THE APPLICATION OF KICK'S LAW TO THE MEASUREMENT OF ENERGY CONSUMED IN CRUSHING*

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Mr. H. Stadler, in his paper "Grading Analyses and Their Application," states Kick's Law as follows:

"The energy required for producing analogous changes of configuration of geometrically similar bodies of equal technological state varies as the volumes or weights of these bodies."

In other words this law says that to break 1 cu. in. of material into two pieces will require ten times more energy than is required to break a piece of exactly similar material of 1/10 cu. in. size into two pieces. With one limitation to be mentioned below this is a statement of a mathematical fact, and, therefore, indisputable.

The law assumes that the tenacity of a material is a constant quantity, which is not absolutely correct. The assumption is sufficiently true for sizes appreciable by the naked eye, but for finer sizes it has been known for many years past not to hold good. The following figures taken from a paper by Gibson & Gregory on "Notes on the Tenacity of Spun Glass," will serve as an example to show the enormous increase in tenacity as such threads become fine.

Diam. in mm.	Tenacity in dynes per sq. cm.
0.009	60×10^7
0.0082	83×10^7
0.005	97×10^7
0.0042	126×10^7
0.000315	405×10^7
0.000186	424×10^7

A similar increase in tenacity has been found in testing fine metallic wires, though to a smaller extent.

Quincke suggested that the great increase observed in the case of metals was due to a surface tension analogous to that observed in liquids, but, whatever the true explanation, it is a well-established fact that fine particles have a greater tenacity than large particles. This being so, Kick's Law becomes more and more inaccurate as the sizes become smaller, even with a material which is otherwise perfectly isotropic; but the discrepancies are probably not very marked until sizes as small as 200-mesh are reached. We may, therefore, apply Kick's Law to the ordinary problems of ore crushing, in so far as this particular point is concerned.

However, though in itself approximately correct, Kick's Law may not be strictly applicable to the problems of ore crushing, because the stipulated conditions of "equal technological state" do not exist in the various stages of crushing an ore. Consider, for instance, a piece of ordinary oxidized auriferous quartz, 4 in. in diam.; it may contain scores of small vugs partly filled with oxide of iron in powdery form, and also small cracks filled with clay. When such a piece is submitted to crushing, the first fractures will take place mostly at cleavages and other weak places. The tenacity of a piece of such ore 4 in. in diam. will, therefore, be relatively less than that of pieces say 1/10th in. diam., because the latter will possess the same original lines of weakness which would already have been taken advantage of at the initial crushing. Further, by the time such a piece of ore was crushed to, say, 10-mesh in water, the greater part of the clay, etc., in the ore would be washed away as slime, and would thus have been converted into slime without any real consumption of energy.

The author has noticed on plotting various screen analyses that the product of a machine re-grinding sands or middlings contains relatively less slime than if the same machine were treating original ore. The only apparent reason for this is that the original ore contained some natural slime, whereas the sand or middling product had previously been nearly freed from such material.

As a further illustration of the difficulties of obtaining "equal technological state," we may refer to the problems of ore dressing. It is often found that after a particular ore has been crushed through a certain aperture, the bulk of the mineral is freed from the gangue. Suppose the mineral be galena, the gangue be quartz, and the mesh 60; in such a case many of the particles larger than 60-mesh would consist of quartz and galena, whereas most of the smaller particles would consist either of quartz or galena, so that if, as seems probable, the attachment of the galena to the quartz is a plane of weakness, the exact condition of equal technological state is not maintained. Mr. Stadler maintains that Kick's Law would apply, but the argument he advances in support of his contention overlooks the point that the plane of attachment of one mineral to another is in all probability a plane of weakness.

In general, regarding the application of Kick's Law to ore crushing, it seems reasonable to conclude:

(1) That it will tend to over-estimate the energy consumed in coarse crushing.

(2) That it will tend to under-estimate the energy consumed in the grinding of non-slimy sand into slime.

(3) That it will tend to over-estimate the work done in making slime from such ores as contain slime as an original constituent.

These conclusions seem to be borne out by what is noticeable in actual practice. Consider, for example, the following instance.

Mr. Stadler mentions that the relative efficiency of stamps decreases rapidly from 78.3% for 9-mesh screen to 39.2% for 1,200-mesh, and to 33.1% for 1,600-mesh. The more one thinks about the action of stamps, the less can one believe that this apparent falling off in efficiency is solely due to the unsuitability of stamps for fine crushing.

However, although Kick's Law may not be strictly applicable to all the problems of ore crushing, there has not yet appeared a more rational basis on which to work. Rittinger's Law, as commonly formulated, viz., that "the work of crushing is proportional to the reduction in diameter" is open to the same objections as above stated against Kick's Law, besides other much more serious objections.

Stadler's adaptation of Kick's Law to ore crushing is, perhaps, marred by the employment of the term "energy unit," but otherwise is a fairly serviceable method, and will, no doubt, become increasingly used.

*A paper presented at a meeting of the Institution of Mining and Metallurgy, May 21, 1914.