Safety Assessment @ Foundry
Coimbatore

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This report is prepared by WISE Management Systems to APITCO under the project “Occupational Health Safety Assessment for Foundries”.

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1 INTRODUCTION

WISE Management Systems performed walk through systems audit on occupational safety and health in foundries in and around Coimbatore clusters. Sincere thanks and appreciation goes to APITCO for arranging visits / audits at short notice and informing companies about the intent and scope of audit. The audit was planned and executed in stages (refer to the attached list in annexure II for additional details).

1.1 FOUNDRY PROCESS IN COIMBATORE

Foundries around Coimbatore produce mainly ferrous metal and spheroidal graphite castings. Ferrous castings are comprised of iron and steel. Ferrous castings typically include:

- Grey cast iron, with good damping and machinability characteristics, but lower durability;
- Malleable cast iron, containing small amounts of carbon, silicon, manganese, phosphorus, sulfur and metal alloys;
- Spheroidal graphite cast iron (SG), obtained by removing the sulfur from the melt of cast iron;
- Cast carbon steel (low-medium-high), with superior strength, ductility, heat resistance, and weldability compared to iron casting.

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2 THE FOUNDRY PROCESS

Many different casting techniques are available. All involve the construction of a container (mold) into which molten metal is poured.

Two basic casting process subgroups are based on **expendable** and **non-expendable mold** casting. Expendable mold casting, typical to ferrous foundries although also used in non-ferrous casting, uses lost molds (e.g. sand molding). Non-expendable mold casting, adopted mainly in non-ferrous foundries, uses permanent molds (e.g. die-casting). Lost molds are separated from the casting and destroyed during the shakeout phase, while permanent molds are reused.

A variety of techniques are used within these two mold casting processes depending on the melting, molding and core-making systems, the casting system, and finishing techniques applied.

Foundry process as outlined in Annexure -.1, includes the following major activities:

→ Melting and metal treatment in the melting shop

→ Preparation of molds and cores in the molding shop

→ Casting of molten metal into the mold

→ Cooling for solidification

→ Removing the casting from the mold in the casting shop

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→ Finishing of raw casting in the finishing shop.

Melting Shop

Different types of melting furnaces and metal treatments are used to produce ferrous and non-ferrous materials depending on the type of metal involved. Cast iron is typically melted in cupola furnaces, induction furnaces (IF). Use of induction furnaces (coreless induction-type furnace for melting and channel induction-type for holding) is preferred over cupola furnaces due to their superior environmental performance.

Cast steel is typically melted in electric arc furnaces or coreless induction furnaces. Cast steel metal treatment consists of refining (e.g. removal of carbon, silicon, sulfur and or phosphorous) and deoxidization depending on the charge metal and required quality of the casting product.

Melted metal may require treatments such as desulfurization, and de-slagging. To remove impurities in the melt, metal flux is added to the furnace charge or to the molten metal. Flux unites with impurities to form dross or slag which is removed before pouring.

Cupola Furnaces

The cupola furnace is the common furnace used for cast iron melting and the oldest type of furnace used in foundries. 7 out of 10 foundries visited for this safety audit were found to be using cupola furnaces. It is a cylindrical shaft type furnace lined with refractory material. The furnace uses coke as a fuel and combustion air. Molten iron flows down the cupola furnace while combustion gases move upward leaving the furnace through its stack. As melting proceeds, new material is added at the top of the shaft through a charging door. Added flux combines with non-metallic impurities in the iron to form slag, which is lighter than molten iron and floats on the top of the

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molten metal protecting it from oxidation. The liquid metal is tapped through a tap-hole at the level of the sand bed and collected into a ladle and / or a holding furnace. The slag is removed through a hole at higher level.

Coke accounts for 8–16 percent of the total charge to provide the heat needed to melt the metal. Melting capacities of cupola furnaces generally range from 3 to 25 metric tons per hour.

Cupola furnaces require a reducing atmosphere to prevent oxidation of the iron as it is melted. Oxidization is minimized by assuring the presence of carbon monoxide (CO) in the combustion gas (about 11-14 percent CO content). This results in inefficient use of the available energy in the coke, and significant CO emissions to the environment.

Alternative technologies can be used to increase the efficiency of the cupola furnace and reduce CO emissions. These include preheating combustion air up to 600°C as performed in the Hot Blast Cupola20; oxygen enrichment; or supersonic direct injection of pure oxygen.

The cupola process also produces a significant amount of particulate emissions. Emission control systems typically require use of high energy wet scrubbers or dry bag house (fabric filter) systems.

Induction Furnaces

Induction furnaces (IF) are used for melting ferrous and nonferrous metals. Melting is achieved through a strong magnetic field created by passing an alternating electric current through a coil wrapped around the furnace and consequently creating an electric current through the metal. The electric resistance of the metal produces heat, which melts the metal itself. These furnaces provide excellent metallurgical control and are relatively pollution free.

The most significant air emissions released by IFs relate to the charge cleanliness resulting in the emission of dust and fumes (organic or metallic). Other emissions result from chemical reactions during holding or adjusting the metal composition, which originate metallurgical fumes.

Molding Shop

Before metal casting can take place, a mold is created into which the molten metal is poured and cooled. The mold normally consists of a top and bottom form, containing the cavity into which molten metal is poured to produce a casting. To obtain tunnels or holes in the finished mold (or to shape the interior of the casting or that part of the casting that cannot be shaped by the pattern) a sand or metal insert called a “core” is placed inside. The materials used to make the molds depend on the type of metal being cast, the desired shape of the final product, and the casting technique. Molds can be classified in two broad types:

Lost molds (single use molds): 1 out of 10 foundries visited in Coimbatore use this method for shell molding. These are specially made for each casting and are destroyed in the shake-out process. These molds are generally made of sand and are clay-bonded, chemically bonded, or sometimes unbonded. Investment casting (lost wax) can also be included in this family;

Permanent molds (multi-use molds): These are used for gravity and low-pressure casting, high pressure diecasting, and centrifugal casting. Typically, permanent molds are metallic.

Sand is the most common molding material used. Sand grains are bonded together to form the desired shape. The choice of binder technology used depends on factors such as the casting size, the type of sand used, the production rate, the metal poured, and the shakeout properties. In general, the various binding systems can be classified as either clay-bonded sand (green sand) or chemically-bonded sand. The differences in binding systems can have an impact on the amount and toxicity of wastes generated and potential environmental emissions.

Green sand, which is a mixture of sand, clay, carbonaceous material, and water, is used as a mold in 85 percent of foundries. The sand provides the structure for the mold, the clay binds the sand together, and the carbonaceous materials prevent rust. Water is used to activate the clay. The mold must be dry otherwise it may present a risk of explosion. Green sand is not used to form cores, which require different physical characteristic than mold. Cores should be strong enough to withstand the molten metal and collapsible so they can be removed from the metal piece after cooling. Cores are typically obtained from silica sand and strong chemical binders placed in a core box. The hardening or curing of the chemical binding system is obtained through chemical or catalytic reactions, or by heat. Sand cores and chemically-bonded sand molds are often treated with water-based or spirit-based blacking to improve surface characteristics.

The advantages to using chemically bonded molds over green sand molds include a longer storage life for the molds; a potentially lower metal pouring temperature; and better dimensional stability, and surface finish to the molds.

Disadvantages include higher costs of chemical binders and energy used in the process; added complexity to reclaim used sand; and environmental and worker safety concerns related to air emissions associated with binding chemicals during curing and metal pouring.

Sand molding – 9 out of 10 foundries visited in Coimbatore involves the use of large volumes of sand, with sand-to-liquid metal weight ratios generally ranging from 1:1 to 20:1. After the solidification process, the mold is broken away from the metal piece in a process called "shake-out" whereby the sand mold is shaken from the metal parts. Most

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of the used sand from green sand molds is reused to make future molds. Reused sand mixtures are also often used to create cores.

However, a portion of sand becomes spent after a number of uses and needs to be disposed of. For this reason, mold and core making are a large source of foundry waste.

Investment casting, (1 out of 10 foundries visited uses this method) also known as the lost wax process, is used to make parts with complex shapes or for high-precision metal castings. An investment mold is obtained by pouring, around (investing) a wax or thermoplastic pattern, a slurry which conforms to the pattern shape and subsequently sets to form the investment mold. After the mold has dried, the pattern is burned or melted out of the mold cavity and the mold is ready to be utilized.

Casting Shop

Pouring the melted metal is the most significant activity in the casting process. Different pouring systems are used depending on the mold and metal type used for casting.

Correct introduction and distribution of poured metal into the mold are provided by a set of columns and channels inside the mold (a “runner system” or “gatting system”). The shrinkage (the difference in volume between liquid and solid metal) is compensated by the presence of an adequate feeder reservoir (a “riser”).

After pouring, the casting is cooled to allow for solidification (first cooling) and it is then removed from the mold for further controlled cooling (second cooling). In sand casting foundries, sand castings enter the shakeout process to remove the mold after solidification. During shake-out, dust and smoke are collected by dust-control equipment. Investment molds and shell molds are destroyed during removal, creating solid waste.

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Since various additives are used in the manufacture of the molds and cores to bind the sand during metal pouring activities, reaction and decomposition products are generated. These include organic and inorganic compounds (amines and VOC).

The generation of decomposition products (mainly VOC) continues during the casting, cooling, and removing operations. Since these products may cause health and odour hazards, they should be extracted and the gas cleaned prior to release.

Finishing Shop

All remaining operations necessary to yield a finished product are conducted in the finishing shop. Depending on the process used, different steps may be required such as removal of the running and gatting system, removal of residual molding sand from the surface and core remains in the casting cavities, removal of pouring burrs, repair of casting errors, and preparation of the casting for mechanical post-treatment, assembly, thermal treatment, and coating.

The metal piece is cleaned using steel shot, grit, or other mechanical cleaners to remove any remaining casting sand, metal flash, or oxide. Small items are usually ground by tumbling, which is carried out in a rotating or vibrating drum. This usually involves the addition of water, which may contain surfactants. Residual refractory material and oxides are typically removed by sand blasting or steel shot blasting, which can also be used to provide the casting with a uniform and improved surface appearance.

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3 OCCUPATIONAL HEALTH AND SAFETY

Occupational health and safety issues during operation, maintenance of foundry facilities are common to those of large industrial facilities, and their prevention and control are reviewed during the walk through audit using General EHS Guidelines.

In addition, the following occupational health and safety issues encountered during foundry activities were closely reviewed:

· Physical hazards

· Radiation

· Respiratory hazards

· Electrical hazards

· Noise

· Fire and explosions

3.1 PHYSICAL HAZARDS

Physical hazards in foundry operations related to handling of large, heavy, and hot raw materials and product (e.g. charging of furnaces)

- Accidents related to heavy mechanical transport (e.g. trucks and forklifts)
- Injuries from grinding and cutting activities (e.g. contact with scrap material ejected by machine-tools)
- Injuries due to falls from elevation (e.g. high platforms, ladders, and stairs).

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3.1.1 LIFTING / MOVEMENT OF HEAVY LOADS

Lifting and moving heavy loads at elevated heights using hydraulic platforms and cranes presents a significant occupational safety hazard in foundries. Audit check points to review the measures to prevent and control potential worker injury include the following;

- Clear signage in all transport corridors and working areas
- Appropriate design and layout of facilities to avoid crossover of different activities
- Flow of processes;
- Sling scheme and strength parameters;
- Training staff in the handling of lifting equipment
- The area of operation of fixed handling equipment (e.g. cranes, elevated platforms) should not cross above worker and pre-assembly areas;
- Proper handling and shielding of moving hot liquids, as well as solid metal parts;
- Material and product handling remain within restricted zones under supervision, proximity of electrical cables / equipment;
- Regular maintenance and repair of lifting, electrical, and transport equipment should be conducted.

3.1.2 PRODUCT HANDLING

Prevention and control of injuries related to handling, grinding and cutting activities, and use of scrap, include the following:

- Locating machine-tools at a safe distance from other work areas, walkways.
-

- Individual, enclosed workplaces provided to prevent accidents resulting from fettling or the use of grinders

- Conduct regular inspection and repair of machine-tools, in particular protective shields and safety devices / equipments;

- Training staff to properly use machines-tools, and use appropriate personal protection equipment (PPE).

3.1.3 HEAT AND HOT LIQUID SPLASHES

High temperatures and direct infrared (IR) radiation are common hazards in foundries. High temperatures can cause fatigue and dehydration. Direct IR radiation also poses a risk to sight.

Contact with hot metal or hot water may result in severe burns.

Control measures for prevention and control of exposure to heat and hot liquids / materials include the following:

- Shield surfaces where close contact with hot equipment or splashing from hot materials is expected (e.g. in cupola furnaces, induction melting ladles, and casting);
- Implement safety buffer zones to separate areas where hot materials and items are handled or temporarily stored.
- Use of appropriate PPE (e.g. insulated gloves and shoes, goggles to protect against IR and ultraviolet radiation, and clothing to protect against heat radiation);
- Regular work breaks and access to drinking water for workers in hot areas;
- Cooling ventilation to control extreme temperatures.

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3.1.4 Exposure to Radiation

Workers may be exposed to gamma rays and related ionizing radiation exposure risks. The following techniques may be used to limit the worker exposure risk:

- Gamma ray testing should be carried out in a controlled, restricted area using a shielded collimator. No other activities should be undertaken in the testing area;
- All incoming scrap should be tested for radioactivity prior to use as feedstock material;
- If the testing area is near the plant boundary, ultrasonic testing (UT) should be considered as an alternative to gamma ray techniques;
- Regular maintenance and repair should be conducted on testing equipment, including protective shields.

3.2 EXPOSURE TO RESPIRATORY HAZARDS

3.2.1 INSULATION MATERIALS

- The use of insulation material is widespread in foundries and handling of this material during construction and maintenance may release fibers and present an occupational health hazard.
- Asbestos and other mineral fibers widely used in older plants may expose people to inhalation risks of cancer-causing substances.

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3.2.2 DUST AND GASES

Dust generated in foundries includes iron and metallic dusts, which are present in melting, casting and finishing shops; and wooden and sand dusts, which are present in the molding shop.

In the former, workers are exposed to iron oxide, and silica dust that may be contaminated with heavy metals such as chromium (Cr), nickel (Ni), lead (Pb), and manganese (Mn). The dust present in the melting and casting shops is generated by high temperature operations, and the fine particle size, and potential metallurgical fumes, creates a serious occupational inhalation risk.

In the molding shop, workers are exposed to sand dust, which may contain heavy metals, and wood dust, which may have carcinogenic properties, particularly if hard wood is used.

Recommendations to prevent exposure to gas and dust include the following:

- Sources of dust and gases should be separated and enclosed;
- Design facility ventilation to maximize air circulation. Outlet air should be filtered before discharge to the atmosphere;
- Exhaust ventilation should be installed at the significant point sources of dust and gas emissions, particularly the melting shop;
- Use automated equipment, especially in the fettling process;

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- Provide a sealed cabin with filtered air conditioning if an operator is needed;
- Provide separated eating facilities that allow for washing before eating;
- Provide facilities that allow work clothes to be separated from personal clothes and for showering / washing after work and before eating;
- Implement a policy for periodic personnel health checks.

Respiratory hazard control technologies should be used when exposure cannot be avoided with other means, such as operations for creating sand moulds; manual operations such as grinding or use of non-enclosed machine-tools; and during specific maintenance and repair operations.

Recommendations for respiratory protection include the following:

- Use of filter respirators when exposed to heavy dust (e.g.fettling works);
- For light, metallic dust and gases, fresh-air supplied respirators should be used.
- Alternatively, a complete facial gas mask (or an "overpressure" helmet) can be used, equipped with electrical ventilation;

· For carbon monoxide (CO) exposure-

- detection equipment should be installed to alert control rooms and local personnel.

In case of emergency intervention in areas with high levels of CO-

- workers should be provided with portable CO detectors, and fresh-air supplied respirators.

3.3 NOISE

Raw and product material handling (e.g. waste metals, plates, bars), sand compacting, wood-model manufacturing, fettling and finishing may generate noise.

3.4 ELECTRICAL HAZARDS

Workers may be exposed to electrical hazards due to the presence of heavy-duty electrical equipment throughout foundries..

3.5 ENTRAPMENT

Workers creating sand molds are exposed to risk of entrapment due to sand collapse in storage areas and during maintenance operations.

3.6 EXPLOSION AND FIRE HAZARDS

Handling of liquid metal may generate a risk of explosion, melt runout, and burns, especially if humidity is trapped in enclosed spaces and exposed to molten metal. Other hazards include fires caused by melted metal, and the presence of liquid fuel and other flammable chemicals. In addition, iron foundry slag may be highly reactive if calcium carbide is used to de-sulfurize the iron.

Recommended techniques to prevent and control explosion and fire hazards include the following:

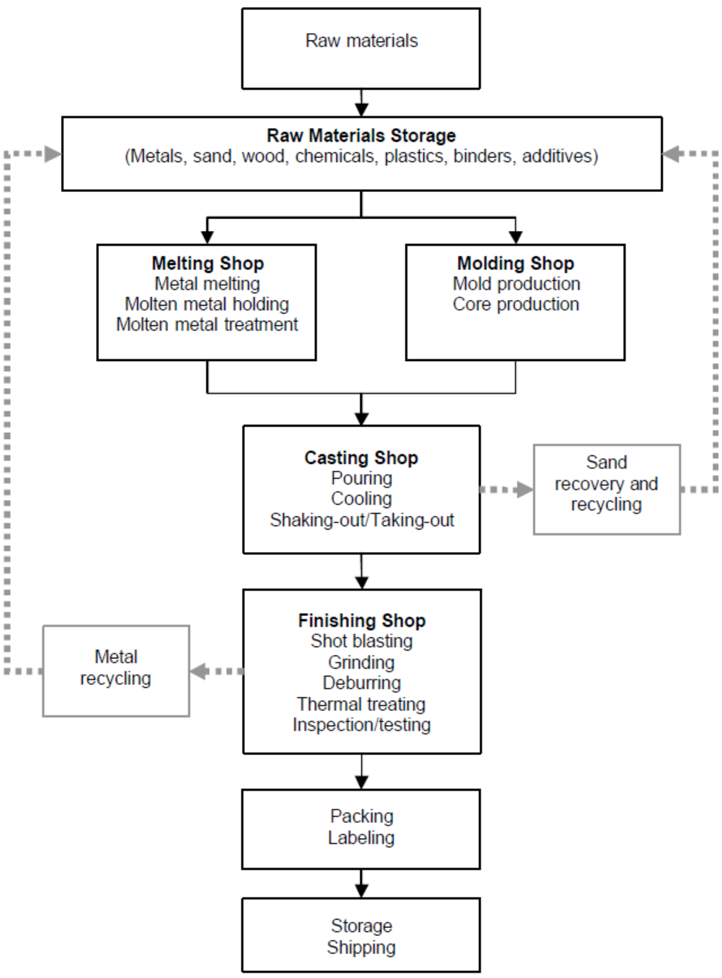
- Design facility layout to ensure adequate separation of flammable gas and oxygen pipelines, and storage tanks, away from heat sources;
- Separate combustible materials and liquids from hot areas and sources of ignition (e.g. electrical panels);
- Protect flammable gas and oxygen pipelines and tanks during "hot work' maintenance activities;

4 OBSERVATIONS & RECOMMENDATION

Refer to annexure -3 for respective client's occupational health and safety observations and recommendations:-

5 GENERAL DESCRIPTION OF FOUNDRY ACTIVITIES

Figure A.1: Flow Diagram for Foundry Operations



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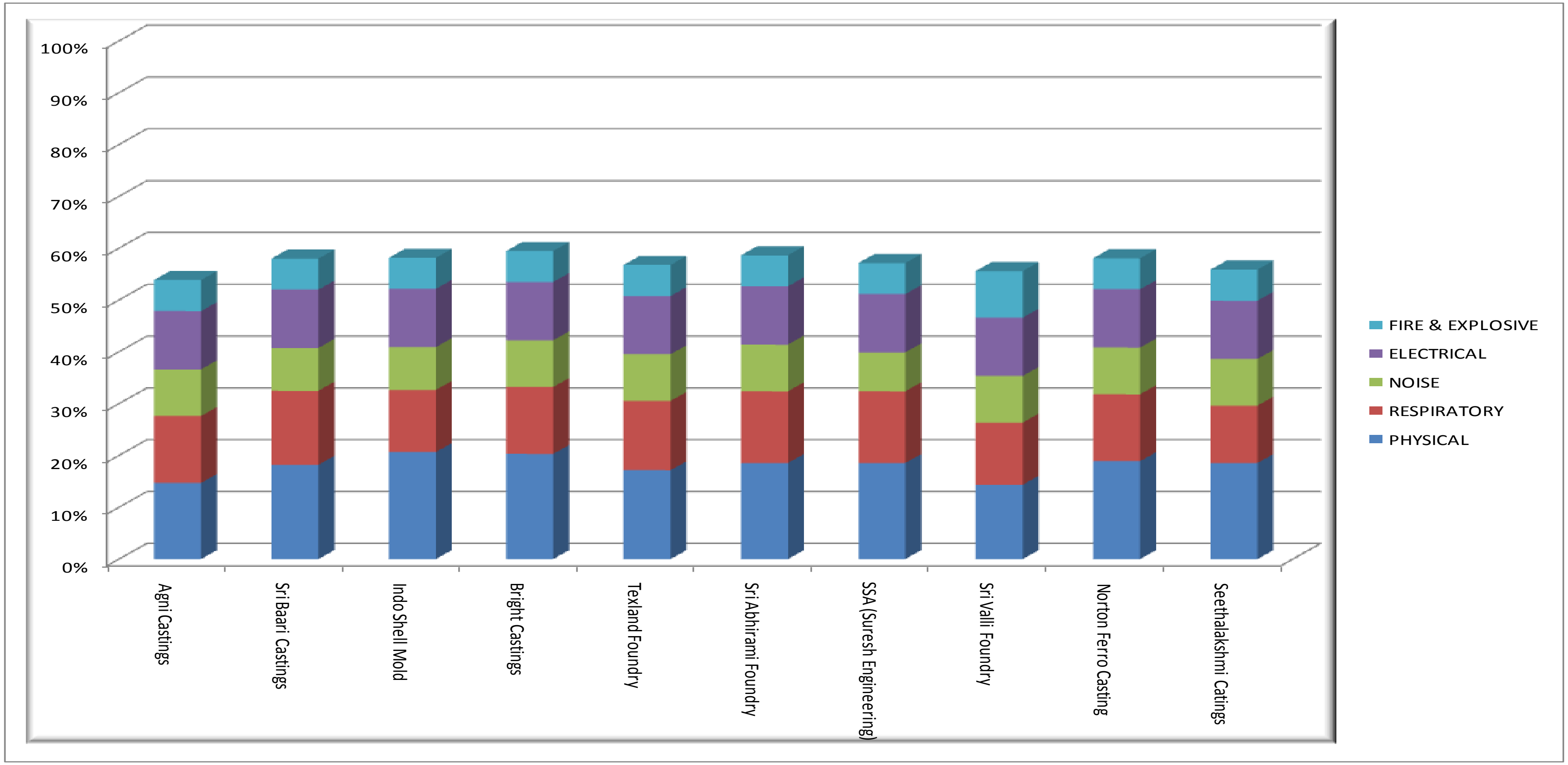
6. OCCUPATIONAL HEALTH AND SAFETY OVERALL ASSESSMENT RESULTS



Client: **Indo Shell Mold**

Date of Assessment: 03.09.2010

s/n	**Observations**	**Pictures**
1	Electrical wiring cluttered – scope for improvement • Objects kept underneath the electrical panel board • Yellow Box marking on the floor wherever practically possible can be implemented • Color coding for electrical cables, pneumatic lines can be implemented	**Pictures were not permitted by the Management**
2	**First aid box – Good Manufacturing Practice -** Management has organized first aiders, fire safety teams. Posters on safety kept in the office areas. • Similar safety awareness posters where feasible can be implemented in the shop floor as well.	
3	**Stores –**Housekeeping scope for improvement for cores, molds, in-progress and final stages of casting stores	
4	**Safety hazard:** Need to provide proper fencing on the first floor near the molding area.	
5	**PPE: Good Manufacturing Practice -** Operators do follow Personal Protective Equipments while handling molds, castings.	
6	• No safety guards for bench, pedestal grinders- cramped work space. • Wire layout for grinding areas can be further improved	
7	***Management is keen to go through detailed safety audit as well as energy conservation audit.***	