Giants of Sampling 4: Robert Hallowell Richards

By Alan F. Rawle[1]

DOI: 10.62178/sst.004.010

1. Introduction

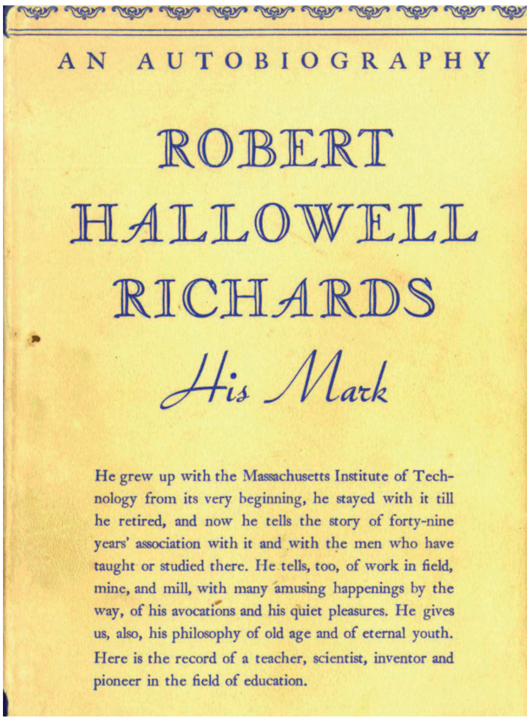
Robert Hallowell Richards was an early but crucial contributor to the theory of sampling. There are several interesting points associated with him:

- He lived to be over 100 years old, born in 1844 (August 26), he died in 1945 (March 27).
- He was in the very first group of students at MIT (Massachusetts Institute of Technology) when it opened in 1865 and graduated in 1868. He then spent 46 years working at MIT before retirement in 1914.
- His first wife, Ellen Swallow Richards, has had much more written about her than her husband as she (among other things) coined the term ecology (although spelled she first spelled it 'oekology'). She was the first female instructor at MIT in 1873 and had published far more extensively than Robert (See: https://en.wikipedia.org/wiki/Ellen_Swallow_Richards).

With regard to sampling, Richards inadvertently rewrote the laws of physics for convenience, and we'll explore that point later.

In terms of source material, Robert Richards wrote an autobiography (Robert Hallowell Richerds His Mark (Boston Little, Brown and Company 1936) Original cost $3). In contrast, Ellen Swallow Richards has had at least 5 biographies and similar books written about her. Richards' autobiography is written in more of a story-like, rather than scientific, manner and may reflect the fact that Richards was 92 or so years old when the book was published.

In the Technology Review (an MIT publication), Arthur Winslow (a graduate of 1881) wrote, in July 1908, an article commemorating 40 years of Richards' service with MIT, so we have plenty of source material to use.



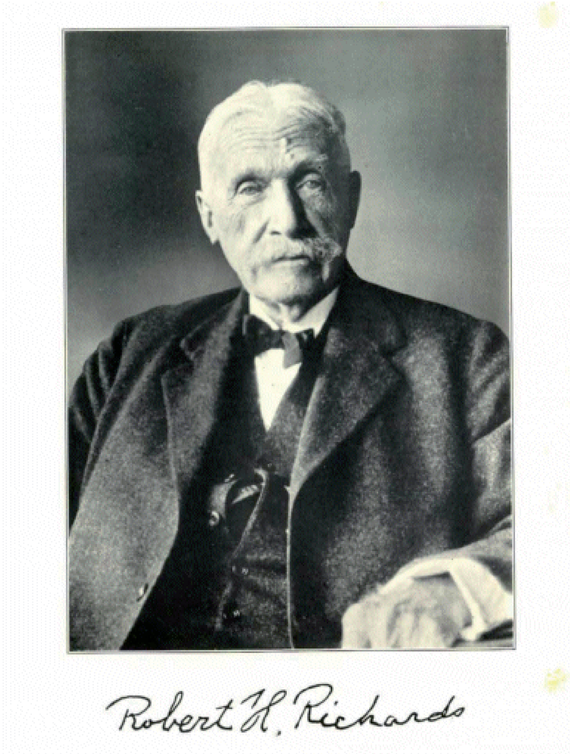


Figure 1: Dust jacket of Richards' autobiography together with the inset picture.

1 Retired. Hardwick, Massachusetts, USA.

Figure 2: Birthplace of Robert Hallowell Richards: Oaklands, Gardiner, Maine as it was in 1852 or so (woodcut from J W Hanson History of Gardiner, Pittston, and West Gardiner Published William Palmer 1852).

2. Early life and education

Robert Hallowell Richards came from a privileged background. 2 towns in Maine were named after his ancestors – Gardiner, Maine (where he was eventually buried) was named after his great-great grandfather, Dy Sylvester Gardiner, and Hallowell (from which his middle name originated) was named after great-great grandfather, Benjamin Hallowell.

The family owned a large estate called "Oaklands" on the Kennebec River. Maine and it was here that Robert was born on August 26, 1844 the sixth child of Anne and Francis Richards.

He was sent to school in England (in 1857 at age 13) with his brother, Harry ("Richards Major and Richards Minor") thanks to his father's interest in the country and lived at Cadlington, Horndean (home of Sir Michael Seymour) for one year before moving to Moorland Cottage, Purbrook, Hampshire (and hearing his first nightingale sing there).

His 4th and 5th years in England were spent at Wellington College, Berkshire where he was influenced by a Mr. Daykyns ("made me study"). Richards states "Mr. Daykyns was also very fond of nature. I once threw a stone at a bunch of sparrows and chaffinches that sat on a hedge. I laughed at my prowess, but he reprimanded me, saying it was wrong to mistreat birds. To this day I have not forgotten the change that was wrought in me by that simple remark".

Figure 3: Oaklands today HABS 1962 (Public Domain Wikipedia)

He returned to the US in 1862 (aged 18) where he moved with his mother to Boston. He tried to get into Harvard aged 19 and failed while his brother, Harry, was very successful there. He then attended Phillips Exeter Academy where, apparently, he was a complete misfit. He states, "I could not adapt myself to the method of education which revolved around learning dead languages by heart". These 'dead' languages were Latin and Greek.

He also tells a story about a mathematics teacher there (called 'Bull' Wentworth) where the conversation went:

"Well, Richards, where did the Pilgrims land?"

"I, having just returned from five years in England, did not know there were such things as Pilgrims". I replied solemnly "On the shore, sir"

In February 1865, his mother sent him a letter informing him that a connection and friend, Professor William Barton Rogers, was just starting the Massachusetts Institute of Technology (MIT) Boston, and she thought that this school might satisfy his needs better than Harvard. She was correct in that opinion and Robert thrived from the practical "observe, study, and record" manner of education. He learned the usefulness of the German language as his textbook on ore dressing was written in that language (Peter Ritter von Rittinger's Lehrbuch der Aufbereitungskunde?). Richards remarks "The method of teaching was completely new to all of us.

We found ourselves bidding goodbye to the old learn-by-heart method and beginning to study by observing the facts and laws of nature" and "We learned... how to observe, how to record, how to collate, and how to conclude". He states in his autobiography "Education ceased to be a plague spot and became a delight".

After graduation in 1868, Richards was asked to continue at MIT as an instructor and thus began 46 years of service. "In 1870, Professor Rogers suffered a stroke. Professor Runkle was elected to succeed him. Storer, the best professor of chemistry the school ever had, was so bitterly opposed to this move that he put on his overcoat and walked out of the school, never to cross its threshold again". "I, being the senior young man in his department, found myself acting head of chemistry of four months in the spring of '71, not be appointment, but by circumstances. It was a case of the old adage: "Nature abhors a vacuum"".

1871 – 3 years after graduating Richards found himself in charge of a department of mining engineering... He continued in that department until retirement in 1914.

He documents his time as follows:
- 1871 – 1873 Mineralogy, assaying, mining laboratory, metallurgical laboratory
- 1873 – 1878 Mineralogy, mining engineering, mining laboratory, metallurgical laboratory
- 1878 – 1883 mining engineering, mining laboratory, metallurgical laboratory, Secretary of the Faculty
- 1883 – 1889 mining engineering, metallurgy and the two laboratories
- 1889 – 1901 mining, and non-ferrous metallurgy, and the two laboratories
- 1901 – 1914 ore-dressing and the two laboratories

He determined the settling/sedimentation curves of materials settling under gravity in water, thereby establishing the fundamental principles of sorting ore by means of jigs and other machines. Indeed, in the days that I took an Extraction Metallurgy course at university we used his classic galena and quartz system as an example of mixed density settling and separation. This is the hindered settling principle where in free settling, a quartz particle (s.g. 2.6) 3.5 times the diameter of a galena particle (s.g. 7.6) settles at the same rate. Under hindered settling conditions (e.g. in a medium of higher density or concentration) the particle of quarts can be 7 times the diameter of the galena particle to settle at the same rate. This has great implications in the concentration and separation of ores and is the basis of the hydraulic classifier. During the period 1895 and 1900 Richards developed the so-called Richards Pulsator Classifier and Pulsator Jig for size and separation of minerals from gangue. The pulsator principle of upward-rising water currents a jig bed can be active 100% of the time a doubling in improvement over the earlier Harz jig. Richards also studied boat paints by running boats though water to see what friction was generated. From these tests he developed a graphite-based paint with the friction about ¾'s of that of comparable paints. He had a wide range of interests including nature (which included hunting and fishing), astronomy, photography, and glassblowing. He was very much an expert in the latter and demonstrated this in several of his metallurgical classes.

Earlier, in 1869 Richards had developed a filter pump for laboratory use which led to later improvements in the form of a jet pump using the injector principle.

Richards served as president of the American Institute of Mining Engineers (AIME) in 1886. He published around 35 original papers in the Transactions of AIME. In 1915, Richards was presented with a gold medal from the Mining and Metallurgical Society of America. The award was under the topic of "Advancement in the Art of Ore Dressing".

Richards main claim to fame, other than being a graduate of the first year of MIT in 1858, was his 4 substantial volumes entitled 'Ore Dressing' (5 volumes if you include the separate index) published initially in 1908 or 1909. Later editions attempted to condense these into 2 or 1 volume as was the forerunner (2 volume set) edition published by The Engineering and Mining Journal in 1903.

He did not take royalties on these publications to reduce costs for his students. These have been developed into print on demand and Google Books downloads, but I still retain an original full set plus the index. The pertinent volume dealing with sampling issues is Volume 2. The page numbering and sections are somewhat confused (IMHO) and thus care needs to be taken in looking through the different volumes from the different years and compilations.

Richards begins his introduction to sampling with the sentence "Sampling consists in obtaining, from a lot of ore, a small portion to weigh out for assay, which shall represent as perfectly as possible the exact proportions of the constituents in the original batch of ore". He then runs through standard manual (e.g., cheese scoop sampler, shoveling) and automated methods (Vezin, Snyder, Collom, Brunton) before proving a table of minimum masses linked to top end size of the sample. I have used this table many times.

Let us examine how the calculation was made. Richards explains the calculation thus: "First, to decide what weight (w) should be taken for assay or analysis after the ore has been ground to 100-mesh (approximately 0.125 mm. diameter) ; second, to compute the number (n) of maximum sized grains passing through a 100-mesh screen that would weigh (w); and third, to cut down to a weight after each crushing which will be equal to n of the maximum sized particles".

My first clue was that the sample size for a top end of 1mm (1000 microns) was stated to be ~ 1.5 kg.

Early in the 1990's I'd carried out similar calculations used in an old Malvern Instruments' application note. I'd come up with a minimum mass of ~ 1.36 kg based on a density of 2.6 g/cm^3 (approximation to silica) which is in the same ballpark. The basis for my calculation was a standard error of 1% (SE is proportional to $n^{1/2}$ so a 1% SE requires 10000 particles) based on the 99th percentile of the distribution. This requires 10000 particles in the x_{99}+ part of the distribution (which makes up 1% of the total mass so we need to multiply by 100 (98 is the actual correct factor as shown by Gy), so we can calculate a theoretical minimum mass for a 1mm top end as (with the size in mm converted to cm):

$$M_s = 10000*100*(\pi/6)*(1000*10^{-4})^3 *2.6$$
$$= 1361 \text{ g} \sim 1.36 \text{ kg}$$

It is the easy to spreadsheet the calculations to allow a simple comparison with the stated table and those numbers supposedly given by Vezin in the Richards' table.

We note that the comparison is excellent and could be made identical by a change in assumed density from 2.60 g/cm^3 to 2.86 g/cm^3.

After giving us this important table, Richards then states" The above rule demands finer crushing than practice indicates to be necessary, and it is, therefore, more expensive than is wise". He further states referencing Brunton "Brunton's results, however, show quantities that are largely in excess of practice".

Table 1: Minimum masses of sample required according to Richards (1903/1908)

This rule may be said to use a constant number of particles whatever their size. The following figures show the weights of different sizes required by this rule on the basis of 0.1 assay ton (2.917 grams) of ore through a 100-mesh screen (0.125 mm.):

128	mm.	3,131	metric tons.
64	"	391	" "
32	"	48.9	" "
16	"	6.12	" "
8	"	764.6	kilos.
4	"	95.57	"
2	"	11.95	"
1	"	1.493	"
0.5	"	186.7	grams.
0.25	"	23.33	"
0.125	"	2.917	"

Table 2: Comparison of the Richards' table with calculations based on a standard error of 1% on the x99 (assumed spherical particles).

d (µm)	d/10000	d^3	Density (g/cm³)	10000*100*(π/6)	Minimum Mass (g)	Vezin (1865/1866)	Vezin/Rawle
1	0,0001	1E-12	2,6	523598,7756	0,000001		
10	0,001	1E-09	2,6	523598,7756	0,001361		
100	0,01	0,000001	2,6	523598,7756	1,36		
125	0,0125	1,9531E-06	2,6	523598,7756	2,66	2,92	1,10
200	0,02	0,000008	2,6	523598,7756	10,89		
250	0,025	1,5625E-05	2,6	523598,7756	21,27	23,3	1,10
500	0,05	0,000125	2,6	523598,7756	170,2	186,7	1,10
1000	0,1	0,001	2,6	523598,7756	1361,4	1493	1,10
1500	0,15	0,003375	2,6	523598,7756	4595		
2000	0,2	0,008	2,6	523598,7756	10891	11950	1,10
4000	0,4	0,064	2,6	523598,7756	87127	95570	1,10
5000	0,5	0,125	2,6	523598,7756	170170		
8000	0,8	0,512	2,6	523598,7756	697015	764600	1,10
10000	1	1	2,6	523598,7756	1361357		

Richards work-around is to take a mass based on the square of the largest particles diameter: "By adopting the rule that the weight shall be proportional to the square of the diameter of the largest particles, we shall obtain a set of figures that will in all probability meet the approval of practising engineers; and which have a definite basis, and thereby do away with a great deal of guess work". He then provides a table (his table 369) and graphical plot based on this assumption.

Table 3: Richards ' Table 369 on sampling weights

TABLE 369.—WEIGHTS TO BE TAKEN IN SAMPLING ORE.

Weight.		Diameters of Largest Particle.					
Grams.	Pounds.	Very Low Grade or very Uniform Ores.	Low Grade or Uniform Ores.	Medium Ores.		Rich or "Spotted" Ores.	Very Rich or Excessively "Spotted" Ores.
		Mm.	Mm.	Mm.	Mm.	Mm.	Mm.
....	20,000	207	114	76.2	50.8	31.6	5.4
....	10,000	147	80.8	53.9	35.9	22.4	3.8
....	5,000	104	56.8	38.1	25.4	15.8	2.7
....	2,000	65.6	35.9	24.1	16.1	10.0	1.7
....	1,000	46.4	25.4	17.0	11.4	7.1	1.2
....	500	32.8	18.0	12.0	8.0	5.0	0.85
....	200	20.7	11.4	7.6	5.1	3.2	0.54
....	100	14.7	8.0	5.4	3.6	2.2	0.38
....	50	10.4	5.7	3.8	2.5	1.6	0.27
....	20	6.6	3.6	2.4	1.6	1.0	0.17
....	10	4.6	2.5	1.7	1.1	0.71	0.12
....	5	3.3	1.8	1.2	0.80	0.50	....
....	2	2.1	1.1	0.76	0.51	0.32	....
....	1	1.5	0.80	0.54	0.36	0.22	....
....	0.5	1.0	0.57	0.38	0.25	0.16	....
90	0.2	0.66	0.36	0.24	0.16	0.10	....
45	0.1	0.46	0.25	0.17	0.11	....	....
22.5	0.05	0.33	0.18	0.12	....	....	....
9	0.02	0.21	0.11	....	....	....	....
4.5	0.01	0.15	....	....	....	....	....
2.25	0.005	0.10	....	....	....	....	....

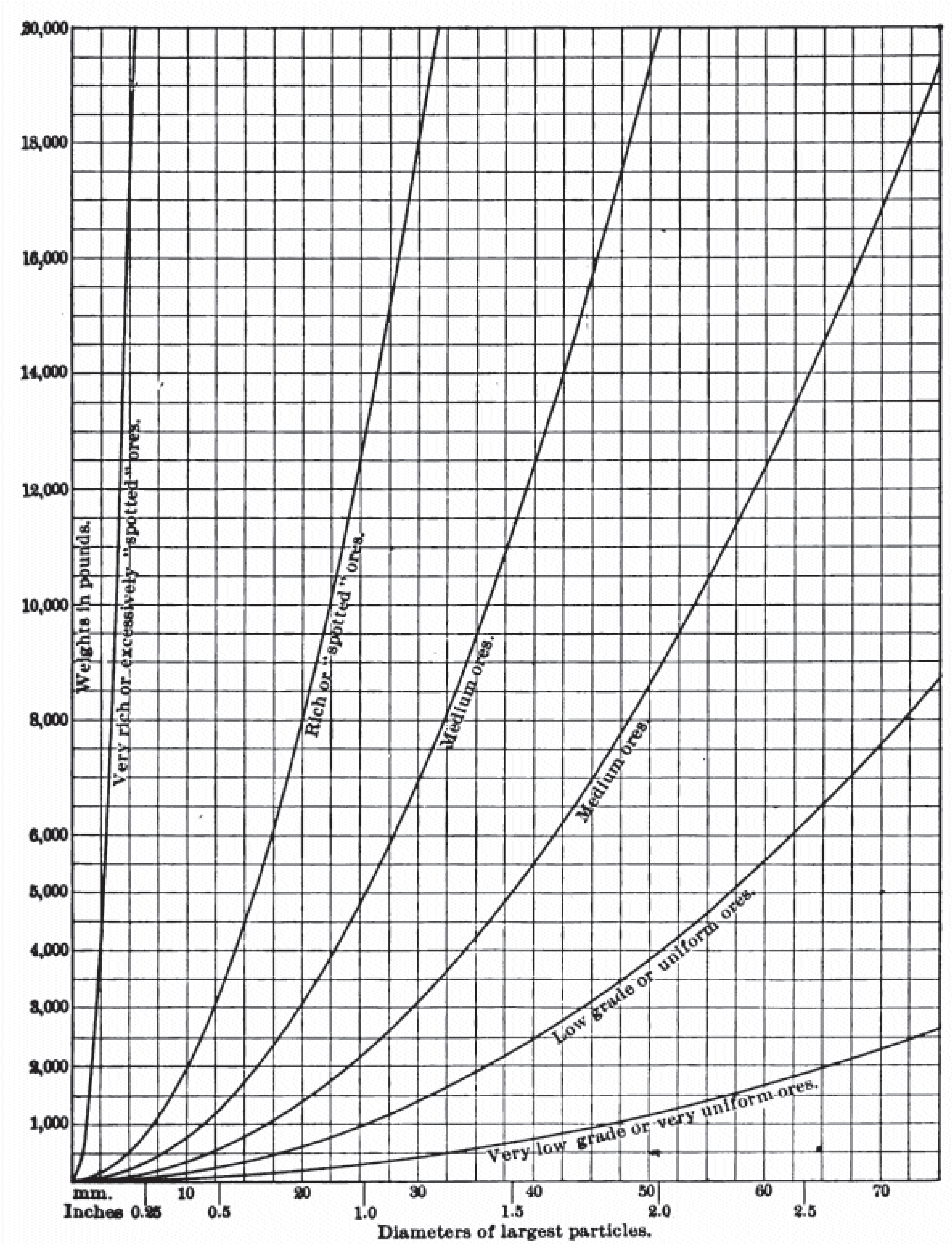


FIG. 485.—SIZES AND WEIGHTS OF ORE FOR SAMPLING.

Figure 4: Richards' graphical representation of sizes and weights of ore for sampling

Again, we see the focus on the type of ore to be sampled, and these assumptions have bedeviled sampling theory since the early days. We also note that the basis for these calculations is usually the derivation of the fundamental sampling error (FSE) ignoring the fact that this is usually the error (or variable) amenable to calculation and only 1 of 7 or 8 other errors which are often considerably larger than this.

The pertinent rules for how much (mass) of sample to take for it to be representative of the whole are based on how many particles are present in the top size (band) to be considered together with the desired precision (expressed as the standard error in statistics). These larger particles may be few in number but make up a substantial portion of the mass or volume of the total system in comparison to the finer or dust-like particles that may be present in the millions or billions. However, we do note that, in many ore dressing scenarios, the material of interest may be softer, denser and thus present in the finer/finest fractions than the unwanted gangue material (typically harder and less dense, if quartz or aluminosilicate).

It is worth exploring in some detail this $M_s \sim fD^a$ formula (where f is a form (shape) factor - 1 for cubes and $\pi/6$ or ~ 0.524 for spheres) multiplied by the density of the material – converts volume to mass - and a is a constant (exactly 3 in theory). Richards had 'amended' this to $M_s \sim fD^2$ on the basis of engineering convenience perhaps indicating the essential differences between a physicist/chemist (exact) and an engineer (empiricism). Thus, I find in my university extraction metallurgy notes from the late 1970's "the minimum mass requirement of "$M_s = kD^n$ where n = 2 to 3, theoretically 3...". This is perhaps an area where the old saying applies "In theory, theory and practice agree. In practice they do not".

Going back to 1922, not long after the publication of Richards' Ore Dressing tomes, we have Demond and Halferdahl in their 2 papers ("Mechanical sampling of ore" Engineering and Mining Journal-Press, v. 114, no. 7, p. 280-284 & "Sampling spotty gold ores" Engineering and Mining Journal-Press, v. 114, no. 22, p. 948) on the mechanical sampling of ore working on the expression:

$$W = kD^a$$

where W is the weight of ore, D is the diameter of the largest particle, and k and a are constants. They tabled sampling data for several crushing plants, where a, the exponent to which the diameter is raised, ranged from 1.0 to 3.76.

They claimed that an a as low as 1.4 should never be used and that a should never be as great as 3.0. Again, we see the difference between scientific exactness and an empirical or convenient approach. This 'convenience' lasted from Richards' time to the 1950s' when Pierre Gy got us back to the correct theoretical approach.

Richards mentions Brunton in his ore dressing books but not in his autobiography, so we don't know if they actually met. We assume that they did. Richards certainly had met Vezin and quotes: "Henry A Vezin was an old friend of mine for many years. In the early days, he knew more about ore-dressing, as practised in Germany, than almost anyone in that country. He was educated there. He was always visionary, however. My first introduction to him was in 1872, riding over the Rocky Mountains in Colorado with two men. We came to a place called Montezuma, where we were treated badly. Vezin told us was that there was one man with us who had written bad things about the place" and continues ""Vezin was a mining expert, mainly a specialist in concentrating. I last met him in Denver, not long before he died, and had a very funny interview with him. It was very characteristic of the man. He was so overjoyed at seeing me that he could hardly contain himself, and he began to tell me a story, and that reminded him of another; he began to tell me that one, and it reminded him of still another and so on. When I left, I concluded that he must have started about fifteen stories and not finished one".

On June 4, 1875, Robert (Bob) Hallowell Richards married Ellen Swallow. The 'courtship' had lasted 2 years or so and seemed to be an intellectual match. In his autobiography Richards wrote, "I had no ideas of what a wife ought to be to me, or what I ought to be to a wife, but I knew that Ellen Swallow's aims in life were along the lines which mine had seemed to follow. I admired her pioneer spirit, and I think she respected me for the hard work which I was doing. The inevitable happened, and one day in the laboratory (June 6th, 1873) shortly after she had received her B.S., I asked her to become my wife. She wished to think it over for a little, and to my everlasting joy, she decided to accept my offer". He was 3 years younger than she was.

Ellen (or Nellie as she was known) has had far more books published about her than many other women. She published extensively and we could write 5 or 10 times more about her than her less famous husband. I would recommend the book by Pamela Curtis Swallow entitled 'The remarkable life and career of Ellen Swallow Richards' (Wiley TMS 2014).

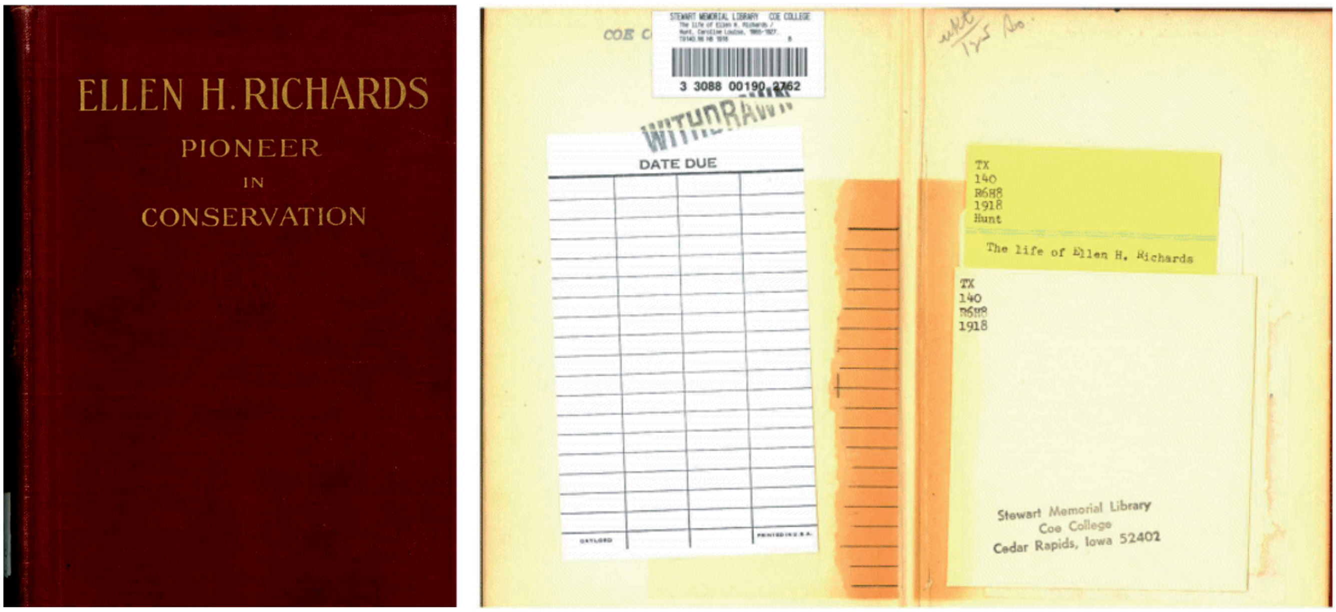


Figure 5: Biography of Ellen (Swallow) Richards – never removed from the library and withdrawn (Rawle own copy).

An early book on Ellen (Caroline L Hunt "The Life of Ellen H. Richards" Whitcomb & Barrows, Boston (1918)) – my copy was never removed from the library – is also recommended.

Ellen was the first woman admitted to any scientific school in the United States and the first female graduate of MIT. She was the first woman to be elected to the American Institute of Mining Engineers. She was also elected a fellow of the American Association for the Advancement of Science, an unusual honor for that time. She developed courses of study, set standards for the training of teachers, organized a professional organization, and edited a journal. The research that she and her colleagues had done clearly showed that exposure to contaminated air, water, food, and soil made people sick. She believed that people had a right to know what they were breathing, drinking, and eating. In a forward-looking speech she wrote:

> *The quality of life depends on the ability of society to teach its members how to live in harmony with their environment — defined first as the family, then with the community, then with the world and its resources.*

In the last decade of her life, she earned a substantial income from teaching, writing, and consulting. When she died of heart disease at the age of 68, she left virtually no estate. She had given all her money away.

As a part of the Massachusetts exhibit at the Chicago World's Fair in 1893, Mrs. Richards operated a "Rumford Kitchen," named for the Yankee-born Count Rumford who had pioneered the science of nutrition. Visitors could watch the expert preparation of food and buy 979.3 calories' worth of baked beans, brown bread, butter, and apple sauce for thirty cents. See: http://www.jphs.org/people/2005/4/14/ellen-swallow-richards-the-first-oekologist.html

The food was served in portions containing a definite amount of nutrition, and the menu card on each table gave the requirement for one-quarter of one day's ration, with the weight and composition of each dish composing the meal. A choice of two or three luncheons, for which the price was thirty cents, was given each day, each containing three or four dishes, though an extra price was made for a glass of milk, for a cup of cocoa, tea or coffee. See: https://libraries.mit.edu/archives/exhibits/esr/esr-rumford.html

In Hunt's book (see above: pages 220 and 221) it is stated "The man, too, from Southern Europe who defiantly said, "You needn't try to make a Yankee of me by making me eat that," pointing to baked Indian Pudding…" I ate Indian Pudding at Durgin Park Restaurant, Boston after my US Naturalization ceremony in Faneuil Hall, Boston in 2008.

One of her main claims to fame though, was in detailed water analyses of Massachusetts. From 1884 until her death, Ellen was an instructor in the newly founded laboratory of sanitary chemistry at the Lawrence Experiment Station, the first in the United States and headed by her former professor, William R. Nichols.

Figure 6: Ellen ‘Nellie’ Swallow and Robert Richards (Courtesy MIT Museum)
Original url: http://libraries.mit.edu/archives/exhibits/wbr-visionary/

In 1887, the laboratory, directed by Thomas Messinger Drown, conducted a study under Richards of water quality in Massachusetts for the Massachusetts State Board of Health involving over 20,000 samples, the first such study in America. Her data was used to find causes of pollution and improper sewage disposal. As a result, Massachusetts established the first water-quality standards in America and its first modern sewage treatment plant at Lowell, Massachusetts. She was a consulting chemist for the Massachusetts State Board of Health from 1872 to 1875 and the Commonwealth‘s official water analyst from 1887 until 1897.

Ellen was a founding ecofeminist who believed that women‘s involvement within the home was a vital aspect of the economy. Her interests in this regard included applying scientific principles to domestic situations, such as nutrition, clothing, physical fitness, sanitation, and efficient home management, creating the field of home economics. But she was also a pragmatist, saying “You cannot make women only contented with cooking and cleaning, and you need not try.” See: http://www.usasciencefestival.org/schoolprograms/2014-role-models-in-science-engineering/751-ellen.html

Figure 7: Note the woman with the ax – bottom left (Courtesy: MIT Museum). Ellen Richards is at the far top left.

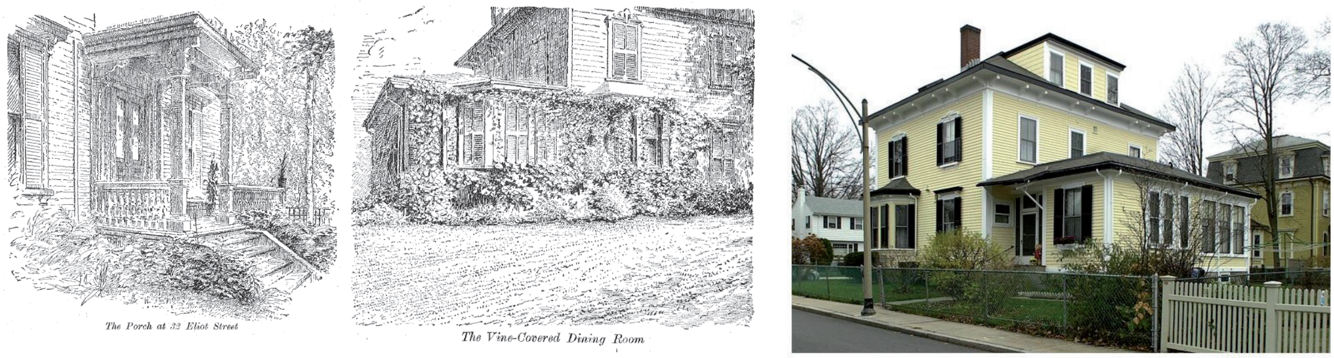


Figure 8: 32 Eliot Street, Jamaica Plain, Boston First 2 drawings from Drawings from Ellen H Richards' biography and last picture from Google Streetview

Their house ("rented and later bought") - 32 Eliot Street, Jamaica Plain, Boston - became an important icon. The house was added to the National Register of Historic Places and declared a National Historic Landmark in 1992 (the Ellen Swallow Richards House). In her honor, MIT designated a room in the main building for the use of women students. In 2023 the address was up for sale at approximately $2.1 million.

In "His Mark" pages 157 – 158, Robert Richards states: " It was my wife's idea to build an addition to our dining room, in order to have sufficient room for the students who used to visit us". "When we first moved to 32 Eliot Street, there was an old well under the corner of the kitchen. It was necessary to pump water by hand into a tank in the attic for the bathroom upstairs. We had city water about 1878. From the start we had gas for light, and after a while bought a gas stove".

In 1973, on the occasion of the hundredth anniversary of Richard's graduation, MIT established the Ellen Swallow Richards professorship for distinguished female faculty members. In 2011, she was listed as #8 on the MIT150 list of the top 150 innovators and ideas from MIT.

Nellie died comparatively young of the same heart ailment as Vezin and was buried in Gardiner, Maine. Robert followed much later in 1946 and was buried next to her. Shortly after Nellie's death, Robert married Lillian Jameson, a former secretary to Ellen. Lillie (born July 14, 1866) died on March 31, 1924, but is buried in Woodbrook Cemetery, Woburn, Middlesex County, Massachusetts. W T Sedgwick in an eulogy entitled "Mrs. Richards' Unique Position: An appreciation of her work at the Institute by Prof. Sedgwick" Boston Transcript, March 31, 1911 stated: "Many gaps left by death are not difficult to fill, but this is not the case with Mrs. Richards. Her position in the Institute and her work in the world were both unique. No one can fill her place. Other women may become experts in water analysis and preside over laboratories, but no one hereafter can possibly gain the peculiar historic equipment which fell to Mrs. Richards. Other women may, and no doubt will, make addresses and write books upon sanitation and the home, but no one else can ever do these things as Mrs. Richards has done them, for the reason that she was herself an evolution and represented an epoch. We are always too prone to undervalue things familiar and near at hand, and Boston and Massachusetts have never adequately appreciated Mrs. Richards or her work. But now that she is gone and no one can possibly take her place, we may begin to realize the extent of our loss".

On August 26, 1944, Roberts Richards celebrated his 100th birthday. He was 100 years old. Interestingly, 10 years earlier on August 26, 1934, he had celebrated his 90th birthday. In his autobiography (page 278), Richards tries to explain in a humorous fashion how he managed to reach that grand old age: "After doing all the things I could think of to help me live to 90 years old, I finally said, "Why do we men have to have our shoulders all covered up when the girls are going with their low necks and short sleeves which toughen them so finely?" So, I started going to bed without any body clothes on, to come as nearly as possible to the girls' result. Upon which, when my lovely opposite girl neighbor heard of it, she wrote:

"*I wear my pink pajamas*
In the summer when it's hot
I wear my flannel nightie
In the winter when it's not
Sometimes in the springtime
And sometimes in the fall
I jump right in between the sheets
With nothing on at all"

Earlier in the text, he outlined his philosophy for health:

Food
Exercise
Amusement
Sleep
Task (or work)

I suspect that this was really Ellen Swallow's statement taken from her home economics courses.

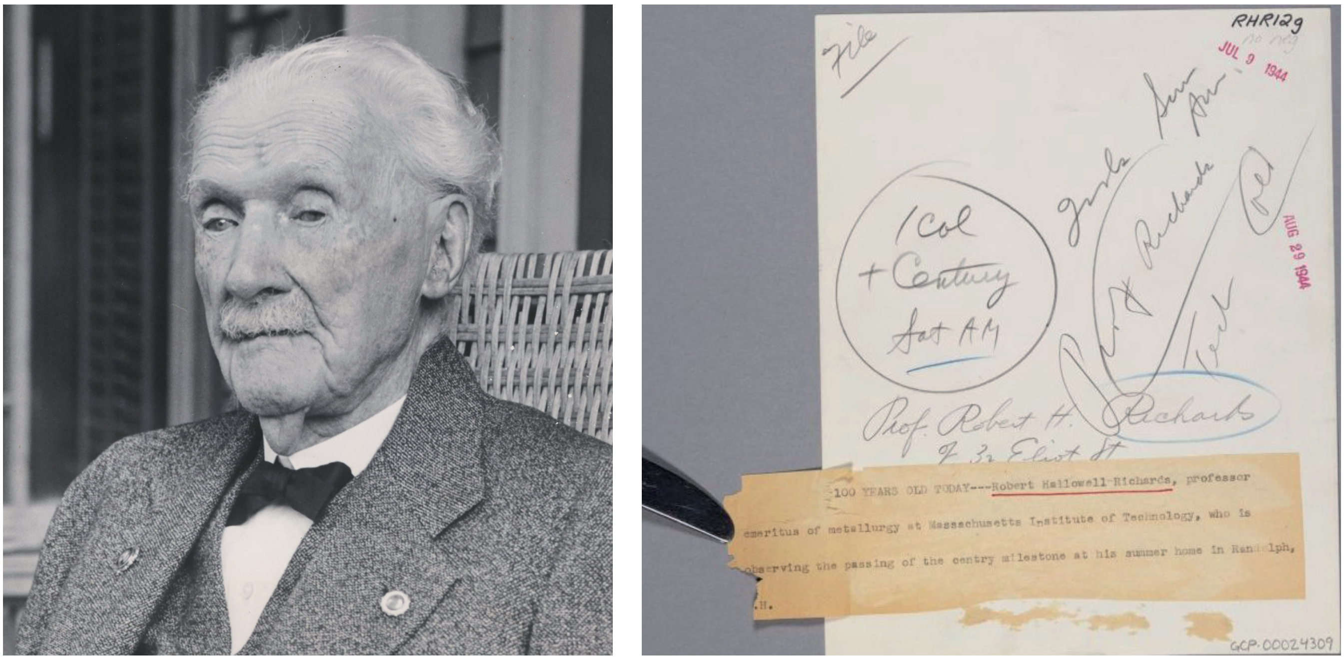


Figure 9: Robert Richards on his 100th birthday (courtesy MIT Museum GCP-00024309).

Robert Hallowell Richards died on March 27, 1945, and is buried next to his first wife (and soul mate), Ellen Swallow in Christ Church Cemetery, Gardiner, Kennebec County, Maine close to his birthplace. Lillian Jameson, who died on March 31, 1924, in Washington DC is buried separately in Woodbrook Cemetery, Woburn, Middlesex County, Massachusetts.

AIME honored Dr. Richards' memory in 1948 by establishing the Robert H. Richards award as the premier award in the field of ore processing.

Further Source Material

In 1946, AIME published a classic volume ('Richards Memorial Volume' No. 169) on Milling and Concentration with a biography written by one of his former students, Frank E. Shephard, mainly based on extracts from Richards' autobiography. This volume contains 2 classic papers (one by Fred Bond and one by Risto Tapani (R T) Hukki – with Gaudin) on comminution. An earlier biography was written by Arthur Winslow in July 1908 to commemorate Richards' 40 years of service to MIT. This was published in 'The Technology Review' (the official MIT journal) Volume X No. 3 249 – 257 with a facing portrait at the beginning.

For Ellen Swallow Richards, see: "Ellen Henrietta Richards, A.M., Sc.D.: A biographical sketch of her life - Her remarkable career and her many public activities" MIT Technology Review Volume XIII, 365-373, (1911) plus the many biographies (Google or Abebooks search!).

A publications list for Ellen Swallow Richards is shown at: http://libraries.mit.edu/archives/exhibits/esr/esr-bibliography.html

ACKNOWLEDGEMENTS

I'd like to give my heartfelt thanks to Elias Trout, MIT Museum and Amanda Hawk, MIT Libraries - Distinctive Collections, for their rapid responses to my inquiries and tracking down the true lineage of a couple of the figures.