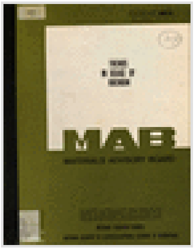

Trends in Usage of Rhenium (1968)

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TRENDS IN USAGE OF RHENIUM

REPORT

of the

COMMITTEE ON TECHNICAL ASPECTS OF
CRITICAL AND STRATEGIC MATERIALS

MATERIALS ADVISORY BOARD
DIVISION OF ENGINEERING - NATIONAL RESEARCH COUNCIL

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Special acknowledgement and thanks are due Mr. David C. Goldberg, who prepared the draft report for the Committee's review and approval.

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ABSTRACT

Rhenium is a rare, expensive, high-melting metal with some unique properties, including a ductilizing effect on several brittle refractory metals. It occurs as an impurity in molybdenite which is associated, in small amounts, with copper ores. Production and consumption have been less than a ton per year, with the potential production, while substantially larger, still definitely limited. Research is disclosing probable valuable applications, leading to the recommendation that efforts to conserve rhenium for probable future applications should receive support.

RHENIUM

Availability

Rhenium does not occur as a distinct mineral species, but is, however, widely distributed in very minor amounts. It is from molybdenite (that which is associated with copper ores) that all current commercial rhenium is extracted. DMIC Memorandum 235 (March 1968) and the January 1968 Bureau of Mines "Commodity Data Summaries," reviewed the current supply situation in adequate detail. It is worth noting that the total world resources of rhenium from molybdenite is about 600 tons with an additional 290 tons from other ores.

The total maximum United States production potential is estimated between a low of 7,500 lb/year to a high of 30,000 lb/year. Mr. J. Maltz of NASA presented a table of production, capacity, consumption, and potential production.* His table (Ref. 1-6 on Page 2) shows a constant increase in production and consumption. Ref. 7 and 8 are in slight disagreement with the cited data. Additional data from other sources are incorporated into this table.

Imports of rhenium metal in 1967 were estimated at 11% of United States consumption, 8% in 1966, 46% in 1965, 14% in 1964, and 4% in 1963. One commercial fabricator foresees a 10% level for the near future.

Research and detailed evaluation of the physical and mechanical properties of the refractory metals and their alloys have received major support during the past decade because of the demanding requirements of the aerospace industry. Rhenium, because of its unique properties, has received a well-deserved share of this attention.

*Presented at the April 25-26, 1968 AIME Refractory Metal Conference in Washington, D. C.

TABLE I - PRODUCTION FIGURES ON RHENIUM (in lbs)

	Production	Capacity	Consumption	Potential Production**
1957	---	1800*	---	---
1958	---	---	---	---
1959	≈100*(1)	---	---	12000*(1)
1960	>200*(2, 4)	---	---	20-30000± (1)
1961	---	---	---	---
1962	1000*(5)	---	---	---
1963	1400*(2, 4)	---	≈ 500*(6)	---
1964	---	>5000*(4)	≈1500*(6)	28000(5, 6)
1965	≈ 2000*(6)	---	≈1600*(3)	---
1966	---	---	≈1200 (7)	---
1967	≈1200 (8) (9)	8000*(5)	---	≈ 12000 (8)

* United States

± Western World

** Added Facility Needed

References:

1. DMIC No. 19, May 1959
2. Port, Chase Brass, Plansee Meeting
3. Colorado School of Mines from Bureau of Mines Data 1965
4. Port, 1964 AIME Meeting
5. Spelman, Metals Progress, February 1968
6. Gonser, 1966 Gilette Lecture
7. "Commodity Data Summaries" United States Department of the Interior, Bureau of Mines, January 1966
8. DMIC Memo 235, March 1968
9. Bureau of Mines indicated 1967 production of 850 lbs due to the copper strike

This high density metal has a melting point exceeded only by tungsten, together with a high modulus of elasticity. Furthermore, it has a hardening effect on platinum, and a ductilizing effect on chromium, tungsten and molybdenum. Thermocouple systems yielding high emf's, which can operate at temperatures to at least 2400°C. are possible using alloys of rhenium with tungsten or molybdenum.

Because of high cost ($630/lb for powder - $1600/lb for mill product) and low industry production capability, few applications except high temperature thermocouples have had widespread commercial usage. However, in recent years a number of developments have taken place which appear to portend extended usage and possible additional production requirements for the metal, particularly if and when high temperature reactor technology and space electrical power systems are restored to the 1967 level of support. It is estimated that 75% of rhenium metal consumption is in research and development refractory metal alloy projects.

Among the new developments that should be mentioned are the structural alloys: tungsten RHC (4%Re-0.35%Hf-0.24%C) and ASTAR 811C (Ta-8W-0.7Hf-1.0 Re-0.024C) and Ag-Re coating for pivot pins for a variable-wing aircraft. Historical applications for Re metal include igniters for flash lamps, electric furnace heaters, contacts for high current applications, vacuum tube filaments, cathodes, and cathode supports and heaters. These latter applications are estimated to consume about 25% of current production. It is known that rhenium is being considered for use as a catalyst in gasoline refinery operations but little specific data are available to estimate quantities.

Another large potential use of rhenium is in the recently developed nickel-base cast superalloy TRW-NASA VI A containing 0.3-0.5% Re which is currently under intensive investigation by the turbine engine manufacturers. This alloy developed under NASA sponsorship for jet engine turbine bucket applications represents a substantial improvement of about 50°F over present-day high strength nickel-base superalloys. Experimental results have shown that the rhenium addition is necessary in maintaining the high temperature properties of the alloy. At the 0.3% Re level in this alloy, a possible annual consumption of 3,000 to 6,000 lbs of rhenium could be expected (blade weight: 1-2 lbs, 100 blades/engine, 1,000 engines/year). Since this consumption level of rhenium is three times the current use level, the developer is exploring reduced rhenium content compositions.

Under AEC sponsorship W-Re-Mo alloys have been developed which should find application in high temperature reactors which are coupled with thermionic devices. There alloys appear to have a good combination of fabricability and useful properties.

There is no definite indication of an immediate upswing in demand for rhenium for application as an alloying element, plating compound, or base metal. It is probable, with reduced AEC support in FY 1969 and 1970 of rhenium-alloy work, the demand will be below the 1,000 lb/year level. Industry can readily meet this requirement. However, it is strongly recommended that industry consider the stockpiling of rhenium-containing residues in view of probable increased future demand.

Since no element other than rhenium has demonstrated as strong a ductilizing effect on Mo, W, and Cr (a pronounced lowering of the ductile-to-brittle transition temperature) it is likely that when research support is re-established an increased demand for rhenium will be seen. It is estimated that this demand will still be below current industry capacity.

Rhenium substitutes as alloy constituents may be found among those elements such as Fe, Co, Ni, Tc, Ru, Rh, Os, Ir, and Pt which increase the Periodic Table Group Number above six. However, none so far have been an adequate substitute for rhenium added singly or in combination. Further research is needed on rhenium substitutes in order to take full advantage of W, Mo, and Cr base alloys.

The recommendations of a NASA Research and Technology Advisory Committee on Materials, which has been studying this element will be of interest to the readers of this report. They are included with permission as Appendix A. We concur with the expressed need for continued research on this metal.

The number one recommendation of the MAB Panel on Rhenium (reported on Page 281 of MAB-154M, Report of the Committee on Refractory Metals, October 15, 1959) is pertinent and still appropriate. It is reproduced as Appendix B.

Summary and Recommendations

Rhenium is a scarce element, and the prospects for substantially increasing production do not appear to be bright. Modest requirements for rhenium have evolved from recent research activities, requirements which so far have not strained reserves or production capabilities. Since some important functions of the element (ductilizer for Cr, Mo, and W, strengthener in high temperature alloys, thermocouple elements) are practically unique, future demand can confidently be anticipated. Therefore the conservation such as by stockpiling, of rhenium (some of which is not recovered during molybdenum processing) should be strongly encouraged. In the meantime, continued research support is endorsed to capitalize on the prospects for solving difficult technical requirements by the use of this unique metal.

Background, References and Correspondence

Rare Metals Handbook, 2nd Edition 1961, Clifford A. Hampel, Reinhold Publishing Company.

Report of the Committee on Refractory Metals, Materials Advisory Board, MAB 154-M(1), October 15, 1959.

Rhenium, edited by B. W. Gonser, Elsevier Publishing Company, 1962.

U. S. Bureau of Mines, "Commodity Data Summaries," January 1968.

Helpful information was provided in correspondence from Dr. E. Hayes, U. S. Bureau of Mines; J. Maltz, NASA Headquarters; Dr. R. J. Lund, Battelle Memorial Institute; J. W. Spelman, Cleveland Refractory Metals; J. A. McGurty, General Electric Company; and F. W. Foyle, Rhenium Alloys, Inc.

APPENDIX A

Resolution approved by the NASA Research and Technology Advisory Subcommittee on October 24, 1968

Whereas the ductilizing effect of rhenium additions in the Group VIA metals has served to focus direct attention to the interrelationship between the electronic structure and gross mechanical properties of metals and, Whereas it now becomes apparent that similar interrelationships underlie a multitude of important technological problems, such as refractory metal ductility and stress corrosion cracking,

Therefore, the Research and Technology Subcommittee recommends that research to link the electronic structure with the mechanical properties of metals and alloys be encouraged.

Specific examples of this recommended research activity as related to the rhenium effect include:

1) Bond structure characterization in the W-Re system.
2) Heterogeneous nucleation studies in the W-Re system (dislocation-solution interactions).

General examples of this recommended research as related to a diversity of problems include:

1) The development of ultra high resolution techniques for detailed study of structures in metals and alloys.
2) Systematic investigation of the mechanical properties of alloy systems with readily characterizable electronic structures.
3) Calculations of mechanical properties based on crystal physics.

The Subcommittee further recommends that the Materials Advisory Board, the NASA laboratories and the university interdisciplinary laboratories (NASA, ARPA, and AEC) explore this activity, and that this program area be reviewed periodically by this Subcommittee.

APPENDIX B

Conclusions and Recommendations
Report of the Raw Material Group, Panel on Rhenium

1. Immediate consideration be given to the establishment of a Government purchasing program, to encourage the recovery of rhenium and provide a stockpile for technical use, so that as much as possible of the known one million pounds of economically recoverable rhenium of the world shall be conserved.

The preferred stockpile material should be pure ammonium perrhenate, NH_4ReO_4. This compound is readily convertible to other compounds of rhenium and to metallic sponge, and can be prepared virtually free of potassium, which even in small amounts produces inferior rhenium metal.

The technology for the recovery of rhenium is sufficiently developed that recovery and delivery of ammonium perrhenate by industry could be initiated within a very short time from waste products, provided than an attractive dependable market for the product were provided.

The lack of a reserve of source material is a serious deterrent in the development of uses for this unusual metal. Industry cannot be expected to spend large sums to develop uses for a material when no supply for production exists.

The United States has the principal known sources of rhenium. It should be conserved for our own future strategic and special economic uses. Chile, a free-world country, is another important potential long-range producer.

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