

IX. APPENDIX I

METHOD FOR SAMPLING TUNGSTEN AND ITS PRODUCTS IN AIR

This sampling method is adapted from NIOSH Method No. P & CAM 173 [65]. Although this method of sampling is recommended, other methods shown to be at least as efficient may be used.

General Requirements

Collect personal samples in the breathing zone of individual employees without interfering with the employees' freedom of movement. Enough samples should be obtained to permit calculation of a TWA concentration and to evaluate the exposure of each employee at every operation or location in which there is occupational exposure to tungsten. Record the sampling locations and conditions, including ambient temperature and pressure, equipment used, time and rate of sampling, and any other pertinent information.

Equipment for Air Sampling

(a) Filter: Cellulose ester membrane filter with a pore size of 0.8 μm mounted with backup pad in a 2- or 3-piece closed-face cassette.

(b) Battery-operated personal sampling pump: The pump should have a means for attachment, such as a clip, to the employee. All pumps and flowmeters must be calibrated using a calibrated test meter or other reference, as described in the Section on Calibration of Equipment.

Battery-operated pumps should be capable of operating at flowrates of 1.5-2.5 liters/minute and must be capable of at least 4 and preferably 8 hours of continuous operation without recharging.

Calibration of Equipment

Since the accuracy of an analysis can be no greater than the accuracy with which the volume of air is measured, the accurate calibration of the sampling pump is essential. The frequency of calibration required depends upon the use, care, and handling to which the pump is subjected. Pumps should be recalibrated if they have been abused or if they have just been repaired or received from the manufacturer. Maintenance and calibration should be performed on a routine schedule, and records of these should be maintained.

Ordinarily, pumps should be calibrated in the laboratory both before they are used in the field and after they have been used to collect a large number of field samples. If extensive field sampling is performed, calibration may also be performed periodically during sampling to ensure the continuous satisfactory operation of the pump and sampler. The accuracy of calibration depends on the type of instrument used as a reference. The choice of calibration instrument will depend largely upon where the calibration is to be performed. For laboratory testing, a spirometer or soapbubble meter is recommended, although other calibration instruments, such as a wet test meter, dry gas meter, or rotameter can be used. The calibration instrument should be calibrated to $\pm 5\%$. The actual setups will be similar for all instruments.

The calibration setup for a personal sampling pump with a membrane

filter is shown in Figure XII-3. Since the flowrate given by a pump depends on the pressure drop across the sampling device, the pump must be calibrated while operating with a representative filter in line. Instructions for calibration with the soapbubble meter follow. If another calibration device is selected, equivalent procedures should be used.

(a) Check the voltage of the pump battery with a voltmeter to ensure adequate voltage for calibration. Charge the battery if necessary.

(b) Place a membrane filter in the holder.

(c) Assemble the sampling train as shown in Figure XII-2.

(d) Turn on the pump and moisten the inside of the soapbubble meter by immersing the buret in the soap solution and drawing bubbles up the inside until they are able to travel the entire length of the buret without bursting.

(e) Adjust the pump flow controller to provide the desired flowrate.

(f) Check the water manometer to ensure that the pressure drop across the sampling train does not exceed 13 inches of water (approximately 1 inch of mercury).

(g) Start a soapbubble up the buret and measure with a stopwatch the time the bubble takes to move from one calibration mark to another.

(h) Repeat the procedure in (f) at least 3 times, average the results, and calculate the flowrate by dividing the volume between the preselected marks by the time required for the soapbubble to traverse the distance.

(i) Record the data for the calibration including volume measured, elapsed time, pressure drop, air temperature, atmospheric pressure, serial

number of the pump, date, and the name of the person performing the calibration.

Collection of Samples

(a) Assemble a sampling train consisting of a 0.8- μ m cellulose ester membrane filter with a portable, battery-operated personal sampling pump.

(b) The recommended sampling flowrate is 2-2.5 liters/minute. Establish the calibrated flowrate as accurately as possible, using the manufacturer's directions.

(c) Measure and record the temperature and pressure of the atmosphere being sampled.

(d) Record the elapsed time. The sample volume is obtained by multiplying the flowrate by the elapsed time.

(e) Immediately after sampling, seal the filter container.

(f) Treat at least one filter in the same manner as the sample (open and reclose cassette, seal, and ship), but do not draw air through it. This filter will serve as a blank.

X. APPENDIX II

ANALYTICAL METHOD FOR TUNGSTEN

The use of an atomic absorption spectrophotometer probably provides the most economical method for the analysis of tungsten. This method is recommended by NIOSH for determining compliance with the recommended tungsten standard. The procedure is based on Method No. P & CAM 173 of the NIOSH Manual of Analytical Methods [65]. Other modifications of the method in extraction [82], dissolution [80], and elimination of interferences [81] may be beneficial in improving the sensitivity. Other methods of analysis of tungsten may be used, provided their precision and sensitivity are determined to be at least equivalent to this method.

Principle of the Method

The sample, collected on a cellulose membrane filter, is washed using a mixture of nitric acid and hydrofluoric acid [80] to destroy the organic matter and to bring tungsten into solution. Samples, blanks, and standards are aspirated into the nitrous oxide-acetylene flame of the atomic absorption spectrophotometer. A hollow cathode lamp for tungsten provides the characteristic lines at 255 [80,81,107] or 401 nm [82-84,108]. The former of these two wavelengths is preferred because of its greater sensitivity. However, the 255 nm line is more susceptible to interferences, especially from molybdenum, manganese, and chromium [81]. The absorption of these lines by the ground-state atoms in the flame is

proportional to the tungsten concentration in the aspirated sample.

Range and Sensitivity

For tungsten, the optimum working concentration is 500 $\mu\text{g/ml}$ [83], and the lowest detectable concentration is 3 $\mu\text{g/ml}$ [84]. The method can be extended to higher concentrations by dilution of the sample. The sensitivity is 35 μg of tungsten/ml/1% absorbance [84]. This value will vary somewhat with the instrument used.

Interferences

Edgar [81] reported enhancement of tungsten absorption caused by the presence of contaminant metals, particularly by vanadium, molybdenum, manganese, chromium, and nickel. He recommended a 2% addition of sodium sulfate to eliminate interference by these other metals.

Precision and Accuracy

In general, this analytical method will provide a coefficient of variation of approximately 2%, depending to an extent upon the instrument used. Keller and Parsons [108] estimated a standard deviation of 0.06% based on their analyses of tungsten in silicate ores. Data on the accuracy and precision of the method are not yet available.

Advantages and Disadvantages

The method is rapid because there is little sample preparation involved. It can be performed with generally available laboratory equipment and by general laboratory personnel. Although interferences by other metals were recognized [81], these interferences were not reported [10,29] in the determination of environmental concentrations of tungsten. However, since the method measures total tungsten, it is not capable of distinguishing insoluble from soluble tungsten compounds. Furthermore, the proposed method will not determine tungstic oxide, an acid-insoluble compound.

Apparatus and Equipment

- (a) Hollow cathode lamp for tungsten.
- (b) Atomic absorption spectrophotometer having a monochromator with a reciprocal linear dispersion of about 6.5 Angstroms/mm in the ultraviolet region and equipped with a burner head for nitrous oxide-acetylene flame.
- (c) Oxidant: Nitrous oxide is required as an oxidant since higher temperatures are needed in the analysis of tungsten.
- (d) Fuel: Acetylene, commercially available for atomic absorption use.
- (e) Pressure-reducing valves: A 2-gauge, 2-stage pressure-reducing valve and appropriate hose connections are needed for each compressed gas tank used.
- (f) Glassware:
 - 15-ml graduated tubes

10-ml and 100-ml volumetric flasks

(g) Plastic Laboratory Ware:

125-ml polytetrafluoroethylene (PTFE) beakers with
PTFE lids

125-ml polyethylene bottles

(h) Hotplates capable of reaching 250 C

Reagents

(a) Doubly distilled or deionized water

(b) Redistilled concentrated nitric acid

(c) Concentrated hydrofluoric acid

(d) 10% aqueous sodium sulfate

(e) Aqueous stock standards of tungsten or cobalt of 2,000 $\mu\text{g}/\text{ml}$

Procedure

(a) Cleaning of Equipment:

Before use, plastic and glassware should be washed with a laboratory glassware detergent, rinsed with tap water, then soaked for 30 minutes with 10% nitric acid. Several rinses with distilled or deionized water should follow.

(b) Analysis of Samples:

Samples are transferred to clean 125-ml PTFE beakers (glassware should not be used at this stage) and several milliliters of concentrated nitric acid and hydrofluoric acid are added to each. Each beaker is covered loosely with a PTFE lid and heated on a hotplate (140 C) in a fume

hood until the sample chars or until a slightly yellow solution remains. Several additions of nitric acid and hydrofluoric acid may be needed to completely ash and destroy the organic material.

Once the ashing is complete, as indicated by a whitish residue in the beaker and following several minutes on the high temperature hotplate (200-250 C), the ash is then dissolved with deionized water and quantitatively transferred to a 15-ml graduated tube. If the sample is expected to be heavily contaminated with such metals as vanadium, molybdenum, manganese, chromium, and nickel, it may be useful to add 2% of sodium sulfate as recommended by Edgar [81] to reduce interferences. Aliquots of this can be diluted if necessary, or the volume can be reduced by evaporation to get the tungsten concentration within the working range of the method.

The sample is then aspirated into a reducing nitrous oxide-acetylene flame and measured at 255 nm (alternatively 401 nm). The other operating parameters are set according to the instrument instructions from the manufacturer. When very low tungsten concentrations are found in the sample, scale expansion can be used to increase instrument response.

Calibration and Standards

From 2,000 μg of tungsten/ml of stock standard solutions, prepare working standards to cover the range between 3 and 1,000 $\mu\text{g}/\text{ml}$. The standard solutions are made in deionized water, with 2% sodium sulfate added if the samples were similarly treated, and are stored in polyethylene bottles. The low concentration standards may deteriorate and should be made on the day they are to be used.

Aspirate the series of standards and record the percentage of absorption.

Prepare calibration curves by plotting on linear graph paper the absorbance versus the concentration of each standard in $\mu\text{g/ml}$. It is advisable to run a set of standards both before and after a sample run to ensure that conditions have not changed.

Calculations

From the calibration curve, read the concentration in $\mu\text{g/ml}$ in the analysis sample.

Blank values, if any, are subtracted from each sample. The concentration of tungsten in air can be expressed as milligrams of tungsten/cubic meter of air, which is numerically equal to micrograms of tungsten/liter of air:

$$\text{mg tungsten/cu m} = \mu\text{g tungsten/V} \times \text{D}$$

where:

$\mu\text{g tungsten}$ = micrograms of tungsten from the
calibration curve

V = volume of air sampled (in liters) at 25 C
and 760 mmHg

D = dilution, if any

XI. APPENDIX III
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 ₂ O=1)		VAPOR PRESSURE
VAPOR DENSITY (AIR=1)		SOLUBILITY IN H ₂ 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				
HEALTH HAZARD DATA				
ROUTES OF EXPOSURE				
INHALATION				

SKIN CONTACT				

SKIN ABSORPTION				

EYE CONTACT				

INGESTION				

EFFECTS OF OVEREXPOSURE				
ACUTE OVEREXPOSURE				

CHRONIC OVEREXPOSURE				

EMERGENCY AND FIRST AID PROCEDURES				
EYES				

SKIN				

INHALATION:				

INGESTION				

NOTES TO PHYSICIAN				

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 _____

ADDRESS _____

DATE _____

TABLE XII-1

CHEMICAL AND PHYSICAL PROPERTIES OF
TUNGSTEN AND SELECTED TUNGSTEN COMPOUNDS

Compound	Molecular Formula	Formula Weight	Melting Point (c)	Density	Solubility g/100cc	
					H ₂ O*	Other
Ammonium metatungstate	(NH ₄) ₆ H ₂ W ₁₂ O ₄₀	—	Decomposes 200	4.0	Very soluble	—
Ammonium paratungstate	(NH ₄) ₁₀ (H ₁₀ W ₁₂ O ₄₆)	—	—	—	Insoluble	Decomposes in acid or alkali
Ammonium phosphotungstate	(NH ₄) ₃ P(W ₃ O ₁₀) ₄	2,931.27	—	—	Slightly soluble	Soluble in alkali, insoluble in acid
Cadmium tungstate	CdWO ₄	360.25	—	—	0.05	Soluble in NH ₄ OH
Calcium tungstate	CaWO ₄	287.93	—	6.062	0.00064 (15 C)	—
"	"	"	—	—	0.00323 (25 C)	Insoluble in alcohol, acid; soluble in NH ₄ Cl
Calcium tungstate (Scheelite)	"	"	—	—	0.0013 (20 C)	—
"	"	"	—	—	0.0002 (90 C)	—
Calcium metatungstate	Ca ₃ H ₄ [H ₂ (W ₂ O ₇) ₆] 27H ₂ O	3,500.96	-7H ₂ O 105	—	—	Decomposes in acid
Cerium (III) tungstate	Ce ₂ (WO ₄) ₃	1,023.78	1,089	6.77	—	—
Cesium tungstate	Cs ₂ WO ₄	380.76	—	—	85.6 (17 C)	—
Cobalt tungstate	CoWO ₄	306.78	—	8.42	Insoluble	Soluble in hot concentrated acid
Copper (II) tungstate	CuWO ₄ ·2H ₂ O	347.42	Red heat	—	0.1 (15 C)	Soluble in NH ₄ OH; insoluble in alcohol; decomposes in mineral acid
Cyclopentadienylbitungsten hexacarbonyl	(C ₅ H ₅) ₂ W ₂ (CO) ₆	665.95	240-2 decomposes	—	—	Soluble in chloroform, CCl ₄ , CS ₂
Iron (II) tungstate	FeWO ₄	303.69	—	6.64	—	—
Lead tungstate	PbWO ₄	455.04	—	—	0.00159 (25 C)	—
Lithium tungstate	Li ₂ WO ₄	261.73	742	3.71	Very soluble	Decomposes in acid; insoluble in alcohol
Magnesium tungstate	MgWO ₄	272.73	—	5.66	Insoluble	"

TABLE XII-1 (Continued)

CHEMICAL AND PHYSICAL PROPERTIES OF
TUNGSTEN AND SELECTED TUNGSTEN COMPOUNDS

Compound	Molecular Formula	Formula Weight	Melting Point (c)	Density	Solubility g/100cc	
					H ₂ O *	Other
Mercury (I) tungstate	Hg ₂ WO ₄	649.03	Decomposes	—	Insoluble	Decomposes in acid; insoluble in alcohol
Mercury (II) tungstate	HgWO ₄	448.44	"	—	"	"
Mesitylene-tungsten tricarbonyl	(CH ₃) ₃ C ₆ H ₃ W(CO) ₃	388.08	160-165 decomposes	—	—	—
Metatungstic acid	H ₂ W ₄ O ₁₃ ·9H ₂ O	1,107.4	—	2.5239 3.6503	88.57 (22 C) 111.87 (43.5C)	—
Phospho-tungstic acid	H ₃ [P(W ₃ O ₁₀) ₄] · 14H ₂ O Tungstophosphoric acid	3,132.39	160-165 decomposes	—	Soluble	Soluble in alcohol and ether
Phospho-tungstic acid	H ₃ [P(W ₃ O ₁₀) ₄] · 24H ₂ O Dodectungstophosphoric acid	3,312.54	89	—	"	—
Potassium tungstate	K ₂ WO ₄ · 2H ₂ O	362.08	921	3.113	51.5	Decomposes in acid; insoluble in alcohol
Potassium metatungstate	K ₆ [H ₂ W ₁₂ O ₄₀] · 18H ₂ O	3,407.08	930	—	Soluble	Decomposes in acid
Silicotungstic acid	H ₈ SiW ₁₂ O ₄₂	2,914.2	—	—	961.5 (18 C)	—
Silver tungstate	Ag ₂ WO ₄	463.59	—	—	0.05 (15 C)	—
Sodium tungstate	Na ₂ WO ₄	293.83	698	4.179	57.5 (0 C) 73.2 (21 C)	—
Sodium tungstate, dihydrate	Na ₂ WO ₄ · 2H ₂ O	329.86	698 Anhydrous	3.23-3.25	41.0 (0 C)	Slightly soluble in NH ₃ ; insoluble in alcohol, acid
Sodium metatungstate	Na ₂ O · WO ₂ · 10H ₂ O	1,169.53	706.6	—	Soluble	Insoluble in acid
Sodium paratungstate	Na ₆ W ₇ O ₂₄ · 16H ₂ O	2,097.12	-12H ₂ O -16H ₂ O	3.987	8	—
Strontium tungstate	SrWO ₄	335.47	Decomposes	6.187	0.14 (15 C)	Insoluble in dilute acid, alcohol
Tungsten (Wolfram)	W	183.85	3,410±20	19.35	Insoluble	Slightly soluble in HNO ₃ , H ₂ SO ₄ , aqua regia; soluble in HNO ₃ +HF, fused in NaOH+NaNO ₃ ; insoluble in HF, KOH

TABLE XII-1 (Continued)
 CHEMICAL AND PHYSICAL PROPERTIES OF
 TUNGSTEN AND SELECTED TUNGSTEN COMPOUNDS

Compound	Molecular Formula	Formula Weight	Melting Point (c)	Density	Solubility g/100cc	
					H ₂ O	Other
Tungsten arsenide	WAs ₂	333.69	Decomposes in red heat	6.9	Insoluble	Decomposes in hot HNO ₃ , hot H ₂ SO ₄
Tungsten diboride	WB ₂	205.47	2,900	10.77	"	Soluble in aqua regia
Tungsten dibromide	WBr ₂	343.67	Decomposes 4,400	—	Decomposes	—
Tungsten pentabromide	WBr ₅	583.40	276	—	"	Soluble, in absolute alcohol, chloroform, ether, alkali
Tungsten hexabromide	WBr ₆	663.30	232	6.9	Insoluble	Soluble in absolute alcohol, ether CS ₂ , NH ₄ OH
Tungsten carbide	WC	195.86	2870+50	15.63	"	Soluble in HNO ₃ +HF, aqua regia
Tungsten dicarbide	WC ₂	379.71	2860	17.15	"	Soluble in HNO ₃ +HCl
Tungsten carbonyl	W(CO) ₆	351.91	Decomposes N 150	2.65	"	Soluble in fuming HNO ₃ , slightly soluble in alcohol, ether
Tungsten dichloride	WCl ₂	254.76	—	5.436	—	—
Tungsten tetrachloride	WCl ₄	325.66	Decomposes	4.624	—	—
Tungsten pentachloride	WCl ₅	361.12	248	3.875	—	Slightly soluble in CS ₂
Tungsten-hexachloride	WCl ₆	396.57	275	3.52	Decomposes (60 C)	Soluble in alcohol, ether, benzene, CCl ₄ , very soluble in CS ₂ , POCl ₃ Impure WCl ₆ decomposes at even lower temperatures
Tungsten hexafluoride	WF ₆	297.84	2.5	3.44 (Liquid) 12.9 g/l (Gas)	Decomposes	Soluble in alkali

TABLE XII-1 (Continued)
CHEMICAL AND PHYSICAL PROPERTIES OF
TUNGSTEN AND SELECTED TUNGSTEN COMPOUNDS

Compound	Molecular Formula	Formula Weight	Melting Point (c)	Density	Solubility g/100cc	
					H ₂ O*	Other
Tungsten diiodide	WI ₂	437.66	Decomposes	6.799	Insoluble	Soluble in alkali; insoluble in alcohol, CS ₂
Tungsten tetraiodide	WI ₄	691.47	"	5.2	"	Soluble in absolute alcohol insoluble in ether, chloroform, turpentine
Tungsten dinitride	WN ₂	211.86	Above 400(vacuum)	—	Decomposes	—
Tungsten dioxide	WO ₂	215.85	1,500 (in N ₂)	12.1	Insoluble	Soluble in acid, KOH
Tungsten trioxide (Wolframite)	WO ₃	231.85	1,473	7.16	"	Soluble in hot alkali; insoluble in acid
Tungsten pentoxide	Mineral blue W ₂ O ₅ or W ₄ O ₁₁	447.70 or 911.39	800-900 Sublimes	—	Insoluble	Insoluble in acid
Tungsten dioxydibromide	WO ₂ Br ₂	375.67	Decomposes	—	—	—
Tungsten oxytetrabromide	WOB ₄	519.49	277	—	Decomposes	—
Tungsten oxytetrachloride	WOC ₄	341.66	211	—	"	Soluble in CS ₂ , S ₂ Cl ₂ and benzene
Tungsten dioxydichloride	WO ₂ Cl ₂	286.75	266	—	Soluble	Insoluble in alcohol; soluble in NH ₄ OH, alkali
Tungsten oxytetrafluoride	WOF ₄	275.84	110	—	Decomposes	Slightly soluble in CS ₂ ; insoluble in CCl ₄
Tungsten phosphide	WP	214.82	—	8.5	Insoluble	Soluble in HNO ₃ +HF; insoluble in alkali, HCl
Tungsten phosphide	WP ₂	245.80	Decomposes	5.8	"	Soluble in HNO ₃ +HF; insoluble in alkali, HCl; soluble in aqua regia
Tungsten phosphide	W ₂ P	398.67	"	5.21	—	Soluble in fused Na ₂ CO ₃ ; insoluble in acid, aqua regia

TABLE XII-1 (Continued)

CHEMICAL AND PHYSICAL PROPERTIES OF
TUNGSTEN AND SELECTED TUNGSTEN COMPOUNDS

Compound	Molecular Formula	Formula Weight	Melting Point (c)	Density	Solubility g/100cc	
					H ₂ O*	Other
Tungsten silicide	WSi ₂	240.02	Above 900	9.4	Insoluble	Soluble in HNO ₃ +HF; insoluble in aqua regia
Tungsten disulfide (Tungstenite)	WS ₂	247.98	Decomposes	7.5	"	Soluble in HNO ₃ +HF, fused alkali; insoluble in alcohol
12-Tungstophosphoric acid	P ₂ O ₅ ·24WO ₃ ·45H ₂ O	6,516.35	—	—	86.75 (92 C)	—

* For the purpose of compliance with the recommended standards, insoluble tungsten compounds include all those for which water solubility is listed as insoluble or less than 0.01 g/100 cc. Soluble tungsten compounds are those listed as very soluble, soluble, slightly soluble, equal to or greater than 0.01 g/100 cc, or decomposes. Those compounds for which no solubility information is listed should be considered soluble unless it can be demonstrated that they are insoluble in water.

Adapted from references 2-6

TABLE XII-2

OCCUPATIONS WITH POTENTIAL TUNGSTEN EXPOSURE

Alloy makers	Melting, pouring, casting workers
Carbonyl workers	Metal sprayers
Ceramic workers	Ore-refining and foundry workers
Cemented tungsten carbide workers	Paint and pigment makers
Cement makers	Papermakers
Dyemakers	Penpoint makers
Dyers	Petroleum refinery workers
Flameproofers	Photographic developers
High-speed tool steelworkers	Spark-plug makers
Incandescent-lamp makers	Textile dryers
Industrial chemical synthesizers	Tool grinders
Inkmakers	Tungsten and molybdenum miners
Lamp-filament makers	Waterproofing makers
Lubricant makers	Welders

Adapted from reference 12

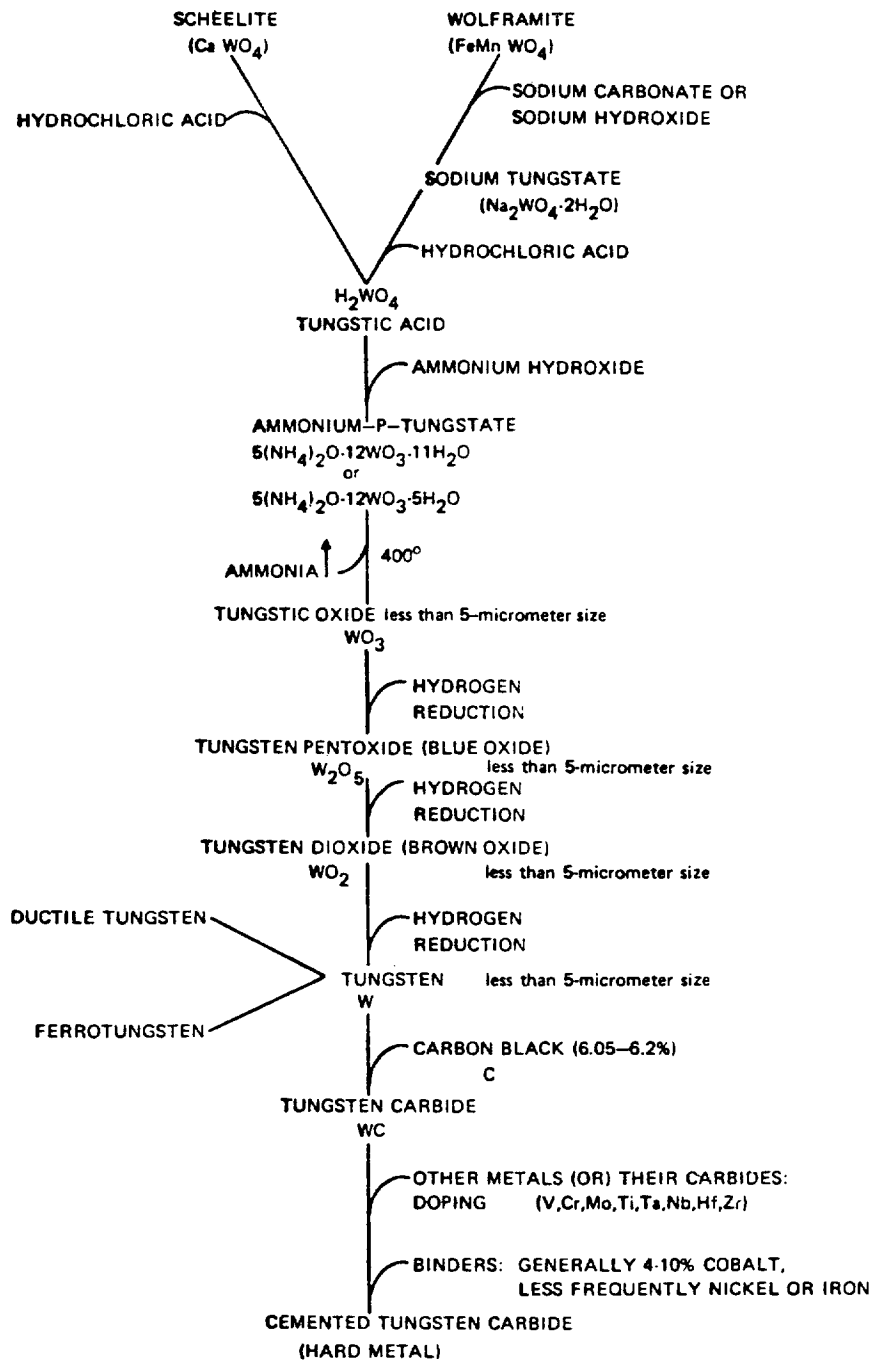


FIGURE XII-1

PRODUCTION OF COMMERCIAL TUNGSTEN COMPOUNDS AND
CEMENTED TUNGSTEN CARBIDE

From references 10 and 11

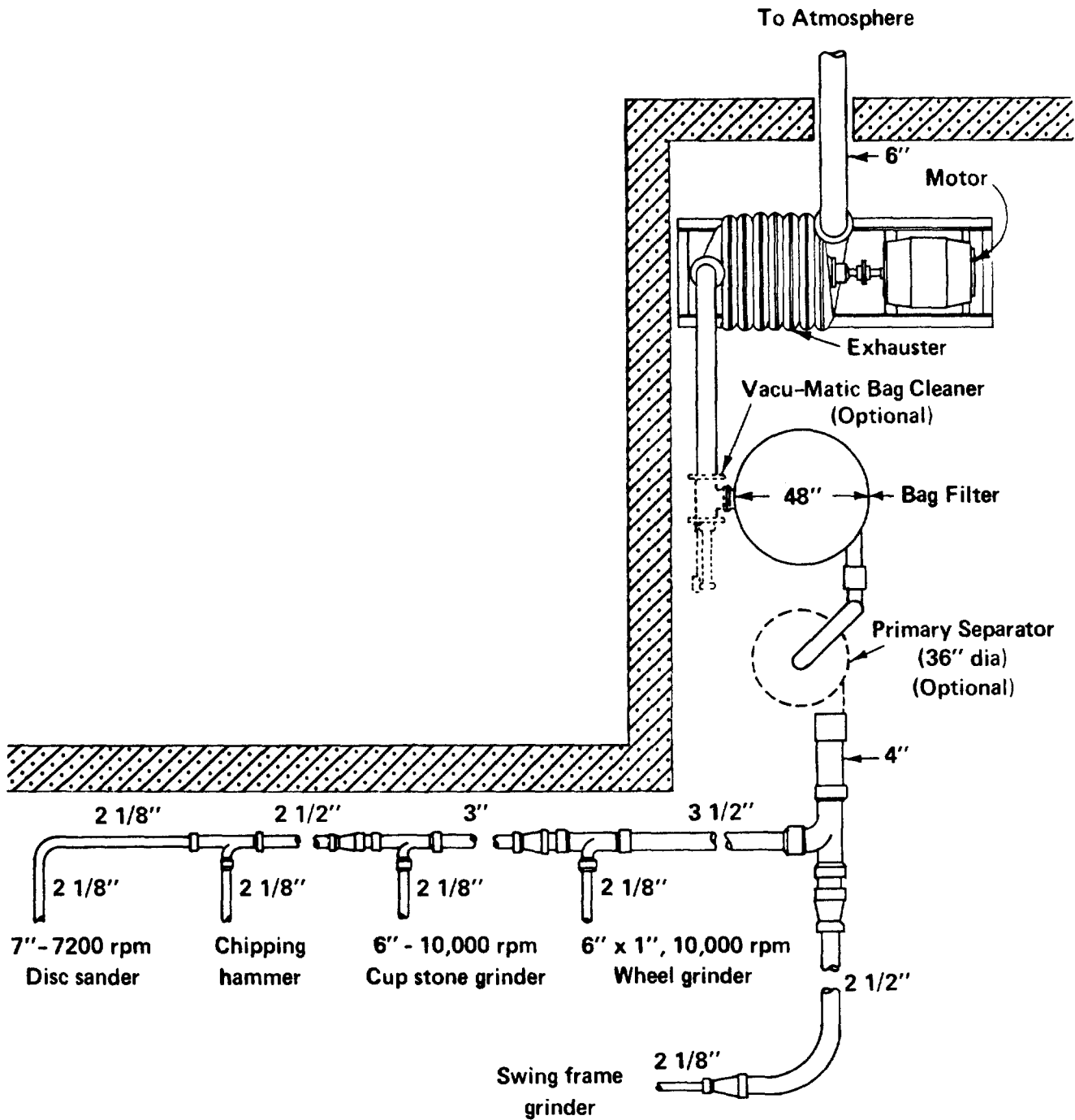


FIGURE XII-2

TYPICAL LOW VOLUME HIGH VELOCITY VENTILATION SYSTEM*

*Bell and socket, smooth-flow type tubing and fittings should be used throughout the system. When system will be used for vacuum cleaning of abrasive materials, Schedule No. 40 and C.I. drainage fittings, or heavier, should be used in place of tubing.

Adapted from reference 61

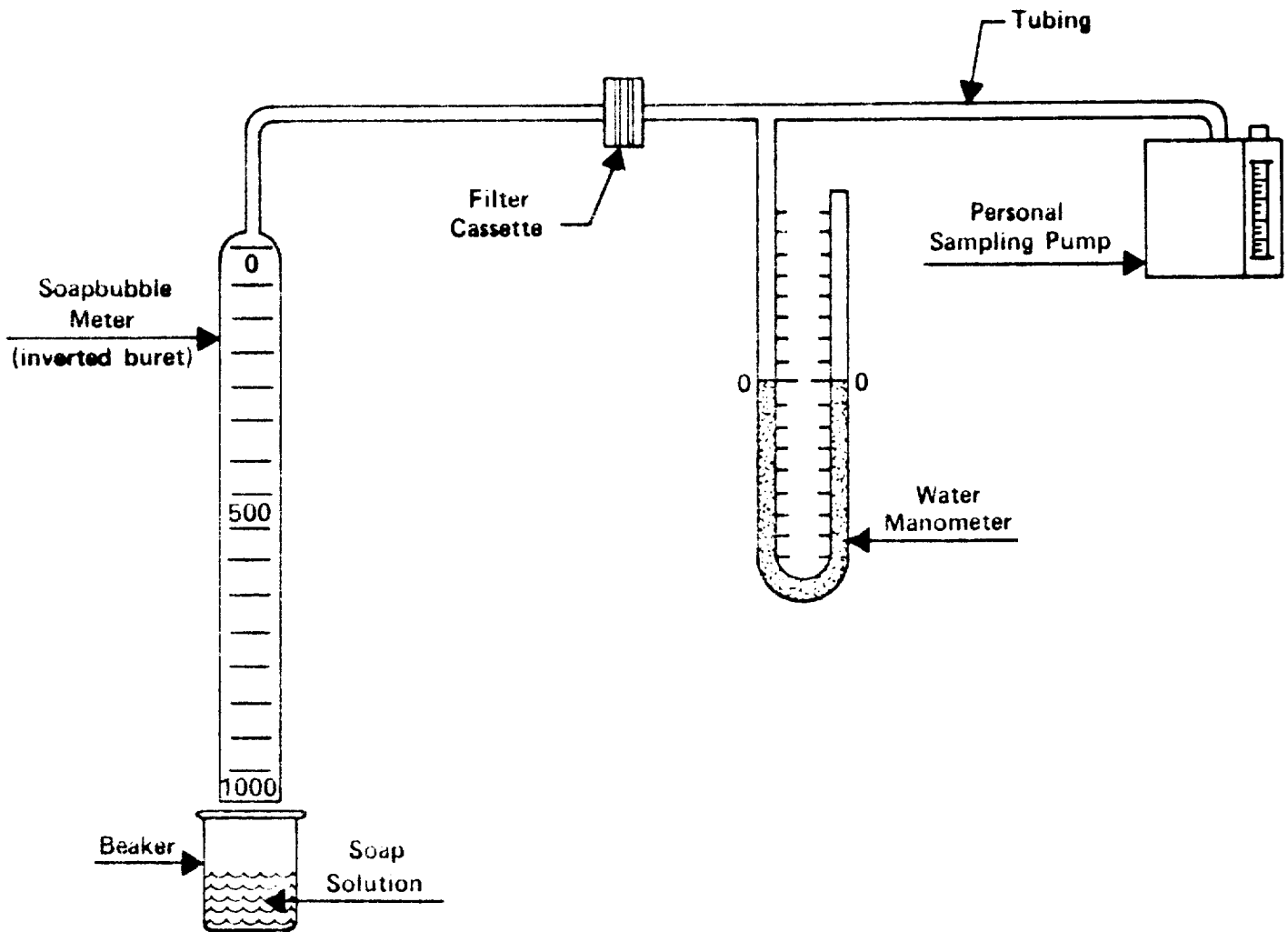


FIGURE XII-3
 CALIBRATION SETUP FOR PERSONAL SAMPLING PUMP
 WITH FILTER CASSETTE