

## XII. APPENDIX III

### ANALYSIS OF URINARY NICKEL

The atomic absorption spectrophotometric method of Nomoto and Sunderman [155], with some simplification of the wet ashing procedure, is recommended.

#### Principle

Preshift and postshift urine samples are collected. The urine sample is wet ashed, the ash is dissolved in water, the pH of the solution is adjusted, and nickel is reacted with ammonium pyrrolidine dithiocarbamate. The complex is extracted into methyl isobutyl ketone. The absorbance of the solution at 232 nm is determined and compared to the absorbance of the standards.

#### Range and Sensitivity

For a 50-ml sample of urine, the detection limit is approximately 0.02  $\mu\text{g}$  nickel/100 ml of urine, which corresponds to a recorder signal equivalent to twice the baseline noise level. This sensitivity is achieved with a three-slot burner, and it is 1.5 times that attained with a single-slot burner.

The useful range for this method is 0.1-2  $\mu\text{g}$  nickel/100 ml for a 50-ml sample. The lower limit is determined by the absorbance of the reagent blank. The upper range may be extended, but the relationship of absorbance

to nickel concentration is no longer linear. However, the working range may be extended to higher concentrations by sample dilution.

The sensitivity of the method and the useful range will vary somewhat depending on the instrument used, the type of burner, height of the aspirator above the flame, and the acetylene-air ratio of the fuel.

### Interferences

The addition of at least a 100-fold excess of arsenic, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, potassium, silver, sodium, zinc, ammonium, carbonate, chloride, citrate, nitrate, oxalate, persulfate, phosphate, or sulfate did not change the absorbance of solutions containing nickel. Solutions containing 0.5  $\mu\text{g}$  of cadmium or 2.5  $\mu\text{g}$  of gold caused a 5% inhibition in nickel absorbance, and 10 mg of cadmium caused a 25% inhibition of absorbance of 0.5  $\mu\text{g}$  of nickel. Concentrations of iron in excess of 100 times the nickel concentration may also cause interference.

### Precision and Accuracy

The coefficient of variation for duplicate analyses of nickel in 50 urine specimens was 10.3%. An average recovery of 100% with a range from 98-102% was obtained when nickel (2.5  $\mu\text{g}/100\text{ ml}$ ) was added to five urine samples.

### Apparatus

- (a) Atomic absorption spectrophotometer with nickel hollow-cathode lamp, air, and acetylene fuel.
- (b) Low-speed centrifuge with head capable of holding 50-ml tubes.
- (c) pH meter with a combination glass-calomel electrode.
- (d) Hotplate.
- (e) Borosilicate or polyethylene bottles.
- (f) Ehrlemeyer flasks.
- (g) Calibrated centrifuge tubes.
- (h) Stoppered vials.
- (i) Volumetric flasks, pipets, graduated cylinders.

### Reagents

All reagents must be ACS certified reagent grade, unless specified otherwise.

- (a) Doubly distilled or deionized water.
- (b) Redistilled concentrated nitric acid.
- (c) Ultrapure sulfuric acid.
- (d) Commercially prepared aqueous stock standard, 1,000  $\mu\text{g Ni/ml}$ .

Working standards are prepared by dilution of the stock solution with 5% nitric acid. Working standards should not be stored longer than 1 week.

(e) Ammonium pyrrolidine dithiocarbamate (APDC), 2 g/100 ml: One gram of APDC is dissolved in 50 ml of water, and the solution is extracted twice with 5 ml of methyl isobutyl ketone (MIBK). This solution is prepared each day.

(f) Phthalate buffer, pH 2.5: 10.2 g of potassium acid phthalate and 39 ml of 1.0 N hydrochloric acid/liter; 10 ml of APDC is added and the solution is extracted 5 times with 25 ml of MIBK.

(g) Methyl isobutyl ketone (MIBK), water saturated.

(h) Ammonium hydroxide, concentrated.

### Procedure

#### (a) Cleaning of Equipment

Clean glassware, prior to first use, by soaking it for 24 hours in 5% nitric acid, rinsing with tap water, and finally rinsing with doubly distilled water. After glassware has been used, wash first with detergent, rinse with tap water, soak in 5% nitric acid for 1 hour, and rinse thoroughly with doubly distilled water. Allow to dry. Use plastic containers for cleaning and do not handle the cleaned glassware with bare hands, as sweating may cause nickel contamination.

#### (b) Collection of Samples

Urine samples of about 100 ml are collected in borosilicate or polyethylene containers. About 1 ml of concentrated hydrochloric acid is added to the specimen upon receipt in the laboratory.

#### (c) Analysis of Samples

(1) Transfer the unknown samples (50 ml of urine) and 50 ml of at least three standards of different concentrations covering the range of interest to separate 125-ml Erhlemeyer flasks, and add 10 ml of a 1:5 mixture of sulfuric:nitric acids to each flask. Heat the flasks on a hotplate in a fume hood, adding additional 1:5 sulfuric and nitric acid in 2-ml increments to each flask until digestion is complete, a white residue

is obtained, and the final volume is less than 2 ml. If low recovery yields are obtained, addition of 1 part of perchloric acid to the digestion mix may overcome this difficulty. Routine use of perchloric acid is not recommended because of its explosive properties.

(2) Allow the flasks to cool, transfer the contents of each flask quantitatively to a 50-ml centrifuge tube, and adjust the volume of each tube to 20 ml with distilled water.

(3) Add 2 ml of phthalate buffer to each sample, and adjust the pH to 2.5 by addition of ammonium hydroxide drop by drop.

(4) Add 2 ml of APDC solution and mix the contents. Then add 3 ml of MIBK and shake for 1 minute.

(5) Centrifuge the tubes at approximately 900 G for 5 minutes.

(6) Transfer the organic phase to a 5-ml stoppered vial.

(7) Aspirate into the atomic absorption unit and read the absorbance at 232 nm. Stabilize the baseline of the atomic absorption unit by aspiration of water-saturated MIBK for 20-30 minutes prior to reading of the samples. Adjust the flame to obtain optimum sensitivity with minimum baseline noise.

### Calculations

A calibration curve is prepared by plotting the absorbance versus the concentration of each standard on linear graph paper. The concentration of nickel that corresponds to the absorbance for the sample is read from the graph.

XIII. APPENDIX IV  
MATERIAL SAFETY DATA SHEET

The following items of information which are applicable to a specific product or material shall be provided in the appropriate block of the Material Safety Data Sheet (MSDS).

The product designation is inserted in the block in the upper left corner of the first page to facilitate filing and retrieval. Print in upper case letters as large as possible. It should be printed to read upright with the sheet turned sideways. The product designation is that name or code designation which appears on the label, or by which the product is sold or known by employees. The relative numerical hazard ratings and key statements are those determined by the rules in Chapter V, Part B, of the NIOSH publication, An Identification System for Occupationally Hazardous Materials. The company identification may be printed in the upper right corner if desired.

(a) Section I. Product Identification

The manufacturer's name, address, and regular and emergency telephone numbers (including area code) are inserted in the appropriate blocks of Section I. The company listed should be a source of detailed backup information on the hazards of the material(s) covered by the MSDS. The listing of suppliers or wholesale distributors is discouraged. The trade name should be the product designation or common name associated with the material. The synonyms are those commonly used for the product, especially formal chemical nomenclature. Every known chemical designation or

competitor's trade name need not be listed.

(b) Section II. Hazardous Ingredients

The "materials" listed in Section II shall be those substances which are part of the hazardous product covered by the MSDS and individually meet any of the criteria defining a hazardous material. Thus, one component of a multicomponent product might be listed because of its toxicity, another component because of its flammability, while a third component could be included both for its toxicity and its reactivity. Note that a MSDS for a single component product must have the name of the material repeated in this section to avoid giving the impression that there are no hazardous ingredients.

Chemical substances should be listed according to their complete name derived from a recognized system of nomenclature. Where possible, avoid using common names and general class names such as "aromatic amine," "safety solvent," or "aliphatic hydrocarbon" when the specific name is known.

The "%" may be the approximate percentage by weight or volume (indicate basis) which each hazardous ingredient of the mixture bears to the whole mixture. This may be indicated as a range or maximum amount, ie, "10-40% vol" or "10% max wt" to avoid disclosure of trade secrets.

Toxic hazard data shall be stated in terms of concentration, mode of exposure or test, and animal used, eg, "100 ppm LC50-rat," "25 mg/kg LD50-skin-rabbit," "75 ppm LC man," or "permissible exposure from 29 CFR 1910.1000," or, if not available, from other sources of publications such as the American Conference of Governmental Industrial Hygienists or the American National Standards Institute Inc. Flashpoint, shock sensitivity,

or similar descriptive data may be used to indicate flammability, reactivity, or similar hazardous properties of the material.

(c) Section III. Physical Data

The data in Section III should be for the total mixture and should include the boiling point and melting point in degrees Fahrenheit (Celsius in parentheses); vapor pressure, in conventional millimeters of mercury (mmHg); vapor density of gas or vapor (air = 1); solubility in water, in parts/hundred parts of water by weight; specific gravity (water = 1); percent volatiles (indicated if by weight or volume) at 70 degrees Fahrenheit (21.1 degrees Celsius); evaporation rate for liquids or sublimable solids, relative to butyl acetate; and appearance and odor. These data are useful for the control of toxic substances. Boiling point, vapor density, percent volatiles, vapor pressure, and evaporation are useful for designing proper ventilation equipment. This information is also useful for design and deployment of adequate fire and spill containment equipment. The appearance and odor may facilitate identification of substances stored in improperly marked containers, or when spilled.

(d) Section IV. Fire and Explosion Data

Section IV should contain complete fire and explosion data for the product, including flashpoint and autoignition temperature in degrees Fahrenheit (Celsius in parentheses); flammable limits, in percent by volume in air; suitable extinguishing media or materials; special firefighting procedures; and unusual fire and explosion hazard information. If the product presents no fire hazard, insert "NO FIRE HAZARD" on the line labeled "Extinguishing Media."



(e) Section V. Health Hazard Information

The "Health Hazard Data" should be a combined estimate of the hazard of the total product. This can be expressed as a TWA concentration, as a permissible exposure, or by some other indication of an acceptable standard. Other data are acceptable, such as lowest LD50 if multiple components are involved.

Under "Routes of Exposure," comments in each category should reflect the potential hazard from absorption by the route in question. Comments should indicate the severity of the effect and the basis for the statement if possible. The basis might be animal studies, analogy with similar products, or human experiences. Comments such as "yes" or "possible" are not helpful. Typical comments might be:

Skin Contact--single short contact, no adverse effects likely; prolonged or repeated contact, possibly mild irritation.

Eye Contact--some pain and mild transient irritation; no corneal scarring.

"Emergency and First Aid Procedures" should be written in lay language and should primarily represent first-aid treatment that could be provided by paramedical personnel or individuals trained in first aid.

Information in the "Notes to Physician" section should include any special medical information which would be of assistance to an attending physician including required or recommended preplacement and periodic medical examinations, diagnostic procedures, and medical management of overexposed employees.

(f) Section VI. Reactivity Data

The comments in Section VI relate to safe storage and handling of hazardous, unstable substances. It is particularly important to highlight instability or incompatibility to common substances or circumstances, such as water, direct sunlight, steel or copper piping, acids, alkalies, etc. "Hazardous Decomposition Products" shall include those products released under fire conditions. It must also include dangerous products produced by aging, such as peroxides in the case of some ethers. Where applicable, shelf life should also be indicated.

(g) Section VII. Spill or Leak Procedures

Detailed procedures for cleanup and disposal should be listed with emphasis on precautions to be taken to protect employees assigned to cleanup detail. Specific neutralizing chemicals or procedures should be described in detail. Disposal methods should be explicit including proper labeling of containers holding residues and ultimate disposal methods such as "sanitary landfill" or "incineration." Warnings such as "comply with local, state, and federal antipollution ordinances" are proper but not sufficient. Specific procedures shall be identified.

(h) Section VIII. Special Protection Information

Section VIII requires specific information. Statements such as "Yes," "No," or "If necessary" are not informative. Ventilation requirements should be specific as to type and preferred methods. Respirators shall be specified as to type and NIOSH or US Bureau of Mines approval class, ie, "Supplied air," "Organic vapor canister," etc. Protective equipment must be specified as to type and materials of construction.

(i) Section IX. Special Precautions

"Precautionary Statements" shall consist of the label statements selected for use on the container or placard. Additional information on any aspect of safety or health not covered in other sections should be inserted in Section IX. The lower block can contain references to published guides or in-house procedures for handling and storage. Department of Transportation markings and classifications and other freight, handling, or storage requirements and environmental controls can be noted.

(j) Signature and Filing

Finally, the name and address of the responsible person who completed the MSDS and the date of completion are entered. This will facilitate correction of errors and identify a source of additional information.

The MSDS shall be filed in a location readily accessible to employees exposed to the hazardous substance. The MSDS can be used as a training aid and basis for discussion during safety meetings and training of new employees. It should assist management by directing attention to the need for specific control engineering, work practices, and protective measures to ensure safe handling and use of the material. It will aid the safety and health staff in planning a safe and healthful work environment and in suggesting appropriate emergency procedures and sources of help in the event of harmful exposure of employees.

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# MATERIAL SAFETY DATA SHEET

I PRODUCT IDENTIFICATION		
MANUFACTURER'S NAME	REGULAR TELEPHONE NO EMERGENCY TELEPHONE NO.	
ADDRESS		
TRADE NAME		
SYNONYMS		
II HAZARDOUS INGREDIENTS		
MATERIAL OR COMPONENT	%	HAZARD DATA
III PHYSICAL DATA		
BOILING POINT, 760 MM HG		MELTING POINT
SPECIFIC GRAVITY (H <sub>2</sub> O=1)		VAPOR PRESSURE
VAPOR DENSITY (AIR=1)		SOLUBILITY IN H <sub>2</sub> O, % BY WT
% VOLATILES BY VOL		EVAPORATION RATE (BUTYL ACETATE=1)
APPEARANCE AND ODOR		

## IV FIRE AND EXPLOSION DATA

FLASH POINT (TEST METHOD)		AUTOIGNITION TEMPERATURE	
FLAMMABLE LIMITS IN AIR, % BY VOL	LOWER		UPPER
EXTINGUISHING MEDIA			
SPECIAL FIRE FIGHTING PROCEDURES			
UNUSUAL FIRE AND EXPLOSION HAZARD			

## V HEALTH HAZARD INFORMATION

<b>HEALTH HAZARD DATA</b>
<b>ROUTES OF EXPOSURE</b>  INHALATION <hr/> SKIN CONTACT <hr/> SKIN ABSORPTION <hr/> EYE CONTACT <hr/> INGESTION
<b>EFFECTS OF OVEREXPOSURE</b> ACUTE OVEREXPOSURE <hr/> CHRONIC OVEREXPOSURE
<b>EMERGENCY AND FIRST AID PROCEDURES</b>  EYES <hr/> SKIN <hr/> INHALATION. <hr/> INGESTION
<b>NOTES TO PHYSICIAN</b>

## VI REACTIVITY DATA

CONDITIONS CONTRIBUTING TO INSTABILITY

INCOMPATIBILITY

HAZARDOUS DECOMPOSITION PRODUCTS

CONDITIONS CONTRIBUTING TO HAZARDOUS POLYMERIZATION

## VII SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED

NEUTRALIZING CHEMICALS

WASTE DISPOSAL METHOD

## VIII SPECIAL PROTECTION INFORMATION

VENTILATION REQUIREMENTS

SPECIFIC PERSONAL PROTECTIVE EQUIPMENT

RESPIRATORY (SPECIFY IN DETAIL)

EYE

GLOVES

OTHER CLOTHING AND EQUIPMENT

## **IX SPECIAL PRECAUTIONS**

**PRECAUTIONARY  
STATEMENTS**

**OTHER HANDLING AND  
STORAGE REQUIREMENTS**

**PREPARED BY**

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**ADDRESS**

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**DATE**

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#### XIV. APPENDIX V

##### GLOSSARY

Calcining--A process in which nickel sulfide is heated and oxidized to form nickel oxide. The sulfur is driven off the feed material but agglomeration of fine particles does not occur.

Cementation--The purification of electrolyte by precipitation with metallic copper.

Converting--The process in which iron is removed by oxidation and concentration in slag. The amount of sulfur required for subsequent operations is also controlled; excess sulfur is driven off as sulfur dioxide.

Cupola furnaces--Used in the "Orford process" (see below) to make copper tops and nickel bottoms after iron was removed. The charge was matte, coke, and sodium sulfide.

Electrowinning--A method of electrolysis which has a net cell reaction and is used to refine soluble anodes of nickel sulfide.

Matte--An impure metallic sulfide mixture produced by smelting of sulfide ores.

Nickel monosulfide--In this document, nickel monosulfide refers to NiS.



Nickel subsulfide--In this document, nickel subsulfide refers to Ni<sub>3</sub>S<sub>2</sub>.

Nickel sulfides--Nickel sulfides refer to nickel-sulfur compounds in nickel matte.

Orford process--Obsolete method for separation of nickel and copper. Copper sulfide is more soluble in sodium sulfide than is nickel sulfide. The copper, therefore, tends to float because sodium sulfide has a specific gravity of 1.9, whereas nickel sulfide, with a specific gravity of 5.7, settles out.

Pentlandite--A nickel-bearing mineral with an ideal formula of (Ni,Fe)<sub>9</sub>S<sub>8</sub> and a nickel content of 34.22%.

Reduction--Conversion of nickel oxide to nickel metal.

Roasting--Oxidizing process in which nickel sulfide ores are heated to oxidize iron and to drive off sulfur as sulfur dioxide. Fluid-bed roasters, multihearth roasters, and sintering machines have been used.

Sintering--A process in which nickel sulfide is heated and oxidized to form nickel oxide. Sulfur is driven off the feed material and agglomeration of fine particles occurs.

Slimes--Anode impurities that do not go into solution in electrolytic tanks.

Smelting--Thermal treatment of nickeliferous sulfide ores or ore concentrates to bring about physical and chemical changes leading to the recovery of nickel and valuable metals.

XV. TABLES AND FIGURES

TABLE XV-1

PROPERTIES AND USES OF NICKEL AND COMMERCIAL NICKEL COMPOUNDS

Compound	Formula	Solubility		Uses				
		Water	Other Solvents	Alloy	Catalyst	Nickel Plating	Pigment, Fixative	Other*
Nickel	Ni	Insol	HNO <sub>3</sub> , HCl, H <sub>2</sub> SO <sub>4</sub>	X	X	X	X	1
Nickel acetate	Ni(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub>	Sol	Alcohol		X		X	
Nickel ammonium chloride	NiCl <sub>2</sub> .NH <sub>4</sub> Cl.6H <sub>2</sub> O	"				X	X	
Nickel ammonium sulfate	NiSO <sub>4</sub> .(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> .6H <sub>2</sub> O	"	Alcohol			X		
Nickel arsenate	Ni <sub>3</sub> (AsO <sub>4</sub> ) <sub>2</sub>	Insol	Acid		X			
Nickel boride	NiB	**	HNO <sub>3</sub> , aqua regia					2
Nickel bromate	Ni(BrO <sub>3</sub> ) <sub>2</sub> .6H <sub>2</sub> O	Sol						
Nickel bromide	NiBr <sub>2</sub>	"	NH <sub>4</sub> OH, ether					
Nickel carbonate	NiCO <sub>3</sub>	"	Acid		X	X	X	
Nickel carbonate hydroxide	NiCO <sub>3</sub> .2Ni(OH) <sub>2</sub> .4H <sub>2</sub> O	Insol	HCl, NH <sub>4</sub> OH		X	X	X	

TABLE XV-1 (CONTINUED)

## PROPERTIES AND USES OF NICKEL AND COMMERCIAL NICKEL COMPOUNDS

Compound	Formula	Solubility		Uses			
		Water	Other Solvents	Alloy	Catalyst	Nickel Plating	Pigment, Fixative Other*
Nickel chloride	NiCl <sub>2</sub>	Sol	Alcohol, NH <sub>4</sub> OH			X	X 4
Nickel chromate	NiCrO <sub>4</sub>					X	
Nickel cyanide	Ni(CN) <sub>2</sub>	Insol	KCN	X		X	
Nickel fluo- borate	Ni(BF <sub>4</sub> ) <sub>2</sub>					X	
Nickel fluoride	NiF <sub>2</sub>	Sol	NH <sub>3</sub> , acid, ether				
Nickel hydroxide	Ni(OH) <sub>2</sub>	"	NH <sub>4</sub> OH, acid				3,5
Nickel nitrate hexa- hydrate	Ni(NO <sub>3</sub> ) <sub>2</sub> .6H <sub>2</sub> O	"	Alcohol, NH <sub>4</sub> OH		X	X	X
Nickel nitrate tetra- amine	Ni(NO <sub>3</sub> ) <sub>2</sub> .4NH <sub>3</sub> .2H <sub>2</sub> O	"				X	
Nickel ortho- phosphate	Ni <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> .8H <sub>2</sub> O	Insol	Alcohol, acid, NH <sub>4</sub> salts			X	X
Nickel oxide	NiO	"	Acid, NH <sub>4</sub> OH	X			X 1
Nickel peroxide	Ni <sub>2</sub> O <sub>3</sub>	"	Acid				3

TABLE XV-1 (CONTINUED)

PROPERTIES AND USES OF NICKEL AND COMMERCIAL NICKEL COMPOUNDS

Compound	Formula	Solubility		Uses			
		Water	Other Solvents	Alloy	Catalyst	Nickel Plating	Pigment, Fixative Other*
Nickel phosphate heptahydrate	$Ni_3(PO_4)_2 \cdot 7H_2O$	"	Acid, $NH_4OH$			X	X
Nickel potassium chromate	$NiK_2(CrO_4)_2$						
Nickel potassium sulfate	$NiSO_4K_2SO_4 \cdot 6H_2O$	Sol					
Nickel stannate	$NiSnO_3 \cdot 2H_2O$						X
Nickel subsulfide***	$Ni_3S_2$	Insol	$HNO_3$				
Nickel sulfamate	$Ni_2O_6S_2NiH_4$					X	
Nickel sulfate	$NiSO_4$	Sol	Methanol		X	X	X 6,7
Nickel sulfate heptahydrate	$NiSO_4 \cdot 7H_2O$	"	Alcohol		X		X 6
Nickel sulfate hexahydrate	$NiSO_4 \cdot 6H_2O$	"	Alcohol, $NH_4OH$		X	X	X
Nickel sulfide	$NiS$	"	$HNO_3$ , $KHS$				

TABLE XV-1 (CONTINUED)

## PROPERTIES AND USES OF NICKEL AND COMMERCIAL NICKEL COMPOUNDS

Compound	Formula	Solubility		Uses		
		Other Water Solvents	Cata- Alloy lyst	Nickel Pigment, Plating	Fixative	Other*
Nickel titanate	NiTiO <sub>4</sub>			X		
Nickel zirconate	NiZrO <sub>5</sub>					3
Nickelic hydroxide	Ni(OH) <sub>3</sub>					5

\*Other uses: 1--fuel-cell electrodes, 2--prisms, 3--batteries, 4--gas-mask absorbant, 5--nickel salts, 6--food additive, 7--blackener for zinc and brass

\*\*Decomposes

\*\*\*Not produced or used, but may form during refining of nickel matte

Adapted from references 4-9

TABLE XV-2

## OCCUPATIONS WITH POTENTIAL EXPOSURE TO NICKEL

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Battery makers, storage	Nickel miners
Catalyst workers	Nickel refiners
Cemented-carbide makers	Nickel smelters
Ceramic makers	Nickel workers
Disinfectant makers	Oil hydrogenators
Dyers	Organic-chemical synthesizers
Electroplaters	Paint makers
Enamellers	Penpoint makers
Gas-mask makers	Petroleum-refinery workers
Inkmakers	Spark-plug makers
Jewelers	Stainless-steel makers
Magnet makers	Textile dyers
Metallizers	Vacuum-tube makers
Mond-process workers	Varnish makers
Nickel-alloy makers	Welders

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Adapted from reference 14

TABLE XV-3

OCCUPATIONAL HISTORIES OF WORKERS AT A NICKEL REFINERY IN PORT COLBORNE, ONTARIO,  
WHO DEVELOPED NASAL CANCER BETWEEN 1930 AND JUNE 1976

Case No.	Year of First Employment	Year of Death (or Diagnosis)	Number of years	From First Employment to Death (Diagnosis)	Years of Employment in Each Exposure Group						Classification with longest Exposure		
					Em- ployed	Furnace				Elec- trolysis		Other Dust	Not Dusty
						Cupola	Calciner	Sinter	Anode				
1*	1920	1955	31.0	35	0	8.5	22.5	0	0	0	0	Sinter	
2	1922	1962	41.9	40	21.5	0	0	0	20.4	0	0	Cupola	
3*	1923	1953	29.0	30	9.0	0.3	0.2	19.2	0	0	0.3	Anode	
4*	1923	1953	29.0	30	0	7.2	21.3	0	0	0	0.5	Sinter	
5	1923	1963	22.2	40	0.9	0	0	0	7.3	0	14.0	Not dusty	
6	1923	1969	31.3	46	0.3	23.0	0	0	0	0	8.0	Calciner	
7*	1924	1955	28.5	31	7.5	0.5	17.0	3.5	0	0	0	Sinter	
8	1924	1973	33.3	49	0	8.7	17.0	0	0	0	7.6	"	
9*	1925**	1948	23.4	23	0	4.3	18.6	0	0	0	0.5	"	
10	1926	1973	37.2	47	0	0	0	37.2	0	0	0	Anode	
11*	1928	1946	15.3	18	0	0	0	0	14.8	0	0.5	Electrolysis	
12*	1928	1957	24.2	29	0.9	0	0	0.2	6.3	15.8	1.0	Other dust	
13*	1928	1957	24.5	29	0	0	18.3	0	0	0.3	5.7	Sinter	
14*	1928	1959	11.2	31	2.8	0	1.5	0.7	0	6.2	0	Other dust	
15	1928	1960	31.4	32	0	2.3	26.2	0	2.9	0	0	Sinter	
16	1928	1960	25.9	32	1.1	22.2	0	0	0	0	2.6	Calciner	
17*	1928	1965	22.3	37	0.3	16.9	1.2	0.7	3.1	0	0.1	"	
18	1928	(1973)	33.3	(45)	0	11.0	1.0	0	21.3	0	0	Electrolysis	
19	1928	(1973)	38.3	(45)	0	0	0.3	0	38.0	0	0	"	
20*	1930	1954	18.6	24	1.7	0	0	0	16.8	0.1	0	"	
21	1930	1975	41.0	45	0	0	0	0	39.4	0	1.6	"	
22	1931	1969	36.6	38	0	0	0	0	36.6	0	0	"	
23*	1933	1959	20.8	26	0	0	16.7	4.1	0	0	0	Sinter	
24	1934	1959	7.4	25	0	3.0	4.4	0	0	0	0	"	
25	1935	(1971)	13.6	(36)	0	5.0	7.6	0	0	0	1.0	"	
26	1935	1972	9.7	37	0	5.0	0	0	4.7	0	0	Calciner	
27	1936	(1966)	30.5	(30)	0	29.5	1.0	0	0	0	0	"	
28	1936	1972	28.0	36	0	7.3	0.2	0	0	0	20.5	Not dusty	
29	1936	(1973)	6.9	(37)	0	0	0	1.1	1.0	0	4.8	"	
30	1940	1971	30.0	31	0	0	4.5	0	25.5	0	0	Electrolysis	
31	1941	1964	22.0	23	0	2.6	4.7	0	13.7	0	1.0	"	
32	1941	(1973)	30.1	(32)	0	4.8	3.3	0	0	0	22.0	Not dusty	
33	1942	1972	28.1	30	0	0	0	0	0	0	21.8(a)	"	
34	1944	1964	25.7	20	0	0	11.0	0	0	0	14.7	"	
35	1944	1967	22.7	23	0	0.2	0	0	21.0	0	1.5	Electrolysis	
36	1956	(1973)	13.6	(17)	0	8.0	0	0	0	5.1	0.5	Calciner	

Mean=25.5 Mean=32.8  
SD= 9.1 SD= 8.4

\*In the study by Sutherland [44] and Inco [41]; all others in the Inco report only

\*\*Cancer of the nasopharynx  
(a)Carpenter

Adapted from Sutherland [44] and Inco [41]



TABLE XV-4

OCCUPATIONAL HISTORIES OF WORKERS AT A NICKEL REFINERY IN PORT COLBORNE, ONTARIO,  
WHO DEVELOPED LUNG CANCER BETWEEN 1930 AND JUNE 1976

Case No.	Year of First Employment	Year of Death (or Diagnosis)	Number of Years	Years of Employment in Each Exposure Group								Classification with Longest Exposure	
				Em- ployed	From First Employment to Death (Diagnosis)	Furnace				Elec- trolysis	Other Dust		Not Dusty
						Cupola	Calciner	Sinter	Anode				
1	1919	1968	37.7	49	0	33.1	0	0.1	0	4.1	0.4	Calciner	
2*	1922	1956	32.2	34	0	0	0	0	0	0	32.2	Not dusty	
3	1922	1961	20.5	39	0	12.2	0	0	8.3	0	0	Calciner	
4	1922	1963	23.1	41	0	0	0	0	0	0	23.1	Not Dusty	
5	1922	1963	21.3	41	0.5	20.8	0	0	0	0	0	Calciner	
6	1922	1968	18.0	46	5.8	0	0.4	0.1	0.3	0.1	11.3	Not dusty	
7	1922	1970	35.4	48	0	0	0	0	35.3	0	0.1	Electrolysis	
8	1923	1966	14.7	43	3.3	10.4	0	0.1	0	0	0.9	Calciner	
9	1923	1966	31.5	43	0	0	(b)	0	0	31.5	0	Other dust	
10	1923	1967	18.2	44	0.2	15.0	0	0	0	0	3.0	Calciner	
11	1923	1968	8.5	45	0	3.3	2.0	1.1	1.8	0	0.3	"	
12	1923	1969	16.4	46	0	0	0	0	4.3	0	12.1	Not dusty	
13	1923	1974	10.3	51	0	0	0	0	0	10.3	0	Other dust	
14*	1924	1954	26.0	30	0	0	0	0	0	26.0	0	"	
15*	1924	1955	28.5	31	7.5	0.5	17.0	3.5	0	0	0	Sinter	
16	1925	1951	13.8	26	0.7	2.6	3.4	0.2	3.8	3.1	0	Electrolysis	
17*	1925	1953	27.8	28	2.9	0.4	24.0	0.5(c)	0	0	0	Sinter	
18	1925	(1961)	19.4	(36)	0	(b)	(b)	0	0	19.4	0	Other dust	
19	1925	(1961)	23.6	(36)	0	2.9	20.7	0	0	0	0	Sinter	
20	1925	1967	34.5	42	0.1	0.1	0	0	0.1	34.2(d)	0	Other dust	
21	1925	(1972)	32.1	(47)	3.8	0.1	0	0.1	0	0.1	28.0	Not dusty	
22	1925	1975	31.8	50	3.8	0.1	0	0	0	0	27.9	"	
23*	1926	1949	22.9	23	0.8	0	0	0	21.8	0.3	0	Electrolysis	
24*	1926	1957	30.0	31	0	0	0	0	0	0	30.0	Not dusty	
25	1926	1967	6.2	41	0.2	1.1	3.0	0	0	1.8	0.1	Sinter	
26*	1927	1953	11.6	26	0.6	8.3	0.2	0	0	0	2.5	Calciner	
27	1927	(1972)	36.0	(45)	0.2	3.9	0.3	0.2	31.3	0	0.1	Electrolysis	
28*	1928	1946	13.6	18	3.5	0.3	0	9.8	0	0	0	Anode	
29*	1928	1954	24.1	26	0.1	0	3.5	0	6.8	13.7	0	Other dust	
30*	1928	1954	24.8	26	0.2	0	9.6	0	0.3	0	14.7	Not dusty	
31*	1928	1955	24.8	27	1.6	1.9	0	0	21.3	0	0	Electrolysis	
32*	1928	1956	25.8	28	3.2	1.8	16.2	0	4.6	0	0	Sinter	
33*	1928	1956	23.2	28	0	3.0	21.4	0	0	0.8	0	"	
34*	1928	1959	27.1	31	0.5	0	17.8	1.7	0.8	0	6.3	"	
35	1928	1963	23.1	35	0	6.4	4.6	0	0	10.4	1.7	Other dust	
36	1928	1964	5.9	36	0	0	0.1	0.5	3.1	1.6	0.6	Electrolysis	
37	1928	1964	16.6	36	0	0	0	0	0.2	13.3	3.1	Other dust	
38	1928	1965	27.6	37	3.0	0.2	0	0.1	0	24.3	0	"	
39	1928	1967	32.8	39	0	0	0	19.2	0	0.1	14.5	Anode	
40	1928	1969	32.7	41	0	0	17.3	0	3.5	0.7	11.2	Sinter	
41	1928	1971	31.9	43	0.5	0.1	0	0	31.0	0.1	0.2	Electrolysis	
42	1928	1972	30.8	44	0	12.8	3.7	0.1	2.9	11.3	2.0	Calciner	
43	1928	1973	15.5	45	0	0	0	0	0	0	15.5	Not dusty	
44*	1929	1954	24.7	25	4.2	0	17.5	0	0	3.0	0	Sinter	
45	1929	1956	11.9	27	0	0	11.9	0	0	0	0	"	
46*	1929	1956	19.9	27	0	0	0	0	18.8	0	1.1	Electrolysis	
47*	1929	1959	33.0	30	1.0	----17.0----	0	0	0	15.0	0	Calciner/ sinter	
48	1929	1960	9.2	31	1.0	0	0	0	7.8	0.1	0.3	Electrolysis	
49	1929	1960	30.7	31	0	5.9	0.7	0	23.2	0	0.9	"	
50	1929	(1962)	20.3	(33)	0	0.3	0.1	17.0	2.8	0.1	0	Anode	
51	1929	1963	12.0	34	2.1	0.4	9.3	0	0	0.2	0	Sinter	
52	1929	1964	16.1	35	0.7	14.5	0	0	0	0.9	0	Calciner	
53	1929	1965	3.7	36	1.8	1.9	0	0	0	0	0	"	
54	1929	(1968)	29.2	(39)	0	0	17.4	0	0	0	11.8	Sinter	
55	1929	1973	36.1	44	0	0	0	0	0	31.3	4.8	Other dust	

TABLE XV-4 (CONTINUED)

OCCUPATIONAL HISTORIES OF WORKERS AT A NICKEL REFINERY IN PORT COLBORNE, ONTARIO,  
WHO DEVELOPED LUNG CANCER BETWEEN 1930 AND JUNE 1976

Case No.	Year of First Employment	Year of Death (or Diagnosis)	Number of Years	Years of Employment in Each Exposure Group								Classification with Longest Exposure	
				Em- ployed	From First Employment to Death (Diagnosis)	Furnace				Elec- trolysis	Other Dust		Not Dusty
						Cupola	Calciner	Sinter	Anode				
56	1929	1973	9.7	44	2.5	0	1.2	0	0	1.0	5.0	Not dusty	
57*	1930	1955	21.8	25	1.9	0.8	0	0	18.8	0	0.3	Electrolysis	
58	1931	1965	34.2	34	0	13.7	13.3	0.1	0.1	4.5	2.5	Calciner	
59*	1933	1953	19.6	20	0	0	0	18.8	0	0.3	0.5	Anode	
60*	1933	1955	22.9	22	0.5	0	0	21.9(c)	0	0	0.5	"	
61*	1933	1958	22.5	25	0	0	0	0	0	0	22.5	Not dusty	
62	1933	1963	28.6	30	0	4.8	23.8	0	0	0	0	Sinter	
63	1933	1967	27.8	34	0	0	0	0	2.0	25.8	0	Other dust	
64	1933	1972	29.0	39	0	0	0.5	0	27.4	0	1.1	Electrolysis	
65	1934	1964	29.1	30	1.6	0	0	0	25.8	0.8	0.9	"	
66	1935	1962	12.2	27	0	0.2	10.2	0	1.8	0	0	Sinter	
67	1935	1965	29.5	30	0	0	0	0.1	0	29.3	0.1	Other dust	
68	1935	1971	31.6	36	0	0.2	0	0.1	1.9	29.3	0.1	"	
69	1935	1971	10.2	36	0	0	0	0	9.8	0	0.4	Electrolysis	
70*	1936	1957	20.8	21	0	5.5	13.8	0	0	0	1.5	Sinter	
71	1937	1961	19.4	24	0	0	0	0.1	17.2	0.2	1.9	Electrolysis	
72	1937	1967	24.4	30	0	0	0	0.1	9.9	0	14.4	Not dusty	
73	1937	1970	28.0	33	0	0	0	0.1	10.5	0	17.4	"	
74	1937	1971	26.1	34	0	0	6.4	0	0	19.7	0	Other dust	
75	1939	1970	12.8	31	0.3	12.1	0	0	0	0.3	0.1	Calciner	
76	1939	1971	27.7	32	0	0.2	5.3	0	0	2.9	19.3	Not dusty	
77	1940	(1973)	26.6	(33)	0	0	0	0	0.1	0.2	26.3	"	
78	1941	1965	10.2	24	0	0	0	0	9.5	0	0.7	Electrolysis	
79	1942	1963	24.8	21	0	2.6	0.2	0	11.0	0	11.0	Electrolysis/ not dusty	
80	1942	1966	22.9	24	0	0	0	0	22.7	0	0.2	Electrolysis	
81	1942	1970	26.7	28	0	1.4	0	0.1	23.5	0	1.7	"	
82	1942	1972	27.2	30	0	0.3	3.2	0	22.8	0.1	0.8	"	
83	1942	1973	28.3	31	0	0.3	0	0	17.7	10.3	0	"	
84	1944	1964	20.0	20	0	4.3	3.5	0	1.4	0	10.8	Not dusty	
85	1947	1962	9.8	15	0	0	0	2.8	0	0.3	6.7	"	
86	1948	1970	14.7	22	0	0	0	0.6	5.8	0.5	7.8	"	
87	1948	1974	5.4	26	0	0	0	0	0	5.1	0.3	Other dust	
88	1950	(1973)	22.8	(23)	0	0	0	0	0	22.8	0	"	
89	1951	1972	20.9	21	0	-----9.2-----	0	0.1	0.1	11.4	0.1	"	
90	1953	1973	17.2	20	0	0.3	0	0	9.5	0	7.4	Electrolysis	

Mean=22.5 Mean=33.0  
SD= 8.3 SD= 8.4

\*Included in the study by Sutherland [44] and Inco [41]; all others the Inco Report only

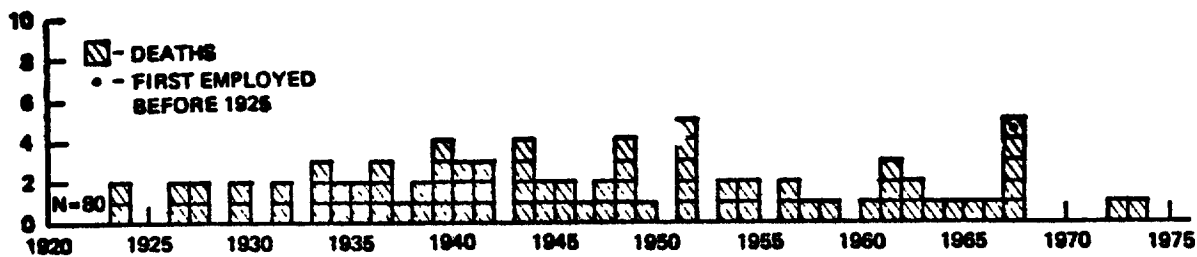
(a)Management

(b)Worked occasionally in maintenance

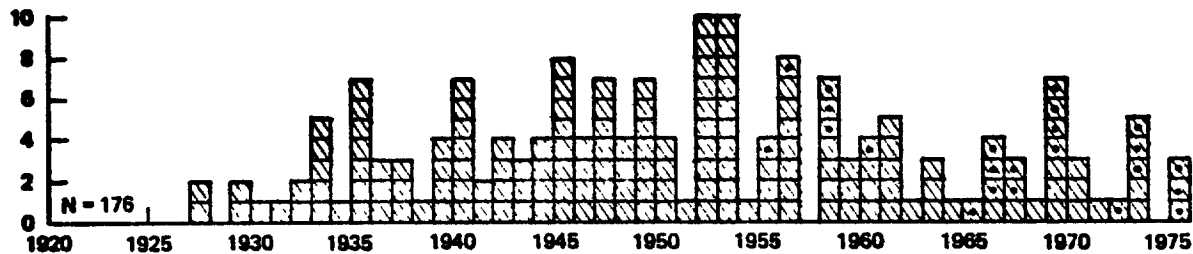
(c)Holder, not exposed

(d)Sinter conveyorman

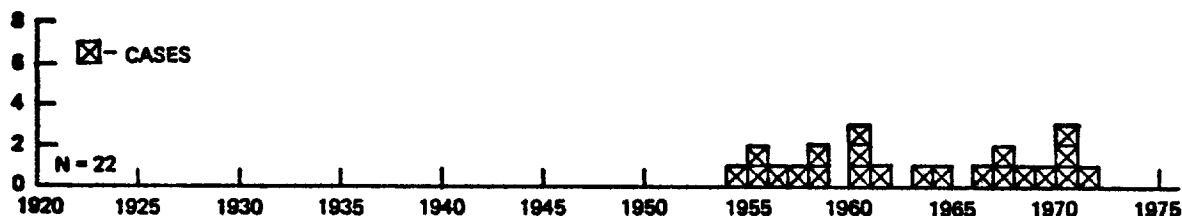
Adapted from Sutherland [44] and Inco [41]



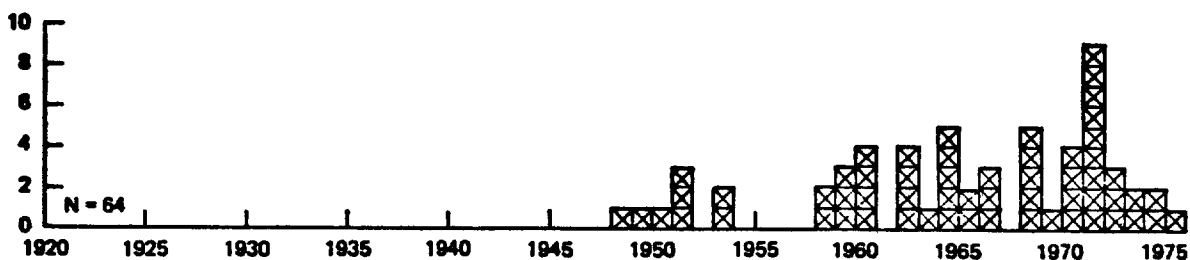
a. NASAL CANCER BY YEAR OF DEATH IN WORKERS AT A NICKEL REFINERY IN CLYDACH, WALES (41)



b. LUNG CANCER BY YEAR OF DEATH IN WORKERS AT A NICKEL REFINERY IN CLYDACH, WALES (41)



c. NASAL CANCER BY YEAR OF DIAGNOSIS IN WORKERS AT A NICKEL REFINERY IN KRISTIANSAND, NORWAY (B Roy, written communication, October 1976)



d. LUNG CANCER BY YEAR OF DIAGNOSIS IN WORKERS AT A NICKEL REFINERY IN KRISTIANSAND, NORWAY (B Roy, written communication, October 1976)

FIGURE XV-1

LUNG AND NASAL CANCERS IN NICKEL REFINERY WORKERS

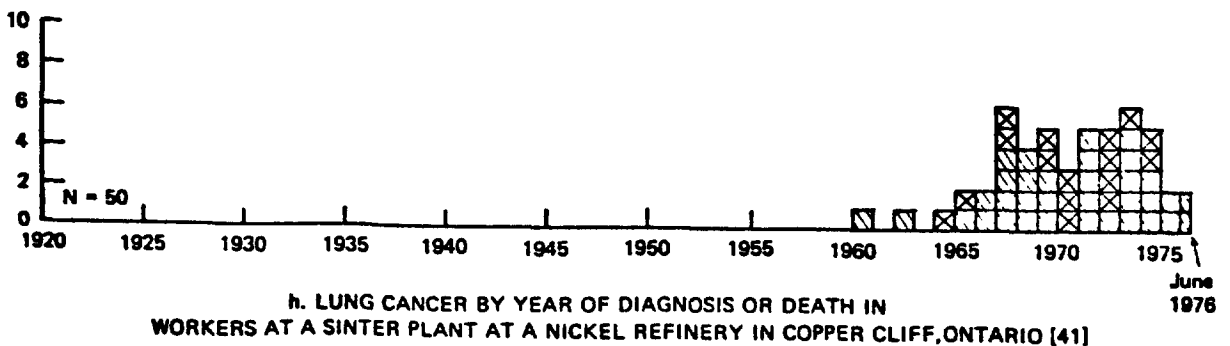
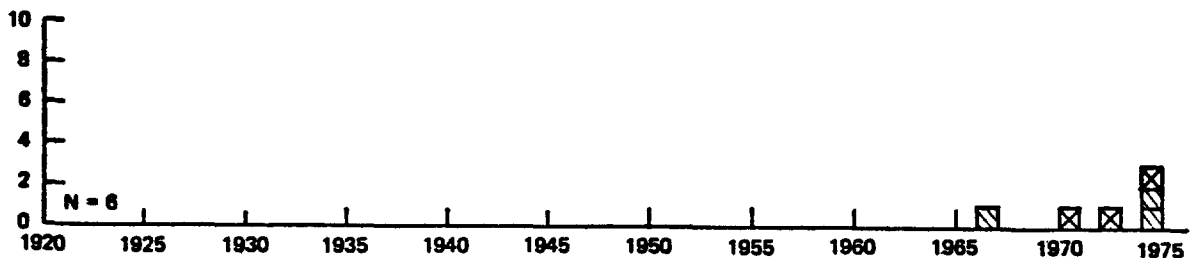
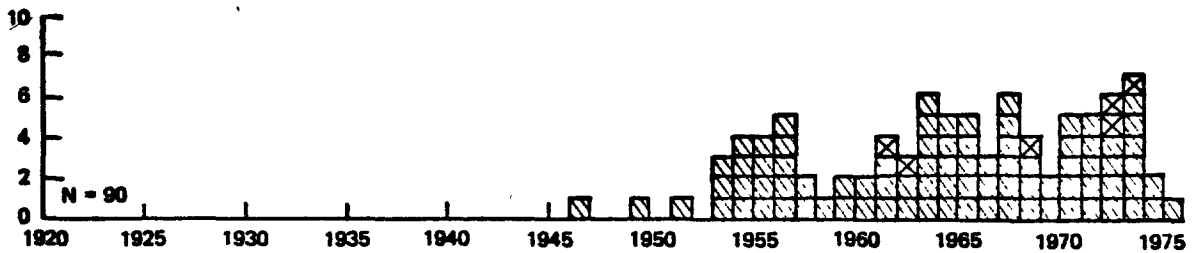
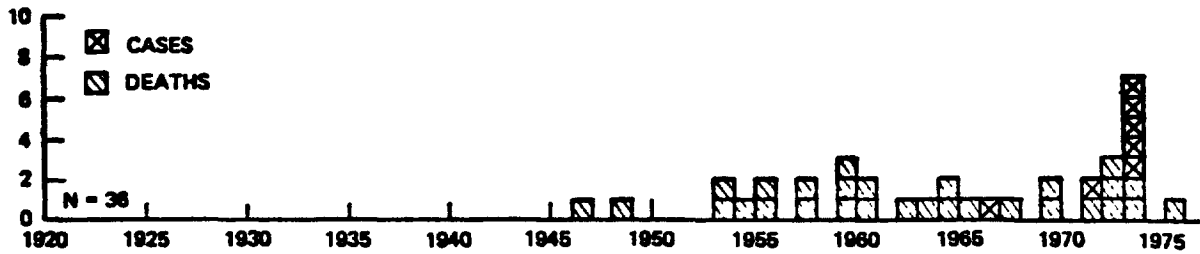
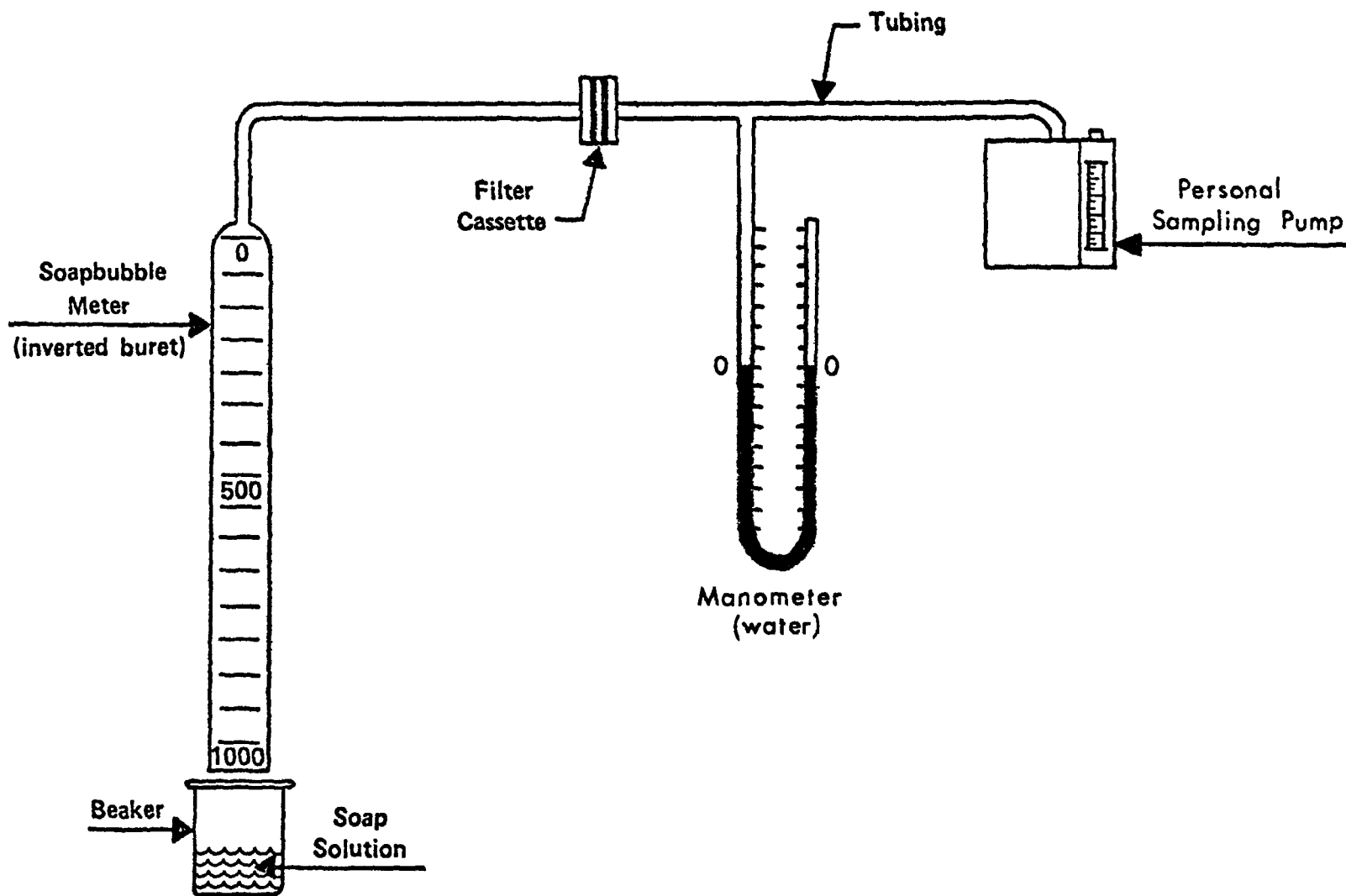


FIGURE XV-1 (CONTINUED)

LUNG AND NASAL CANCERS IN NICKEL REFINERY WORKERS

FIGURE XV-2 CALIBRATION SETUP FOR PERSONAL SAMPLING PUMP WITH FILTER CASSETTE



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