart of EAF operations. The EAF has evolved into a highly efficient melting apparatus and modern designs are focused on maximizing the melting capacity of the EAF. Melting is accomplished by supplying energy to the furnace interior. This energy can be electrical or chemical. Electrical energy is supplied via the graphite electrodes and is usually the largest contributor in melting operations. Initially, an intermediate voltage tap is selected until the electrodes bore into the scrap. Usually, light scrap is placed on top of the charge to accelerate bore- in. Approximately 15 % of the scrap is melted during the initial bore-in period. After a few minutes, the electrodes will have penetrated the scrap sufficiently so that a long arc (high voltage) tap can be used without fear of radiation damage to the roof. The long arc maximizes the transfer of power to the scrap and a liquid pool of metal will form in the furnace hearth at the start of melting the arc is erratic and unstable. Wide swings in current are observed accompanied by rapid movement of the electrodes. As the furnace atmosphere heats up the arc stabilizes and once the molten pool is formed, the arc becomes quite stable and the average power input increases. Chemical energy is be supplied via several sources including oxy-fuel burners and oxygen lances. Oxy-fuel burner’s burn natural gas using oxygen or a blend of oxygen and air. Heat is transferred to the scrap by flame radiation and convection by the hot products of combustion. Heat is transferred within the scrap by conduction. Large pieces of scrap take longer to melt into the bath than smaller pieces. In some operations, oxygen is injected via a consumable pipe lance to "cut" the scrap. The oxygen reacts with the hot scrap and burns iron to produce intense heat for cutting the scrap. Once a molten pool of steel is generated in the furnace, oxygen can be lanced directly into the bath. This oxygen will react with several components in the bath including, aluminum, silicon, manganese, phosphorus, carbon and iron. All of these reactions are exothermic (i.e. they generate heat) and supply additional energy to aid in the melting of the scrap. The metallic oxides that are formed will end up in the slag. The reaction of oxygen with carbon in the bath produces carbon monoxide, which either burns in the furnace if there is sufficient oxygen, and/or is exhausted through the direct evacuation system where it is burned and conveyed to the pollution control system. Auxiliary fuel
Refining operations in the electric arc furnace have traditionally involved the removal of phosphorus, sulfur, aluminum, silicon, manganese and carbon from the steel. In recent times, dissolved gases, especially hydrogen and nitrogen, have been recognized as a concern. Traditionally, refining operations were carried out following meltdown i.e. once a flat bath was achieved. These refining reactions are all dependent on the availability of oxygen. Oxygen was lanced at the end of meltdown to lower the bath carbon content to the desired level for tapping. Most of the compounds which are to be removed during refining have a higher affinity for oxygen than the carbon. Thus the oxygen will preferentially react with these elements to form oxides which float out of the steel and into the slag. In modern EAF operations, especially those operating with a "hot heel" of molten steel and slag retained from the prior heat, oxygen may be blown into the bath throughout most of the heat. As a result, some of the melting and refining operations occur simultaneously.

3. COMPANY PROFILE

SVS EQUIPMENTS Pvt Ltd. engages in the manufacturing and supply of sheet metal components. The company manufactures body parts for in addition to manufacturing Air dryers, water chillers, filters, auto drain valves, heatless hryer, frames, cross member links, and joints for chassis and suspension components for passenger car systems. SVS Auto company was originally set up in the year 2016, mainly to manufacture dryers, and chillers at Coimbatore.

In the year 2017 the Company established a Press Shop for manufacturing of Sheet Metal Components and Welded Sub-assemblies to meet the growing stringent quality requirements of automobile industry. The company went for its first public issue in March, 2018.

Auto is svs Group Company, SVS Group created a new meaning for excellence in manufacturing of Sheet Metal Parts and Welded Assemblies, Exhaust Systems, Axles, High Tensile Fasteners, Tubes, Special Purpose Vehicles and Waste Management Services.

The Group has embraced international systems and processes, implementing them at all levels, in every unit, and across all parameters. This has resulted in prestigious certifications from global institutions. The Group companies have consistently met and surpassed world-class standards, while accumulating a wealth of knowledge and expertise in the industry.

3. OXYGEN PIPELINE

3.1 PIPING SYSTEMS

Above-ground oxygen piping systems should follow good mechanical design practices as applied to any other above-ground piping system. Above-ground carbon steel piping should be painted to an approved specification to protect against atmospheric corrosion. Above-ground portions of pipeline systems should connect to underground portions through an electrically insulated joint to isolate the underground cathodic protection system. All above ground pipelines shall have electrical continuity across all connections, except insulating joints (could be either flanges or monobloc) and shall be earthed at suitable intervals to protect against the effects of lightning and static electricity. The electrical resistance to earth of the installed aboveground piping system should not exceed 10 Ohms for lightning protection. Flange bolting will provide the necessary electrical bond provided the bolts are not coated with a dielectric material or paint and are well maintained to avoid rust. In the case of short above ground sections, where insulating flanges are not used, the pipe should be insulated from the support structure by means of an isolating pad. Above-ground piping should be routed as far away as practical from other lines and process equipment containing fluids that are hazardous in an oxygen environment. If located in a multi-line pipe-rack, the mechanical joints in the oxygen line should not be located close to the mechanical joints in other fluid lines where hazardous mixtures could result if simultaneous leaks or failures occurred. Consideration should be given to protecting other fluid lines opposite mechanical joints in oxygen lines from fire. Oxygen lines should not be exposed unnecessarily to external forces that can cause a failure or dangerous situation such as external impingement from hot gas or steam vents, vibration from external sources, leaking oil dripping onto the line, etc.

3.2 PIPING AND FITTINGS

Impingement Sites

Impingement occurs when the flow stream changes direction abruptly or when the presence of eddies leads to the impact of particles with the system walls. Pipe impingement sites include, but are not limited to, the following

- Tees, both butt weld and socket-weld and socket weld elbows
- Branch connections such as fabricated branches, weldolets, sockolets, and thread lets
- Multiple-hole diffusers and surrounding body
- Short-radius elbows (radius of curvature < 1.5 d)
- Socket-weld and threaded reducers
- Reducers (eccentric and concentric) with greater than 3:1 inlet to outlet reduction section ratio (for flow from large to small)
- Mitered elbows (mitered cut angle more than 20°) Piping downstream of a pressure let-down valve up to a length of 8 pipe diameters (pipe diameters can be based on valve outlet size).

Non-impingement

- sites include but are not limited to the following
  - straight piping runs;
  - butt-weld tees, with long (or smooth) crotch radius (for flow from main to branch);
  - long radius diameter elbows (equal or greater than 1.5 diameter);
  - 90-degree mitered elbows made of 6 pieces (5 welds) as well as 45-degree mitered elbows made of 3 pieces (2 welds), providing that all internal surfaces are ground smooth

IJESC, June 2021

http://ijesc.org/
• Eccentric and concentric reducers with a maximum 3 to 1 reduction ratio.
• Specific Piping Locations

Bypass piping
Selection of piping material on the inlet and outlet of the bypass valve, shall be given special consideration since this piping is often exposed to both high velocities and turbulent flow during pressurization. Bypass piping upstream of the bypass valve is defined as a non-impingement site. The possibility of bi-directional flow shall be considered. Thus, exempt materials are recommended downstream of the bypass valve, and for the entire bypass piping system if bidirectional flow is possible.

PIPING UPSTREAM OF VENTS AND BLEEDS
Branch piping upstream of vent and bleed valves and any system isolation bleed valves (i.e., between isolation valves) should be designed as bypass piping.

INLET PIPING TO PRESSURE RELIEF VALVES
The material selection of inlet piping to a PRV shall be based on the relief valve set pressure and the maximum flow capacity of the relief valve.

PIPING DOWNSTREAM OF VENT VALVES AND PRESSURE RELIEF VALVES
Associated vent piping material selection shall be based on the impingement velocity curve. Corrosion-resistant material is commonly used for vent lines since the pipe is open to atmosphere and invites condensation with daily temperature fluctuations. Carbon steel piping may be used for vent piping when the venting is controlled to avoid turbulence immediately downstream the vent valve. However, exempt materials may provide both corrosion resistance and combustion resistance. Pressure relief valves should be located in the open air so that they discharge in a safe area. If they are unavoidably located inside buildings or enclosures, the vent piping shall discharge outside. Consideration shall be given to the location of the vent outlet, height, direction, adequate spacing, etc. in order to minimize risks due to oxygen-enriched atmosphere in the surroundings.

PIPING DOWNSTREAM OF PRESSURE LET-DOWN SITES
The piping downstream of a pressure let-down valve (throttling or process control valve) experiences high velocity and highly turbulent gas flow. The pipe wall downstream of a throttling or process control valve is considered an impingement eddy site for a distance equivalent to a minimum of 8 pipe diameters where pipe diameters is based on the valve outlet size. Particles in the eddy flow regime impinge on pipe walls at a greater velocity than determined by the gas flow calculations. Because of the eddy flow particle velocity, exempt materials should be considered for the piping in the eddy site zone.

GASKETS
Gaskets of an oxygen-compatible material shall be sized and installed to match the internal diameter of the pipe thereby eliminating a space where particles can accumulate. Gaskets should be full face so they can be positioned concentrically in a flange joint and thereby eliminate any protrusion of the gasket in the flow. Spiral wound gaskets shall be manufactured such that they are clean for oxygen service. Spiral wound gaskets shall have inner rings to prevent inner radial buckling of the windings.

THREAD SEALANTS
The oxygen user shall confirm that the thread sealant material is compatible for oxygen service at the maximum service pressure and temperature. PTFE products (tape) can be used according to their specifications including cleanliness in order to ensure compatibility with oxygen service. Minimal amounts of thread sealant should be applied to prevent extrusion out of the joint. Provisions shall be made to prevent contamination of open containers of thread sealant.

4. HUMAN ERROR ANALYSIS
The application of human error analysis (HEA) techniques is to predict possible errors that may occur in a task. The next stage of error analysis is to identify error recovery possibilities implicit within the task, and to specify possible remedial strategies to eliminate the causes of errors or to enhance their likelihood of recovery before the consequences occur. The consequences of possible unrecovered errors are also often considered error analysis. The requirements for error analysis techniques are therefore as follows

• Provide assistance to the analyst in exhaustively identifying possible errors.
• Identify error recovery opportunities.
• Develop error reduction strategies (ERS).
• Consider the consequences of possible errors for risk assessment or for cost-benefit analysis when considering alternative ERS.

There are a wide range of potential applications of HEA techniques. In a process plant, the various operating modes include normal operating conditions, maintenance, plant disturbances and emergencies. After carrying out a task analysis to define the worker’s role in these areas, error analysis can be used to identify possible human failures with significant consequences and to specify appropriate hardware procedures, training, and other aspects of design to prevent their occurrence. The other main application area for predictive error analysis is in chemical process quantitative risk assessment (CPQRA) as a means of identifying human errors with significant risk consequences. In most cases, the generation of error modes in CPQRA is a somewhat unsystematic process, since it only considers errors that involve the failure to perform some pre-specified function, usually in an emergency (e.g., responding to an alarm within a time interval). The fact that errors of commission can arise as a result of diagnostic failures, or that poor interface design or procedures can also induce errors is rarely considered as part of CPQRA. However, this may be due to the fact that HEA techniques are not widely known in the chemical industry.

5. RESULT AND DISCUSSION
From the Human Error Analysis conducted, it was able to identify each and every human error that could possibly occur in every task. Based on the calculated human error probabilities and error identification the following suggestions was provided in the SOP.

• A sign board shall be placed where maintenance work is carried out.
• The work area shall be prevented from unauthorized entry and a security guard shall be placed.
• There should not be any vehicles, compressors, motors, electrical and electronic devices, ignition sources and overhead lines in the maintenance area and the IC should see to it
• I/C shall verify the work permit of the service personnel.
• A tool box meeting shall be conducted by I/C.
• The maintenance work shall be completely supervised by the I/C’s
• The work section shall be completely disconnected from the pipeline.
• Blind valves shall be installed at both the ends to close the openings.
• Mechanical locking/closure is done by using double block and bleed valve.
• Tags shall be placed to indicate that equipment has been locked in the shut-off position.
• Oxygen concentration shall be monitored continuously by using portable O2 analyser.
• Then, the maintenance work (welding/cutting) is carried out.
• After the work is completed, the working section is kept untouched for 3 hours.
• The mechanical locking is dismantled.
• The blind valves are removed.
• The section is connected with the pipeline.

6. CONCLUSION

From the Human Error Analysis conducted, it is understood that human error plays a dominant role in the probability of occurrence of accident and the hazards involved in oxygen pipeline are under-estimated by the employees as well as management. The checklist collected clearly portrays that there are lags in fire fighting methods, safety measures, SOP and employees training in case of oxygen pipeline and handling. In that critical environment, the probability of occurrence of human error is very high but the probability of occurrence of human error can be reduced drastically if the lags in SOP are rectified. Hence, based upon the analysis, suggestions are provided in this project for the improvement of SOP which is discussed in the results. In addition, a new SOP is formulated for maintenance of oxygen pipeline which is currently not available in the industry and this formulation was done based upon the references from various standards. In future, this maintenance SOP may be helpful while carrying out maintenance in oxygen pipeline.

7. REFERENCE


