V. WORK PRACTICES

Increased risks of dermatitis from contact with nickel, especially with solutions of nickel compounds [28,29], and increased risks of cancer of the respiratory organs from airborne forms of nickel [43,44] are the primary hazards reported from workplace exposure to inorganic nickel. Workers may be exposed to dusts, fumes, mists, or liquids containing nickel. Operations most likely to generate airborne nickel particles include welding, grinding, melting, cutting, pyrometallurgic refining, and the handling of finely divided nickel compounds. In operations at temperatures approaching the melting points of the nickel compounds being used, nickel fumes may be generated. The production of nickel catalysts and nickel salts, hydrometallurgic refining, and the plating of objects with nickel involve potential exposure to liquids or mists containing nickel. Particularly in these operations, therefore, work practices, along with the engineering controls described in Chapter IV, must be directed toward reducing skin and eye contact with inorganic nickel and preventing inhalation of airborne nickel.

Enclosing materials, processes, and operations is completely effective only if the integrity of the system is maintained. Such systems must be inspected frequently by qualified persons for leaks, and any leaks must be repaired promptly. The condition of seals and joints, access ports, and other such potential release points require special attention. Similarly, points where excessive wear or stress occur must be inspected regularly. Scheduled preventive maintenance, which offers more protection to the worker than maintenance performed only after problems arise, should be practiced.

Employers must limit access to areas where occupational exposure to nickel may occur to those employees needed for the process. Records of employees entering these areas must be made and included in the employees' permanent files. Signs warning of the hazards of entry into areas containing airborne nickel contamination must be prominently displayed.

To limit skin contact with nickel and to minimize the resulting risk of sensitization, as well as to prevent exposure of the employees and their families outside the workplace, workers occupationally exposed to inorganic nickel must wear work clothing, which must be changed daily and not worn outside of the workplace. Work clothing must consist of coveralls (or any other combination of clothing which offers the same protection, such as trousers and shirt or skirt and blouse), hat or other head covering, hose or other leg covering, and shoes. Gloves should be provided where necessary.

Workers exposed to liquids or solutions containing nickel must be provided with suitable protective equipment. Such equipment should include corrosion-resistant clothing (impervious boots, gloves, and aprons or coats), acidproof hoods, and splashproof goggles. Full-body protective clothing may be necessary where it provides the only practical means of ensuring healthful working conditions [237]. Skin abrasions increase the risk of dermatitis [29]; therefore, protective clothing and gloves should be of sufficient strength to reduce the likelihood of such contact. In operations involving high temperatures or molten metal, both personal protective equipment and work clothes should be sufficiently flame retardant to adequately protect employees.

Change rooms, lockers, showers, and protective clothing, where needed, must be provided for and used by employees occupationally exposed to nickel. Employees must wear the protective clothing provided by the employer, change clothing in rooms containing lockers which allow for the separation of street and work clothing, and shower after the work shift.

While there have been no reports of effects on workers' families due to inorganic nickel brought into the home, it is good practice to collect clothing worn by employees at the job site and to have the employer launder the clothing. Clothing must be stored and laundered to prevent exposure of those handling the soiled clothing [237].

Employees occupationally exposed to inorganic nickel must not eat, handle, or store food in the work area. While evidence of the oral toxicity of nickel is limited, animal studies [121,123] indicate adverse effects on reproduction from orally administered nickel. While these effects are nonspecific and therefore may or may not have an impact on man, they do indicate a toxic action of ingested nickel. Good practice requires the limitation of absorption of heavy metals in any form. Similarly, smoking and the carrying of uncovered smoking materials in the work place must be prohibited and employees should be instructed to wash their hands before smoking outside the workplace. Hogetveit and Barton [221] have observed that employees who eat outside of nickel work areas have lower urine and plasma levels of nickel.

Frequent washing of exposed skin is the most effective means of preventing dermatitis in operations where the employees are exposed to solutions or liquids containing nickel. Nonimpervious clothing that becomes contaminated during the work shift must be changed and not worn again until the nickel is removed from the clothing. Washrooms convenient to production areas must be provided for all employees occupationally exposed to nickel. Employees must be required to wash prior to any eating or smoking, before breaks and lunch periods, and at the end of the work shift.

The employer must provide a respiratory protection program. The requirements for such a program are listed in 29 CFR 1910.134 and 30 CFR 11. A clean and well-maintained supplied-air or self-contained respirator must be available to each employee required to wear a respirator in his work. Workers who are expected to use respirators for entry into an area of overexposure to nickel must be trained in respirator use as well as in other emergency activities the worker may be expected to perform.

Where nickel-containing dusts are generated, it is important that they be removed by vacuum rather than swept or blown away [235]. Where there is no danger from electrical equipment or high-temperature furnaces, water may be used to wash away accumulated dusts, provided a fine mist of water is first applied to prevent dusts from becoming airborne. Prompt cleanup of spills and dusts, repair of all leaks and equipment, and proper storage of material must be emphasized to all supervisory personnel, and employees must be properly trained in these procedures. Spills of nickel solutions may be neutralized, if appropriate, then washed with water [238] into a sanitary sewer (if in accordance with local, state, and federal regulations) or an impoundment pond.

Workers involved in maintenance operations may be exposed to inorganic nickel through unusual or nonroutine tasks. Maintenance personnel must be given thorough training in the use of local exhaust ventilation, respirators, and other necessary protective devices. Employees entering vessels or enclosed spaces where airborne nickel may be present must follow proper entry procedures, including the use of adequate respiratory protection, as required.

Nickel solutions may be acidic; therefore, when eye contact occurs, employees should immediately and thoroughly rinse the affected eye with water for 15 minutes [239]. If a solution is corrosive due to chemicals other than nickel, a physician should be consulted. Abrasions and wounds should be kept covered; but if, in spite of precautions, abraded skin is exposed to inorganic nickel, the area must be washed immediately with mild soap and water, and cleaned by debridement if necessary. If intact skin is exposed to inorganic nickel, the area should be washed with mild soap and water.

Nickel metal and alloys, although highly resistant to corrosion, should be stored so as to prevent formation of any surface contamination which may be released into the environment during subsequent handling. Acids which corrode nickel must not be stored with nickel products or compounds. Storage containers of inorganic nickel should be labeled, and, if solutions are stored, adequate dikes for the containment of spills must be provided. Reduced nickel catalysts should be stored in non-oxidizing atmospheres to prevent fire [233]. Finely divided or reduced nickel compounds also must not come into contact with gases containing carbon monoxide which may result in the formation of nickel carbonyl [13 (pp 495-527)].

VI. DEVELOPMENT OF STANDARD

Basis for Previous Standards

A Threshold Limit Value (TLV) of 1 mg/cu m (1,000 μg/cu m), measured as nickel, for workplace exposure to nickel metal dusts or fumes and to soluble nickel salts was proposed by the American Conference of Governmental Industrial Hygienists (ACGIH) in 1964, and adopted in 1966. The 1966 Documentation of the Threshold Limit Values [240] contains information supporting this TLV. The increases in deaths from lung and nasal cancer in nickel refinery workers in Norway, Wales, and Canada were noted, but a specific carcinogenic agent was not implicated. Experimental studies by Hueper [82,96,97] and Gilman and Ruckerbauer [87] were cited. Hueper reported that finely divided nickel metal powder produced injection-site tumors in the pleural cavities, muscle tissues, and other tissues of rats and guinea pigs [96,97], and that inhalation of 15 mg/cu m of powdered nickel produced lung tumors in these species [82]. Gilman and Ruckerbauer [87] reported that injection-site tumors were produced in rats and mice injected with dust from the effluent stack of a nickel refinery in Ontario. The 1966 Documentation [240] also noted that dermatitis ("nickel itch") was common in nickel platers. The TLV Committee emphasized, however, that a TLV of 1 mg/cu m for nickel dusts or fumes and for soluble nickel salts, measured as nickel, was probably too high to prevent dermatitis or sensitization caused by soluble nickel salts. The 1971 edition of the Documentation [241] does not differ in substance or conclusion from earlier editions.

A change in the TLV for soluble nickel salts from 1 mg/cu m to 0.1 mg/cu m, measured as nickel, was proposed by the TLV Committee in 1974 and adopted in 1976 [242]. The TLV Committee also has proposed a short-term exposure limit of 0.3 mg/cu m for a 15-minute exposure to soluble nickel salts [242]. The proposed Documentation of the Threshold Limit Values [243] indicated that three soluble nickel salts, nickel chloride, nickel sulfate, and nickel nitrate, are of industrial importance. A report by Bingham et al [131], indicating that inhalation exposure to nickel chloride at a concentration of 0.1 mg/cu m, measured as nickel, for several weeks caused hyperplasia and increased mucus secretion in the lungs of rats, was cited in the proposed Documentation [243]. An unpublished report by Clary [132] was also cited, indicating that inhalation of nickel chloride at a nickel concentration of 1 mg/cu m for 6 months produced increases in lung weight and in the cellular vascularity of the walls of the alveoli of rats and guinea pigs and aggravation of preexisting, reversible lesions in the lungs. Dermatitis in nickel platers and effects on glucose metabolism in animals were also mentioned [243].

In 1976, the Committee proposed a TLV of 1 mg/cu m, measured as nickel, for workplace exposure to dusts and fumes of insoluble inorganic compounds from nickel sulfide ore-roasting operations [243]. The 1976 Documentation [243] cited studies by Loken [42], Saknyn and Shabynina [58], Morgan [36], and Sutherland [44] which indicated to the ACGIH that lung and nasal cancers were associated primarily with exposure to high levels of dusts and fumes generated by the high-temperature calcination and sintering of impure nickel subsulfide. The ACGIH considered inconclusive the results of animal experiments designed to reproduce the nasal and lung cancers seen in nickel workers [78,80]. They stated in the Documentation [243], however, that cancers continue to be found in workers exposed to nickel subsulfide before 1960. Fluid-bed roasting was introduced in Canada in 1960 and no cancers have been found in workers first exposed since that time. The TLV committee concluded that, since 16 years is insufficient time to evaluate the effects of that process change on the development of cancer in nickel workers, their recommendation of 1 mg/cu m must be tentative.

Standards for occupational exposure to nickel compounds in other countries are listed in Table V-1 [244-246].

The Federal Republic of Germany published standards [247] and documentation [248] for occupational exposure to breathable dusts of metallic nickel, nickel sulfide, nickel sulfide ores, nickel oxide, and nickel carbonate, as they may develop in manufacturing and processing. Based on epidemiologic studies by Doll [37] and Shaknyn and Shabynina [58] and animal experiments by Hueper [82,96,97], nickel was classified as a substance known to be capable of producing cancer in humans and for which, therefore, no safe maximum workplace concentration could be established [248].

The present US standard (29 CFR 1910.1000) for workplace exposure to nickel metal and soluble nickel salts measured as nickel is an 8-hour TWA concentration limit of 1 mg/cu m (1000 μg/cu m). This standard is based on the TLV for workplace exposure adopted by the ACGIH in 1968.

TABLE VI-1

OCCUPATIONAL ENVIRONMENTAL LIMITS
FOR NICKEL IN FOREIGN COUNTRIES

Country and Compound	μg of nickel/cu m
Bulgaria	
Nickel and its oxides	500
German Democratic Republic	
Nickel metal*	500
Japan	
Nickel metal	1000
Rumania	
Nickel, soluble compounds	500
Sweden	
Nickel metal*	10
USSR	
Nickel metal*	500
Nickel monoxide and sulfide dust	500
Nickel metal and soluble compounds**	500

*From Winell [245]
**From Roschin and Timofeevskaya [246]

Other data adapted from Permissible Levels of Toxic Substances in the Working Environment [244]

Basis for the Recommended Standard

(a) Permissible Exposure Limits

Deaths from lung cancer and nasal cancer in nickel workers were first reported in 1932 [21], but the agents causing these cancers still have not been conclusively identified. Epidemiologic studies have shown that workers engaged in refining nickel from sulfide ore [35,37,39-41,43-45] have an increased risk of death from cancer of the respiratory organs. Some of these cancers have been associated with furnace work [43-45]; the high-temperature calcination and sintering of nickel sulfides, in particular, have been implicated [36,44,45]. However, occupational histories (Tables XV-3 and XV-4) of workers who developed cancer of the respiratory organs at one nickel refinery [41] show that some of these cancers occurred in cupola and anode furnace workers, in electrolysis workers, and in workers in other dusty operations as well. Auxiliary operations, including the crushing and grinding of nickel matte and the cleaning of calciner flues, have also been implicated [36]. In a refinery where nickel was purified electrolytically, increased mortality from lung and nasal cancer was observed in workers whose longest employment had been in the electrolysis department [43]. Cases of nasal cancer have been reported in other plants that refine nickel electrolytically [41,48]; some of these workers had no known additional exposure to nickel from work in other parts of the refinery (see Table XV-3) [41].

At least six cases of kidney cancer have been recorded in nickel refinery workers; three of these cases were observed in a group of 225 electrolysis workers in Canada [44] and the other three occurred in workers at a nickel refinery in Norway (E Pederson, written communication, November 1976). Animal studies [138,150] have shown that nickel may accumulate in the kidneys. Nickel subsulfide administered to rats by intrarenal injection produced carcinomas; nickel metal and nickel monosulfide did not [103]. No information was found for other nickel salts or for routes of administration more analogous to human exposure. This limited information is the first to suggest that nickel may contribute to the development of cancer of the kidney.

Epidemiologic studies of other industries that use nickel are limited. Preliminary studies [41,47] of workers at a nickel alloy plant showed a slight excess (O/E ratio of 1.57) of cancer of the respiratory organs in retired hourly workers [47], but not in the plant population as a whole (O/E ratio of 0.97) [41]. Three deaths from nasal cancer occurred in workers from this plant; at least two of these workers had been involved in calcination of nickel sulfide ore, a process not normally used in an alloy plant. A mortality study [46] of nickel miners and of refinery workers employed in the mill and separation areas and as converter furnace workers did not show a statistically significant increase in deaths from cancer of the respiratory organs (7 observed, 6.81 expected). The number of deaths from these cancers was too small to determine conclusively whether or not there was a carcinogenic risk for nickel workers in these occupations.

Although dust from a Canadian nickel refinery flue was found to contain nickel subsulfide, nickel oxide, and nickel sulfate [87], no additional information has been found on individual compounds to which nickel workers were exposed. Based on process information [10,23,36,41] it seems likely that calciner, sinter, and converter furnace workers were exposed mainly to dusts and fumes of nickel sulfides and nickel oxide. After 1933, exposures at the refinery in Clydach, Wales, probably differed from Canadian operations since the sulfur contents of the feed materials at Clydach were reduced [23]. After 1945, the feed material in Clydach was nickel oxide [36]. In Canada, cupola furnace workers may have been exposed to nickel sulfides; anode furnace workers were exposed to nickel oxide, although some exposure to elemental nickel may have been possible. In electrolytic refining, the tanks contain nickel salts, such as nickel sulfate and nickel chloride, in an acid solution [10]. Worker exposure varies with operating conditions, such as the current density and the temperature of the contents of the tank. Auxiliary operations in electrolytic refining could involve exposures to additional nickel compounds, such as nickel metal and nickel carbonate; the relevance of these exposures cannot be resolved without more detailed occupational histories. Nickel miners and at least some mill and separation workers were probably exposed to the mineral pentlandite [10]. Workers who developed cancer of the respiratory organs were generally exposed to mixtures of several nickel compounds and only rarely to a single compound. In addition, some of the groups of workers who had only a slight increase in incidence of cancer were exposed to the same compounds as those groups of workers that did have an increased risk of cancer.

The limited area-monitoring data available [41] are not sufficient to determine the exposures of workers who developed lung or nasal cancer. However, the amount of nickel dusts and fumes present in the immediate area can be classified into high, moderate, and low exposure categories. More than four orders of magnitude separate the highest (about 150 mg/cu m) and the lowest (0.006 mg/cu m) estimated values [41]. High nickel dust and fume concentrations occurred in the Clydach calciner buildings from 1902 to 1925 and at the Port Colborne and Copper Cliff sinter plants in Ontario, Canada. Moderate exposures were more likely around the Clydach calciners after 1925 and in the nickel alloy plant. Lower exposures would be expected near converter furnaces, and the lowest exposures should have occurred in mill and separation areas and in nickel mining [41]. It is not possible, in retrospect, to determine if some workers employed in areas with high dust levels were able to avoid these exposures over at least part of the work shift; however, this exposure classification parallels the lung and nasal cancer incidences observed in these groups.

Animal studies [81-83] do not clearly indicate that exposure to airborne nickel metal increases the risk of developing cancer of the respiratory organs; metaplastic changes were noted in the lungs of rats [82,83] and guinea pigs [82], but hamsters showed almost no effects attributable to exposure to nickel [83]. However, the inhalation of nickel subsulfide at 1 mg/cu m for about 80 weeks produced benign and malignant pulmonary tumors in rats [78]. Inhalation of nickel oxide by hamsters did not produce an excess incidence of pulmonary tumors over that seen in controls [80]. Questions regarding the suitability of some animal species for nickel carcinogenicity testing, the latent period necessary for the production of the effect, and the failure to produce any nasal cancers make the results of animal studies equivocal.

Nevertheless, nickel refinery workers have had an increased mortality rate from lung cancer and nasal cancer. Although lung cancer might be accounted for by factors in the refinery environment other than nickel, the high incidence of nasal cancer cannot. It must therefore be concluded that exposure to airborne nickel was a major contributing factor in a substantial portion of the excess deaths from lung and nasal cancer in nickel refinery workers. Based on this conclusion and supporting animal data, NIOSH considers that nickel subsulfide is a respiratory system carcinogen. Since many workers who developed nasal cancer were probably exposed to nickel oxide as well, and since others developed nasal cancers after using nickel salts, such as nickel chloride and nickel sulfate, these compounds are probably also carcinogenic. Although the evidence implicating metallic nickel is not as strong, metaplastic changes have been noted in animals exposed to nickel metal [82], and the air-oxidation of fine dusts of nickel metal probably results in inhalation of nickel oxide by workers exposed to airborne nickel metal. Metallic nickel, therefore, must be considered a suspect carcinogen. Despite a lack of adequate experimental animal studies that might confirm the carcinogenicity of all nickel compounds, the chemical properties of those that can be implicated in the development of cancer are diverse, and many other nickel compounds would be expected to have similar toxicologic properties. There is no evidence to suggest that inorganic nickel is carcinogenic when ingested. NIOSH therefore concludes that, in the absence of evidence to the contrary, nickel metal and all inorganic nickel compounds, when airborne, should be considered carcinogens.

The full significance of data showing that nickel and its compounds cause injection-site sarcomas is not clear, and these data have not been used in judging occupational tumorigenic potential. However, they suggest that nickel and its compounds should not become imbedded in skin, for example from entrainment in healing wounds.

Nickel is a common contact allergen; in a study of contact dermatitis patients it was determined that in approximately 7% of all cases, both occupational and nonoccupational in origin, the patients were sensitive to nickel [32]. In the workplace, appreciable skin contact with nickel solutions has produced dermatitis [28,29], although heat has been implicated as an additional factor [18,27], possibly because sweating enhances the dissolution of nickel salts. Cuts and abrasions from plated items [28,29] and the use of degreasers in electroplating [29] have been mentioned as contributing factors in the development of nickel dermatitis. Once a worker has been sensitized, that sensitivity has been retained [29,30], so that the worker may develop recurring dermatitis upon additional contact with nickel. Work practices, including appropriate clothing, and protective equipment should be used to minimize the chance of becoming sensitized to nickel. Because the measures needed to ensure that a worker will never come into contact with nickel in any form in the workplace are too severe to be practical, the standard will not adequately protect already sensitized workers in all situations.

The worker must be protected to minimize the risks of sensitization resulting from contact with nickel and of cancer resulting from exposure to airborne nickel. For these reasons, occupational exposure to nickel is defined as working with compounds, solutions, or metals containing nickel that can become airborne or spill or splash on the skin or in the eyes. If there is occupational exposure to nickel in a workroom, all employees assigned to that area, even temporarily, for any purpose including maintenance or repair, should be regarded as occupationally exposed. This definition does not include the wearing or use of nickel-containing products, such as pens, watches, typewriters, or stainless steel sinks that may be encountered in the workplace. The handling of solid products, eg, ingots, bars, or stainless-steel tools, by workers is also excluded provided that particle-generating operations such as grinding, cutting, or welding are not performed on these solid products.

There is overwhelming evidence that nickel refinery workers have had an excess of deaths from cancer of the respiratory organs. Evaluation of this evidence has led NIOSH to conclude that many of these cancers were nickel-induced, and that inorganic nickel should be regulated as a carcinogen. In the absence of adequate information on the amount of inorganic nickel that can be inhaled over a working lifetime without an excess risk of cancer, it is proposed to recommend a permissible limit based on the lowest TWA concentration of nickel reliably detectable over a single work shift.

Nickel is ubiquitous in the environment, and this factor must be considered in establishing a permissible exposure limit. Nickel concentrations in ambient air in urban locations averaged 0.017 μg/cu m [225], although some higher concentrations have been reported. The Huntington, West Virginia, area, for example, has had nickel concentrations in ambient air averaging 1.2 μg/cu m [223]. Since 10 μg of nickel must be collected to be measured reliably by the recommended analytical method, interferences from nickel in ambient air would be minimal for the 700-liter volume of air specified for sampling collection. NIOSH therefore recommends that exposure to inorganic nickel be controlled so that no worker is exposed to airborne nickel in excess of 15 μg/cu m, measured as nickel, in a 10-hour period.

(b) Sampling and Analysis

Measurement of total airborne nickel is considered essential since the development of nasal cancers in nickel workers suggests that the respirable fraction alone is not a good indicator of the worker's exposure to nickel. On the other hand, very large fragments, not breathable by the worker, may be cast into the air by operations such as grinding or welding. Thus, the sampling method should provide the best possible estimate of the nickel actually available to the worker in the breathing-zone air. For this reason, closed-faced sampling is recommended. A cellulose mixed-ester filter is recommended because it has a low nickel content and is easily digested in acids, so that this filter will provide minimal interference in subsequent nickel analysis. The recommended sampling method is described in Appendix I.

The analytical method used should be capable of measuring the amount of nickel present in the breathing-zone air of a worker when a sample is collected over a period of time approaching the length of the workshift. The error of measurement at the limit of detection should not exceed a 10% relative standard deviation under normal working conditions, and the amount of nickel in the blank should be minimized. For flame AAS, these conditions can be met by collection of a 700-liter air sample, use of a filter with a low nickel content, and digestion in a minimum amount of acid. Flame AAS has been shown to be accurate and precise, has been thoroughly tested, and provides quick and simple analyses [206]. Flame AAS is recommended for the analysis of nickel samples, as described in Appendix II. Other methods, such as polarography and emission spectroscopy, may be more suitable in specific applications and can also be reliable.

With chemical analysis, there is no practical means of distinguishing only those nickel compounds identified in the standard, since some, but not all, organometallic compounds containing nickel exist also in a solid form. Therefore, in rare instances, the total particulate nickel measured could include both inorganic nickel and compounds specifically exempted from the recommended standard. In those situations where mixed exposures to both types of nickel may occur, the total airborne particulate nickel must be considered inorganic nickel.

(c) Medical Surveillance

It is proposed that mandatory medical surveillance include preplacement and periodic examinations of the lungs, the upper respiratory tract, and the skin. Pulmonary function tests and chest X-rays should be performed to aid in the detection of any adverse effects of nickel on the lungs. Examinations of the upper respiratory tract should identify any evidence of nasal erosions or perforations and should be directed to the detection of possible adverse effects, including hyperplastic or premalignant changes. Examinations of the skin should be directed to identification of any evidence of nickel sensitivity; patch tests should not be performed routinely because of the possibility that they may, themselves, sensitize the worker. Preplacement and interim medical histories should supplement the information obtained from the medical tests. Periodic examinations should be given annually to workers frequently exposed to nickel to permit early detection of adverse effects on the respiratory organs and of sensitization to nickel. Medical records should be retained for 40 years after the last occupational exposure to nickel because cancer of the respiratory organs has been observed as long as 40 years after employment in a nickel refinery. Many of the cases of cancer listed in Tables XV-3 and XV-4 occurred from 30-40 years after cessation of employment.

Smokers should be counseled on their possible increased risk of developing lung cancer from exposure to airborne nickel.

Specific tests to detect cancer, to measure kidney function, or to determine the extent of exposure to airborne nickel are recommended. Although the benefits of sputum cytology for the early detection of cancer are controversial and there are only a limited number of adequately trained personnel to perform these examinations, the results of an ongoing sputum cytology screening program for former nickel workers have been encouraging [56,57]. Cytologic examination of sputum to supplement chest X-rays is therefore recommended, particularly for nickel workers whose medical or work histories may indicate a high risk of developing lung cancer. A questionnaire designed to assess chronic respiratory symptoms is suggested to supplement medical and work histories. The concentration of nickel in the urine has not been adequately correlated with the individual's health status to warrant a requirement for biologic monitoring [222], but urinary nickel has been used as an index of exposure for groups of workers [221,222]. Although there is evidence that ip injection of nickel chloride in rats can result in proteinuria [148], the possibility of kidney damage in humans exposed to inorganic nickel has not been adequately studied. In addition, kidney damage may be unlikely at exposure concentrations near the recommended TWA concentration limit. However, general kidney function screening tests, such as the measurement of protein or albumin in the urine, are not difficult to perform. Therefore, kidney function tests are recommended for workers exposed to inorganic nickel.

(d) Personal Protective Equipment and Clothing

Protective clothing is recommended in order to minimize the risk of dermatitis in unsensitized workers likely to have appreciable skin contact with solutions of nickel. This equipment should include, where appropriate, face shields, shoe covers, aprons, gloves, and arm shields or coats. Fire-retardant work clothing should be worn where there is a chance of skin burns from molten nickel. Only self-contained or air-supplied respirators are recommended for working in areas where airborne nickel is present, since inorganic nickel is considered a carcinogen.

All foreseeable events that could result in the necessity of escape from a hazardous area should be evaluated to establish evacuation procedures and to determine the equipment needed. Escape equipment should be kept in readily accessible locations. A self-contained breathing apparatus with positive pressure in the facepiece should be provided for escape except for those situations in which the time required to put on the respirator exceeds the time otherwise needed to escape from the area or in which an immediate life-threatening situation does not exist.

(e) Informing Employees of Hazards

Continuing education is an important part of a preventive hygiene program for employees exposed to inorganic nickel. Workers should be instructed periodically by properly trained persons about possible sources of exposure, adverse health effects associated with exposure to nickel, engineering and work practice controls in use or being planned to limit exposure, and environmental and medical monitoring procedures used to check control procedures. The function of monitoring equipment, such as personal samplers, should be explained, so that employees understand their part in environmental monitoring. Medical monitoring procedures, especially the use of chest X-rays and pulmonary function tests, and their importance in detecting possible adverse health effects should be explained.

(f) Work Practices

Inorganic nickel, when airborne, can cause cancer in the respiratory system, and it can produce dermatitis, especially if there is appreciable skin contact with nickel-containing materials. Thus, procedures used for the cleanup of spills, waste disposal, general housekeeping, and storage of inorganic nickel should minimize dispersion of nickel and the worker's contact with nickel. Personal hygienic measures should be adopted to eliminate wound contamination and accidental intake of nickel and to further reduce the probability of sensitization to nickel. Because of the severe adverse effects associated with exposure to inorganic nickel, entry into areas where there is occupational exposure to nickel should be restricted to those persons needed to perform the job. Records of persons entering restricted areas should be maintained to provide documentation of those workers who are occupationally exposed to nickel. In order to prevent the spread of nickel contamination beyond the workplace, work clothing should be removed and the worker should shower at the end of the work shift. Soiled clothing should be stored and laundered in a manner not harmful to persons who handle or launder them.

(g) Monitoring and Recordkeeping Requirements

Industrial hygiene surveys should be made as soon as possible after the promulgation of a standard based on these recommendations and within 30 days of any process change. Where there is occupational exposure to nickel, the TWA concentration limit for each employee should be determined and the workplace air around every operation should be sampled and analyzed quarterly in order to provide the protection necessary to minimize the risk of respiratory cancer.

Records of environmental measurements should be retained for 40 years after the last occupational exposure to nickel to permit correlation with any chronic health effects which may ensue.

VII. COMPATIBILITY WITH OTHER STANDARDS

Ambient air quality standards for nickel have not been established. Other standards and guidelines which have been published are described below. Since these are not air standards, they appear to be compatible with the recommended TWA environmental concentration.

The Environmental Protection Agency (EPA) has issued effluent guidelines and standards for electroplating. For existing establishments, using the best available technology to reduce effluents, the maximum discharge allowed for any 1 day is 160 mg/sq m/operation (32.7 pounds/million square feet/operation), and the average value for 30 consecutive days must not exceed 80 mg/sq m/operation. For new sources, the daily maximum has been reduced to 80 mg/sq m/operation and the 30-day average limit to 40 mg/sq m/operation. These effluent limitations apply to discharges of nickel and other pollutants resulting from the process in which a ferrous or nonferrous base material is rack or barrel electroplated with nickel, copper, chromium, zinc, or any combination thereof. These standards were published in 40 CFR 413 (39 Federal Register 11510, March 28, 1974; amended by 39 Federal Register 26642, July 22, 1974).

EPA has not established a primary drinking water standard for nickel. EPA is preparing Quality Criteria for Water [249] which will not have direct regulatory force but will form the basis for judgment in several EPA and state water programs. The nickel criterion, not based on human toxicity, is 1% of the 96-hour LC50 for fresh and marine aquatic life. Values given for the 96-hour LC50 ranged from 4.6 to 9.8 mg/liter in soft water and from 39.2 to 42.4 mg/liter in hard water.

The Food and Drug Administration has not established a tolerance for nickel in food or food products.

VIII. RESEARCH NEEDS

In the development of this document, information was found on a limited number of nickel compounds. Before the hazards to the work population from exposure to metallic nickel and inorganic nickel compounds can be thoroughly evaluated, extensive epidemiologic and toxicologic research is required. Epidemiologic studies are needed to assess the risk of cancer associated with exposure to airborne nickel in operations other than those already studied. These studies should include nickel alloy workers, nickel catalyst makers, nickel salt producers, nickel-cadmium battery makers, nickel platers without concurrent exposure to chromium, and workers engaged in the roasting and smelting of sulfur-free nickel ores.

For all nickel workers, including those exposed to nickel sulfides, the risk of developing cancer in sites other than the respiratory organs, such as the kidneys, needs to be studied. The effects of smoking, dermatitis, and chronic respiratory disease on nickel toxicity need to be examined to determine if some worker groups have an increased risk of developing cancer. Determinations of the concentrations of nickel and of other substances present in the air, eg, sulfur dioxide, arsenic, and other metals, should be included in epidemiologic studies to determine whether any toxicologic interaction is additive, potentiating, independent, or antagonistic.

Studies are also needed to determine whether adverse effects other than cancer, which have been observed in animals exposed to inorganic nickel by various routes of administration, are applicable to human exposure. Effects on the lungs and kidneys and on glucose metabolism need to be examined. Information is needed on both humans and animals to clarify whether there is an effect of nickel on the functioning of the thyroid and pituitary glands and on the developing fetus.

Toxicologic studies in animals are needed to establish both acute and chronic effects of the many nickel compounds that have not been studied. In addition, long-term inhalation studies in a suitable animal species are needed to better assess the carcinogenicity of such nickel compounds as nickel chloride, nickel sulfate, nickelous and nickelic oxide, and metallic nickel.

Limiting worker exposure to inorganic nickel to the maximum extent possible should be an immediate goal. Improved control technology, particularly in furnace operations, and the development of a flameless atomic absorption method for analysis of airborne nickel are needed. Should additional studies indicate that all inorganic nickel compounds need not be controlled to the same exposure limit, analytical methods that can identify individual compounds will be necessary.