Industrial Hygiene -A Geothermal Perspective

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Introduction

Geothermal development not only poses formidable technical obstacles, but also environmental, health and safety challenges for steam suppliers and electricity producers alike. Hazards such as air pollution, confined spaces, noise, environmental (heat and cold) stress, repetitive motion tasks, and hazardous substances demand that not only employees be trained and aware, but that they take the responsibility for protecting their own health and safety on and off the job.

Industrial Hygiene (IH) is a relatively new discipline which recognizes, evaluates and controls those environmental factors and stresses arising in or from the workplace (1). The Williams-Steiger Occupational Safety and Health Act of 1970 (2) created a federal agency (OSHA) to develop, regulate and enforce standards which employers and employees must follow to insure a workplace as free as practicable from recognized hazards, which are likely to result in injury, disease or death. The real world practice of IH typically overlaps with other disciplines such as: engineering, analytical chemistry, physics, toxicology, epidemeology, and others.

Recognition

Recognizing potential health hazards involves a preliminary assessment of all materials and processes likely to contribute to unhealthful conditions. This initial screening process may be divided by job task, occupation or area to help determine the magnitude and extent of the impacted work force for each identified hazard. During a facility walk-through, detailed observations and information should be accurately recorded on forms or data sheets. Existing records such as previous injuries, known health and safety hazards (i.e. chemical mixtures), environmental monitoring field notes, duty rosters, radiation sources, ventilation measurements, etc. should be organized in such a manner as to best serve as the basis for solving immediate problems. Effective data management can also assist in prioritizing relative exposure risks while building a foundation of knowledge for future corrective action. Hazard recognition is also done to help select the most appropriate locations to conduct more comprehensive health exposure evaluations in order to determine if control measures are needed before workers experience injury or adverse effects.

Evaluation

Health hazard evaluations attempt to quantify employee exposures by comparing them to OSHA standards[1]. In the absence of a specific OSHA standard, other references can be used to assist in the evaluation of workplace exposures[2]. These "investigational" evaluations make use of technical instruments and equipment including direct reading meters, air sampling pumps, collection media and calibration systems. The key is to select an instrument and analytical method which is hazard specific irrespective of anticipated interferences. Variables such as sample times, duration, location, meteorlogical conditions, etc. also need to be factored in to the evaluation. Generally the more reproducible the results, the more statistical confidence the data has.

1 OSHA has adopted exposure standards for many hazardous substances (air contaminants, noise, etc.) which are typically normalized to daily time weighted averages (TWA).
2 National Institute for Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH) are two additional entities that also publish such data.

Controls

The primary goal of industrial hygiene is to control occupational health hazards. Types of controls include: proper engineering design, raw material substitution, process changes, ventilation, housekeeping, equipment maintenance, personal protective equipment (PPE), employee training and information(**3**)

Design-

Factors to consider in determining an optimal engineering design include: the physical and chemical characteristics of the contaminant(s); regulatory compliance standards, the required removal efficiency; installation and maintenance costs. Engineering controls should be designed at the blueprint stage since retrofit upgrades can be quite complicated and result in costly production or manufacturing process down times.

Substitution-

This could be replacing toxic materials with non-toxic ones or changing the physical conditions of raw materials from granular to briquets or pellets. Extreme caution should be used when substituting one chemical for another to ensure that another hazard is not created (e.g. fire hazards).

Process Changes-

Most changes are usually made to cut costs, improve quality or productivity. In some instances processes can be modified to reduce total airborne gases, vapors or particulate. A couple of examples include wetting the raw materials (dust suppression), and brush painting or dipping instead of compressed air spraying.

Ventilation-

The two major types of ventilation are local exhaust and dilution. Local exhaust ventilation captures and contains contaminants before they can be released into the workplace. For local exhaust to be effective the process or equipment is enclosed to the extent possible and the capture efficiency is high enough to maintain sufficient directional air flow into the hood, duct, etc. Local exhaust systems can be used to conserve or reclaim reusable materials. Dilution (or general) ventilation removes or adds relatively clean air to the workplace. The principle makes use of natural convection through openings (doors, windows) or movement by fans or blowers. Guidelines to use this type of ventilation include contaminants with low toxicity, no collection or filtration required prior to discharge to the environment, small quantities of contaminants released at uniform rates, no corrosion or or equipment damage from diluted contaminant levels. Dilution ventilation should not be used where there are significant, localized sources of highly toxic air contaminants.

Housekeeping-

Where toxic materials are used, good housekeeping practices are essential. Spills must be cleaned up immediately, leaking containers or dispensers should be transferred to intact vessels for reuse if possible. Avoid build-up or accumulation of contaminated articles (rags, debris, etc.) which could pose exposure hazards (e.g. solvents). Dust should be vacuumed up before it can dispersed by vibration or random air currents into employee breathing zones.

Equipment Maintenance-

Routine preventative maintenance can reduce costly equipment breakdowns and contamination of the work place. Maintenance activities must include steps to minimize employee exposures from surface contact, cleaning operations, etc.. All tools and equipment used should be compatible with the job task (e.g. non-sparking) and must be properly decontaminated at the conclusion of work.

Personal Protective Equipment-

Personal protective equipment (PPE) is used when the hazard cannot be removed or controlled to the extent necessary to protect worker health and safety. Before using PPE, it is wise to also consider adminstrative controls to reduce exposures such as : restricted area access, restructuring work periods, and job rotation. PPE is often used in conjunction with both engineering and administraticve controls. PPE taken by itself does nothing to reduce or eliminate the hazard. Equipment failure subjects the user to an immediate hazard. Types of PPE include protective clothing, eye, face, hearing and skin protection (including barrier creams and lotions). Respiratory protection warrants its own discussion. Respirators can generally be divided into two types: air-purifying (APR's) and supplied air (SAR's). As the name implies, APR's purify the air and must not be used in oxygen deficient atmospheres[1], extreme temperartures, unknown concentrations of toxics or toxics with poor warning properties (e.g. H2S). SAR's provide a separate air supplies and greater protection factors. Table I lists subcategories of respirators with their associated protection factors (PF). A PF of 10 will reduce the outside concentration of a specific contaminant by 1/10 in the users breathing zone[2]. SAR's provide greater respiratory protection but tend to be somewhat cumbersome and restricitve with limitations on air supply quality and quantity. Figure I illustrates the respirator selection process. A medical evaluation of all personnel required to wear respirators is conducted to insure their physical fitness to do so.

Employee Training and Information-

In order to work with and implement the engineering and administrative controls outlined above, workers must be knowledgeable about the hazards associated with their jobs and have appropriate equipment, training and resources necessary to perform them safely. Training emphasis is usually placed on "process-equipment" and "procedural". Process-equipment training is generally provided to supervisors to familiarize them with an overview. Procedural training tends to be focused on field workers. The intent is to alert personnel to job hazards and make them aware of written information which is available. Field operators should be provided with a detailed instruction manual outlining procedures for all types of contingencies.

<u>OSHA Jurisdiction</u>

The provisions in the Occupational Health and Safety Act of 1970 are numerous. In general, the Secretary of Labor is delegated the authority by the U.S. Congress to insure that every employee have safe and healthful working conditions by:

- ❒ Requiring employers to maintain accurate monitoring records and inform employees of results.
- ❒ Providing procedures for investigating alleged violations, issue citations, assess fines, penalties, etc.
- ❒ Providing 50/50 funding with states wishing to establish their own program[3].
- ❒ Establishing the National Institute of Occupational Safety and Health (NIOSH) for research purposes.
- ❒ Promulgating new or revised rules, regulations or standards for current or anticipated hazards.

[3] Less than 19.5% by volume is deemed to be oxygen-deficient.
[4] This assumes a proper face to facepiece seal.
[5] Which are at least as effective as the federal program.

Standards-

The Secretary of Labor promulgates health hazard standards which are based upon research, demonstrations, experiments and such other information as may be relevant and appropriate. NIOSH only provides the information and recommendations about health hazards while OSHA has the final authority to promulgate them. Other considerations when standards are proposed include: substantiating scientific evidence, implementation feasibility, and past experiences with similar health and safety laws. Standards can be broken into four (4) separate categories: design, performance, vertical and horizontal. Design standards include detailed specifics such as ventilation flow rates. Performance standards state the end result objective and leaves the "how-to" up to the employer. Vertical standards apply to a particular industry (electric utility) where horizontal standards apply to broad areas across the board (e.g. confined spaces).

Violations-

In some cases violations may not be found in the workplace (i.e. compliance with OSHA standards) but with the employers' establishment . In these cases, citations and/or civil penalties may be proposed. Types of standard violations include: imminent danger, serious, other and de minimus. Imminent danger violations are issued when there is a reasonable certainty that an existing hazard can be expected to cause immediate serious physical harm before the hazard can be removed or controlled through normal operating procedures. Serious violations have a high probability that death or physical harm could result and that the employer had knowledge or should have had knowledge that the unsafe condtion existed. (e.g.machniery guards). Other violations have a direct impact on workplace safety but are not anticipated to cause serious injury. De minimus violations have no direct or immediate impact on job health and safety but indicate administrative non-compliance (e.g failure to use an engineering control). Penalties may be adjusted (up or down) depending on the employer's good faith, violation history and business size.

The Geysers

Seventy two miles north of San Francisco in the Mayacamas Mountains between northern Sonoma and Lake counties lies the largest complex of geothermal generating units in the world (4). Since the mid-1950's, geothermal development has occurred at a rapid rate. Today, over twenty (20) generating plants which use naturally occurring steam to generate power and to provide transmission voltage support for communities in central and northern California. Steam piping and power generating stations are spread throughout a Known Geysers Resource Area (KGRA). The Geysers geothermal work environment is as unique as the natural resource itself. Geothermal steam also contains within its mass other entrained gases some of which are listed in Table II. The most ubiquitous and malodorous (toxic) gas is hydrogen sulfide (H2S). There are a number of other hazardous substances including, inorganic arsenic, mercury, asbestos (serpentine rock), and bulk H2S abatement chemicals such as concentrated caustic soda, sulfuric acid, hydrogen peroxide, etc. In addition to chemical-type hazards, several other physical-type hazards are present such as noise, confined spaces, and environmental stresses (heat or cold).

Hydrogen Sulfide (H2S)-

H2S is a colorless, flammable gas and is listed by the federal Environmental Protection Agency (EPA) as an extremely hazardous substance[1]. It is a human poison by inhalation and a severe irritant to the eyes and mucous memebranes. Moreover, the poisonous action of H2S is compounded by the fact that sense of smell becomes fatigued (olafactory desensitization) after repeated or prolonged low level exposures.

[7]Reported in the EPA Toxic Substance Control Act (TSCA) inventory(5)

Hydrogen Sulfide (continued)-

Olafactory fatigue poses a significant health risk because increasing concentrations can go undetected by workers as they get used to the smell. It is for this primary reason that air purifying respirators must not be worn in H2S-containing atmospheres[8,9]. Table III compares H2S concentrations with associated health effects(6). It is interesting to note that H2S toxicology is based on respiratory paralysis (asphyxiant) versus combination with the blood as in the cases of carbon monoxide and hydrogen cyanide poisonings.

Inorganic arsenic-

Arsenic is widely distributed in the earth. There are more than 150 arsenic bearing minerals most of which contain iron and sulfur such as arsenopyrite ($FeAs_2$-FeS_2). It is not surprising then to find relatively small quantities entrained in the geothermal steam as well. As the geothermal energy is converted to mechanical energy to turn a turbine-generator, mineral solubility decreases thereby depositing geothermal scale (including arsenic) on equipment and piping surfaces. During maintenance activities, this scale is sometimes removed using mechanical methods (grinding, buffing, etc.) which could cause the release of airborne dust contaminated with arsenic[10]. Arsenic primarily in its oxidized states (As2O3) is a listed human carcinogen. It is taken into the body via inhalation and to a lesser extent ingestion. During the late 1970's and early 80's, air monitoring studies suggested that airborne concentrations of inorganic arsenic exceeded regulatory "trigger" levels. As a preemptive measure, hygiene facilities were built and procedures developed to minimize potential employee exposure on the job and family exposures from contaminated clothing laundered at home.

Mercury-

Mercury is not only found in sandstone, limestone and cinnabar (HgS)[11], but is commonly used in instrumentation such as (mercoid) switches, thermometers and manometers. This liquid element can be released through improper handling, storage or use. Because of its physical state and relatively high vapor pressure, it is not only difficult to recover but it also can evaporate posing inhalation and skin absorption hazards(7). Toxicological effects via inhalation include: muscle weakness, headache, diarrhea and liver changes. Signs of overexposure may also include: fine tremors, renal disease and ocular lesions. Appropriate PPE is required when handling elemental mercury or cleaning up spills coupled with environmental monitoring of the activity.

Asbestos-

Asbestos is a generic term that applies to a group of naturally occurring hydrated mineral silicates[12] which are found in serpentine (rock) formations throughout California. The fibrous form has high tensile strength, heat and chemical resistance and favorable frictional properties. It is found in all types of products from transite pipe to brake shoes and is rigorously controlled and regulated as a carcinogen. Because its use is so widespread, it could be found in insulation, wiring, roofing felt, etc. Identifying asbestos-containing material is an on-going effort at the Geysers. Demolition activities are almost always preceded by a thorough investigation of materials suspected of containing asbestos. Regulatory notifications are strictly required and enforced prior to any asbestos removal. Diseases associated with long term asbestos exposure include: lung cancer, asbestosis and mesothelioma (cancer of the pleural lining of the chest cavity).

8 Poor warning properties.
9 NIOSH does approve certain APR's for use in H2S environments for emergency egress only.
10 In addition to other metals
11 Cinnibar was mined extensively in the KGRA during the 1950's and 60's.
12 Examples include chrysotile, crocidolite and amosite.

H2S Abatement Chemicals-

H2S is the predominant air pollutant emitted from power plants at the Geysers. In order for power plants to maintain their permits to operate, H2S emissions must be kept below permit conditions. In order to keep H2S emissions below allowable limits, chemicals are added to the circulating water systems which oxidize and entrain sulfur and its byproducts. Large quantities of corrosive chemicals such as caustic soda (sodium hydroxide), sulfuric acid and hydrogen peroxide in various combinations are used for this purpose. Chemicals like these usually cause acute health effects such as skin, eye and nasal irritation or burns. While these chemical feed systems are separate and predominantly closed, operational and maintenance personnel have a possibility of encountering these chemicals or their residues during the course of their routine work. Specific handling and spill response procedures have been developed and put in place to minimize contact with these chemicals.

Noise-

Noise is a sound that usually bears no information. It is sound that is unwanted by the listener due to its unpleasantness. Noise can be physiologically harmful and is physically indistinguishable from other sounds. Sound energy produces a hearing sensation perceived by humans. Vibrational energy usually refers to a nonaudible phenomena of tangible touch or feeling. Noise exposure falls into three general classes: continuous, intermittent and impact. If excessive noise is suspected in the workplace, sound surveys are done to quantify it. The decibel is the unit measure of noise. If workplace noise levels exceed 85 decibels (db), the employer must implement a hearing conservation program. The elements of a hearing conservation program include........:

Concluding Topics:

- ❒ Environmental monitoring for alleged exposures.
- ❒ Medical surveillance activities
- ❒ Hazard Communication
- ❒ Confined Space
- ❒ Emerging Issues

1. Ergonomics
2. EMF
3. Heavy Metals (lead/cadmium)

About the Author:

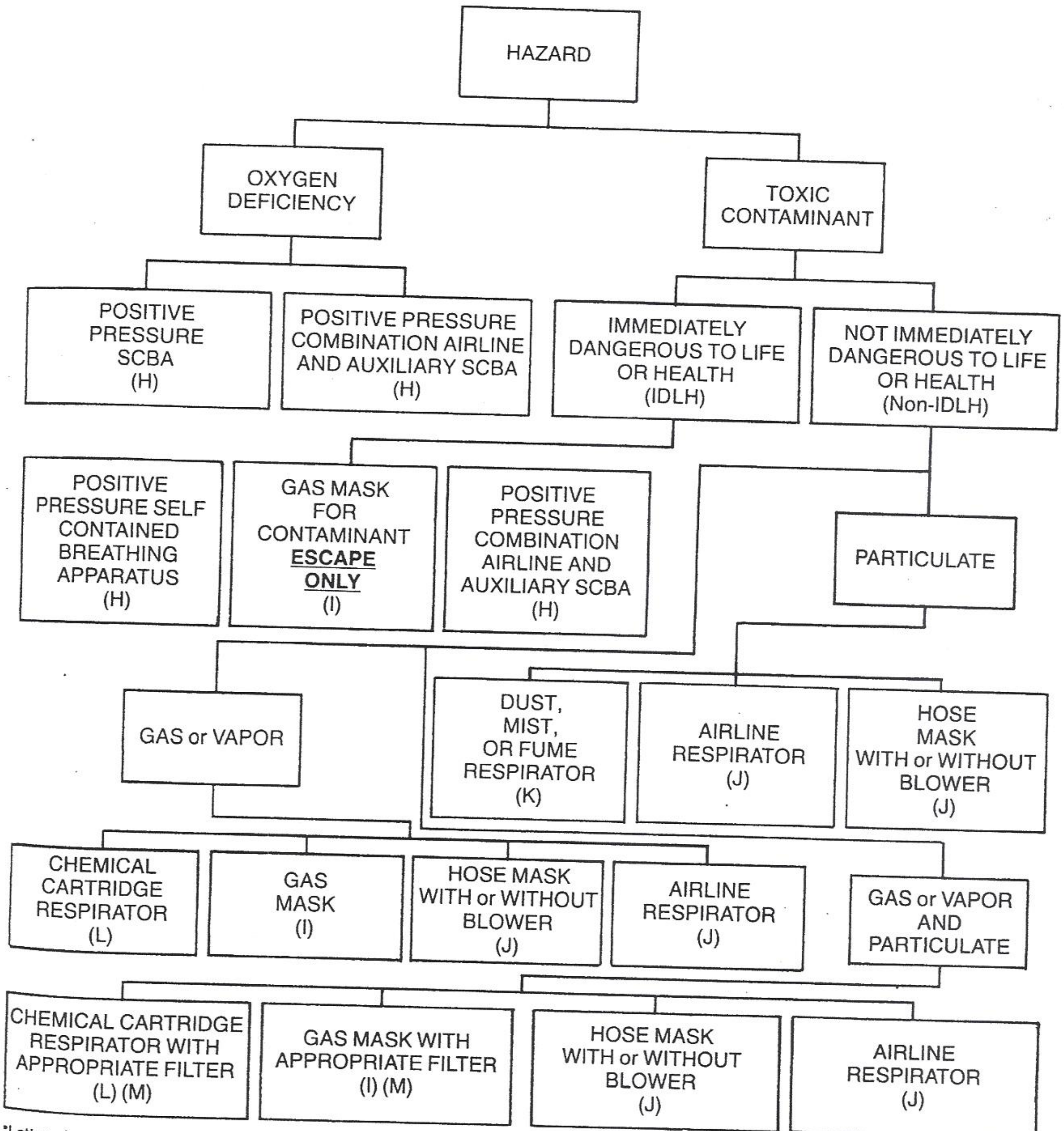
See attached resume.

References (not in the order cited in the text):

1. Fundamentals of Industrial Hygiene
2. Dangerous Properties of Industrial Materials
3. Threshold Limit Values, ACGIH
4. NIOSH Pocket Guide to Chemical Hazards, June 1990.
5. Cal OSHA Title 8 General Industry Safety Orders, Sections 3403-5300.
6. Fed OSHA 29 CFR Parts 1910, subpart G and Z.

7. Patty's Guide to Industrial Hygiene and Toxicology, 1977
8. OSH Act of 1970, Public Law 91-596, 29 USC Sec. 651

Table 23-A. Outline for Selecting Respiratory Protective Devices*



*Letters in parentheses refer to Subpart of 30 *CFR* Part 11.