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Pahasa Quarterly, So. Dak. School of Mines. 1916.

TUNGSTEN

BY A. C. RUBEL

*"The first thought which occurs to the uninitiated on hearing the word 'Tungsten' is almost certain to be of the latest form of incandescent bulb. The remarkable qualities of the filament lamp, drawn from ductile tungsten, in the economy of current has caused the tungsten filament lamp to take the place of the earlier types of incandescent electric lights. The fact that tungsten can be drawn to smaller sizes than any other known metal while retaining its remarkable strength and pliability permits of the shipping of tungsten lamps with the smallest percentage of breakage and gives long service. By its use, at least two and one-half times as much as the old carbon filament is given at half the cost for electricity and the light is white as against the orange red of the carbon lamp. The use of tungsten in electric bulbs has resulted in an enormous saving of current which in the aggregate amounts to many millions of dollars per annum. Lately, greatly improved lamps in which the wire is wound in helices and in which the globes are filled with nitrogen, have brought the consumption of electricity down to 0.4 to 0.5 watt per candle and have produced the closest approach to white light. These lamps are furnished in candle powers up to 2,000. Nevertheless, the total tungsten used for electric light purposes represents a very small proportion of the annual consumption.

Not so very many years ago tungsten was almost a waste product. Following its introduction for incandescent lamps and the discovery of its striking properties as an alloy in steel, many new uses have been developed, particularly in electrical work where it has been found of inestimable value. In the manufacture of projectiles, shells, etc., the tensile strength, which exceeds that of iron and nickel, and the fact that its melting point is higher than that of any other known metal, has made its use a prime necessity. On account of its extraordinary strength an alloy of tungsten and aluminum can be used in automobile construction where lightness combined with strength are of major importance.

The use of tungsten has also greatly increased in the making of magnetos, permanent magnets, speed indicators and similar instru-

*Tungsten—Carlisle & Co.
ments, car springs, sounding plates and wires for musical instruments; in weighting silk, in the manufacture of strained paper, in glazing porcelain, in bronze powder, pigments for paints, in Roentgen ray apparatus, in coloring glass, in the preparation of salts for making colored cotton goods "fast," or washable, and to render cloth non-inflammable.

The steel industries of the country, however, provide the great field for tungsten ore today. Its remarkable qualities have made it indispensable as an alloy in high speed steel—that is, steel employed for making tools used in metal-turning lathes running at high speed—to which tungsten imparts the peculiar property of holding its temper at higher temperatures than will any carbon steels. As an admixture it is used in varying quantities; for saw-blades, from 1% to 2% tungsten is used. For the high-speed tools, for lathes used in working up metals, a quantity sufficient to make from 16% to 20% tungsten is added.

Tungsten steel drills, by holding their temper, when red hot, can be run at many times greater speed than carbon steel drills and, therefore, result in a great saving in labor costs. Lathes equipped with these tools can be made to cut four times as fast as with carbon steel tools. It is stated that the use of tungsten steel tools in the manufacture of automobiles has, by the economy in working costs, been largely instrumental in the great reduction in car prices which has taken place of recent years.

At one time the presence of tungsten in ore was considered detrimental to the manufacture of steel. But later experiments revealed the proper method of using the metal and what had once been thought to be a detriment was transformed into a highly valuable adjunct.

Tungsten and the salts produced from it are used in the following products:

- Tungsten Metal
- Ferro-Tungsten
- Tungstic Acid
- Tungstate of Soda
- Tungstate of Calcium
- Tungsten Copper
- Aluminum Tungsten
- Nickel Tungsten
- Tungsten-Molybdenum-Metal
- Ferro-Tungsten-Molybdenum
- Tungstate of Ammonia

The production of tungsten as a metal of commercial importance is a matter of very recent origin and is due almost entirely to the rapid strides of the last ten or fifteen years in the development of alloy steels. In practically all of the classifications of the past few years, tungsten is put under the heading of "rare metals," but it was lack of demand rather than supply which caused it to be so classified.
With the great increase in the production of alloy steels there has been a general activity in the development of properties producing this metal, until at the present time its production amounts to a figure both in tonnage and value which puts it among the staple metals of the world. What will be the future development depends on the advances in its metallurgy, but that it has become a valuable asset of the world’s mineral wealth cannot be doubted.

"Tungsten," the mineral, which in former years had been mistaken for an ore of tin, was first discovered by Crousted, who named it “tungsten,” meaning heavy stone. Later, Scheele, the great Swedish chemist, found that the mineral scheelite, named after him, contained lime as a base and a peculiar acid, which was recognized as a new metallic compound. It is the metal in this acid radical which yields the metallic tungsten.

There are only three tungsten minerals of commercial importance, although there are several more of secondary importance which occur usually in close combination with the important ones. The commercial ores together with their properties and descriptions are given as follows:

**WOLFRAMITE (FeOMnOWO)**

Wolframite is a heavy mineral of from a resinous to metallic lustre and black to brownish, black color. It has a hardness of from 5 to 5.5, i.e., it can be scratched only with difficulty, using a hard steel knife; a specific gravity of 7 to 7.5 (heavy) and a streak, when scratched over an unglazed porcelain surface, varying from black to reddish brown, depending upon the content of iron and manganese.

In composition, wolframite is a tungstate of iron and manganese, represented by the chemical formula FeO, MnO, WO₃. It is considered, however, as an intimate mixture of iron and manganese tungstates FeWO₃ and WnWO₃, that is a mixture of these two compounds in any proportions such that the sum of their molecular weights always equals the weight of the total molecule FeO, MnO, WO₃.

An average chemical analysis of this ore in fairly pure form runs as follows:

- Tungsten trioxide (WO₃) 40 to 70 per cent.
- Ferrous oxide (FeO) 10 to 20 per cent.
- Manganese oxide (MnO) 20 to 9 per cent.
- Impurities 30 to 1 per cent.

This occurs in considerable quantities in the Boulder and Ouray
districts of Colorado, and in South Dakota. It is, in fact, probably the most important and widely distributed of the ores.

**HUBNERITE (MnWO₄)**

Hubnerite, named after the German mineralogist who first investigated it, is probably the second ore in importance. It has a nonmetallic lustre, a color varying from brownish red to hair brown, and a streak running from yellowish brown to greenish grey. It has a hardness of 4.5-5 (scratched with a knife with difficulty), a specific gravity of 7 (heavy), and possesses a perfect cleavage, i.e., splits easily along certain well defined planes. It occurs usually in bladed forms and seldom in well defined crystals.

The composition in a pure ore runs about—

\[
\begin{align*}
\text{WO}_3 & \quad 76.9 \text{ per cent.} \\
\text{MnO} & \quad 23.1 \text{ per cent.}
\end{align*}
\]

although the MnO is still isomorphous FeO. It may be considered, however, as a tungstate of manganese. Its occurrence in greatest quantities is in Arizona, Colorado and Nevada.

**SCHEELITE (CaWO₄)**

Scheelite, which is probably third in importance as an ore of tungsten, has a vitreous lustre, a color from greenish grey to white, a light streak, and fairly perfect cleavage. Its hardness is 4 to 4.5 and specific gravity of 6. The composition of a fairly pure sample runs about—

\[
\begin{align*}
\text{WO}_3 & \quad 80.5 \text{ per cent.} \\
\text{CaO} & \quad 19.5 \text{ per cent.}
\end{align*}
\]

It is widely distributed, but occurs chiefly in Colorado, Connecticut and Arizona.

The rarer tungsten minerals, which, when they are of any importance, occur in intimate combination with the principle ores, are as follows:

**Tungstite** (WO₃H₂O) occurs naturally only in the form of a powdery earthy mass of yellow or greenish color. It is very soft, has a specific gravity of 6.5 to 7.2 (fairly heavy) and occurs in combination with wolframite and hubnerite.

**Stolzite** (PbWO₄) occurs in very small acute pyramidal crystals with a columnar structure arranged spherical groups. It has a hardness of 3 (easily scratched by knife), a specific gravity of 7.8 to 8.2 (heavy), conchoidal fracture, color gray, brown green or red, a greasy lustre, is easily fusible, and reacts for both lead and tungsten. This mineral occurs in small quantities with quartz and mica.
Feberite (FeWO₄) occurs in compact granular aggregates resembling wolframite. It is black in color, has a brownish black streak and a vitreous lustre.

The following table summarizes the distinctive properties of the minerals of tungsten:

<table>
<thead>
<tr>
<th>Name</th>
<th>Color</th>
<th>Lustre</th>
<th>Hardness</th>
<th>Sp. Gr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wolframite</td>
<td>Brn.-blk. to blk.</td>
<td>Res. to sub-metallic</td>
<td>5-5.5</td>
<td>7.2-7.5</td>
</tr>
<tr>
<td>Huebnerite</td>
<td>Brn.-blk. to blk.</td>
<td>Res.</td>
<td>5-5.5</td>
<td>6.9-7.3</td>
</tr>
<tr>
<td>Scheelite</td>
<td>Wht. yel. brn.-redh. brn.</td>
<td>Vit. to adam</td>
<td>4.5-5</td>
<td>5.9-6.1</td>
</tr>
<tr>
<td>Tungsite</td>
<td>Yel. to grnh. yel.</td>
<td>Non-met.</td>
<td>1.5-2</td>
<td>6.5-7.2</td>
</tr>
<tr>
<td>Stolzite</td>
<td>Gray brn. grn.</td>
<td>Sub-met.</td>
<td>4-4.5</td>
<td>6.8-7.1</td>
</tr>
</tbody>
</table>

All of these minerals show a test for tungsten by any of the methods given, and in addition to that they will show a distinctive test for the substance contained as a base, such as iron, lime, etc.

**DETERMINATION OF TUNGSTEN**

The presence of tungsten in any of these minerals is readily ascertained by either wet or dry methods:

Boil a portion of finely powdered ore with a mixture of four parts hydrochloric and one part nitric acid for about two hours in a porcelain dish over a simmering flame. If the ore contains tungsten, yellow spots of the trioxide appears on the dish. If a little tin or pure zinc be added and boiling continued, a blue color is obtained, which fades to brown.

No distinctive blow-pipe test exists.

A quick determination may be had by fusing on a platinum wire six volumes of soda to one of ore, pulverizing, dissolving in water acidulated with hydrochloric and boiling with tin or zinc; the same results as above will be obtained.

The ores may be quickly told from magnetite, with which they are often confused, by touching some powdered mineral with a magnet. The tungsten ores are non-magnetic before reduction.

**OCCURRENCE**

The ores of tungsten are produced in all parts of the world as shown by the following table, but at the present time the greater part comes from the United States, the states of Arizona, Colorado, Nevada, South Dakota and Connecticut producing the most. There are also deposits either being worked or capable of being worked in Montana, New Mexico, Idaho, Oregon, Washington, California and
North Carolina. The great impetus given to the prospecting for tungsten ores by the prevailing high prices and the great demand in the last few years has opened up many possibilities hitherto unknown, and has practically lifted the metal out of the "rare" classification. The uses are, even yet, limited, although the future use in metallurgical practice offers great possibilities in the development of alloys as well as the pure metal.

**WORLD'S PRODUCTION OF TUNGSTEN**

<table>
<thead>
<tr>
<th>Mineral Resources</th>
<th>1913</th>
<th>1908</th>
<th>1909</th>
<th>1910</th>
<th>1912</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>497</td>
<td>817</td>
<td>1912</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australasia—</td>
<td>New South Wales</td>
<td>244</td>
<td>325</td>
<td>321</td>
<td>398</td>
</tr>
<tr>
<td>Queensland</td>
<td>426</td>
<td>517</td>
<td>873</td>
<td>553</td>
<td>637</td>
</tr>
<tr>
<td>Tasmania</td>
<td>5</td>
<td>29</td>
<td>68</td>
<td>71</td>
<td>68</td>
</tr>
<tr>
<td>New Zealand</td>
<td>88</td>
<td>79</td>
<td>179</td>
<td>140</td>
<td>337</td>
</tr>
<tr>
<td>Austria</td>
<td>40</td>
<td>39</td>
<td>40</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>Bolivia</td>
<td>170</td>
<td>152</td>
<td>210</td>
<td></td>
<td>472</td>
</tr>
<tr>
<td>England</td>
<td>237</td>
<td>382</td>
<td>278</td>
<td>264</td>
<td>192</td>
</tr>
<tr>
<td>France</td>
<td>113</td>
<td>54</td>
<td>39</td>
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<td>42</td>
<td>95</td>
<td>100</td>
<td></td>
<td></td>
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<tr>
<td>India</td>
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<td>400</td>
<td>1329</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peru</td>
<td></td>
<td>12</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>106</td>
<td>673</td>
<td>948</td>
<td>902</td>
<td>1228</td>
</tr>
<tr>
<td>Spain</td>
<td>226</td>
<td>129</td>
<td>153</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>599</td>
<td>1469</td>
<td>1833</td>
<td>1172</td>
<td>1152</td>
</tr>
</tbody>
</table>

**PRODUCTION AND VALUE IN UNITED STATES 1900 TO 1913**

<table>
<thead>
<tr>
<th>Year</th>
<th>Tons</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>46</td>
<td>$11,040</td>
</tr>
<tr>
<td>1901</td>
<td>179</td>
<td>27,720</td>
</tr>
<tr>
<td>1902</td>
<td>184</td>
<td>34,040</td>
</tr>
<tr>
<td>1903</td>
<td>232</td>
<td>43,638</td>
</tr>
<tr>
<td>1904</td>
<td>740</td>
<td>184,090</td>
</tr>
<tr>
<td>1905</td>
<td>803</td>
<td>268,875</td>
</tr>
<tr>
<td>1906</td>
<td>928</td>
<td>348,867</td>
</tr>
</tbody>
</table>

Tungsten ores are of igneous origin and usually occur in small, pinching veins distributed over wide areas, closely associated with quartz and fluorite. These veins are found at all depths and may run from a mere trace to several inches in width. The ore contains, as a rule, two or more of the tungsten minerals in varying proportions, and runs from 20 to 60 per cent tungsten trioxide. These ores are mined by the ordinary deep mining methods, although there is some slight placer production. Almost the entire recovery is taken as concentrates by the large steel mills of the central and eastern states.

The metal is readily obtained in pure condition by the reduction
of the trioxide $\text{WO}_3$ with a calculated amount of charcoal in the electric or regenerative gas furnace. For this purpose the oxide is mixed with 11 per cent charcoal and 5 per cent pitch or resin, when the metal separates out in the furnace in the form of a white, dense metal. In this form the metal is used in the electric industry for filaments and as contact points on spark coils, when near and high temperatures are combined. It has also been successfully applied to the manufacture of thermo-couples, instruments for scientific work, pen points, drawing dies, knife blades, and as a fire-proofing material. The chief use of the metal, however, is in the manufacture of alloy steel, to which tungsten imparts the property of holding its temper under much greater temperatures than carbon steels. Hence, it has met with great use in the manufacture of cutting tools for metals. For this alloy purpose, a ferro-tungsten is used, that is, crushed ore ($\text{WO}_3$) is mixed with a given amount of iron scrap, pulverized quartz and pitch, and the mass smelted in a specially constructed furnace. The resulting ferro-tungsten is added to the steel in amounts varying from 1 to 20 per cent.

**Tungsten in Arizona**

Tungsten is found in many parts of Arizona, and offers a most substantial possible addition to the present tremendous metal production of the state. The location and brief description of some of the better known and producing properties is as follows: (See map.)

**Cochise County**

*Whetstone Mountain District.*

Wolframite bearing veins, disseminated in quartz and granite and containing a little scheelite, occur about 12 miles south and a little east of Benson on the western slope of the Whetstone Mountains. The property has been taken over by the American Tungsten Company, recently organized, and it reported that the installation of a concentration plant at a cost of $75,000 is planned. A small force of men have been at work on the property.

*Dragoon District.*

Huebnerite, accompanied by small quantities of scheelite, occur with fluorite in quartz veins cutting granite and in places derived from these veins. The major production in this region has been from placers, but the Primos Chemical Company at Russellville is installing a plant for the treatment of the ore mined from the stains and Boericke property of this district, and there will no doubt be a large increase in production.
Lewiston (Bowie) District.
Scheelite occurs in veins with pyrite and chalcopyrite in the Chiracahua Mountains in this region, but no production is reported.

MOHAVE COUNTY

Greenwood District.
Wolframite is found in quartz veins cutting granite rocks in the Aquarius Range, 12 miles from Owens on the Big Sandy River. Small hand-picked quantities of ore have been shipped for several years, being hauled about 65 miles to Kingman on the Santa Fe. In May of 1915 the principal property, owned by O. D. M. Gaddis and Ed. Williams, was acquired by the Tungsten Mines Company. A 50-ton concentration plant was installed and a mill, capable of a large production, was built. The ore thus far handled is said to be, when concentrated, the richest ever shipped from a mine of that character in this country.
This property, embracing 44 claims, is chiefly of granite in which ore occurs in fissure veins from one to three feet wide and traceable to distances of up to 3000 feet. Present development to only a short depth shows ore in bands between quartz, and disseminated in the vein filling. These veins attain a maximum width of 2 inches of solid wolframite, although there is little regularity to them, the vein in places being almost barren.

MARICOPA COUNTY

White Pichacho District.
A vein bearing wolframite, from 1 to 2 inches wide, occurs on the New York claim in this district, but has proven of little value thus far.

Cave Creek District.
The Pittsburg Tungsten Mines Company has purchased the Cave Creek property and is developing it with reported success. Several shipments of ore have been made and a concentration plant is planned.

PIMA COUNTY

Ajo District.
A four-inch vein of wolframite, carrying tungsten of high grade, is reported from this district. Some development work has been done, but few details are obtainable.

Arivaca District.
Huebnerite, accompanied by wolframite and a little scheelite, and, in the oxidized portions, tungstite, occurs in quartz veins in the Las
Guigas Mountains. Two properties are being extensively operated, and several hundred men are employed, the material being hauled to Tucson, a distance of 70 miles. Extensive tests are being made on this property, and its future development seems assured.

Narrow quartz veins carrying wolframite and grey scheelite with fluorite and pyrite cut sericite schists on the west side of the Hualpai Mountains, 18 miles northeast of Yucca. Small quantities of ore have been shipped.

**PINAL COUNTY**

*Old Hat District.*

Scheelite occurs in gold and silver ores in the Maudina mines of which some production has been made. Scheelite is reported in the same district.

**SANTA CRUZ COUNTY**

Small quantities of wolframite have been worked 7½ miles north of Nogales.

*Calabasas District.*

Three miles southeast of Calabasas, quartz veins from a few inches to two feet wide, carrying wolframite and a small quantity of scheelite, cut granite. A little ore has been taken out in prospecting, but to no great extent.

**YAVAPAI COUNTY**

*Tip Top District.*

Wolframite is found in silver veins in this district. Up to a short time ago, little had been done to prospect them, but in the past few months prospecting has gone on rapidly, and a considerable quantity has been developed and shipped.

**GILA COUNTY**

Reports of ores of some value in the Globe District are being investigated by certain mining interests in the state, but little has thus far been given out.

*Undoubtedly the bulk of the research in the manufacture and use of ductile metallic tungsten has been carried out by the highly efficient corps of scientists under the direction of Dr. W. R. Whitney in the General Electric Company’s wonderful research laboratories. Dr. C. G. Fink, of the company’s staff, gives the probable or possible uses of worked tungsten as follows:

The ductile metal is practically insoluble in all of the common
acids; its melting point is higher than that of any other metal; its
tensile strength exceeds that of iron and nickel; it is para-magnetic;
it can be drawn to smaller sizes than any other metal; and its specific
gravity is 70% higher than that of lead. It was natural that a metal
with such striking properties as these should soon find application
other than that for incandescent lamps.

Wrought tungsten has been substituted with success for platinum-
iridium as contact points in spark coils, voltage regulators, telegraph
relays, etc. The service far exceeds that for platinum and platinum-
iridium contacts, due to the greater hardness, higher heat conductivity,
and lower vapor pressure of tungsten as compared with platinum.

Electric laboratory furnaces with tungsten resisters are of two
types. In one a tungsten wire is wound on an aluminum tube in an
air-tight box with a hydrogen atmosphere. In the second a tungsten
metal tube takes the place of the helical carbon resister in an Arsem
vacuum furnace.

Tungsten gauze is used successfully for separating solids from
acid liquors in the laboratory. This gauze could well be used on a
commercial scale; for example, for the removal of sludge from copper
refining baths, and for centrifugal apparatus in general whenever
acids liquids or acid gases are dealt with. Furthermore, it might
be used in apparatus such as described by Cottrell for the removal of
sulphuric mist from gases.

Wrought tungsten targets for Roentgen tubes have proved to be
one of the most interesting applications.

For thermo-couples the tungsten molybdenum couple is not less
interesting. The electromotive force increase with the temperature
up to about 540 degrees S., then decreases and passes through a milli-
volts at about 1300 degrees C. This couple is very convenient for
high temperature measurements in the tungsten-hydrogen furnace.

For standard weights, tungsten is also well suited, since wrought
tungsten can be made so hard that it will readily scratch glass and
still be ductile; furthermore, the density is high (19.3 to 314) and
it is unaffected by the atmosphere. Tungsten weights remain won-
derfully constant.

Besides the applications of tungsten cited above, many others have
been but partly worked out and others merely suggested. Owing to
its chemical stability the finest sizes of wire down to 0.0002 inch or
0.0005 millimeter in diameter are well adapted for galvanometer
suspensions and for cross hairs in telescopes.

It has also been suggested to use these fine wires in surgical opera-
tions in place of the coarser gold and silver wire. A further suggestion is the use of the wire in musical instruments.

Acid proof dishes and tubes have been made out of tungsten; furthermore, tungsten wire recommends itself as a unit resistance, since it can be made absolutely pure, can be duplicated, and is not corroded.

Since tungsten is paramagnetic and elastic, it is being tried out in electrical meters, replacing the phosphor-bronze springs. Similarly watch springs could be made which would never become magnetized. Finally, tungsten pen points, tungsten drawing dies, tungsten knife blades, tungsten reinforced asbestos curtains and fire-proof coverings, etc., were mentioned."

The price continued gradually upwards until in March, 1916, it is quoted at $65 per unit.

The excessive demands for self-hardening tool steels for use in the manufacture of war munitions has been largely the cause of the unusual fluctuations, the present high quotations being more or less due to abnormal war conditions.

While it is hardly to be expected that tungsten will maintain its present high fluctuating and unstable price there is no doubt of its retaining a considerable value, as American manufacturers are assured of a constant supply of the minerals. The abnormal prices, due to war conditions, will undoubtedly not last, but it is extremely doubtful if the United States ever returns to Germany for its supply of the ferro-tungsten alloys. It is an industry that has immense possibilities in Arizona, and may be safely developed without fear of depression after the European war.

Some of the buyers of tungsten are:

Crucible Steel Co. of America, Pittsburg, Pa.
Atkins Kroll & Co., 311 California St., San Francisco.
Bethlehem Steel Co., South Bethlehem, Pa.
Chemical Products Co., Box 1812, Washington, D. C.
Electro Meallurgical Co., Niagara Falls, N. Y.
Primos Chemical Co., Primos, Pa.
Vanadium Alloys Steel Co., Latrobe, Pa.
Sam E. Wegland, 117150 Michigan Ave., Chicago, Ill.
Hatcher & Carpenter, Tucson, Arizona.