NFPA No.

481

PRODUCTION, PROCESSING, HANDLING AND STORAGE OF

TITANIUM
1961

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Official NFPA Definitions

Adopted Jan. 23, 1964. Where variances to these definitions are found, efforts to eliminate such conflicts are in process.

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Units of Measurements

Units of measurements used here are U. S. standard. 1 U. S. gallon = 0.83 Imperial gallons = 3.785 liters. One foot = 0.3048 meters. One inch = 25.40 millimeters. One pound per square inch = 0.06805 atmospheres = 2.307 feet of water. One pound = 453.6 grams.

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Titanium.

NFPA No. 481—May 1961

This standard was prepared by the NFPA Committee on Combustible Metals. It was initiated in 1955, tentatively adopted in 1957, and with certain revisions was finally adopted by the National Fire Protection Association at its annual meeting in May 1958. Amendments were adopted in June 1959 and May 1961.

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Alternate.

E. D. Zeratsky, Fire Equipment Manufacturers Assn., Inc. (Alternate to A. B. Guise)

Changes Adopted in May 1961

464. Revised to require interlocks of dust-producing machines and dust collectors so that any residual hydrogen will be swept from the collector before the machine can be started.

STANDARD FOR THE PRODUCTION, PROCESSING, HANDLING AND STORAGE OF TITANIUM

NFPA No. 481—May 1961

CONTENTS

CHAPTER 1. INTRODUCTION.

11. Purpose and Scope.

111. The purpose of this standard is to call attention to the fire and explosion hazards associated with the production, processing, handling and storage of titanium. Information and recommendations are based on present knowledge of the properties and characteristics of the metal and processes now in vogue. Past experience with other combustible metals indicates that unexpected hazards may develop as changes are made in handling or processing procedures and caution is urged in adopting any untried methods. This is particularly true where any heat treatments, salt baths, or processes involving the use of acids are contemplated.

112. In addition to fire hazards it is known that fine titanium powder, like many other finely divided metal powders, presents a serious dust explosion hazard and this characteristic is mentioned briefly in this standard pending a more complete treatment of this phase of the problem by the Dust Explosion Hazards Committee.

12. Definitions.

TITANIUM is the term used in this standard to refer to either the sponge or ductile metal and alloys having the generally recognized properties of titanium that may be marketed under different trade names.

SHALL is intended to indicate requirements.

SHOULD is intended to indicate recommendations or that which is advised but not required.

APPROVED refers to approval by the authority having jurisdiction.

The terms PROPERLY, SAFELY, SUITABLE and ADEQUATE shall be interpreted as conditions subject to determination by the authority having jurisdiction.

13. Properties and Characteristics of Titanium.

131. Titanium, a silver-gray metal is classed as a light metal. It is as strong as the ordinary varieties of steel but only about 56 per cent as heavy as steel. It is about 1½ times as heavy as aluminum but some titanium alloys are up to three times as

strong as the best available aluminum alloys on a volume basis. The atomic weight is 47.90, specific gravity 4.5, and the melting point 3140° F. Information on the tensile strength, hardness, fatigue properties and other mechanical characteristics is available from a number of sources such as literature published by various titanium producers, the U. S. Bureau of Mines, et al. Data on the physical, chemical and mechanical properties as reported in technical articles may differ somewhat because of the difficulties encountered in obtaining pure metal or comparable samples of alloys.

132. Titanium is combustible under certain conditions and presents some fire hazards during production of the raw sponge, melting of the sponge, casting, machine operations that produce fine turnings or chips, powder production and the handling and disposal of scrap which contains some fines.

133. In molten form titanium either dissolves or is contaminated by every known refractory. Slight contaminations apparently have little effect on the flammable characteristics of chips, turnings or powder produced in machining operations but may have an important bearing on ignition and explosion hazards associated with acid or salt bath treatments.

134. Titanium combines readily with oxygen, nitrogen and hydrogen at temperatures considerably below its melting point and freshly exposed surfaces have a tendency to form an adherent oxide coating quickly.

14. Tests for Titanium.

141. In certain machinery or equipment titanium may be used for only a few parts. To identify such parts and to make the proper separation of scrap which may contain pieces of titanium two relatively simple methods are available.

a. Spark Test. Distinctive sparks are thrown off when a piece of titanium is held against a grinding wheel. The white lines traced by the flying sparks end with a burst that produces several brilliant white rays or branches.

b. Glass Test. The softer grades of titanium and titanium alloys are able to wet glass and can be identified by rubbing a moistened piece of the metal on a piece of glass. If the metal is relatively soft titanium it will leave distinctive gray-white marks on the glass.

15. Combustibility and Explosibility.

151. In tests at Bureau of Mines laboratories with titanium powders having a particle size of less than 200 mesh, ignitions of dust clouds in air were obtained at temperatures ranging from 330° C. to 590° C. (630° F. to 1090° F.) while ignitions of dust layers occurred at 380° C. to 510° C. (720° F. to 950° F.). In some cases dust clouds ignited at lower temperatures than static layers of the same dust. The results of more recent laboratory tests are given in unpublished reports of the Bureau of Mines, Factory Mutual Engineering Division Laboratories and other testing agencies.

152. Coarser particles such as those produced in sawing operations ignite easily, and in tests conducted at Underwriters' Laboratories and reported on Data Cards 511 and 512*, ductile titanium in the form of very thin chips and fine turnings could be ignited with a match. Heavier chips and turnings ignited and burned when heated in the flame of a Bunsen or blast burner. Small pieces of titanium sponge could also be ignited with a Bunsen burner. Titanium sponge or coarse turnings when ignited burn slowly with the release of great heat.

153. Heavy castings or ingots may give some indication of burning when being cut with an oxyacetylene torch but when sufficient surface is available to permit radiation cooling below the critical temperature the burning ceases when the torch is removed.

154. Combustion can occur in atmospheres other than air. One of the fine powder samples that ignited in air as a cloud at 480° C. (900° F.), and as a layer at 460° C. (860° F.) could also be ignited as a layer in pure carbon dioxide at 680° C. (1260° F.). At red heat (1300° F.) titanium decomposes steam to free hydrogen and above 1475° F. titanium burns readily and vigorously in atmospheres of pure nitrogen.

16. Extent of the Hazard.

161. Commercial production of titanium began in 1948 but for several years only small quantities were available. By 1956 production of titanium sponge had increased to about 15,000 tons. Only a few sponge-producing plants are in operation but others

*See Appendix for availability.

are under construction. The production in 1957 was approximately 25,000 tons. In sponge-producing plants the extent of the fire hazard is closely related to the process which will be described specifically in a later section.

162. Output of titanium mill products in 1956 is reported to have been about 5,000 tons. Many companies have indicated that they are ready to enter the processing field as the demand for mill products increases. The aircraft industry is a large user of titanium and other civilian markets will probably develop as production increases and costs decrease. In addition to the usual fire hazards associated with the use of flame and heat in metal industries there are certain specific hazards in the so-called combustible metals and experience has shown that where such metals are processed the fire hazard is ever present and is particularly evident in the handling and disposal of finely divided scrap.

CHAPTER 2. SPONGE PRODUCTION.

21. Process.

211. In the Kroll-Bureau of Mines process, the one most generally used for producing titanium sponge, a quantity of purified titanium tetrachloride is fed into a steel reaction chamber containing molten magnesium. The reduction that takes place at 750° C. (1382° F.) produces titanium sponge and magnesium chloride. A detailed and illustrated description of the process and equipment used is given in Bureau of Mines Report of Investigations No. 4879, Recent Practice at the Bureau of Mines Boulder City, Nevada Titanium Plant.*

212. Another process uses liquid sodium instead of molten magnesium in the reduction chamber and the by-product is sodium chloride instead of magnesium chloride. This reduction takes place at 850° C. (1562° F.).

213. Both reductions must be conducted in dry, oxygen-free atmospheres. Helium or argon can be used to create the oxygen-free atmosphere required in the process. It is usual to provide an air conditioned "dry room" in order to charge the reduction reactors. These dry rooms are provided either as part of the furnace room or adjacent to the furnace room.

22. Building Construction.

221. Buildings in which reaction chambers and furnaces are located present fire hazards similar to those found in magnesium foundries and should be of fire-resistive or noncombustible construction; however, concrete floors are satisfactory for titanium-producing plants. Adequate provision should be made for explosion venting in accordance with the recommendations in NFPA No. 68, Guide for Explosion Venting.*

222. The main building should have adequate ventilation and doors at more than one location remote from each other. See NFPA Building Exits Code, No. 101.* Explosion venting windows are recommended.

223. Dry rooms should be of fire-resistive construction. Dry rooms may be closed off to prevent the entrance of moist air in quantities greater than the capacity of drying equipment but more than one exit should be provided.

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*See Appendix for availability.

224. Floors in furnace rooms and dry rooms should be noncombustible, preferably of concrete, brick or steel plates. Floors should be slightly crowned or sloped to prevent any accumulation of water in the vicinity of the reactors or furnaces and safety run-offs or other provision should be made at the furnaces to contain or direct any spills of molten metal into safe channels free of water.

23. Storage of Raw Material and Sponge.

231. Magnesium Ingots for use in the Kroll process should be stored in accordance with NFPA No. 48, Standard for the Storage, Handling and Processing of Magnesium.*

232. Titanium tetrachloride is a volatile, noncombustible liquid that reacts with water or water vapor in the air to form hydrochloric acid. Containers should be stored in a cool, well-ventilated dry place away from areas of acute fire hazards. Containers should be labeled plainly, stored carefully to avoid mechanical injury and kept closed until used.

233. Titanium Sponge, after being cooled, should be stored in covered metal cans in buildings or rooms containing no ordinary combustibles and separated from areas where acute fire hazards exist.

24. Mechanical Equipment.

241. Furnaces and reaction chambers should be inspected and checked regularly under technical supervision to detect defects and prevent leaks. No equipment found to be defective may be used until damaged parts are replaced or repaired and properly tested to insure safe operation.

242. Furnace settings must be kept dry and free of iron scale.

243. Fuel supply lines shall have control valves at an accessible location remote from reactors.

244. Benches, stands, tables, etc., used in furnace rooms or other areas where special fire hazards exist should be noncombustible.

245. Fans handling combustible dust or gas and air mixtures shall be constructed in accordance with NFPA No. 91, Blower and Exhaust Systems.*

*See Appendix for availability.

25. Electrical Equipment.

251. All equipment, including motors in areas containing combustible dust, shall be of the type approved for use in Hazardous Locations, Class II, Group E, and shall be installed in accordance with the requirements of Article 502 of NFPA No. 70, the National Electrical Code.*

252. In the reduction of titanium tetrachloride by molten magnesium a pressure is built up in the reduction reactor which must be bled off. Magnesium chloride and titanium tetrachloride fumes should be removed at the pressure relief point through a vent or hood to the outside of the building to prevent short circuiting of electrical equipment and damage to process control instrumentation.

26. Fire Prevention.

261. Because of the strong affinity of titanium and magnesium for oxygen, particularly at elevated temperatures, as well as the tendency of magnesium to ignite in air at a temperature close to its melting point the reduction that produces titanium sponge must be carried on in an enclosed oxygen-free container. See NFPA No. 69, Standard for Inerting for Fire and Explosion Prevention.*

262. To insure the effectiveness of the inert gas system, precautions shall be taken to have available always a sufficient supply of inert gas to meet anticipated needs and a reserve supply for emergency use. An inert gas-dispensing system installed for process requirement can be used for fire extinguishing under certain conditions. See Par. 274.

263. All pipes, fittings, valves, etc., in the inert gas dispensing or distributing system should be checked to insure an uninterrupted flow of gas to the reactors or elsewhere as needed.

264. All containers used to receive molten metal must be thoroughly dried before using. All metal added to melting pots containing molten metal shall be thoroughly predried.

265. Good housekeeping is essential. Supplies should be stored in an orderly manner with properly maintained aisles to permit regular inspection and segregation of incompatible materials.

*See Appendix for availability.

266. Ordinary combustible material such as paper, wood, cartons, packing materials, etc., must not be stored or allowed to accumulate near furnaces or other ready sources of ignition.

267. Supplies of material in the reactor building and dry rooms should be limited to amounts needed for normal operation.

27. Fire Protection.

271. The combustibility of certain forms of titanium in carbon dioxide or nitrogen as well as air, and the ineffectiveness of ordinary extinguishers on certain types of titanium fires, make fire protection a difficult problem. Extinguishers of the type developed especially for combustible metal fires are recommended for controlling and containing small fires.

272. Portable fire extinguishers of appropriate size and type should be provided at locations where the presence of ordinary combustibles constitutes the principal fire hazard. See Standard for Installation, Maintenance and Use of Portable Fire Extinguishers, NFPA No. 10.* If titanium is present, instructions should be given to employees and warnings conspicuously posted calling attention to the fact that only extinguishers of the type developed for use on combustible metal fires should be used on burning titanium.

273. Automatic sprinklers should be installed in sections of the plant which are of combustible construction or where appreciable amounts of ordinary combustibles comprise the principal hazard. Where automatic sprinkler protection is provided a deflecting shield or hood shall be provided over the furnaces, reactors or other places where hot or molten metal may be present.

274. Argon or helium can be used to extinguish burning titanium in places where all the air can be displaced. Practically, this form of fire protection is limited to airtight enclosures or closed containers.

275. Segregation into small units is always desirable where fire protection is being planned and such procedure is recommended wherever raw material or the finished sponge is handled.

*See Appendix for availability.

28. Safety Precautions for Personnel.

281. Special clothing of the type worn by foundry workers, including high foundryman shoes, shall be worn by employees engaged in tapping operations at the furnaces in titanium sponge plants.

282. Clothing shall be fire retardant, easily removable with snap fasteners and without cuffs or pockets. Caps or hoods and standard-type face protectors shall be worn by workers tapping furnaces.

283. Titanium metal is considered physiologically inert and no unusual effects have been noted on persons handling it but titanium tetrachloride, in contact with moist air or water, hydrolyzes to evolve hydrogen chloride fumes which are very toxic. Personnel working with this material or transferring it into or out of storage should wear protective clothing designed to provide protection against skin contact and approved type respirators to avoid inhaling the fumes, and chemical goggles to protect the eyes.

284. In locations where toxic dusts or special fume hazards are present, adequate respiratory protection should be required.

29. Shipping Regulations.

291. The Interstate Commerce Commission has no special regulations governing the shipment of titanium metal except in powder form. Shipments of powder will be treated under a separate heading.

292. Special shipping regulations are in force for the shipping of titanium tetrachloride. The white label is required and the size and number of containers are limited (See I. C. C. Shipping Regulations for Acids and Other Corrosive Liquids).*

*See Appendix for availability.

CHAPTER 3. MELTING PLANTS AND MILLS.

31. Conversion of Sponge to Ingots.

311. The conversion of titanium sponge to usable forms of ductile metal presents some perplexing problems. Unlike other metals that can be melted and cast or molded without unusual complications, titanium because of its strong affinity for oxygen, hydrogen, and nitrogen, and the tendency to become contaminated with other materials must be melted in special crucibles in an absence of reactive gases. Titanium ingots reasonably free from contaminants can be obtained by melting crushed or broken pieces of sponge in induction or electric arc furnaces under a protective blanket of argon or helium or in vacuum. There is a tendency for the molten metal to pick up carbon if a graphite crucible is used and the present method is to build up individual ingots by melting under vacuum with a titanium consumable electrode in a water-cooled copper crucible.

NOTE: Efforts are being made to provide a major improvement by substituting a nonreactive type of coolant instead of water because all the possibilities of water coming in contact with molten metal have so far not been eliminated.

312. Serious occurrences with the present type of melting furnaces are indications of inherent hazards and their continued use with water coolant requires the adoption of certain safeguards.

(a) Attention is called to the extreme importance of continuity of water supply for water-cooled crucibles. In this connection provision shall be made for some form of visual and audible signal to alert operators should water circulation fail. Preferably such signal or alarm circuit should be further extended to automatically interrupt current supply to the crucible in the event of failure of water circulation. An emergency secondary source of supply shall be provided adequate to cool automatically the molten metal below the failure point of the crucible.

(b) Precautions should also be taken to eliminate the possibility of water leakage into the crucible. Electrical fields have been used to keep arcs safely centered, minimizing arcing through crucible walls.

(c) Pressure-relief devices such as rupture discs or other suitable means shall be provided to aid in releasing pressure if a water leak occurs in the system. Means shall be provided to prevent reflux of air through the pressure-relief port. The relief pressure for the relief device should be set slightly above the maximum water pressure in the furnace jacket and below the internal testing pressure of the furnace.

(d) Positive protection for all personnel shall be provided. Protection should consist of a suitable barricade or test cell of the vault-type design. A vault-type barricade shall have a weak side to relieve internal pressure in a direction away from the location of all personnel.

(e) Consumable electrodes, especially of a compacted type, should be of such density, rigidity and geometry to afford a suitable current path to the arc without developing excess hot spots or promoting spalls. Spall-offs, especially on the electrode side walls, can promote crucible wall burn-throughs due to secondary arcing.

313. Caution should be used in handling and storing ingots that have been wet with water during melting. The ingots may be embrittled and may contain internal stresses which will cause them to shatter upon cooling.

32. Casting.

321. There is not as yet in general use any procedure for making large castings although several small casting furnaces have been made. Some castings have been made by using tungsten electrode furnaces, copper crucibles and water-cooled copper molds set up within an inert gas-filled enclosure.

322. All titanium furnace crucibles or molds should be designed to avoid contact of molten metal with water. Insofar as possible any foreseeable component failure which might result in a water-molten metal contact should be prevented.

323. Molten metal spills are hazardous under any condition and are particularly dangerous when reactive metals are involved. When titanium is being cast, provision should be made to retain spilled metal under vacuum or inert gas protection. Again, all contact with water should be positively prevented.

324. As in other casting operations molds should be predried and heated to remove volatiles before molten metal is allowed to contact them. In the present type of casting furnace evacuating and inerting are designed to eliminate the moisture hazard.

33. Forging.

331. Forging is the most popular method of forming titanium parts because there are relatively few complications in the process. Gas or electric furnaces with close and accurate heat controls can be used. The principal precaution necessary is to avoid overheating of the billet for metallurgical reasons. Forging temperatures range from about 1600° F. to 2300° F. with some preheating of larger sections at lower temperatures. All possible precautions should be taken to eliminate combustibles from areas where the heated metal could serve as a source of ignition.

332. Fire protection in forging areas may be of the type generally provided for fires in ordinary combustibles, electrical fires or oil fires.

34. Rolling.

341. Special shapes can be rolled from titanium billets on ordinary rolling mills such as those used for rolling stainless steel. Temperature control during rolling is important. To prevent contamination at higher temperatures titanium is usually formed by what is known as warm rolling and in some cases it is worked at room temperatures.

342. No unusual fire hazards are present in titanium rolling operations at normal temperatures and ordinary types of fire protection equipment will generally be found satisfactory.

35. Stamping.

351. Best results in stamping operations seem to be obtained when both sheets and dies are heated. Furnace or resistance heating can be used for stock but some liquid medium for heat transfer to the die is recommended.

352. All sources of heat present some fire hazard and the ordinary precautions to prevent ignition of combustibles by heated surfaces should be taken in areas where stamping is performed.

36. Heat Treating.

361. The heat treatment of titanium under normal conditions requires no unusual precautions; however, caution is urged in

attempting any untried form of heat treating because of the possibility of increased reaction between the metal and its surroundings at elevated temperature.

362. ANNEALING. Although the application of heat to titanium is generally avoided because of the increased possibility of contamination, there are a few instances in which annealing at about 1400° F. is desirable. Fire protection should be provided for the ordinary hazards associated with the operation of furnaces.

363. VACUUM ANNEALING. This form of annealing is principally employed to remove hydrogen from the metal. Hydrogen discharge lines shall be vented to the outside atmosphere. An inert gas such as argon or helium shall always be employed for back filling.

364. SOLUTION TREATMENT, QUENCHING AND AGING. Many titanium alloys require heat treatments other than annealing. Quenching media may be cold metal blocks, inert gases, air, liquid salt baths, oils, water and aqueous solutions.

365. DESCALING. Mineral acids and molten alkali salts used to remove oxides or scale formed on titanium during forging, hot rolling or other processing may react violently with the metal at certain temperatures. Thin sheets of titanium have ignited in salt baths and suitable precautions should be taken by proper temperature control to prevent ignition.

366. DEGREASING. Carbon tetrachloride, trichlorethylene and other solvents have been used in titanium degreasing operations. Usual precautions for the operations of solvent degreasers should be observed when degreasing titanium.

37. Fire Prevention and Protection.

371. In addition to the hazards specifically mentioned elsewhere, special attention should be given to elimination of the commonly recognized fire hazards.

372. Ordinary combustibles — packing materials, cartons, etc.—should not be stored or allowed to remain within the working area.

373. Good housekeeping is essential. Aisles must be kept open to permit ready access to incipient fires with first aid fire protection equipment.

374. Fuel lines to gas or oil-fired furnaces or other equipment shall be equipped with emergency shut-off valves installed at an accessible location remote from the equipment being served. All lines and fittings shall be inspected regularly to detect corrosion or mechanical damage that would cause leaks.

375. Open tanks in which flammable solvents are used shall comply with the Standard for Dip Tanks, NFPA No. 34.*

376. Sponge stored at melting plants should be in covered metal cans or drums in buildings or rooms containing no ordinary combustibles and separated from areas where acute fire hazards exist.

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*See Appendix for availability.

CHAPTER 4. MACHINE SHOPS.

41. Cutting and Welding.

411. Small pieces of metal required for machining are sometimes cut in rough form from larger pieces of rolled or forged stock or formed by welding individual parts into the desired shape. Welding must be performed under inert gas protection to avoid contamination or burning of the metal.

42. Turning.

421. Specially designed lathe tools are necessary for satisfactory work with titanium. Tools must be kept sharp. Water or water base cooling is usually necessary on all lathe work to prevent ignition of chips and turnings because temperatures at the tool face may be as high as 2000° F. The heat generated on heavy cuts may be sufficient to ignite oil type coolants. In some instances carbon dioxide has been used successfully for cooling.

43. Sawing.

431. The small particles and dust produced in sawing titanium are combustible and may present a serious explosion hazard if allowed to accumulate where the material can be dispersed to form a dust cloud. The heavier particles should be caught in a metal container that can be emptied frequently at a safe place outside the plant and the light floating dust should be collected by hoods installed near the point of production and connected with a wet-type collector similar to those used for the collection of magnesium dust.

44. Grinding.

441. To provide protection against possible dust ignitions, it is recommended that all grinding operations be equipped with suction hoods connected to wet-type dust collectors and that the sludge be removed at frequent intervals from these collectors to a safe place outside of the building.

45. Milling.

451. Milling operations may produce fine chips or dust that can be ignited readily. Continuous removal of such material from the milling machine by suction or brush is recommended. Chips

and dust removed by brushing may be kept in metal containers that are collected at frequent intervals and emptied at a safe place outside the building.

46. Dust Collection, Cleaning and Dust Disposal.

461. Dust Collection. Dust should be collected by means of suitable hoods or enclosures at each dust-producing operation, such enclosures to be connected to a water precipitation type of separator, and the suction unit installed in such a way that the dust shall be converted to sludge without contact, in a dry state, with any high-speed moving parts. Figures 1 and 2 show typical water-washed dust collectors servicing fixed and portable grinding units. Figure 3 shows diagrammatically four methods of dust precipitation used in the collectors shown in Figures 1 and 2.

462. Dust Collecting Ducts. Connecting ducts or suction tubes shall be completely bonded and grounded and as short as

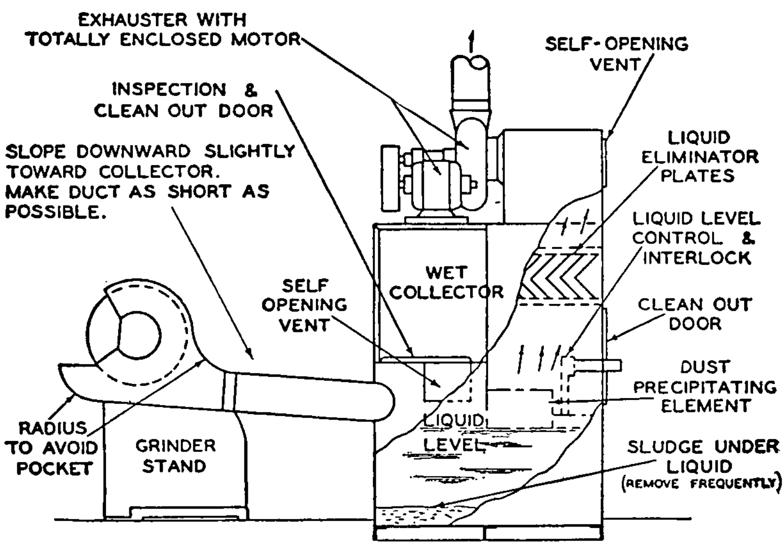

Fig. 1

Note: This drawing is schematic and intended only to indicate some of the features which should be incorporated in the design of a collector. The volume of all dust-laden air spaces should be as small as possible.

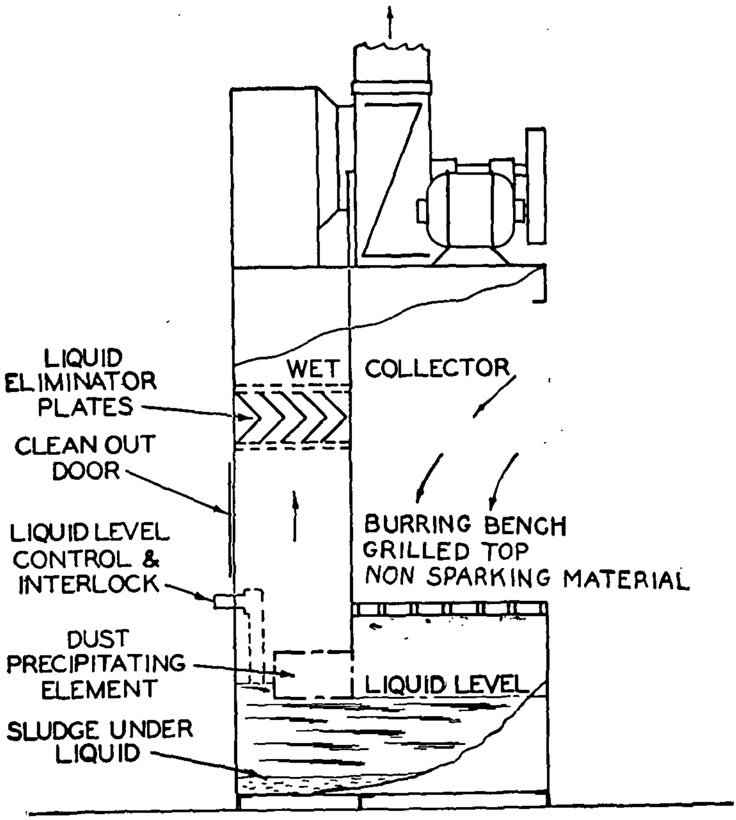

Fig. 2

possible, with no unnecessary bends. Ducts shall be carefully fabricated and assembled, in accordance with the Standard for Blower and Exhaust Systems, NFPA No. 91.*

463. Number of Separator Units. Each machine shall be equipped with its individual dust-separating unit, except that with multi-unit machines not more than two dust-producing units may be served by one separator. Not more than four portable dust-producing units in a single enclosure or stand may be served by one separator unit.

*See Appendix for availability.

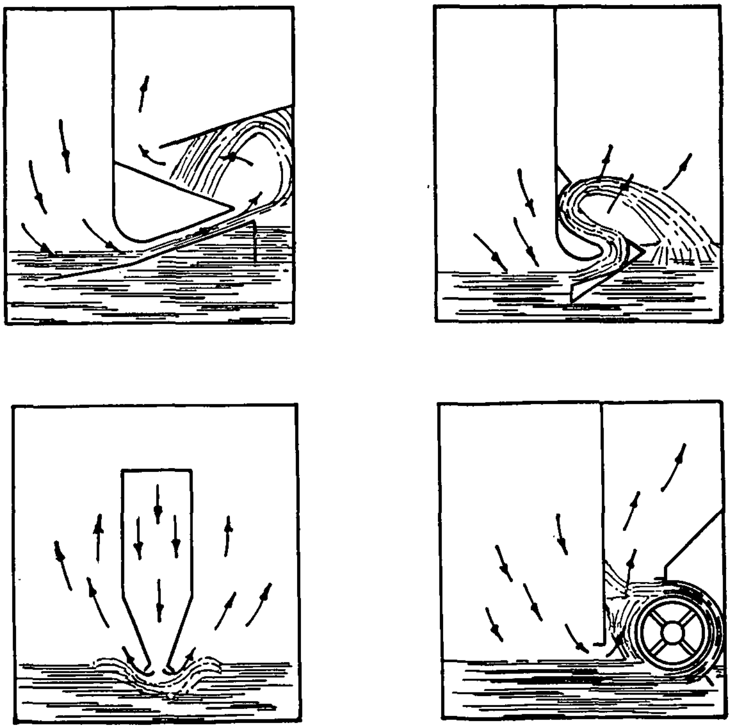

FIG. 3

464. POWER SUPPLY INTERLOCKS. The power supply to dust producing machines shall be interlocked with the motor driving the exhaust blower and the liquid level controller of the wet collector in such a way that improper functioning of the dust collecting system will shut down the machine it serves. A time delay switch or equivalent device shall be provided on the dust producing machine to prevent the starting of its motor drive until the wet collector is in complete operation and several changes of air have swept out any residual hydrogen.

465. CLEANING. Systematic cleaning of entire area involved, including roof members, pipes, conduits, etc., should be conducted daily or as often as conditions warrant, (1) by use of soft brushes and nonsparking scoops and containers, or (2) by

means of a fixed suction pipe and outlet vacuum cleaning system, provided the separator unit is of the water-precipitation type and provided also that the suction piping system is of standard mild steel pipe and standard recessed drainage fittings, with a check valve installed at each outlet. Implements and hose used in connection with stationary vacuum systems should be bonded and grounded. Nonsparking tools and nozzles are recommended. A rupture diaphragm shall be provided in the piping at its connection to the inlet side of the separator in such a way that a possible explosion in the piping may be safely vented to atmosphere.

466. Dust Disposal. Sludge from dust separators and vacuum cleaning unit precipitators should be removed at least daily or as often as conditions warrant. Covered vented steel containers, preferably of not over fifty pounds capacity each, should be used to transport the collected sludge to a safe point for storage or disposal by mixing with sand and burying or burning by approved methods.

Note: Sludge should be burned in a segregated area at a safe distance from combustible material. The burning area may be a layer of fire brick or hard burned paving brick with sufficient slope to permit it to drain properly. The wet sludge should be spread in a layer three or four inches thick. Ordinary burnable refuse is placed over the wet grinding sludge and ignited. The burning refuse supplies enough heat to dry and ignite the top surface of the sludge and the entire pile burns.

467. Housekeeping. Good housekeeping is essential. All stock, material in process and finished products shall be kept in an orderly arrangement that will prevent blocking of aisles and exits, permit ready access to machines, fire extinguishers and control equipment and facilitate cleaning and the removal of waste material. See pertinent NFPA codes or standards such as the Building Exits Code,* and the Standard for the Installation, Maintenance and Use of Portable Fire Extinguishers.*

47. Scrap Collection and Storage.

471. Chips, turnings and other titanium fines should be collected from the pans under machines and from other places at such frequent intervals as may be needed to prevent the accumulation of any large amount, and always at the end of each day's work.

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*See Appendix for availability.

472. Titanium fines to be salvaged should be placed in covered, plainly labeled, clean, dry, steel containers and stored in an outside yard area sufficiently removed from any buildings or removed to a detached scrap storage building or to a special scrap storage room of fire-resistive or noncombustible construction with adequate provision for explosion venting to the atmosphere. Such rooms or buildings should have explosion vents equivalent to thin glass windows or skylights of area at least equal to one square foot to each 15 cubic feet of room volume. Titanium fines, if stored indoors, should be in a well ventilated building.

473. Titanium fines which are not being salvaged should be disposed of by burning in thin layers at a safe location where surrounding combustible material will not be ignited by heat or flying pieces of burning metal.

474. Titanium fines which are to be recovered should be kept free of all foreign matter. Fines wet with animal or vegetable oils may ignite spontaneously.

48. Fire Prevention and Protection.

481. Special precautions should be taken to eliminate the common fire hazards frequently found in metal working plants: unnecessary storage of ordinary combustibles, defective electrical equipment, spills of oil and grease, and delayed removal of rags or other material subject to spontaneous combustion.

482. No open flames nor electric or gas cutting or welding equipment shall be used for repairing machinery or for other purposes in the shop area while the machines are in operation. If the use of cutting and welding equipment becomes absolutely necessary in making repairs, building additions, alterations, etc., all shop machines producing fines or dust shall be shut down and the entire section where the work is to be done shall be thoroughly cleaned to remove all accumulations of fines, dust and other combustible material. All gas or electric cutting or welding operations should be carried out under the observation of a responsible person who has adequate fire fighting apparatus at his disposal and training in its use. He should be assigned no other duties during the cutting or welding operation which he is to observe.

483. Suitable extinguishing agents for titanium fires such as those developed for combustible metal fires should be kept

within easy reach of every operator performing a machining, grinding or other operation on titanium. Suitable extinguishing powder should be kept in substantial containers with easily removable covers and a hand scoop provided at each container for applying the powder.

484. Containers of extinguishing powder or other extinguishing agents for titanium fires shall be plainly labeled.

485. When the building in which titanium parts are stored or machined is of combustible construction, or cartons, crates or other combustible packing materials constitute a fire hazard and quantities of titanium fines that are present are not sufficient to create an explosion hazard, standard automatic sprinkler protection is recommended. Extreme caution must be exercised to prevent the discharge of water on fires in finely divided titanium.

CHAPTER 5. POWDER PRODUCTION AND USE.

51. Process.

511. There are a number of different processes used in the production of metal powder but not all of them are applicable to the manufacture of titanium powder. Ordinary methods of grinding produce an excessively oxidized product not suitable for certain purposes. Reduction of titanium oxide and some forms of milling titanium metal are generally used to produce the limited amount of powder now required commercially. To reduce oxidation and possible ignition hazards, milling may be performed under water or in an inert atmosphere. Some powders are given a very light copper coating during the manufacturing process.

52. Properties and Characteristics.

521. Milled titanium powders are usually dark gray in color, angular in shape and have a tendency to adhere to each other.

522. Like many other metal powders titanium is capable of forming explosive mixtures with air. See Figure 4. The ignition temperature of dust clouds formed in laboratory equipment with different samples of powder ranged from 330° C. to 590° C. (626° F. to 1094° F.). The minimum explosive concentration determined in these tests was 0.045 oz. per cu. ft. Measurements of maximum pressure produced in explosions in a closed bomb at a concentration of 0.5 oz. per cu. ft. ranged from 46 to 81 pounds per sq. in. The average rate of pressure rise in the explosibility tests was 250 to 3,400 pounds per sq. in. per sec. and the maximum rate of pressure rise was 550 to over 10,000 pounds per sq. in. per sec. The minimum energy of electrical condenser discharge sparks required for ignition of a dust cloud was 10 millijoules and for an undispersed dust layer the minimum value was 8 microjoules. Some samples of titanium powder could be ignited by electric sparks in pure carbon dioxide as well as in air. At elevated temperatures in some cases titanium was found to react in nitrogen as well as in carbon dioxide.*

53. Shipping and Handling.

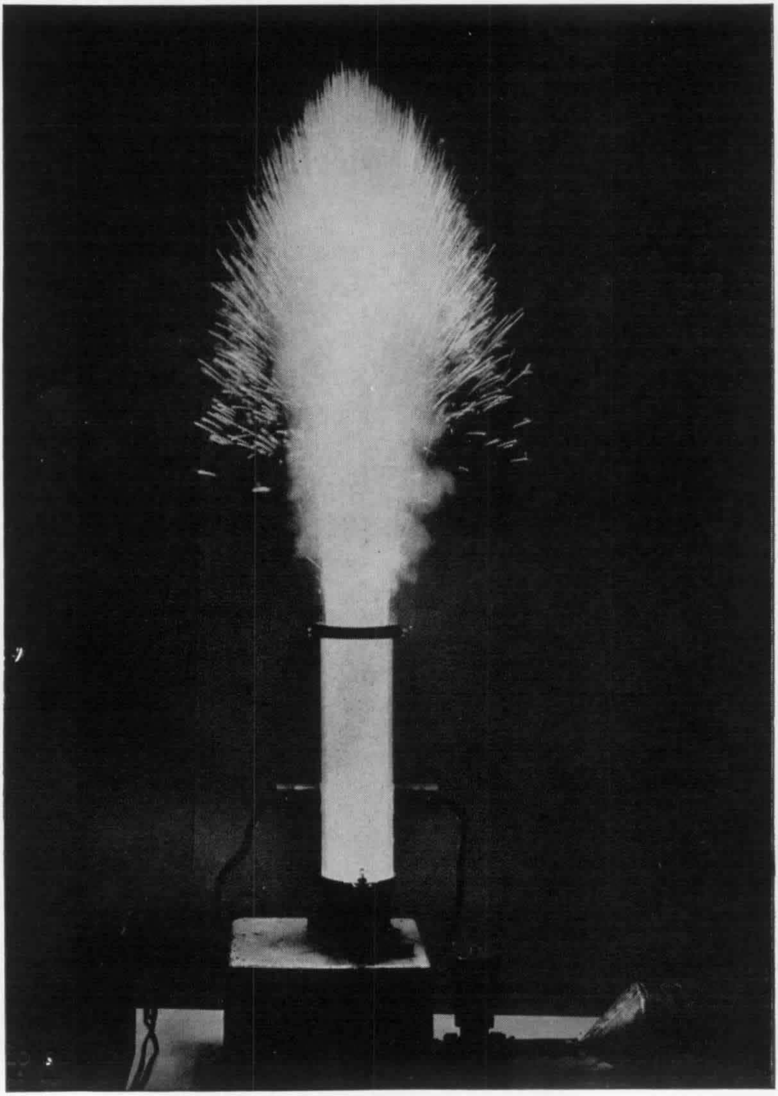
531. Special precautions are necessary in shipping and handling titanium powder because of the flammable and explosive characteristics. Where conditions permit, some powder is shipped wet in tightly closed cans packed within an exterior container. In cases where specifications do not permit wet shipment, recommended practice is to use double containers, securely sealed and packed, the inner containers being flushed with inert gas before filling. Titanium powder is listed as a flammable solid and I. C. C. shipping regulations* require a yellow label.

532. Drying of powder received as a sludge or in a moistened condition can be most effectively accomplished in a vacuum drier at a temperature not exceeding 110° C. (230° F.).

533. Drying rooms should be of fire-resistive construction, segregated and as remote from other operations as possible with suitable explosion vents provided in walls or roof.

534. All electrical equipment in drying room shall be of the type approved for use in locations where metal powder is

*Bureau of Mines Report of Investigations 3722, Inflammability and Explosibility of Metal Powders, Oct. 1943: and Report of Investigations 4835, Explosive Characteristics of Titanium, Zirconium, Thorium, Uranium and Their Hydrides, Dec. 1951. See Appendix for availability.



Bureau of Mines, U. S. Department of Interior

Fig. 4. An ignition of 0.3 gram of titanium powder by a high voltage electrical spark in the explosibility apparatus at the Bureau of Mines Laboratory.