4.3 Hazard Identification, Risk Assessment and Risk Control (HIRARC)

4.3.1 Hazard Identification

Hazards exist in every workplace in different forms and required to be identified, assessed and controlled regarding the work processes, plant or substances. As the most important steps in risk managing process, hazard identification is always arguably the most important part in safety analysis effort that need to identify, control or conduct in close consultation with the people.

According to Ericson (2005), there are several approaches typically used to help in identifying hazards. One approach is by using component checklists which is based on previous experience analysis to evaluate trigger events, possible threats and causal factors. Another approach is by using an experience on similar systems and updating a hazard analysis can be developed from a previous program. Design practices, regulations, and standards also could assist in development of analysis.

In this study, hazards in the overall process at the Company was identified by HIRARC based on Guideline of HIRARC by DOSH (2008) (Appendix 4), together with Company's data from ESH Department, interview, review and also study method. Workplace hazards must be identified by sample of legislation, supporting codes of practice, guidance and develop hazard checklist.

Other methods are reviewing relevant Malaysian and international standards, other published information and also reviewing industrial or association guidance. OSHA 1994 recommends the use of engineering or work practice controls in eliminating hazards to the greatest extent possible that depends on the hazards or workplace conditions.

Everyone must be proper in identifying the problems because it can be difficult to access the risk or postulate solutions where the identification of hazards should involve a critical appraisal of all activities. A similar problem is that OHSMS tend to focus upon easily identified hazards such as 'trips and falls' rather than the identification of potential major hazards (Hopkins, 2000; Walker, 1998).

In characterizing known hazards, it takes persistence and creativity to identify new ways of system design that can lead to an accident. As the best ways to protect employees, OSHA 1994 requires that employers must protect employees from workplace hazards that can cause injuries by controlling hazards at its sources. This requirement was done to fulfill the Regulation on ***Act 514 (OSHA) 1994, Part IV – General Duties of Employers and Self-employed Person; Section 15 General Duties of Employers and Self-employed Persons to Their Employees; Practicable Sec. 3 (2); (1) Severity of Hazard (2) Knowledge of Hazard and Risk involved*** (Appendix 1).

In terms of manpower, organizations need to hire the right person for the right job to ensure the minimization of workplace hazards. The study of Hassan, Nor Azimah and Chandrakantan (2005) found that hiring practices is one aspect that requires serious attention by companies as employees should be hired based on good safety records from previous experience in other companies. Companies in particular sectors should pool their resources to set up certification bodies to train and certify employees in OSH. The process of HIRARC requires 4 simple steps (HIRARC by DOSH, 2008) in Appendix 4; (1) Classify Work Activities; (2) Hazard Identifications; (3) Risk Assessments; (4) Risk Controls.

4.3.2 Classify Work Activities

The process and source at each process was discussed in detail in Table 4.5. The work activities/ processes involve scrap process, steelmaking, continuous casting, hot strip rolling, and steel product.

Table 4.5: Process, Source and Detail Process Involved

PROCESS	SOURCE	DETAIL
Scrap	Compress the scrap and stress transporting crushing	Scrap iron or iron is used as essential raw materials. It is used and graded based on its quality, crushed and compressed to reduce its size. Limestone, graphite added, transported to EAF
Steel making	Blasting process in EAF and smelting process at LF	Electrical current is used to melt the metal. Second melting process is carried out at LF by high temperature of up to 1500^{o}C for melting process
Continuous Casting	Cutting the billet	Using big iron mots, molten steel from LF is then transported to making section
Hot Strip Rolling	Re-heating Oven	Billets of various lengths are transported to the rolling mill, reheated in the furnace up to 1050^{o}C. The reheated hot billets pass through different types to form the end products
Steel Product	Loading Process	The end products of these processes, packed and transported to stores

4.3.3 Hazard Identifications Process

Summarized based on data in Table 4.6, Table 4.7, Table 4.8 and Table 4.9

In this study, from hazard identification process, the hazards at steel factory consist of (1) health hazard (2) safety hazard and (3) environmental hazard. Details of **Health Hazards** at steel factory are as follows (Table 4.6); (1) Chemical; dust, chemical substance and particle, asbestos or insulation material (2) Physical; noise, (3) Psychosocial and physiological; thermal stress and gases. Some recommended measures to prevent and control the health hazard was taken by management such as (1) Chemical; provide a sealed cabin with filtered air conditioning, Install cooling ventilation, develop management plan (2) Physical; structure employees' work schedule (3) Psychosocial and physiological; ventilation & administrative controls.

Other than that, the findings on **Safety Hazards** at steel factory were shown in Table 4.7. In sum, based on the data, detail health hazards at steel factory are as follows; (1) Explosion and Fire Hazard (2) Heavy Loads/ Grinding & Cutting/ Rolling Hazard (3) Heat and Hot Liquid Hazard. Some recommended measures to prevent and control the health hazard was taken by management, detail as follows; (1) Explosion and Fire Hazard; Design facility layout (2) Heavy Loads / Grinding & Cutting / Rolling Hazard; (i) Specific load handling and lifting procedures (ii) Grinding and Cutting Activities; Conduct regular inspection (iii) Rolling Processes and Activities; Provide grids and rails (3) Heat and Hot Liquid Hazard; Implement safety buffer zones.

Next, the detail findings on **Environmental Hazards** based on sections, was shown in Table 4.8 as follows; (1) Iron oven preparation; dust (2) Coke ovens; dust, emissions, gases (3) Blast furnaces; silica, gases, asbestos (4) Steelmaking; dust, asbestos (5) Finishing operations; acids, dust, gases (6) Steam generation; gases, asbestos.

As a conclusion, everyone at the factory was responsible to avoid and prevent this hazard. From surveys and observation, the actions were taken as follows; (1) the employers have identified and provided appropriate PPE that will offer adequate protection (2) the employers was actively enforce the use of PPE in alternative technologies, because work plans or procedures cannot eliminate or sufficiently reduce hazard or exposure (3) the PPE provided must be implemented by employees to protect part from the hazards and injuries.

i) HIRARC- Health Hazards at Steel Factory and Recommended Measures

Table 4.6 Health Hazards and Recommended Measures
(SOURCE: Based on Company' Data, ESH Department)

HAZARD	PROCESS	DISCRIPTION	RECOMMENDED MEASURES TO PREVENT & CONTROL
Chemical *(Dust)*	Dust generated Melting and casting processes In raw material storage, BF and coke oven plant Melting and casting	Exposed to iron oxide and silica dust that can be contaminated with heavy metals; Cr, Ni, Pb Dust generated by high temperature operations, is finer and more easily inhaled than in the rolling processes Employees are exposed to mineral dust, may contain heavy metals. In addition, BF tapping results in graphite are released	*Gas and Dust* - Sources of dust and gases should be separated and enclosed. Exhaust ventilation should be installed at the significant point sources of dust, gas emissions, particularly BF topping area - Provide a sealed cabin with filtered air conditioning if an operator is needed in a contaminated area and provide separated facilities that allow for washing before eating *Respiratory Protection* - Use of filter respirators when exposed to heavy dust equipped with electrical ventilation - High temperature operations exposed to gas inhalation hazards, may contain heavy metals
Chemical *(Chemical substance& particles)*	IS mills, particularly in coke oven, COG refinery plant	May be exposed to contact and ingestion hazards, where naphthalene, heavy oil compounds, are present	- Install cooling ventilation to control extreme temperatures and implement work rotations providing regular work breaks - Access to a cool rest area, and drinking water

Chemical *(Asbestos or insulation material)*	Plants	Asbestos and other mineral fibers have been widely used in plants and may pose a risk from inhalation of cancer causing substances	- A plant-wide survey and a management plan for asbestos containing insulation materials should be completed by certified professionals. Damaged or friable material should be repaired or removed - Performed by properly trained, certified contractors and personnel following internationally accepted procedures for repair or removal
Physical *(Noise)*	Any rolling mills in production processes (BF, BOF, EAF, CC)	Hearing loss induced by noise can be either temporary or permanent can result from physical interference with the transmission of sound.	- The industrial hygienist should make appropriate noise and control it. Develop measurements and recommendations if a noise problem is suspected - Employee work schedule should be structured so that an employee's time in a high noise area does not exceed the time weighted 8 hour average of 90 dBA, based on FMA limits exposure to noise
Psychosocial & Physiological *(Thermal stress)*	Heat collected Heat Stroke	Damage to vital organs (brain, liver, muscle, kidney) and loss of consciousness Cramps (muscle especially lower limbs), extreme fatigue including dizziness and fainting)	- Heat collected in body exceeds the capacity body. Heat Stroke is a mechanism to stop sweating and body temperature above 40.5 ^{O}C - Ventilation & Administrative Controls; a) Training and procedures and reducing exposure b) Limits of work and rest, monitoring of temperature a) Drinking cold water (10 – 15 degrees Celsius) b) Salt (a total of 150 to 200 mL every 15 - 20 minutes)
(Gases)	In BF, BOF and coke oven plant	Exposed to gas inhalation hazards of carbon monoxide	- For carbon monoxide (CO) exposure, detection equipment should be installed to alert control rooms and local personnel. In case of emergency intervention in areas, employees should be provided with portable CO detectors, and fresh-air supplied respirators

(ii) HIRARC- Safety Hazards at Steel Factory and Recommended Measures

Table 4.7: Safety Hazards and Recommended Measures
(SOURCE: Based on Company' Data, ESH Department)

HAZARD	PROCESS	DISCRIPTION	RECOMMENDED MEASURES TO PREVENT & CONTROL
Explosion and Fire Hazards	Coal handling facilities associated with IS mills	Handling of liquid metal may result in explosions causing melt and burns Fires caused by melted metal, and the presence of liquid fuel and other flammable chemicals Due to heating during natural oxidation of new coal surfaces, coal dust is combustible and represents an explosion hazard	- Complete dryness of materials prior to contact with liquid iron & steel - Design facility layout to ensure adequate separation of flammable gas, oxygen pipelines, and combustible materials and liquids from hot areas and sources of ignition - Protect flammable gas, oxygen pipelines and combustible materials during 'hot work' maintenance activities - Storage structures should be designed to minimize the surface areas on which coal dust can settle, and it must have dust removal systems
Heavy Loads / Grinding & Cutting / Rolling	Handling of large, heavy raw materials and product Mechanical transport Grinding and cutting Rolling processes	BF & EAF charging, storage and movement of billets, movement of large ladles containing liquid iron and steel Trains, trucks and forklifts. Contact with scrap material ejected by machine-tools. Collision and crushing high speed rolled materials and processes	*Specific Load Handling and Lifting Procedures* - Description of load to be lifted (dimensions, weight, position of center of gravity). Train staff on the handling of lifting equipments and driving mechanical transport devices - The area of operation of fixed handling equipment should not cross above worker, pre-assembly areas. Material and product handling should remain within restricted zones under supervision

	Lifting and moving heavy loads	Using hydraulic platforms and cranes at elevated heights present a significant occupational safety hazard in steel mills	*Grinding and Cutting Activities,* - Locate machine-tools at a safe distance from other work areas - Conduct regular inspection and repair of machine-tools, in particular protective shields and safety devices / equipment, PPE *Rolling Processes and Activities* - Provide grids around stands and shields where rolled material could accidentally come off rolling guides - Provide rails along transfer plate with interlocked gates that open only when machine is not in use
Heat and Hot Liquid Hazards	Contact with hot surfaces Cooling spray zone of continuous casting Splashes of melted metal	Heat is generated and used all over a steel plant. Heat stroke can be a constant risk, especially during warm weather High temperatures and direct infrared radiation are common hazards and high temperatures in integrated steel mills. Potential contact with hot metal or water can cause fatigue and dehydration.	- Provide shield surfaces where close contact with hot equipment or splashing from hot materials is expected in coke oven plants, blast furnaces, BOF, EAF, continuous casting and heating oven in rolling plants - Implement safety buffer zones to separate areas where hot materials and items (e.g. billets, thick slabs, or ladles) are handled - Use appropriate PPE (insulated gloves and shoes, goggles to protect against IR and ultraviolet radiation, and clothing to protect against heat radiation and liquid steel splashes) - Care must be taken to control over exposure in the form of extreme radiant heat in many locations where there are hot or molten materials. There are also many locations where strenuous work may have to be done in hot location

(iii)HIRARC- Environmental Hazards at Steel Factory and Recommended Measures

Table 4.8: Environmental Hazard and Recommended Measures
(SOURCE: Based on Company' Data, ESH Department)

NO	AREA	SOURCES OF HAZARD	SPECIFIC AREAS	HEALTH HAZARDS	EXAMPLE OF HAZARD
1	Iron oven preparation	Sinter plant	General Bag house	• dust	• iron oxides, silica, lead
2	Coke ovens	Coal handling		• dust	• coal bins, coal bunkers
		Coke handling		• dust and emissions	• coke, coke oven emissions
		Coke ovens	Hot coke oven	• emissions	• designated substance
				• gases	• H2S and CO
		Byproduct plant	Hot coke oven	• coke oven gas	• CO, H_2S, toluene, xylene
				• gas and volatiles	• coal tar pitch and anhydrous ammonia
			Insulation on tanks	• ammonia	
		Miscellaneous	CO gas lines	• gas and drip legs	• CO and naphthalene

3	Blast furnaces	Cast house Around furnace Stoves, Scrubber Slag pits	Furnace lining Blast mains Confined spaces	• silica • gas and noise • asbestos, Gas • gas	• silica products • CO and asbestos • CO • SO_2
4	Steelmaking	General Precipitator bag house Waste heat boilers	During reline Leaded steels, Bag house Mild steel tubes	• dusts, radiant heat • dust •confined spaces • asbestos	• iron oxides, and lime, silica • iron oxides, lead • lime • asbestos
5	Finishing operations	Pickling acid regeneration Annealing Cleaning lines Tinning lines	Acid mist Vapor Batch anneal (blankets)	• acid and dust •fiber and gas • corrosive • acid	• HCI and iron chloride dust (irritant) • ceramic fiber and CO • sodium hydroxide • sulphuric acids & others
6	Steam generation	Central boiler facility Waste heat boilers	Some areas Mild steel tubes	• fired by gases • high noise	• CO, BF gas, natural gas • asbestos • asbestos

Table 4.9: HIRARC- Hazard and Risk Priority

(SOURCE: Based on Company' Data, ESH Department)

NO	HAZARD IDENTIFICATION			RISK ANALYSIS				RISK CONTROL	PIC
NO	**ACTIVITY/ process**	**HAZARD**	**CAUSE/ EFFECT**	**EXISTING RISK CONTROL**	**(L)**	**(S)**	**RISK**	**RECOMMENDED CONTROL MEASURES**	**PIC**
	SMR Process								
1	EAF Dust (at Sinter Plant, BF, Steelmaking area)	Dust / Powder	-Eye tissue -Rubbing cause abrasion of cornea -Irritate the skin and may produce skin abrasions	-Wear safety glasses with side shields -Use impervious gloves to protect skin -Rinse immediately with plenty of water				-In case of contact with eyes, seek medical advice -Keep material in a well-ventilated area, storage procedures -Exhaust Ventilation & Filter outlet air	-Medical -Use PPE -Supervisor
2	Thermal Process	Hazardous Combustion Products	Respiratory Dermatitis & Skin Lesions	-Wash immediately with soap and water -Cuts or abrasions should be treated promptly				-Prevent release to air, sinks, drains, sewers, or water runoff -Appropriate NIOSH/ MSHA approved respiratory protection must be provided	-Management -Use PPE -Supervisor
3	Hot stoves & pipelines (BF, Steelmaking)	Flammability Properties (leak out)	Respiratory Dermatitis & Skin Lesions	-Keep product damp to minimize fire hazards				-Containment procedures by prevent release to air, sinks, drains, sewers	-Use PPE -Management
4	Many Hazardous Location (BF, CO)	Fumes	-Metal fume fever, -Irritation to eyes, -Mucous membranes -Respiratory Problem -Dermatitis	-Wear safety glasses with side shields for eyes/ face -Do investigation on complaints of the irritation to eyes and skin lesions				-Use Filter respirators -Use Filter air conditioning -Design facility ventilation	-Chemist -Engineer -Use PPE

	CSP Process								
5	Direct current EAF	Fire & Burn Hazard	-Respiratory Problems	-Avoid inhaling any combustion products				-Fire Fighting Equipment/ Instructions -Fire fighters should wear self contained breathing apparatus, protective clothing	-Supervisors -Use -PPE
6	Steel Plant	Heat Generated & Explosion	-Fever -High Temperature -Vomiting	-Care must be taken to control overexposure -Wear PPE -Drinking Water				-Install Cooling Ventilation -Cool rest area	-Supervisor -PPE
7	Production Process (BF, BOF)	Toxicities from Product Material	-Ingestion Problem -Gastrointestinal Disturbances, -Fever, Vomiting,	-First Aid -Do not induce vomiting unless directed to do so				Seek Medical attentions	- First Aid -Medical
8	Thermal processing (Coke Oven Plant)	Thermal Stress	-Produce Skin Abrasions, Lesions, or Cuts -Extreme Fatigue (dizziness & fainting)	-Use component exposure limits				-Administrative Controls -Ventilation	-Chemist -Management
	SPT Process								
9	Elevated workplace (Continuous Casting)	Noise Exposure	-Hearing Loss -hypertension, -premature ejaculation -hearing impairment	PPE- Ear Plug				-Hearing Protection -Warning signs	-PPE -Industrial -Hygienist
10	Elevated workplace (Continuous Casting)	Hot Liquid Hazard	Heat Stress	-Appropriate PPE -Seek medical attention immediately				-Safety buffer zone -Cooling pray zone -Provide shield surfaces	-PPE -Supervisor -Medical

4.3.4 Heat Stress Management

In steel industries, many of the processes generate heat to the workplace. A workplace with temperature of more than 37^{o}C can influence the body heat exchange with the environment (Alpaugh and Hogan, 1992). At highly heated workplace, body temperature would start to rise depending on the environmental heat. For this reason, body temperature is good indicator for accumulated effects on heat stress (Nag *et al.*, 1999).

In this study, one of the most overlooked hazards at steel factory' workplace is heat. In previous research has found that excessive exposure to heat at the workplace will develop heat stress (NWOSU, 2000; Cullen and Nadel, 1994). The bodily response to total heat stress is called the heat strain (NIOSH, 1986). Heat stress is the aggregate of environmental and physical work factors that constitute the total heat load imposed on the body (Alpaugh and Hogan, 1992).

Temperature range from relatively at low 150^{o}C to extreme cases of 250^{o}C. The heat ejected from machines and molding processes can contribute to a heat stress that requires evaluation (Burges, 1995). At steel mill, an extreme heat involved in HSM Process which includes the departments of DC-EAF (Figure 3.13), Ladle Furnace (Figure 3.14), Thin Slab Caster (Figure 3.15), Hot Strip Mill (Figure 3.17) and LCS (Figure 3.18).

However, in this study, the plant was fully automated. Employees almost in pulpits and control room where most of the manual task was handled by machines and forklifts. These had greatly reduced the manual lifting activities and therefore, reduce the heat load on the employees (Helander, 1991).

In reviewing the case study from Azwan and Rampal (2001), they also recorded 96.2% out of 164 respondents selected for a heat stress study at two major steel plants was 37.5°C. The highest value of body temperature measured was 37.3°C and 37.4°C after 2 hours and after 8 hours of work respectively. There was a significant difference for body temperature measured at different work durations. Body temperature of below 38.0°C (threshold value) is considered as respondents' safe exposure (ACGIH, 1999).

Other's effects on the exposure to excessive heat are as follows; (1) associated with nephrolithiasis (Borghi, 1993), (2) testicular cancer (Zhang, 1995) and (3) poor semen quality (Bonde, 1992). (4) A high incidence of uric acid stones was present in the workers who were exposed to heat stress (Borghi, 1993). (5) Beside rectal temperature as a measure of body temperature, ear canal temperature can also be used. It was carried out by inserting a sensor in the ear canal (NIOSH, 1986). Further exposure may result in (6) heat cramps, (7) heat exhaustion, (8) heat syncope and (9) heat stroke (Kroemer *et al.*, 1994). Crockford (1981) said the hot environment in these industries has a profound effect on (10) employees' comfort, (11) productivity, (12) safety and health.

As conclusion, some employees at this steel factory were exposed to heat stress; however, preventive measures to excessive heat exposures which can cause physiological strain and eventually lead to poor health outcome, must be addressed by the management in order to sustain productive and healthy employees.

Some techniques below were important to complete the HIRARC process. Based on company data' and information's, all the item in the list below was discusses detail in each sections; Accident and Incident Investigations (Section 4.3.5), Work Place Inspections (in Sec. 4.3.6) and Failure Tree Analysis (FTA) (Sec. 4.3.7)