The other fine-crushing apparatus, such as the ball-mill, the pan, the sample-grinder, the bucking-plate, etc., will be discussed under the heads of sampling and metallurgical apparatus.

3. *Sizing.*—The sizing or sifting of ore is more tedious in the laboratory than it is in the mill, because the screening surface is necessarily smaller, and all sifting has to be done without the use of water. If there is only a moderate quantity of ore, the sizing is best done by hand on a platform covered with an iron plate [6]. Sieves with wooden frames from 24 to 18 inches in diameter, and iron or brass wire-gauze having from 4 to 20 meshes to the linear inch, are well suited for this purpose. With very small quantities of ore, nests of sieves with metal frames, 8 inches in diameter, and wire-gauze ranging from 20 to 120-mesh are convenient; the screenings to be caught in a metal pan. With large quantities of ore the sifting has to be done by machinery, and the shaking sieves referred to above are used for this purpose. There are fourteen of these, representing the sizes 2-, 4-, 5-, 6-, 8-, 10-, 12-, 16-, 20-, 30-, 40-, 50-, 60- and 80-mesh. They sift per hour about 2,000 pounds of 8-mesh ore, 1,000 pounds of ore ranging from 14- to 30-mesh, 300 pounds of 50-mesh, and about 150 pounds of 60- to 80-mesh material. As this work is somewhat slow, it is better to do it in separate sizing-boxes. Two inclined boxes, having screens of 3-, 10-, 18-, 30- and 60-mesh, and 4-, 8-, 14-, 24-, 24- and 50-mesh respectively, are satisfactory for the purpose. They are made of ½-inch pine, are 90 inches long, 18 inches wide and 5 inches deep, and have wooden covers screwed down on a felt band. They are oscillated 200 times per minute, by an eccentric and connecting rod, which gives them an end-shake. The ore is fed into the hopper at the upper end, and drops on a piece of galvanized iron, whence it passes on to the first (the coarsest) sieve. What is too coarse to pass strikes a dam at the opposite end and is discharged into a vertical spout at the side, to which a cloth bag is attached, through which it passes into a pail. It would seem as if the Coxe gyrating screen, which does such excellent work in sizing all sorts of minerals, might well be suited for laboratory purposes, either in the form of a single screen or a nest of screens. The trommels, as commonly employed in large scale working plants, are out of place in a laboratory. If a trommel is to be used, the polygonal form seems the most suitable, as the different screens could be easily adjusted and removed. It would be necessary in all cases to house the trommel.

4. *Hydraulic Classification.*—Hydraulic grading is done at present in the Institute laboratory only in an ascending current of water. Grading in a horizontal current of water, or *Spitzkasten*, will shortly be introduced, as it has been proved to be indispensible for the successful working-up of fine slimes. Now the fine sands and slimes are only settled, but not graded. Hydraulic classification is practiced with small samples of finely-pulverized ore, as a preliminary test before working small lots. The samples are treated in the Richards pointed tube,* where the mixed sands, held in equilibrium by an ascending stream of water are, by slightly slackening the current, drawn off slowly into the glass bulb, which, when filled, is exchanged for another. The contents of each bulb are then separately sifted through a nest of graded sieves, and weighed and examined, to find out just how effective the work has been, and what will be the best sieve-size for the trial test. In working, the material, after it has been crushed to the proper size, is passed through the automatic feed-trough [8], or the Cornish feeder [7], into a Richards *Spitzlutte* [9], when the discharge of the spigot will go to the jigs [10 and 11] and the overflow either to the vanner [16] or the slime-table]12], or first to the former, and, as tailings, to the latter. It is proposed to have the overflow, when worked directly on the slime-table, run first over a *Spitzkasten*, and then to feed separately the spigot-discharge, thus insuring better work. Another way of using the Richards *Spitzlutte* is to feed only carefully-sized ore, when the spigot, in many cases, will give clean heads and the overflow clean tailings, provided there are no included grains. The capacity of the *Spitzlutte* with a ½-inch spigot, is about three-quarters of a ton of sized material to 1 ton of mixed material per hour.

The automatic feed trough and the Cornish feeder serve to convert dry pulverized ore into liquid pulp, delivering it to the *Spitzlutte*, the jigs or the slime washers. The feed trough is of wrought-iron, 10 inches wide at the top, 3 inches at the bottom and 7 feet long, and is placed in an inclined position on a wooden trestle. On the inner side the trough is marked off, so that the same quantity of ore may be washed down by the travelling jet in the same interval of time, which is usually one minute. The travelling jet is a ¾-inch iron pipe, pointed downward and fixed in a wooden truck, having two of its wheels on one edge of the trough and the other on a rail 3 inches away from the opposite edge. The pipe is connected by a rubber hose with the water main. The carriage is pulled up the inclined trough by a weighted cord, running over a pulley at the upper end of the trough to a shaft near the roof, around which it is wound once or twice and kept taut by the weight. To this weight is fastened a second cord, running over a pulley near the roof to the lower end of the trough, which serves to raise the weight, and thus to lower the carriage. In order to prevent the rubber hose from obstructing the upward travel of the carriage and the even flow of the water, it is suspended from the rail by small grooved wheels, and the loops are replaced by 6 iron pipe return bends. Thus the suspended hose shows three zigzags, which are close together when the carriage is at the lower end of the trough, and separate as it travels upward, but are held together at the upper ends by strings, which do not allow them to get more than 24 inches apart.

The Cornish automatic feeder is a four-sided truncated pyramid of sheet-iron. It is 24 inches high, and the bases are 18 and 12 inches square. To the smaller base are attached four legs, on which it stands in a sheet-iron box, 16 inches square and 6 inches deep, contracted at one end into a spout. The legs (pieces of angle iron) firmly connect the hopper and the box, leaving a distance of ½-inch between them for the ore to pass through. This is charged into the hopper and washed down the spout by a jet of water playing usually between the walls of hopper and box, but occasionally (if especially quick feeding is desired), upon the ore in the hopper.

5. *Jigging.*—The jigs in use for water sorting are plunger jigs and movable sieve jigs. The former are represented by two Collom jigs [10 and 11 and Fig. 3], used for ores ranging from 30 to 5-mesh, the latter by a Richard's jig [17] for sizes larger than 5-mesh.

The Collom jigs are two compartment machines. They are supported by a V-shaped iron frame on either end. The screen frames are 12½ by 18½ inches. The length of stroke is adjustable to ¾-inch and the number of strokes can be varied by the use of three-step pulleys, 8, 10 and 12 inches in diameter, from 130 to 180 per minute. The ore coming from the feed trough, the feed hopper or the spigot of the *Spitzkasten* travels over the jig, while the tailings at the opposite end are collected and unwatered in a sheet-iron box. From this they are drawn at intervals, while the water which overflows goes into the water tanks [18]. The jigs have no automatic discharge for concentrates; since, for the purposes of instruction and experiment, it is better to stop them every little while and skim off the different layers formed. The manner of working, therefore, is the same as that of large scale one-compartment jigs. The reason for having a two-compartment jig is that "every machine as far as practicable, should have its guard."† Any middle product not remaining on the first sieve will be collected on the second sieve and thus prevented from passing off into the tailings. The Collom jigs here described were put in to replace two three-compartment Harz jigs formerly in use, the screen frames of which 16 by 12¾ inches, were much too small to do satisfactory work. The reciprocating motion was derived from an excentric adjustable to 2 inches; and the number of strokes could be varied from 100- to 200 per minute by four step-pulleys, 6, 7½, 9 and 10½ inches in diameter. The jigs had an automatic side discharge for heads.

The movable sieve jig serves to illustrate the lectures, to work ore coarser than 5-mesh and to do the water sorting in graded crushing and jigging. The sieve frame is 14 inches wide, 22 inches long and 12 inches deep, the ore bed can reach a depth of 10 inches. The rods of the screen frame, ¾-inch in diameter, are divided into two parts to facilitate taking the machine apart. The two lower or jigging rods, 48 inches long, are forked at their lower ends and have an eye at the top through which passes a connecting rod, ¾-inch in diameter, suspended from the upper or excentric rods, which are 25 inches long. The excentrics are adjustable to 2 inches, the excentric shaft is 51 inches long and 1⅝ inches in diameter. It has a conical pulley with seven steps, its smallest diameter being six inches, its largest 8¼ inches. The number of strokes per minute ranges from 100 to 200. The counter shaft is placed 14 inches above the excentric shaft; and the whole is attached to a strong wooden frame. The water tank in which the ore is jigged is 33 inches long, 27 inches wide and 22 inches deep. Small boards extending from the sides into the tank serve as guides for the screen frame. The hutch work is drawn off at the sides; the tank rests on a wooden box and its top is 36 inches from the floor.

6. *Slime-Washing.*—Of the different machines in common use for working slimes [*i.e.*, material not coarser than 30-mesh] only two are represented in the laboratory: a Frue vanner [16] and a convex continuous round table [12]; a greater variety being excluded by the lack of space.

The Frue vanner is of normal size, *i.e.*, it has an inclined rubber surface 4 feet wide and 12 feet long. Either plane or corrugated belts are used. The normal adjustment for full work in the laboratory [inclination of belt 3½ inches in 12 feet, travel of belt 32 inches per minute, and 195 shakes of 1-inch throw per minute] has to be changed, if the pulp flows directly from the light three-stamp battery upon the vanner, as the battery furnishes only about 1½ tons of pulp in twenty-four hours, while the normal rate of the vanner is 5 tons. The simplest way is to change the inclination to 2½ inches in 12 feet and to regulate the flow of water accordingly. If the vanner is to do full work, the pulp from the battery is collected in the settling tanks and fed at the required rate and with the necessary water by the Hendy feeder of the stamp-battery. In order to permit this, the connecting-rod of the friction-plate is replaced by an excentric rod, the excentric of which has a 2-inch throw, and is on a small counter-shaft near the ceiling. The counter-shaft is driven from the upper shaft of the laboratory and makes 100 revolutions per minute. The ore which is fed by the carrier-plate is washed by a jet of water into a sheet-iron trough and conducted from behind the mortar into the ore-spreader of the vanner.

The convex continuous round table is 8 feet in diameter and has a slope of ¾ inch to the foot. It is of ⅛-inch sheet-iron, painted with tar, sanded and rubbed smooth, and is supported by an umbrella-frame. It receives its pulp from a fan-shaped distributor, which discharges against one side of a central cone, 14 inches high and 18 inches in diameter, and its wash-water on the opposite side from a horizontal curved pipe with perforations on the inner side. The three products, tailings, middlings and heads, flow into a circular launder. The compartments for heads and middlings are 12 inches wide and hopper-shaped; that for the tailings is 6 inches wide. The heads and middlings are drawn off at intervals into a pail; the water of the heads compartment overflows into that of the middlings, and the overflow of these into the tailings launder. The heads are washed off by jets of water; the middlings are sprayed in the usual way. The machine treats from 1 to 1½ tons of ore per day.

There are in the laboratory, of course, the ordinary implements for panning and vanning to check the work done by jigging and slime-washing, and to assist in amalgamating operations.

7. *Electro-Magnetic Separation.*—The magnetic separation of magnetite or of iron ore rendered magnetic by a preliminary roasting is represented by a small Chase endless-belt machine* placed near the tank [32]. This receives the waste-water from a 6-inch Pelton water-wheel which drives the concentrator. Many interesting data of magnetic separation are recorded in the journal of the laboratory. It may be incidentally remarked that a small Pelton wheel forms a most satisfactory motor for any apparatus that is to be driven independently in a laboratory having water under pressure at its disposal. Of course, a pressure-regulator is necessary to equalize the uneven flow obtaining in a city main.

8. *Dry Concentration.*—There are no arrangements in the laboratory for dry concentration. To make tests that would be in any way satisfactory would require too much space.

9. *Distribution of Power and Water.*—The machinery of the laboratory is driven by a 15 horse-power upright engine [24] having a common side-valve. Its cylinder is 9 inches in diameter; it has a 9-inch stroke, and is usually run at 200 revolutions per minute. The main shaft, 1¾ inches in diameter, is on the ground floor and runs the entire length of the milling-room. Its position is approximately indicated by Nos. 1 and 3 in the plan (Fig. 1). It makes 240 revolutions per minute. Near the double ball-grinding mill [36.1] it is connected with the counter-shaft of the same diameter placed near the ceiling. This also runs the entire length of the mill-room along the center line of the Frue vanner. It makes 200 revolutions per minute. Thus the different machines are set in motion either from the main or counter-shaft, the choice depending upon the location and direction of the belts.

The large dynamo [25], an Eddy shunt-wound machine of 50 volts and 50 amperes, is driven at the rate of 2,200 revolutions per minute. It has a separate driving shaft, 1¾ inches in diameter, making 550 revolutions per minute. The small dynamo [26], also an Eddy machine of 2 volts and 50 amperes, is connected with a counter shaft, and makes 1,400 revolutions per minute. Electricity has so far been used in the laboratory only for the separation of ores and for the deposition of metals. For electric fusion a differently wound dynamo would have to be added, in order to secure the necessary amperage.

The water required in the laboratory is received from the city main, but is not conducted directly to the different machines, since there would be no regularity in the flow. It runs into the end compartment of the water-tank [18], from the bottom of which a centrifugal pump, 18 inches in diameter, delivers it into a 2-inch main pipe running along the upper platform, on which are placed the machines Nos. 13, 14, 18, etc. Two-inch tees supply the different machines from the top of the main. By the aid of separate pipes and 3-way cocks the overflow from the jigs can be pumped upon either the vanner or the round table, the overflow of the vanner upon the table, and the contents of the settling tanks upon any of the washing-machines or into the sewer.

10. *Auxiliary Apparatus*—By referring to the plan (Fig. 1) and its legend, the different auxiliary apparatus used in ore dressing and in metallurgical work can easily be seen. Prominent among these are, for instance, the steam drying tables [19], on which the products are dried so as to permit comparison of the weights of ore before and after treatment.

The plan does not show the thirty odd large bins, 4 feet wide, 4 feet deep and 4

* Trans., xxiv., 438.

†Richards, Trans., xxii., 701.

* Trans., xxi., 503.