APPENDIX IV

OPINIONS RELATING TO ALL PHASES OF MINING OPERATIONS AND ESTIMATES OF TAILINGS PRODUCTION

TERRY MCNULTY, D. SC., P. E.

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

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CLEANUP AND ABATEMENT ORDER NO. R5-2014-XXXX

ATLANTIC RICHFIELD COMPANY
UNITED STATES DEPARTMENT OF AGRICULTURE,
UNITED STATES FOREST SERVICE

WALKER MINE TAILINGS
PLUMAS COUNTY

—

CLEANUP AND ABATEMENT ORDER NO. R5-2014-YYYY
ATLANTIC RICHFIELD COMPANY

WALKER MINE
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WALKER
MINING COMPANY

Opinions Relating to All Phases of Mining Operations and Estimates of Tailings Production

Terry McNulty, D. Sc., P. E.

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Opinions of Mineral Engineer Terry McNulty

I, Terry McNulty, D.Sc. P.E., am a fourth generation miner, with a Doctorate in Extractive Metallurgy and Professional Engineer registration in Metallurgical Engineering. I offer opinions in the case on the basis of my lifelong experience in the mining industry, my undergraduate and graduate education, and my 60-years of working with mining companies and around mines in North and South America and overseas.

1. Experience Growing Up in a Mining Family

I represent the fourth generation in my family to work in the mining industry. In April 1859, my paternal great grandfather was part of a group of prospectors that entered the Summit District north of where Leadville, CO is now located. The north boundary of the Climax waste dumps is McNulty Gulch. He later managed a turquoise mine near Cerrillos, NM for the Tiffany Company. His son, my paternal grandfather, began as a miner, but advanced to Mine Manager at Mineral Park, AZ. My maternal grandfather worked all of his life as a timberman, blacksmith, and underground miner in Arizona. My father and his two brothers were underground miners, but my father learned chemistry through the ICS and ultimately became a Chief Chemist.

As a youth, I lived with my parents in very remote prospecting and mining exploration camps in the interiors of Brazil and former British Guiana. I also lived in the mining and milling camps of Goldroad, AZ and Vanadium, NM. I began working as an apprentice assayer at Anaconda's uranium mining operation near Grants, New Mexico at age 15 and had the advantage of good summer/vacation jobs throughout my last 2 years of high school and all of undergraduate school. My entire professional life has been spent working for, or providing technical services to, the mining industry.

2. Education and Employment Related to Mining

I obtained a B. S (Chemical Engineering), an M. S.(Metallurgical Engineering), and a D. Sc. (Extractive Metallurgy) Degrees from Stanford University, Montana School of Mines, and Colorado School of Mines, respectively. (Refer to my CV at the end of this report.) I also studied geology, mineralogy, mining and processing practices. From 1954 through 1960, I worked as an intern in various mining industry operations. During 1961 to 1983, I was employed by various mining companies with responsibilities for process development, plant operations supervision, technical support, and general management, as detailed in my CV. As a mineral industry consultant for the last 26 years, I have been employed by scores of mining and processing entities throughout the U. S. and overseas. As a consultant I have provided consulting services in application of new technologies, process development, and productivity improvements to approximately 150 mines and processing plants worldwide. This has given me the opportunity to observe operations and management structures that have prevailed in many diverse corporate cultures. My CV also includes a list of my patents and publications

During my career with ACM, I worked in or visited many mines and concentrators and worked closely with mine geologists and exploration geologists. I was Concentrator Superintendent at a Canadian copper operation with responsibilities for plant operations, maintenance, and tailings disposal and all related decisions. I have served as a Manager of R&D and Technical Services, where my department and I provided a spectrum of services to all mining and processing operations and made appropriate recommendations to senior managers. In this role, we never gave orders to foremen, miners, equipment operators, or concentrator operators. We followed industry custom by supplying technical expertise and advice, but did not supervise. Please see my attached Curriculum Vitae for the story of my work in mining going back some 60 years.

3. Honors Received for My Work In Mining

As noted in the copy of my Curriculum Vitae (attached), during my career in mining, I have been honored to receive –

(a) Medal of Merit, American Mining Hall of Fame, 2010
(b) Election to National Academy of Engineering, 2005
(c) Richards Award for Distinction in Mineral Processing, AIME, 2003
(d) Distinguished Alumni Award, Montana Tech., 2002
(e) Henry Krumb Memorial Lecturer, AIME, 1989
(f) Distinguished Career Achievement Medal, Colorado School of Mines, 1989

4. Materials Considered

In preparation of my report and development of my opinions, I have reviewed ACM Sales Co. records, historical records produced by California Regional Board and the Prosecution Team exhibits, various historical and non-historical files from other sources, and Walker Mining Company annual reports.

5. Compensation

I am being compensated by Atlantic Richfield Company at a uniform hourly rate of $300 for consulting and testimony.

6. Statement of My Opinions

On the basis of my lifelong experience with mines, my undergraduate and graduate training in mine-related disciplines, and my 60-year work experience in the mines and mining industry, together with my review of voluminous documents produced in this case, including materials in the Anaconda collection at the University of Wyoming, I have developed the following opinions:

1. All mines are different because of location, geology, nature of target minerals, extractive resource economics and the individual and corporate personalities of the companies which operate and consult with respect to each mine.

2. Yet mining generally occurs in six phases: (a) exploration and development of ore reserves, (b) mine development, (c) ore extraction, (d) concentrating, (e) product shipment, and (f) waste disposal.

3. In reviewing the documents available relating to the Walker Mine, I see no evidence that Anaconda Copper Mining Company ("ACM") or International Smelting and Refining Company ("IS&R") sought to have, or in fact had, any influence over WMC's ore extraction, concentrating, product (concentrate) shipment, or waste disposal.

- (a) Mine development work was performed by WMC's own staff. ACM and IS&R guided and made recommendations concerning prospecting and mine development, and at times required WMC to seek approval before commencing underground activities about prospecting and reserve development, but all underground prospecting work, including core drilling was undertaken by WMC.
- (b) Geologists on the WMC staff received the recommendations from IS&R / ACM geologists and supported mine development with WMC's own staff.

(c) Day-to-day, mining geologists on WMC's staff also supported mining and ore extraction.
(d) Processing ore through the concentrator was undertaken by WMC.
(e) Handling and shipment of concentrate was undertaken by WMC.
(f) Construction and maintenance of the tailings ponds and the disposal of concentrator waste ("tailings") was undertaken by WMC.
(g) Neither AMC, nor IS&R, had any control over WMC concerning the Walker Mine's waste disposal activities.
(h) These spheres of influence in mining operations at the Walker Mine were generally consistent with what I have observed in the other mines I have visited, studied, and/or worked in.

7. Bases for My Opinions

A. Basis for Opinions Concerning Prospecting, Exploration, and Development

In most mining operations, underground mining (referred to above as ore extraction) is guided on a daily basis by geological engineers, usually referred to as <u>mine geologists</u>, and the responsibilities of the mine geologist are described in the following sections of my report. On the other hand, identification and definition of a mineralized zone that can be added to the mines reserve inventory is based on prospecting by a specialist called an <u>exploration geologist</u>. Exploration geologists are key personnel in the first of the six phases of mining (referred to above as exploration and development of ore reserves).

Underground mining and mineral concentration are universally the same as to general features, although each mine is different with regard to the physical and chemical characteristics of the ore, accessory minerals, and host rock. The common features are as follows:

(1) <u>Exploration and Reserve Development</u>

Prospecting by diamond drilling and extraction of core samples is done from "stations", often excavated into one side of a main drift or haulage tunnel. With the exception of the volume of rock removed to create the station, typically a room no more than ten feet on each side and 6-8 feet high, little material has to be blasted and moved.

(2) Mine Development (to Gain Access to Ore)

Often, vertical shafts are sunk from the ground surface, and they usually begin at exposed mineralization, called an "outcrop" on the surface. Additionally, or alternatively, horizontal openings (drifts or crosscuts), inclines or declines, or raises or winzes are driven from a haulage tunnel to a location near or in mineralization. Ideally, these openings are made in ore, but they sometimes must be made in waste. They are advanced by drilling small-diameter holes, loading the holes with cylindrical "sticks" of explosive, arming the explosives with detonators ("caps") and breaking the rock into fragments of manageable size.

(3) Ore Extraction (breaking and removing ore from the mine workings)

Diamond drilling guides short-range definition of the geometry and grade of a mineralized section of rock, often a vein structure, by providing the mine geologist with the information needed to assist the mine foreman with planning of shift-to-shift work.

Production drilling, using the same equipment ("jacklegs" and "stopers") used in mine development makes hole that can be loaded and blasted.

Mucking, originally done by men with hand shovels, was by the 1930s, almost entirely done with the aid of small front-end loaders called "mucking machines". The broken rock ("muck) was loaded into small rail cars, typically with a capacity of 0.5-5 tons.

Tramming was the act of hauling loaded cars to a location on the surface, typically just outside the portal of the haulage tunnel.

(4) Concentrating (milling and treatment of ore)

Concentrating of the desired minerals such as copper sulfide grains is almost always carried out on the surface, although a few concentrating plants have been located inside underground mines. The ore is crushed and ground in successive stages by various types equipment to reduce the maximum particle dimension to a few hundredths of an inch or less. At this size distribution, and it varies with local mineralization, the desired mineral grains have been "liberated" from the country rock and are small enough to be readily suspended by mechanical agitation of a mud ""slurry" that usually consists of three parts water to one part ore by weight.

The concentrate, typically representing only a small fraction of the ore weight, but containing over 90 percent of the desired mineral originally present in the ore, is filtered to remove most of the water, the filtrate is returned to the grinding mills, and the concentrate is ready for shipment.

(5) Product Shipment

Unless there is a smelter adjacent to the concentrator, the concentrates must be shipped. In order to minimize the cost of shipping water, it is customary to thicken the concentrate slurry, then filter it to a point where is contains only about 8-12 percent moisture. Both the thickener overflow water and the filtrate are recycled.

Shipment of the concentrate to a smelter was once done in mule-drawn wagons, but truck and rail transportation became the industry standard by the late-1920s.

(6) Waste Disposal

The economics of mining are such that a careful distinction is made regarding waste rock even before it has been drilled and blasted. If it can be left in-place without impairing access to ore, it will be. If it must be moved, it will be left underground as backfill if possible. If waste rock must be trammed to the surface, it will be placed in a dump located so as to minimize transportation cost. Outside the mine workings, the waste (tailings) created during concentration usually has no value, so it is accumulated for disposal on the mine property. However, the water contained in the tailings has value and is often reclaimed from the settled tailings for reuse.

At the Walker mine, all of the foregoing operations were carried out, but there were local variations that suited copper sulfide ("chalcopyrite") mineralization associated with iron ("pyrite" and "magnetite") in quartz vein rock. The vein was essentially a tilted tablet over 500 feet deep, 15 to 50 feet thick and about two miles long. The vein was not continuously mineralized; instead, there were five distinct orebodies that were separated by hundreds up to several thousand feet along the vein. Some extended nearly to the surface, while two were deeper below-surface. The vein walls ("country rock") were very hard, homogeneous, and devoid of sulfide mineralization. It was therefore possible to remove ore selectively with minimum dilution by barren waste rock.

Mine development at Walker began with shafts, and the ore was initially hoisted to the surface ("shaft collar") and loaded into tram cars suspended from a cable running in a continuous loop. The mile-long tramway descended approximately 900 feet to the concentrator feed bins and crushers. There was a personnel camp near the shaft and another near the concentrator. Draft animals and wagons originally hauled concentrates to a rail siding, but a 9-mile overhead tramway to the railroad was constructed in 1919 and 1920. During 1920 and 1921, the 700 level haulage tunnel was driven 3,000 feet northward from a portal near the concentrator to intersect the vein. Electric trolley locomotives and cars with 2.75 ton capacity were used to tram ore[1].

Concentration was always accomplished by the selective flotation process. The ore was reduced in a series of jaw and roll crushers to a top size if 0.375-inch, then ground in rotating cylindrical ball mills to a top size of about 0.01-inch with half of the particles finer than 0.003-inch. Although the ore initially contained as much as 10 percent copper, the ore "grade" had declined to less than 2 percent copper by 1926[2].

The concentrates were thickened and filtered before being conveyed by a 9-mile tram way to a rail loading station for transportation to the IS&R smelter at Tooele, UT.

"Development" is a term which was used by WMC in the same two ways as the term was generally used throughout the mining industry and described above. In extensive correspondence between WMC geologists and IS&R and ACM geologists who provided advice on "development", the term was used to mean development of future reserves. In this context, the goal of development was not to open up access for extraction of ore, but to create a path through the country rock adjacent to the vein. If mineralized rock was produced in development, it would have been removed and processed. In my opinion, the volume of waste created by reserve development through mineralized rock (if any) would have been negligible, compared with tailings wastes generated from WMC's ore extraction.

Generally, in this first of the six phases of mining, the exploration geologist is looking to the future with the objective of ensuring that the mine's life will be sufficient, not only to pay back major investments like a new and larger concentrator, but also to maximize shareholders' return on their earlier investments. At WMC's Walker Mine, exploration geologist Reno Sales, who had developed the science of underground exploration in Butte, and Paul Billingsley, provided guidance on matters relating to exploration on behalf of ACM and IS&R

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[1] *Anaconda's Walker Mine and Mill,* Engineering and Mining Journal, Vol.117, No. 18, May 3, 1924, pages 725-730. (Ex. 36.)

[2] Walker Mining Company Annual Report for 1926. (Ex. 52.)

to Walker Mining Company's geologists for their consideration, and at times required WMC's staff geologists to obtain their approval to proceed.

At times, the correspondence shows Reno Sales expressed frustration that his geological direction and advice related to development of ore reserves was not being followed. While it is clear that his opinions were respected, it is also clear that local variables may have influenced acceptance. (Exs. 115, 39, 47.)

Although WCM's mine geologists, like Seth Droubay, were very competent, they likely did not possess the interest, training, or expertise to serve as exploration geologists. In any case, their day-to-day job was to direct the second phase of mining (ore extraction). If Sales and Billingsley had not been available, WCM would have had to pay for a geological exploration consultant, but it is very unlikely that they could have found any as competent as the ones made available to them by their IS&R and ACM.

Of all the documents reviewed in this case, none present any evidence that exploration geologists (active in the first phase of mining) or any other representative of IS&R or ACM had any direction, supervision or control, over the disposal of mining wastes produced by the Walker Mine operations.

B. Basis for Opinions Concerning Ore Extraction Operations

Whereas the art and science of prospecting, exploration, and resource development is essentially strategic and long- range, the practice of operating a mining and processing complex (that is, the activities constituting the later five phases – mine development, ore extraction, concentrating, product shipment and waste disposal) is purely tactical. Generally, in the mining industry, there are daily, weekly, and monthly production targets, and every attempt is made to plan for periodic and very brief maintenance and repair shutdown, but most decisions are reactionary and based either on brief conversations between supervisors and subordinates at the beginning or end of a shift or are made on-the-run during the shift. The information on which these decisions are based may range from changes in ore characteristics underground to a change in equipment availability to substitution for an ill or injured worker.

I will address organizational structure and personnel classifications and responsibilities in the following sections of this report, but want to preface those comments with clarification of jurisdictional considerations regarding the creation and management of wastes.

(1) Mining Phase Three – Ore Extraction

Extraction of the copper ore from the Walker Mine was driven by economics that govern the so-called cutoff grade (COG), the copper concentration below which downstream processing would cost more than the recovered value. At Walker, the cutoff grade varied with the market price, but likely followed an industry standard of 0.5% copper, or 10 pounds of copper per ton of ore. Any rock containing less that the COG was likely designated "waste rock". If the waste rock came from the ore vein and contained some copper mineralization, WMC would have treated it as a mineral asset, not waste. This asset was probably hauled ("trammed") to a dump outside the 700 level tunnel's portal and stockpiled for future processing in response to favorable copper price. However, the host ("country") rock that bounded the vein on both sides of the Walker Mine contained no copper. If it was drilled and blasted to provide access to a mineralized zone that could be stope-mined,[3] waste rock would likely have been used to backfill the stope to minimize future unintended caving or to provide a working platform. The expense of tramming waste rock from underground would only have been authorized by WMC management if there were no cheaper or better destination.

The mining method used in the Walker Mine was a technique called "shrinkage stoping" and it basically involved driving access workings into a steeply tipped nearly tabular quartz vein over 500 feet high, two miles long, and 15-50 feet thick. This vein structure contained five orebodies, the South, Central, North, 712, and Piute (or Paiute). The shrinkage stoping technique is described in an E&MJ article[4] and a summary in The Mines Handbook[5]

Mining was occurring in tandem with ore reserve development in different parts of the mine, e.g., above the 700 level, while WMC was prospecting below or in other ore bodies. (Exs. 65, 81, 64, 60.) I estimate that waste rock trammed from the underground amounted to less than 5 percent of the total mass or volume of material (ore plus waste rock) removed from the Walker Mine. This type of information was presented in weekly reports from the Mine Manager to the President of WMC. In the report dated March 13, 1937 from L. F. Bayer to J. R.

[3] In shrinkage stoping, ore is mined out in successive inclined (or vertical) slices, working upward from a haulage level. After each slice is blasted, enough broken ore is drawn down from below to provide a working space between the top of the broken ore and the top ("back") of the stope.

[4] "Anaconda's Walker Mine and Mill," Engineering and Mining Journal, Vol. 117, pages 725-730, May 3, 1924. (Ex. 36.)

[5] "Walker Mining Company," The Mines Handbook, pages 685-687, 1931. (Ex. 69.)

Walker,[6] under the General heading, total breakage (rock drilled and blasted) was 13,340 tons of ore and 531 tons of waste (3.99%), but total production (rock hauled from underground) was 11,649 tons of ore and 208 tons of waste (1.75%). Clearly, about 60 percent of the waste was left underground. Some waste rock could have been deposited near the portal and the concentrator (where hand-sorting of waste rock from a conveyor was sometimes practiced), but it likely contributed no pollution because it contained minimal metal concentrations (less than the COG). Regardless, creation, haulage, and disposal of waste rock were the responsibility of the WMC mine supervisors (the Mine Foreman and his shift foremen). This was also true of any waste rock displaced during prospecting activities, since the same foremen, drillers, miners, and trammers who produced ore also produced and handled the waste rock.

Water draining from the Walker Mine workings was used by WMC for drinking and drilling underground if it was clean and potable, but excess clean water was used in processing and became the responsibility of the WMC Concentrator Superintendent. In about the first half of 1926,WMC stope mining caused surface subsidence which allowed ingress of oxygenated surface water and, likely, naturally-occurring microbes such as *thiobacillus ferro-oxidans* that would have generated ferric iron, a powerful oxidant for metal sulfides. This caused the mine water to become acidic, for copper to dissolve, and for processing to be initiated for removal of dissolved copper. This process, called "cementation", involved WMC contacting the acidic water with metallic iron scrap to precipitate metallic copper (Ex. 54.). According to the 1932 (Ex. 72.), 60 tons of precipitates containing 60-63% copper were produced by this method. Cementation is a process whose optimization requires knowledge of chemistry and metallurgy, so the WMC Concentrator Superintendent devised a metallurgical solution to address this aspect of WMC mining operations. I have seen no evidence that IS&R/ACM directed management of clean or contaminated waters.

A June 20, 1926 report from V. A. Hart to J. R Walker[7] makes it clear that surface subsidence that followed underground stope mining diminished the miner's access to known ore reserves and allowed surface water to enter the workings. Furthermore, Hart leaves no doubt that WMC operators were responsible for prompt expansion of tailings pond capacity.

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[6] Mine Progress Report and Report on Concentration Operations, March 13, 1937. (Ex. 81.)
[7] Walker Mining Company report, V. A Hart to J. R. Walker, June 20, 1926. (Ex. 51.)

(2) Mining Phase Four – Concentrating

At the Walker Mine, ore was processed by crushing and grinding to a consistency resembling fine beach sand. When the ore fragments were reduced to this size, the copper sulfide minerals, along with undesirable grains of iron sulfides, were physically liberated from the quartz host. Also, the particles were then small enough to be readily suspended in water to yield a fluid mud, called "slurry", that was suitable for treatment by the flotation process. A reagent called a "collector" and *pine oil,* one of a family of "frothers" were added to the slurry. Finely ground lime was added to alter the surface chemistry of the iron sulfides and air was introduced to the bottoms of Callows-type flotation cells. Copper mineral grains became attached to rising air bubbles and overflowed the cells as froth "concentrates", while iron sulfide particles and bits of quartz left the flotation cells as an under-flowing "tailings" stream that was conveyed by a sluice or flume to an impoundment as a waste containing less than about 0.1-0.2 percent copper. WMC filtered the concentrate which was sent to the IS&R smelter at Tooele, UT, via overhead tramway to a railway terminal.

Dr. F. L. Quivik, a historian, in his Expert Witness Statement, page 19, noted that B. S. Morrow, who was ACM's Superintendent of Concentration, submitted recommendations about the design of the new WMC concentrator. ACM made Morrow available as a consultant to offer suggestions concerning the design of the new concentrator. Morrow did not, and could not, order WMC to follow his suggestions. Moreover, Morrow never had any role in the ongoing concentrator operations.

The Walker Mining Company's sole operation was at Walkermine, CA, and it was fully integrated with all of the support required for sustaining, maintaining, and repairing equipment. In addition to the operating, maintenance, and service personnel and facilities, there were bunkhouses and family homes, mess hall and kitchens, commissary, clinic and hospital, sawmill, machine shop, electrical shop, warehouse, a theater, various recreational facilities, and a school suitable for about 65 children. Total employment at Walkermine typically included 350-550 hourly personnel and 30 monthly (salaried) staff.

In a typical mining operation the size of the Walker underground mine in the late-1920s to late-1930s, there would have been about 200-250 hourly employees including stope miners, development miners, equipment operators, railcar motor men, support miners, diamond drillers, electricians, mechanics, maintenance workers, helpers, underground laborers, and surface laborers. In the concentrator (mill) there would have been approximately 60 hourly employees including crusher operators, flotation operators, thickener and filter operators, samplers, mechanics, electricians, and laborers. (Ex. 138.)

Salaried WMC personnel reporting to the WMC Mine Manager included a Mill Superintendent (with responsibility for concentrator operations), Mine Foreman, Chief Engineer and Geologist, Master Mechanic, Chief Clerk, and administrators responsible for the hospital and medical staff, school, fire protection, street and building maintenance, heating plant, and livestock stables for draft animals. There were clerks, accountants, draftsmen, assayers, stenographers, custodians, and other support personnel. (*Id.*)

Reporting to the President of the Walker Mining Company located in Salt Lake City, the Managers during the life of the operation at Walkermine, CA, included L. F. Bayer, H. A. Geisendorfer, V. A. Hart, H. M. Hartmann, and H. R. Tunnel. It was the Manager's role to receive information from subordinates, to made decisions that their direct-reports could not make, and to communicate with the President and his Board of Directors. The Manager was totally responsible for steady and profitable operation and could only do this if he conversed regularly with subordinates, then exercised absolute authority. Differing personality traits and technical expertise would have influenced the degree to which he accepted and implemented suggestions and recommendations from outsiders and the extent to which he delegated his responsibilities. There were a few examples of bypassed authority such as correspondence between Seth Droubay and both Murl Gidel and Reno Sales, but appear to have been infrequent. I have seen no documentation of communication between employees of ACM or IS&R and the WMC Mine Foreman, who would have supervised all mining activities, including prospective diamond drilling and exploration development. Here, it is important to recognize that diamond drilling was an integral part of short-range ore development, but that the same men and equipment also drilled prospecting holes when instructed to do so by the WMC Mine Geologist on recommendations from his exploration consultants, Sales and Billingsley.

(3) Mine Phases Five and Six – Waste Disposal / Product Shipment

I was asked to offer my opinion on tailings management and to estimate annual production of tailings by the WMC flotation concentrators and my methodology was as follows:

1) At Walker Mine, tailings management was the responsibility of the WMC concentrator personnel (who reported to the Mill Superintendent), not only because it was produced at Walker Mine, but also because those workers were experienced in pumping and handling of slurries and in reclaiming water for use by the concentrator. Geologists were not involved in these operations.

2) Concentration of ores from the Walker Mine began in September 1916. However, the first WMC document that I have noted relating to tons of ore milled and concentrates produced was the "Report of Walker Mining Company at The Special Stockholders' Meeting Held At Phoenix, Arizona May 3, 1925". This report presented monthly statistics, including copper recovery and concentration ratio (grade of copper in concentrates divided by ore grade). The ore grade was 7.96 percent copper in May 1922, declining to 4.40% in February 1923. The earliest concentration ratio given was 3.104 and I have assumed that a ratio of 3 was applicable to all earlier production unless better information was available.

3) I then referred to annual volumes of the USGS publication, Mineral Resources of the United States ("MR"). No statistics were presented prior to 1920, but a 75 tons of ore per day (tpd) concentrator was started up in September 1916, shipping concentrates to the IS&R smelter at Toole, Utah. The mill (concentrator) was expanded to 100 tpd in 1917 and continued at this capacity through 1918. In 1920, the Walker mill at 200-225 tpd apparently ran continuously and was second in Plumas County production to the Engel mill. During 1921, the mill did not operate, as the tramway that had delivered ore to the mill from the production shaft collar was replaced by the 700 level haulage tunnel, and the mine camp was moved to the vicinity of the mill camp. The mill was operated again during 1922 at a capacity of 225 tpd and the ore tonnage milled was given in E&MJ for that calendar year. By 1924, the new concentrator was at full capacity. The first two WMC annual reports were for Fiscal Years that ended July 31, 1924 and July 31, 1925. This left unreported gaps for the first half of calendar year 1924 and the last half of calendar year 1925, so I have used the annual statistics from MR for calendar years 1924 and 1925.

4) Related to tailings disposal, a June 20, 1926 report from V. A. Hart to J. R Walker[8] makes it clear that WMC operators were responsible for prompt

[8] Walker Mining Company report, V. A Hart to J. R. Walker, June 20, 1926. (Ex. 51.)

expansion of tailings pond capacity, noting that WMC needed to raise the tailings dam. Furthermore, correspondence seeking approval of the downstream tailings location was between WMC and the U.S. Forest Service. (Exs. 8-22.) WMC alone provided the assurances required by the Department of the Interior to approve the downstream tailings reservoir. (Ex. 24.)

5) Any waste rock that was hauled to the surface would have been stockpiled, not crushed and concentrated, so that waste would not have contributed to the tailings volume. Ore extracted during exploration development would have been concentrated and tailings would have been produced, but my examination of the documents has led me to conclude that the quantity attributable to exploration would have been negligible.

6) The following estimates for 1916 through 1921 assume 4 months of operation in 1916, 9 months in 1920, and 12 months in all other years. I have further assumed that, during 1916, 1917, and 1918, the mill only ran at 80 percent of design capacity. This was typical for small single-circuit inexpensive concentrating plants during that era. I assumed that, by the end of 1918, the miners and the mill operators and maintenance personnel had developed sufficient experience that 90 percent "availability" was likely. The operation was closed on October 1, 1920 and remained closed throughout 1921.

Table 1
Estimated Tailings Production 1916 through 1921

Year	Capacity	Months	Avail.	Tons Ore	Tons Conc.	Tons Tailing
1916	75 tpd	4	0.8	9,000	3,000	6,000
1917	100	12	0.8	29,040	9,670	19,370
1918	100	12	0.8	29,040	9,670	19,370
1919	200	12	0.9	65,340	21,780	43,560
1920	200	9	0.9	49,005	16,335	32,670
1921	200	0	0	0	0	0

Table 2 summarizes WMC's annual production from 1916 through closure on October 30, 1941, with the figures for 1922 through 1941 based on published statistics for annual tons milled and concentrates produced. I have relied on Mineral Resources of the United States for 1939 because the best available copy of the WMC Annual Report for 1939 was illegible. Tailings production by the WMC concentrator simply equaled the dry tons of ore milled minus the dry tons of concentrates produced.

Table 2
Annual Tailings Production (all figures in dry short tons)

YEAR	ORE	CONCT.	TAILINGS	SOURCE
1916	9,000	3,000	6,000	MR, 1916, p.244
1917	29,040	9,670	19,370	MR, 1917, p. 244
1918	29,040	9,670	19,370	MR, 1918, p. 435
1919	65,340	21,780	43,560	MR, 1919, p. 206
1920	49,005	16,335	32,670	MR, 1920, p. 179
1921	0	0	0	MR, 1921, pp. 186,188
1922	38,652	12,884	25,768	E&MJ, Vol. 116, No. 8, 1923, p. 338
1923	87,041	14,567	72,474	MR, 1923, p. 211*
1924	205,903	25,738	180,165	MR, 1924, p. 218*
1925	263,411	25,079	238,332	MR, 1925, p. 312*
1926	250,082	17,824	232,258	WMC Annual Report
1927	340,156	19,268	320,888	WMC Annual Report
1928	391,275	22,654	368,621	WMC Annual Report
1929	457,637	32,375	425,262	WMC Annual Report
1930	518,509	33,266	485,243	WMC Annual Report
1931	432,294	25,342	406,952	WMC Annual Report
1932	34,741	1,771	32,970	WMC Annual Report
1933	0	0	0	WMC Annual Report
1934	0	0	0	WMC Annual Report
1935	89,524	3,995	85,529	WMC Annual Report
1936	453,794	21,998	431,796	WMC Annual Report
1937	447,050	21,116	425,934	WMC Annual Report
1938	66,822	2,516	64,306	WMC Annual Report
1939	367,041	17,342	349,699	MR, 1940, p. 241**
1940	437,450	20,881	416,569	WMC Annual Report
1941	291,438	14,387	277,051	WMC Annual Report
1942	0	0	0	WMC Annual Report
TOTAL	5,354,245	393,458	4,960,787	

- The WMC Fiscal Years were 8/1/1924-7/31/1925, leaving unreported gaps. FY 1926 was CY 1926 and thereafter.
- The best available WMC Annual Report copy was illegible.

TERRY MCNULTY
MINERAL PROCESSING and CHEMICAL ENGINEERING
CONSULTANT

EDUCATION
B.S. Chemical Engineering, 1961, Stanford University
M.S. Metallurgical Engineering, 1963, Montana School of Mines (now Montana Tech)
D.Sc. Extractive Metallurgy, 1967, Colorado School of Mines
Registered Professional Engineer, Colorado, No. 24789
Registered Member, *Society for Mining, Metallurgy, and Exploration*

1989 – Present
PRESIDENT - T. P. McNulty and Associates, Inc.
Work has personally been conducted for over 250 clients including mining companies, secondary metal producers, utilities, chemical and hydrocarbon producers, engineering and environmental service firms, law firms, the World Bank and other financing institutions, agencies of domestic and foreign governments, universities, and technology developers. These clients have been located in the U.S., U.K., Brazil, Australia, Canada, Switzerland, Mongolia, Colombia, Mexico, Venezuela, Russia, South Africa, and Chile.

Types of work performed have included (1) evaluation of acquisition candidates and expert testimony, (2) management consulting and strategic planning, (3) project management, process engineering, and cost estimation in base and precious metals, uranium, nonmetallic minerals, and industrial chemicals, (4) direction of research programs, (5) plant audits, (6) participation in formal (NI 43-101 compliant) studies, and (7) assistance in developing and commercializing innovative technologies. Currently (February 2014), 9 of the original Associates are still consulting; they include metallurgists, a chemical engineer, a geologist, and a mining engineer.

1983 - 1988
PRESIDENT and CEO of Hazen Research, Inc.
I provided general and technical management to this R&D contracting company through the mineral industry depression of the mid-1980's. There were 105 employees at the low point and 145 at the end of 1988, a year of record profits. I participated in many of the 1400 projects completed during my tenure and managed a variety of them. Project activity included precious metals, base metals, yttrium and the Rare Earths, heavy minerals, coal, brine chemicals, uranium, beryllium, gallium, germanium, boron and lithium compounds, other nonmetallic minerals, and industrial wastes. Processing technologies included comminution, flotation, gravity concentration, heap leaching, CIP/CIL, autoclave oxidation, solvent extraction, electrolysis, selective crystallization, roasting, and smelting.

1980 – 1983
VICE PRESIDENT- TECHNICAL OPERATIONS, Kerr-McGee Chemical Corp.
I was responsible for overall direction of technical activities, for licensing of in-house technology, and for identification and evaluation of acquisition candidates. Working with other

officers, marketing personnel, centralized technical groups, and engineering and technical staffs at local operations, I directed the development and implementation of programs for new plant construction, plant performance improvement, cost reduction, environmental compliance, product quality improvement, and commercialization of new products. Business units for which I had these responsibilities included potash, soda ash, sodium chloride, sodium borates, sodium sulfate, boric acid, potassium sulfate, synthetic rutile, titanium dioxide pigments, vanadium metal and chemicals, lithium compounds, sodium chlorate, perchlorates of sodium, potassium, and ammonium, electrolytic manganese metal and manganese dioxide, phosphate pebble and concentrates, co-generated electric power, carbon dioxide, and treated forest products.

1974 - 1980
MANAGER - RESEARCH and TECHNICAL SUPPORT - The Anaconda Co.
I managed all ore processing R&D, process engineering, and technical support related to design, equipment selection, commissioning, and plant performance improvement. R&D projects covered the spectrum from laboratory testing of exploration samples to extensive pilot plant programs. Processing flow-sheet development and plant design and startup services were provided to nine operations employing minerals beneficiation, hydro-metallurgy, or pyrometallurgy. Commodities influenced by this work included aluminum, copper, lead, zinc, manganese, nickel, uranium, vanadium, chromium, molybdenum, gold, silver, tungsten, Platinum Group, and various nonmetallic minerals.

1972 - 1974
SUPERVISOR of PROCESS ENGINEERING - The Anaconda Company
I managed process development, process engineering, and equipment selection activities for a copper concentrator, a lead/zinc/silver concentrator, a copper smelter retrofit, and two hydrometallurgical (leach/SX/EW) copper plants. I participated in or directed the startups of all of these facilities.

1970 - 1972
CONCENTRATOR SUPERINTENDENT - Anaconda Canada Ltd.
I supervised completion of design and construction of a 1,000 ton/day copper, zinc, gold and silver flotation concentrator with an acid leaching and copper cementation circuit, and then was responsible for startup and operation. Other duties included supervision of plant maintenance, tailings disposal, water reclamation, and the analytical laboratory.

1966 -1970
SENIOR RESEARCH ENGINEER - The Anaconda Company
I participated in or managed projects including recovery and refining of beryllium oxide, recovery of alumina from clay, and the hydrometallurgy and pyrometallurgy of copper. My contributions included three novel processing routes for recovery of copper from complex non-sulfide ores.

1960 - 1965

RESEARCH & TESTING ENGINEER - The Anaconda Company

I provided plant testing and startup or temporary operating supervision in plants producing copper, lead, and zinc concentrates, electrolytic zinc, refined copper, ferromanganese, sulfuric acid, phosphoric acid, and various by-products such as arsenic trioxide. During 1961-63, I worked full-time while pursuing a Masters degree part-time. From late-1963 to early-1966, I was on leave to complete doctoral studies, but continued to work on copper smelting and copper fire refining projects for Anaconda.

PROFESSIONAL SOCIETY MEMBERSHIPS & ADVISORY APPOINTMENTS

I am a member of AIME (TMS and SME), the National Academy of Engineering, the Mining and Metallurgical Society of America, and the Mining Foundation of the Southwest.
Trustee Emeritus - Colorado School of Mines
Board of Governors - The Mining Foundation of the Southwest

PATENTS & PUBLICATIONS

Two patents in copper metallurgy and over 40 publications in the fields of (1) minerals processing and the extractive metallurgy of iron, copper, uranium, and precious metals, (2) process control, (3) energy conservation, (4) mineral industry trends, (5) waste treatment, (6) project management, and (7) technology development.

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PUBLICATIONS & PRESENTATIONS

Studies in the System Iron-Carbon-Oxygen, M.S. Thesis, Montana School of Mines, May 1963.
A Study of the Physical Chemistry of Copper Fire Refining, D.Sc. Thesis, Colorado School of Mines, June 1966.
Absorption of Sulfur Dioxide in Mercury, Transactions of the AIME, T. P. McNulty and A. H. Larson, June 1967.
Leaching of Copper Silicate Ore with Aqueous Ammonium Carbonate, International Symposium on Hydrometallurgy, T. P. McNulty and R. F. Frantz, Chicago, February 1973.
Applications of Hydrometallurgy in Future Mineral Processing Operations, presented to the National Science Foundation, Washington, D.C., July 1975.
The Role of Instrumentation in Energy Conservation in Copper Production, *Proceedings* of the 7th Mining and Metallurgy Division Symposium of ISA, Denver, February 1978.
Challenges in the Minerals Industry, Mines Magazine, April 1979.
Instrumentation Requirements in Uranium Mining and Processing, Proceedings of the Mining and Metallurgy Division Symposium of ISA, Phoenix, May 1980.
Changing Energy Economics in Extractive Metallurgy, Society of Mining Engineers Annual Meeting, Salt Lake City, October 1983.

A Profile of Control in Process Metallurgy, First International Symposium on Modeling and Control in Mineral Processing and Process Metallurgy, Los Angeles, February 1984

Processing of Gold and Silver Ores, AIME 12th Intermountain Minerals Conference, Vail, CO August 1984.

Innovation Sharpens the Competitive Edge, American Mining Congress, Phoenix, September 1984.

Trends in Mineral Processing, Northwest Mining Association Annual Convention, Spokane, December 1984.

Frontier Technology in Hydrometallurgy: 1980-1984, T. P. McNulty, P. B. Queneau, and J. E. Litz, AIME Annual Meeting, New York, February 1985.

Modular and Portable Processing Plants, Society of Mining Engineers Annual Meeting, at St. Louis, September 1986.

Process Mineralogy of Precious Metals, AIME, Mineral Processing Division Annual Meeting, Colorado Springs, May 1987.

The Role of Ore Testing in the Development of Small Mines, Clear Creek County Metal Miners' Association, Idaho Springs, CO, January 1988.

Comparative Costs of Pretreatment of Refractory Gold Ores, AIME Mineral Processing Division Annual Meeting, Colorado Springs, May 1988.

Pretreatment of Refractory Gold Ores, American Mining Congress, (Denver), September 1988.

Impact of Environmental Regulation on Mineral Processing and Hydrometallurgical Plants, R. B. Coleman and T. P. McNulty, Chapter 37 in the D.W. Fuerstenau Symposium, Volume II, December 1988.

Research and Development, Materials and Society, pp. 189-191, 1989.

1989 Henry Krumb Lecturer in Extractive Metallurgy, a 5-lecture traveling series sponsored jointly by the Society of Mining Engineers and The Metallurgical Society of AIME.

A Metallurgical History of Gold, American Mining Congress, San Francisco, September 1989.

Treatment of Smelter Flue Dusts, a presentation only at the American Mining Congress, New Orleans, September 1990.

Economics of Bioleaching, T. P. McNulty and D. L. Thompson, Microbial Mineral Recovery, pp.171-182, 1990.

Adjustable Speed Drives Cut Costs in Mining and Processing, T. P. McNulty and D. L. Thompson, National Western Mining Conference, Denver, February 1991.

Some Advantages of Using Contract Research and Development, N. Hazen and T. P. McNulty, 205th ACI National Meeting (Denver), April 1993.

Technologies for Treatment of Mining and Processing Wastes, T. P. McNulty and D. L. Thompson, SME Short Course, "Remediation: The Foundation of Our Future", 1993.

Pollution Prevention in Mining and Mineral Processing, Plenary Session Paper at USBM/CSM/EPA Joint Symposium, Snowmass, CO, July 1993.

Electricity in Mine Transportation, D. L. Thompson and T. P. McNulty, November 1993.

Adjustable Speed Drives Yield Process Improvements in Mining and Minerals Processing, L. E. Kissinger, D. L. Thompson and T. P. McNulty, September 1995.

Innovative Technology: Its Development and Commercialization, written for presentation in SME Session, *Managing Innovation*, Orlando, FL, March 1998.

Recommendations Arising from Plant Performance Audits, written for presentation in SME *Plant Operators' Symposium*, Orlando, FL, March 1998.
Ammonia Leaching of Copper Concentrates: an Update, Proceedings - Copper Hydromet Roundtable '99, published January 2000.
Sulfate Disposal from Ammoniacal Solutions, Copper Hydromet Roundtable 2000, September 2000.
Banning Cyanide Use at McDonald - An Attack on Open-Pit Mining, R. H.
DeVoto and T. P. McNulty, Mining Engineering, December 2000, pp. 19-27.
Comparison of Alternative Gold Extraction Lixiviants, Mining Environmental Management, May 2001.
Pyrometallurgy, a section prepared for the SME Mining Reference Handbook, 2002.
Overview of Metallurgical Testing Procedures and Flowsheet Development, Mineral Processing Plant Design, Control and Practice Conference, Vancouver, BC, October 20-24, 2002, pp.119-122.
Mineral Processing in the Third Millennium, Robert H. Richards Award Annual Lecture, SME Annual Conference, Cincinnati, OH, February 26, 2003.
Minimization of Delays in Plant Startups, SME Plant Operators' Forum, February 25, 2004.
Metallurgical Advances and Their Impact on Mineral Exploration and Mining, K.O. Hoal, T. P. McNulty, and R. Schmidt, 2006 Society of Economic Geologists Special Publication 12, Chapter 12, pp.243-261.
Leaching, a section prepared for Perry's Chemical Engineers' Handbook, 8th Ed., 2007.
Minerals, Critical Minerals, and the U.S. Economy, NRC Committee on Critical Mineral Impacts on the U. S. Economy, the National Academies Press, October 2007.
The Role of Process Development in Risk Reduction, Prepared for presentation at the 2014 Conference of Metallurgists in Vancouver.

PROFESSIONAL RECOGNITION

Distinguished Career Achievement Medal, Colorado School of Mines, 1989
Henry Krumb Memorial Lecturer, AIME, 1989
Distinguished Alumni Award, Montana Tech, 2002
Robert H. Richards Award for Distinction in Mineral Processing, AIME, 2003
Election to the National Academy of Engineering in 2005
Medal of Merit, American Mining Hall of Fame, 2010