Report #357103, Sampling Oroya Copper.

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REPORT NO. 357103

SAMPLING OROYA COPPER

For

CERRO de PASCO COPPER CORPORATION

And

UNITED STATES METALS REFINING COMPANY.

cont'd.

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99 John Street
New York, N. Y.
May 10, 1926.

Report #357103

Cerro de Pasco Copper Corporation,
15 Broad Street,
New York City. and

U. S. Metals Refining Company,
61 Broadway,
New York City.

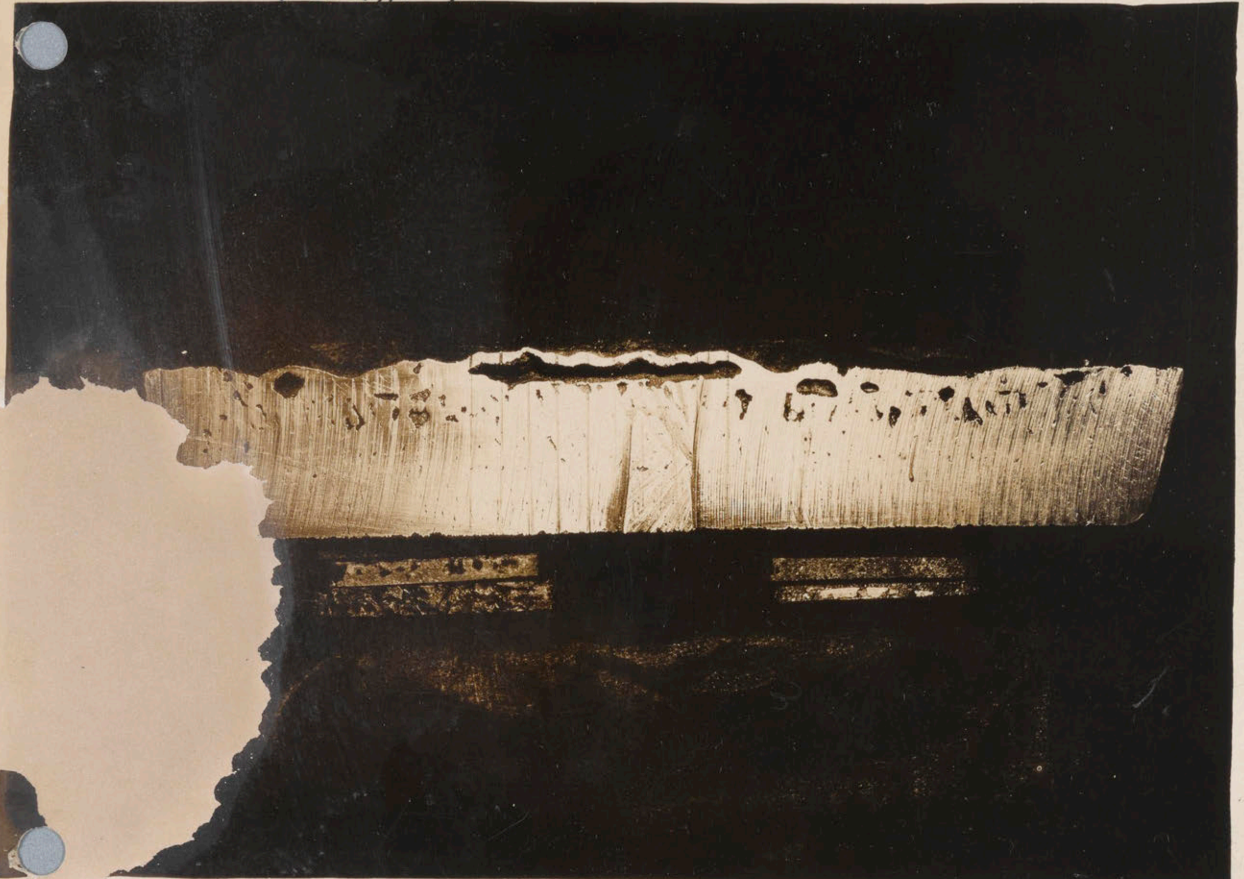
Gentlemen:-

In accordance with instructions given to us on January 15th and January 19th, 1926, investigation has been made of the sampling methods employed on Oroya blister copper at the Smelter in Peru and at the Refinery, with the object of discovering the cause of the differences in valuation which have occurred, and to recommend such changes in practice at either or both places as shall bring the respective valuations into reasonably close agreement - as nearly as possible to the true contents of the valuable metals. Much experimental sampling and testing has been done at the Smelter and at the Refinery with the same object. Reports containing details of this work - covering about two years - were submitted by both Smelter and Refinery. These were reviewed in detail to gather information that might bear upon our investigation, and to avoid duplication of experimental work.

In your joint memorandum handed to us on January 15th, it was stated that "it is not the intent to conduct any experimental campaign beyond such minor tests as may be required to settle some vague point." After considering all the data submitted by both sides, it became evident that much, if not all, the experimental work conducted up to the latter part of 1925 was futile. Inferences drawn from it are incorrect and of little value in determining new lines of work. Experimental work, based upon discoveries concerning the large entrainment of borings in the templet method of sampling - first considered by either of you in the latter part of 1925 - has thrown a new light upon the subject, and has rendered necessary further experimental work, on a considerable scale, in order to determine (at least approximately) the tendency and extent of sampling errors occurring heretofore in the Refinery method, and the adoption of means to rectify them.

Investigations at Oroya by Dr. Edward Keller, acting as our representative, have been carried on at the same time as the work done at the Refinery. Dr. Keller's report to us is included herewith.

Briefly, sampling at Oroya has been done by taking small castings from the molten metal as it flows from the mixer. These are sawed to obtain the assay samples. Sampling at the Refinery has been done by the templet drilling method of boring which is the only practical method of sampling blister at the receiving point. Lots are drilled with tops and bottoms of the bars up alternately. Leaving out of consideration for the moment the sources of error that may beset both sampling methods in themselves, comparison of assays between Smelter and Refinery is difficult for other reasons, which may be avoided or at least reduced. Owing to the practice of the Smelter to feed rich silicious silver ore directly to the converters, without bedding, the blister is quite variable in silver. When sampling is done at the Smelter from molten metal, wide variation extends only from one mixer charge to another; when it is done at the Refinery variation is from bar to bar, that is, one bar in a Refinery lot may contain, for example, 300 ozs. per ton; the next one, 600 ozs. per ton, or more. Only by long averages is it possible to determine differences in valuation between Smelter and Refinery. Great variation from bar to bar throws a heavy responsibility on the templet method. Accuracy depends upon the so-called law of averages, whereby errors in different lots tend to compensate one another. Obviously the greater the difference among individual bars the longer the average will have to be that differences may neutralize one another. How long an average is necessary in the case of Oroya bullion, as now shipped, is a problem that cannot be solved by any data available. The conditions would be improved if the Smelter would bed the silver ore or add it to the converters uniformly so as to make a more uniform product. It would be further improved if shipping lots were so marked that they could be sorted at the Refinery into lots corresponding to shipping lots, or at least into lots wherein the individual bars would be approximately of the same gold-silver tenor. Either of these suggestions would of course add to expense, but sampling by the templet method would be improved and short comparisons could be made. Another, indeed the principal, reason that Oroya bullion is difficult to sample at the Refinery, aside from the high silver tenor, is the condition of the bars. They consist of solid metal with comparatively few holes or interstices, covered with a thin top crust, in the form of blisters. The blisters are often large, some exceeding seven inches in diameter; others smaller, but opening into one another at some point, so that the whole top crust may be regarded as a separate layer with space between it and the solid underlying metal but attached to the underlying metal at many points and always firmly around the edges. The bars, Photograph #1



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seem to be preatically solid throughout. Photograph #1, which represents a cross section of a bar from shipment received during March, 1926, (Lot O-2) - taken without special selection - illustrates the condition described. This condition could be altered by a slight change in metallurgical practice at Oroya, that is, by less blowing, whereby a pimple rather than a blister surface would be made, but such a change would introduce other complicating factors; for example, more lead would remain in the metal; this is undersirable, because it would entail a refining penalty and furthermore it would bring about changes in the way silver segregates, which is already complicated enough. The practice of "double pouring" that is, adding more molten metal to a mold the contents of which may have begun to solidify, probably helps the formation of large blisters. At all events, it introduces new factors in the solidification process that interfere with normal segregation and makes the bars more heterogeneous.

These suggestions and remarks are made as bearing upon the difficulty of accurate sampling at the Refinery. The problem is to find a way to sample such heterogeneous metal accurately, as it is now produced, without regard to changes in metallurgical practice that might simplify the sampling process.

Difficulties in sampling Oroya bullion are not peculiar to it alone. The same difficulties affect all argentiferous blister to some extent. Oroya bullion is silver-rich as compared with most other bullion, causing discrepancies, which would otherwise pass without much notice, to become so apparent that investigation becomes imperative.

Only recently we have investigated, in a much less elaborate way, some differences between Smelter and Refinery sampling on bullion containing only 50-60 ozs. of silver per ton, and find them to be explained in part by the entrapment of silver-rich borings in the templet method, and in part by probable errors in taking small samples from the converter charges at the Smelter. It is a fact, however, that the Refinery practice of alternate top and bottom boring without regard to entrapped silver-rich borings (which occur in both directions of drilling) accounts for about half of the difference between Smelter and Refinery sampling. The parallel between this bullion and Oroya is not exact since the bullion referred to is not blistered to anything like the same extent as Oroya, but differences are, in part, due to the same causes.

Differences, particularly in silver, between Smelter sampling from molten metal and templet boring at the Refinery on the high silver bullion received from Mexico by the Baltimore Refinery of the American Smelting & Refining Company have, in the past, been wide. It has been stated that investigations at both plants had reconciled these differences so that now they had practically disappeared. The Baltimore Refinery still practices alternate top and bottom drilling by the templet method. Changes at the Smelter, apparently, were the main cause of improvement in agreement. We were permitted by Mr. Peirce to examine the returns of a series of assays at Baltimore. While long averages may balance one another, in nearly all those that were examined the templet method results were lower in silver than the Smelter. This copper is received in lots corresponding exactly to shipping lots so that comparisons may be made lot by lot. Assays of individual lots differed in some cases by twenty ounces of silver per ton; the average difference in the lots examined appeared to be about 4 ozs. per ton,- the templet method giving the lower figures. There was no opportunity to examine the bars to determine whether or not heavy entrapment of borings could occur. So far as the brief examination made served to show, the differences between Smelter and Refinery were very large on individual lots and continued large over fairly long averages. Whether or not they would agree on very long averages was not investigated because it seemed that identical lots showing the variations mentioned must still be subject to sampling errors of such magnitude at one or both plants that little information bearing on our problem could be gained without examination of both sampling methods in detail.

It has long been known that the templet method of sampling by drilling is subject to errors. Samples taken by drilling with the rough top surfaces of the bars up, weigh less than samples taken by drilling with smoother bottom surfaces up. Top-drilled samples are generally poorer in silver, a trifle poorer in gold, and richer in copper than bottom-drilled samples. In sampling Mt. Lyell and some other copper bullion twenty-five, or more, years ago, it was shown that when the drill penetrates the top crust from beneath, as it does in bottom drilling, an area of silver-rich, copper-poor crust somewhat larger than the drill hole was broken out and included in the borings. This breaking away of top surface larger than the drill,hole was called "cratering". The gains in precious metals and loss in copper from this source were supposed to offset the losses that occurred through loss of silver-rich, copper-poor metal occuring in top-drilling. As a compromise measure, alternate top and bottom drilling was established; it soon became general sampling practice notwithstanding the fact that "cratering" seldom occurs. In this earlier practice no account was taken of errors that may occur by loss of drillings through retention in interstices beneath the surfaces of the bars. This source of error has been investigated only recently. In the case of Oroya bullion it has been shown to be so large as to vitiate all samples taken by the templet method. Errors in top-drilling are much larger than those in bottom-drilling, but they occur in both.

Even bottom-drilled samples are too low in silver. This has been shown by experimental work done at the Smelter and at the Refinery. Attempts were made to get correct samples by retrieving entrapped drillings, but only a fraction of the entrapped drillings was recovered. While these experiments show tendencies, especially toward silver, they are not quantitative, and do not serve to establish the true copper-silver-gold assays of any particular lots.

With the foregoing in mind the Refinery, at our request, has made weighted averages of all assays of Oroya bullion received during 1924 and 1925. The records show which lots were top-drilled and which were drilled from the bottom. Omitting details, the average figures shown are:

1924

	Copper	Silver	Gold
Top	97.456	378.937	1.085
Bottom	97.443	380.204	1.092
Variation of bottom . .	-.013	+ 1.267	+.007

1925

	Copper	Silver	Gold
Top	97.398	422.643	1.127
Bottom	97.385	426.660	1.137
Variation of bottom . .	-.013	+ 4.017	+.010

The results confirm those of all prior experience - that top-drilling of copper bullion gives lower silver-gold and a trifle higher copper than bottom drilling.

In order to rectify errors in the templet method as used at the Refinery and at the same time to get samples that would indicate whether or not the method used at the Smelter shows accurately the value of the bullion, it is important to determine as nearly as possible the copper-gold-silver contents of lots that had been shipped intact and which had been sampled and assayed at both Smelter and Refinery by their usual methods. Six lots of 336 bars each were available. Four of these, Nos. 11-B, 11-C, 11-D and 11-E, had been sampled previously by the Refinery using their regular 168-hole templet and also another templet which varied from the regular method principally in the spacing of drill holes. Each lot had been sampled by top-drilling and again by bottom-drilling, using the same templets. These lots were intact at the Refinery. Two others 336-bar lots, 26A and 26B,-received at the Refinery in January and February, had not been sampled by the Refinery at the time our work was started there. Another lot, 11A, had been shipped to the Nichols Copper Company and had been sampled and assayed by them. Four bars from this lot were used for experimental purposes; otherwise it has not been used in our work.

Various methods to determine the real copper-gold-silver contents of these lots were considered: It had been suggested to mill all the bars to destruction. After brief investigation, this plan was rejected because of excessive cost of milling machines sufficient to handle the work, the length of time required to do the work, and the errors that would be incurred in sampling down fifty or sixty tons of millings in each lot.

Smelting each lot per se was impractcal on account of the impossibility of a perfect clean-up. Dissolving the lots electrolytically, using the bars as anodes, had also been suggested. This was not feasible, even if it could be accomplished by constructing special tanks, because a large amount of undissolved copper "scrap" would be produced, different in composition from the original bars. This would have to be sampled by melting with resulting unknown losses; it was rejected because it is not possible to sample and assay rich silver-gold slimes with sufficient accuracy for the object in view.

Sampling by templet sawing was considered. Investigation of available sawing apparatus showed that the method is not workable in the case of converter bars. Slow-moving band saws, or those with reciprocating motion, like hack-saws, might be used, but the cost and time required to cut about two thousand converter bars would be prohibitive. Rapid-cutting circular saws could be constructed for this special purpose. These are necessarily of heavy metal with large teeth which make chips or sawings too large to be milled . Moreover, all rapid-cutting saws require the use of a lubricant, otherwise the saw is quickly destroyed. While sawing is admirably adapted to sampling small castings by slow cutting, or to rapidly cutting large pieces like wire bars or cakes, where the solid metal is to be examined, it is not suitable for sampling heterogeneous and porous converter bars where the sawings are desired for the sample.

All of the foregoing suggestions were useless because in addition to determining the real metallic contents of the lots mentioned, it was desired to use a method of sampling that could be applied practically to all future lots. Supposing that some one of the suggested methods could be adapted by special expedients to the evaluation of the lots in question, it is obvious that none of them could be used in regular work.

Drilling by the templet system is the only practical method to sample copper bullion at the receiving point.

Examination of grinding apparatus at the Refinery and of the means used for dividing the samples after grinding, showed that no errors could be attributed to any part of the work after drilling. There is substantially no loss in weight in grinding, screening or dividing. This was determined by experiment on samples of Oroya borings at the Refinery. Whatever sampling errors occur, they must be in drilling and not in any other part of the work. With this in mind, some experiments were made by using a 1-inch drill rather than the 17/32-inch drill ordinarily used. It seemed that errors due to the retention of drillings in interstices would thus be greatly reduced. The larger drill would take approximately four times the weight of drillings taken by the smaller drill. The number of interstices or openings passed by the circumference of the larger drill would be only twice as many as those passed by the smaller drill, thus theoretically reducing the chances of retention 50%. The larger drill hole would permit the easier removal of retained drillings from the interstices. Experiment, however, showed that these theoretical factors do not work in practice. The greater force on the larger drill, even when driven at comparatively slow speed, throws the borings further into all available openings; the retained drillings appeared to be as great in proportion in the larger sample as in the smaller; they are not easier to recover. The method was rejected without further experiment.

At this time it was discovered that the top crust on Oroya copper could be hammered flat to the underlying metal without breaking it or losing any superficial oxide. Hammering closed all interstices immediately below the top surface, thus eliminating at least 90% of the openings where drillings could be retained. Experiment showed that, after hammering the top surfaces in an area several inches square in the neighborhood of the templet hole, the bars could be drilled without apparent loss of drillings either on the rough top surfaces, which by hammering became sufficiently smooth to permit nearly all the drillings to be swept up, or in interstices below the surface. The question was raised that perhaps hammering spread the silver-rich top crust by swagingit into a thinner layer, thus impoverishing the area of the drill hole. It was supposed at this time that the thin crust shown in Photograph #1 was richer in silver and poorer in copper than any other horizontal section of the bars. Tests to determine whether or not spreading would occur and also to show the relative weights of top and bottom borings after hammering were made as follows:

Ten bars from Lot 0-26-B were hammered in areas about 4 inches square. Two drill holes were bored in the same hammered section - one from the bottom and one from the top - the holes being placed as near one another as possible. Top drillings and bottom drillings were saved separately, weighed and assayed, showing:

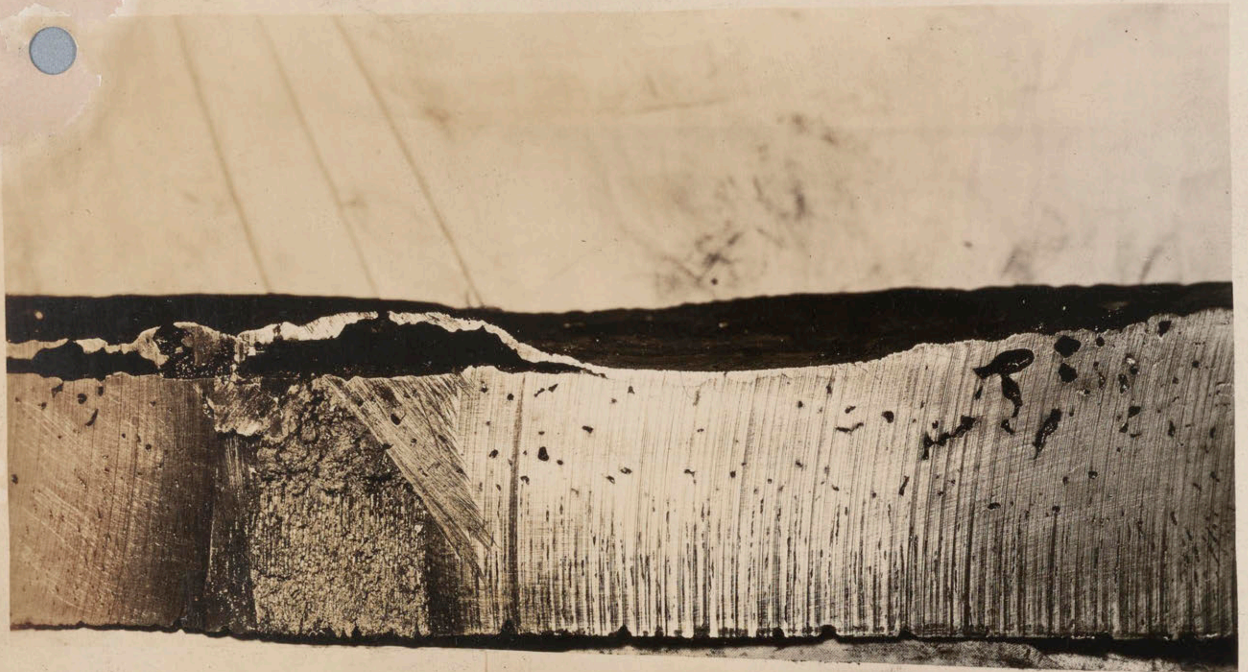
	TOP	BOTTOM
Weight:	695 gram.	694 gram.

Assays (not corrected)

	Copper	Silver	Gold	Copper	Silver	Gold
Ledoux	97.44	338.2	1.35	97.44	339.4	1.37
U.S.M.R.Co.	97.28	337.1	1.35	97.27	339.0	1.35

2

2540



#3

No 4

No 5

The drillings weigh substantially the same. The assays are within the usual limits of accuracy for duplicate samples. The drill holes, so far as could be seen by examination from top and bottom surfaces, showed no interstices sufficiently large to retain borings. The experiment was too small to be other than indicative, but served to show that most, if not all, errors due to retention of drillings might be eliminated by hammering.

A bar showing large blisters was hammered over one section of the blister, then cut by sawing so as to intersect blister and hammered section. The result is shown in Photograph #2 - 2540, and #3 - 2541. No. 2 shows a full cross section while No. 3, on a larger scale, shows only the blister and the hammered section. It will be seen that the blistered top is flattened to the solid underlying metal so perfectly as to appear welded to it. Spreading of the top surface, if it occurred at all, must be small. To determine to what extent, if any, spreading might occur, a bar, cut by sawing, was marked at ten points along the blistered top, corresponding marks being made in the solid metal by small saw cuts. Measurements in nine sections thus developed were made exactly half way between the saw cuts. The bar was then hammered to flatten it, after which measurements at the same points were again made. The test is illustrated by Photographs No. 4 and No. 5. Measurements of blister thickness before and after hammering were:

	Before		After
1.	4.2	m.m.	4.0
2.	3.	"	2.5
3.	3.	"	3.
4.	5.	"	4.
5.	3.	"	3.
6.	3.	"	3.
7.	3.	"	3.
8.	2.5	"	2.5
9.	5.	"	4.5
	31.7		29.5

difference 2.2 m.m. 7%.

The average thickness at the measured points was apparently slightly reduced. This was caused by a slight spreading over the cut edge since there was nothing there to prevent it, and a small "overhang" was apparent. If the hammered portion has been supported on this side by continuation of the blister instead of by empty space, spreading would not have occurred. Still another test showed that even if limited spreading occurred it could have no appreciable effect upon the sample. The blister crust is relatively thin. It is not the horizontal section which is richest in silver, poorest in copper. The solid metal beneath the crust

Oroya Copper

Segregation Test 1/4 Method Hammered Bars

336 holes templat 84 holes in each quarter 17/32 drill

Lot 0-11-A Top drilled

Cu. 96.89 Ag. 602.6 Au. 0.94 A	B 96.99 586.5 0.93
C 96.92 603.6 0.91	D 96.99 580.7 0.91

Lot 02 Top drilled

Cu. 97.45 Ag. 375.7 Au. 1.22 A	B 97.39 383.1 1.25
C 97.44 365.7 1.22	D 97.44 369.2 1.23

Lot 0-11-A Bottom drilled

Cu. 96.94 Ag 599.2 Au. 0.91 A	B 96.85 592.0 0.91
C 96.91 584.5 0.90	D 96.79 595.4 0.91

Lot 02 Bottom drilled

Cu. 97.55 Ag. 342.0 Au. 1.66 A	B 97.52 339.6 1.65
C 97.50 340.8 1.65	D 97.49 352.2 1.67

Lot	Bar	Side of Bar	Average of Bar	Variation from Average %	Maximum Variation	
011-A	#1	Top	96.95 593.5 .9225	Cu. -.06 Ag. -2.10 Au. -1.3	C to D Ag. 3.9%	
011 A	#2	Bottom	96.87 592.8 .905	" +.07 " -1.20 " -0.8	A to C " 2.5%	
02	#1	Top	96.43 373.4 1.23	" -.04 " -2.6 " +2.5	C to B " 4.7%	
02	#2	Bottom	97.54 343.7 1.66	" +.04 " +2.5 " +.70	B to D " 3.7%	

Average of Ledoux + U.S.M. Co's Assays.

Silver Assays not Corrected

Plate 1

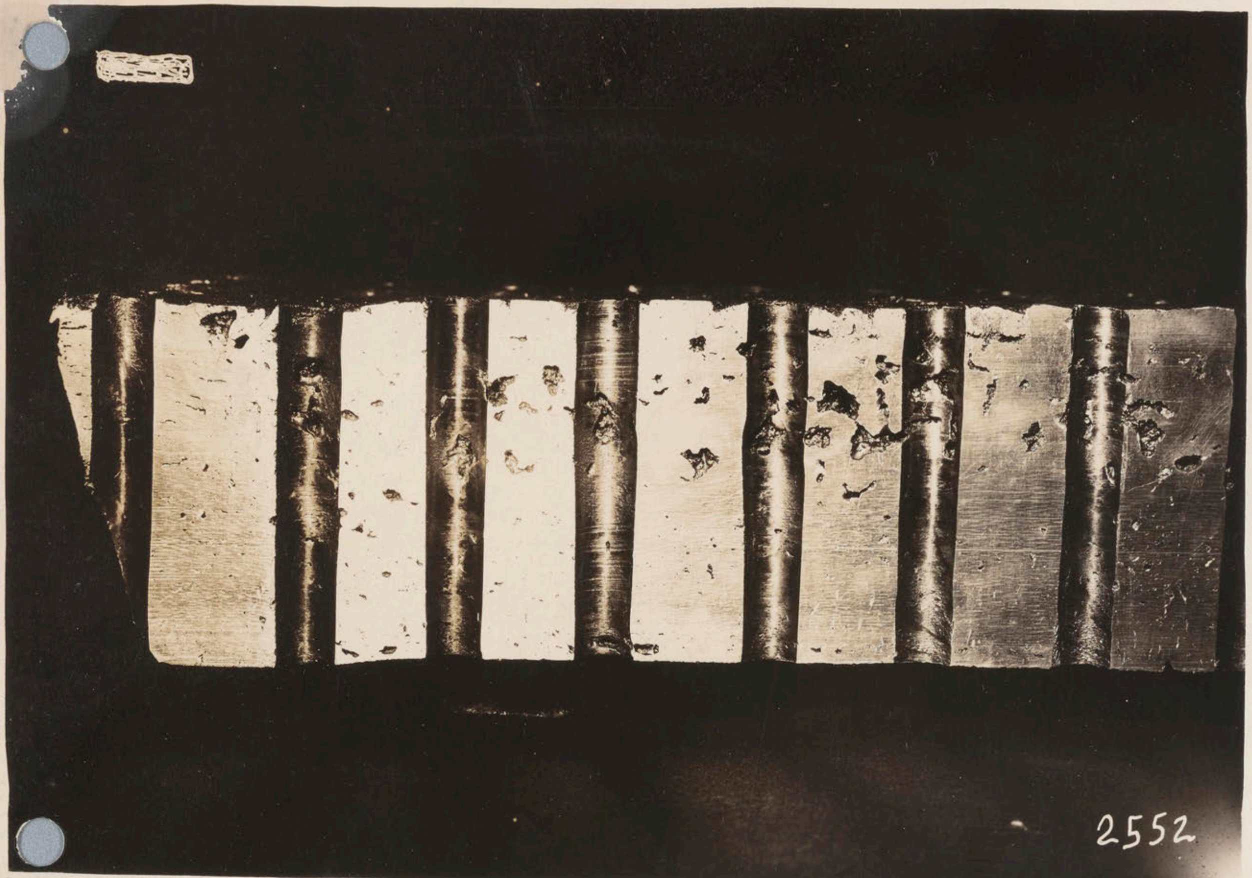
is richer in silver and poorer in copper to a depth of at least 3/4-in.
Top blisters of two bars from Lot 0-26-A were removed by cutting with a chisel. These were cut into small pieces and assayed. Drill holes 3/4" deep were made in the solid metal at the points where the blisters had been removed. These drillings were also assayed:

	Top Crust			Borings from Beneath Top Crust		
	Copper	Silver	Gold	Copper	Silver	Gold
Ledoux	--	554.6	1.25	--	581.0	1.20
USMR Co.	96.87	546.9	1.25	96.65	582.1	1.25

The factor of varying vertical segregation will be considered in more detail later.

Experiments made at the Smelter and at the Refinery long ago had indicated wide differences among different quarters of the same bar. At that time Oroya bullion was higher in lead and lower in silver than at present, averaging over 1% lead and around 300-ozs. in silver. It is well known that lead, much over the small proportion that may be held in solid solution in copper, causes abnormal segregation of silver. The more lead the worse the segregation. In copper bullion containing only very small proportions of lead, or none, segregation of silver is always toward that part of the bar that solidifies last. The outer portions and edges of bars low in lead are always poorer in silver than the inner parts. Increased lead contents cause segregation in the opposite direction; the metal that set first is silver-rich compared to the central parts. The lead factor probably had much to do with the contradictory results regarding segregation that were found in former experiments. The results of older experiments made by drilling four quarters of the same bar by a full templet, thus making 84 holes in each quarter, were also affected by retained drillings. No reliable conclusions regarding assays of different quarters were ever obtained. Now that lead in Oroya bullion is around 0.5%, or less, and the way to eliminate drilling errors has been indicated, it becomes important to know what the differences among quarters of the same bar might be. Two bars from a lot arriving about this time (0-2) and two from Lot 11-A (Nichols), which are must richer in silver, were used for this purpose. After hammering the whole top surface of each bar to close cavities, they were drilled by the regular Refinery templet - 84 holes in each quarter. One bar from each lot was drilled from the top, the other from the bottom - except the drill holes in the bevels, which were necessarily drilled from the top. The results are shown on Plate #1.
Differences among quarters are not abnormal. The maximum silver difference is 4.7%. The maximum difference of any quarter from the average of the whole bar is 2.6%. These differendes are much

No 6

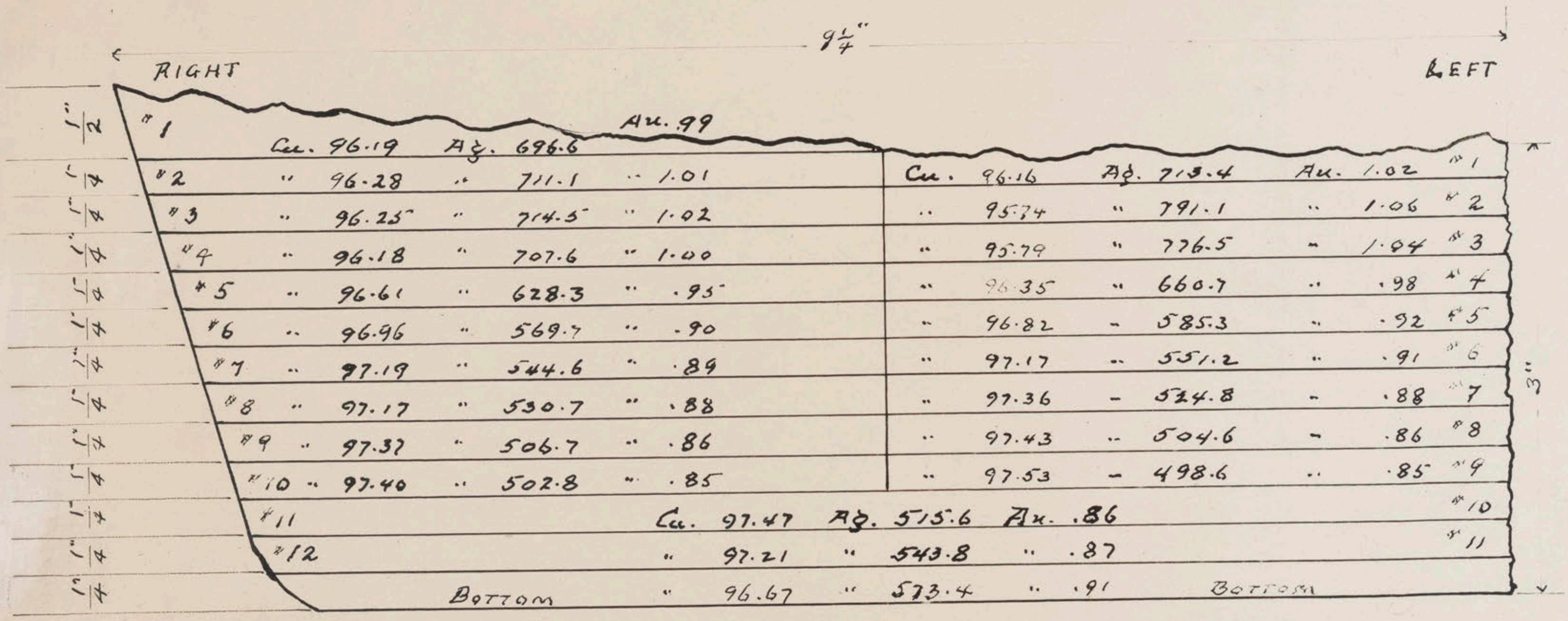


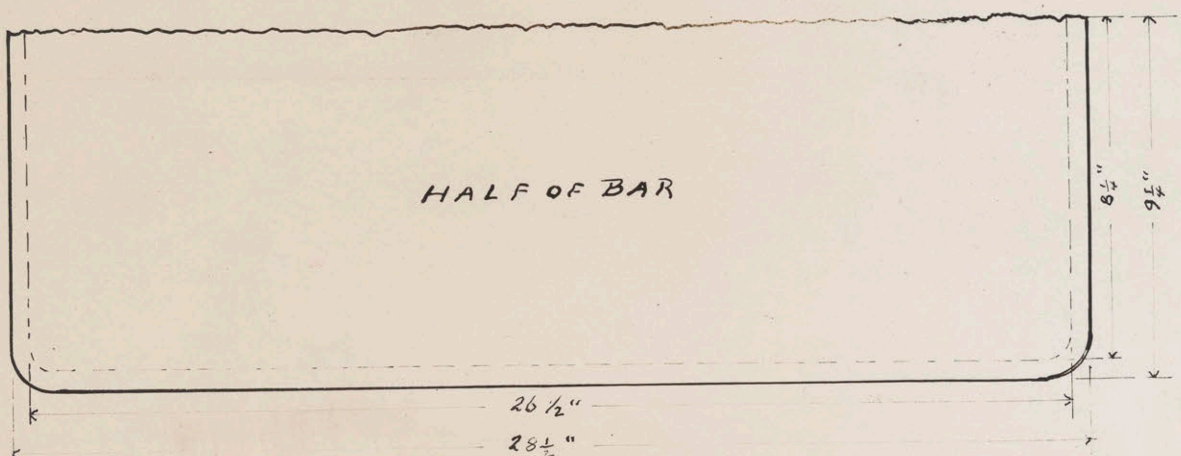
No 7

OROYA COPPER

SEGREGATION TEST BY MILLING WITH PLANER

LOT O-11-A





Ledoux & Co's Assays
Averaged by weight

Cu.	Ag.	Au.
96.814	602.64	0.929

	RIGHT		LEFT	
#1	4472 Gms.			
#2	1918 "		1931 Gms.	#1
#3	3285 "		3768 "	#2
#4	3826 "		4016 "	#3
#5	3721 "		3964 "	#4
#6	3503 "		4076 "	#5
#7	3502 "		4140 "	#6
#8	3470 "		3891 "	#7
#9	3395 "		3130 "	#8
#10	3087 "		3981 "	#9
#11		5925 Gms.		#10
#12		3892 Gms.		#11
TOTAL		3100 "	BOTTOM	

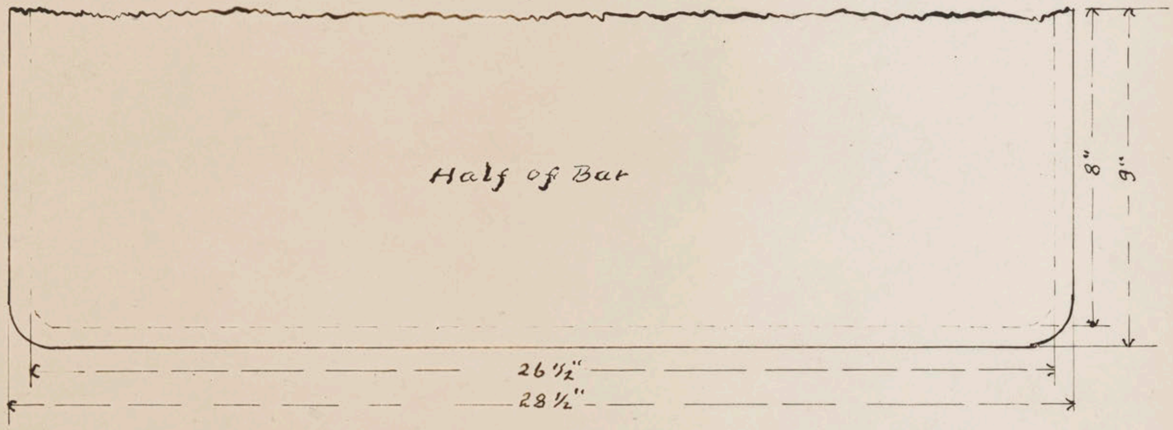
Plate 2

Oroya Copper

Segregation test by milling with planer — Bar #2

9″ — Right / Left — 3″

		Right						Left						
-¼	#1	Cu.	97.83	Ag.	363.6	Au.	1.87	Cu.	96.95	Ag.	393.9	Au.	1.96	#1
-¼	#2	"	97.48	"	349.7	"	1.83	"	97.20	"	374.3	"	1.89	#2
-¼	#3	"	97.52	"	344.0	"	1.79	"	97.24	"	376.4	"	1.88	#3
-¼	#4	"	97.57	"	3468	"	1.80	"	97.10	"	424.6	"	1.97	#4
-¼	#5	"	97.74	"	319.2	"	1.74	"	97.21	"	389.0	"	1.92	#5
-¼	#6	"	97.98	"	289.1	"	1.66	"	97.61	"	320.7	"	1.73	#6
-¼	#7	"	98.01	"	269.9	"	1.59	"	97.85	"	284.0	"	1.66	#7
-¼	#8	"	98.09	"	256.0	"	1.57	"	97.89	"	267.9	"	1.58	#8
-¼	#9	"	98.17	"	249.8	"	1.57	"	98.03	"	258.3	"	1.60	#9
-¼	#10							Cu. 97.42	Ag. 228.9	Au. 1.49				#10
-¼	#11							" 98.51	" 205.8	" 1.41				#11
-¼	Bottom							" 98.56	" 195.2	" 1.39				Bottom



Ledoux & Co's Assays
Averaged by weight

Cu.	Ag.	Au.
97.705	298.57	1.677

	Right		Left	
#1	1903 Gms.		2124 Gms.	#1
#2	3387 "		3919 "	#2
#3	3537 "		3552 "	#3
#4	3408 "		3792 "	#4
#5	3573 "		4386 "	#5
#6	3436 "		4207 "	#6
#7	3331 "		3941 "	#7
#8	3255 "		3792 "	#8
#9	3288 "		3999 "	#9
#10		9867 Gms.		#10
#11		6281 "		#11
	Total	3933 "	Bottom	

Plate 3

less than those indicated by many of the older tests. These assays are not corrected.

After drilling these four hammered bars, one of them was sawed across so as to bisect a full line of drill holes. The appearance is shown in Photograph #6 and in an enlarged section in Photograph #7. Comparing these with Photographs Nos. 1 and 2, it will be seen that the large top cavities are closed completely and that there is little chance for retention of drillings in the small gas pockets penetrated by the drill.

So far as the records submitted show, no experimental work had been done either at the Smelter or at the Refinery to indicate the nature and extent of vertical segregation in Oroya bullion. This is important because it bears upon the causes of error through loss of drillings either in top or bottom sampling by the templet method.

Two bars of Oroya bullion, one from Lot 11-A and one from regular shipment as received, Lot O-2, were split lengthwise under the hammer - thus giving half bars on the long section. The outer section, which included the bevel, was designated as right top; the inner section, left top. These bars were planed in quarter-inch horizontal sections. The planings from each section were weighed and assayed separately, except that the three bottom sections were planed as entities without being divided into right and left. This was necessary because the uneven bottoms of the bars would not permit close adjustment on the planing machine after they had been thinned.

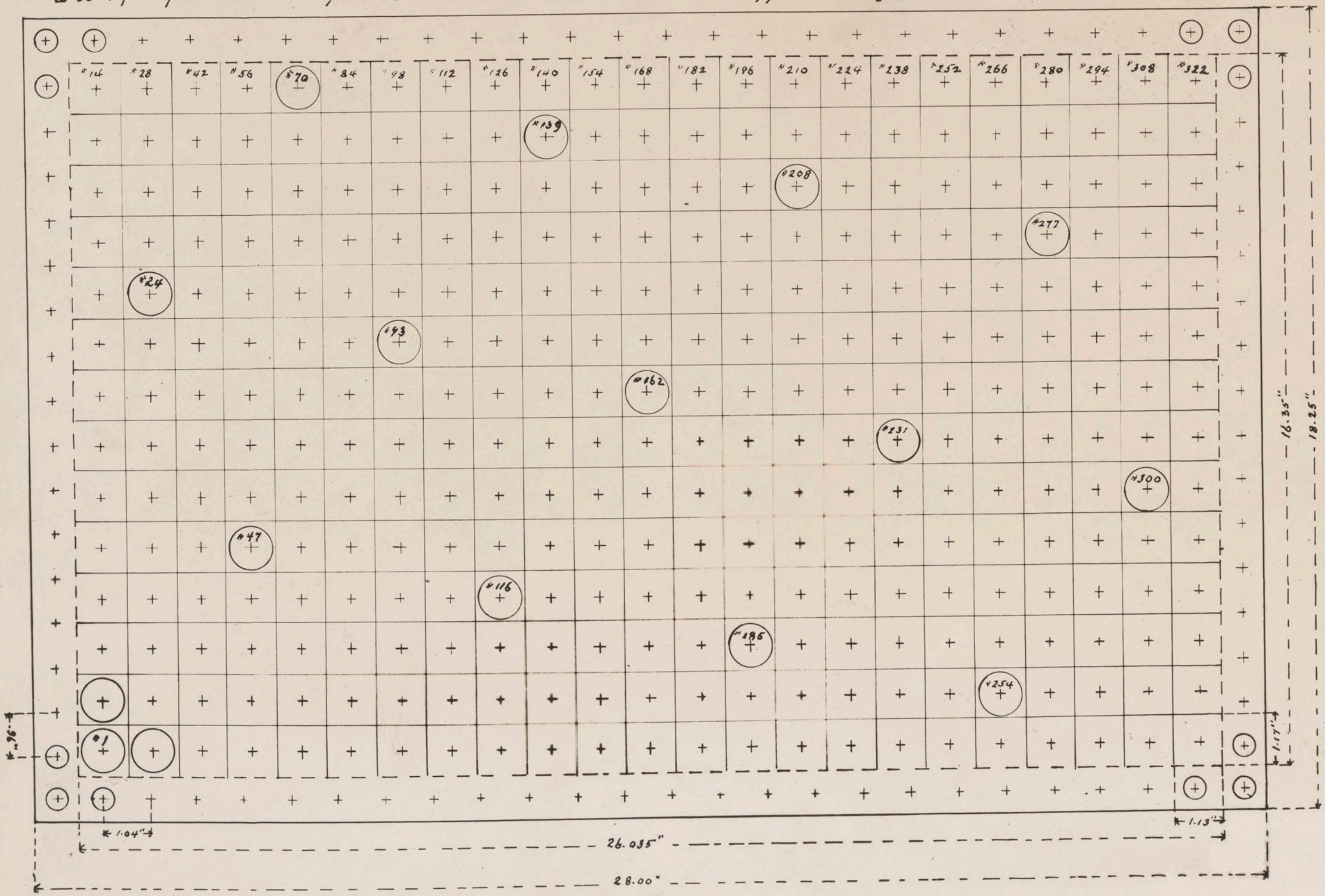
Plates 2 and 3 show how the planing was done and give the weights and assays of each section in detail.

It will be seen, in general, that copper varies inversely with silver and gold within the limits of assaying errors. The upper top crust is not the richest in gold and silver. The area containing the greater proportion of precious metals is toward that part of the bar that set last, that is, an area toward the midline of the bars and within an inch or so of the upper surface. The principal variation is vertically from bottom toward top, the upper inch containing average proportions of silver from 30 to 50% greater than the lower, and gold from 15 to 30% greater.

These tests explain beyond doubt causes for inaccuracy in the templet method as it has been used at the Refinery. Any loss of borings in drilling, through retention in interstices or otherwise, will affect the silver assay; to a less degree the gold assay, and to a still less degree the copper. In drilling either from top or bottom, the borings retained in interstices come, for the most part, from silver-rich zones, but the proportion of retained drillings is far greater in top drilling than in bottom drilling so that the aggregate error in top-drilling is greater because in top

406 hole templet for bottom drilling Croya Copper.

Rectangles 1.17" x 1.13" - 322 holes $\frac{17}{32}$" dia. Applied to a 336 cake lot there would be 14 cakes extraneous to templet, these to be drilled at every 23rd hole in positions shown.
For top drilling the bevel, 84 edge holes $\frac{3}{8}$" dia. requiring four revolutions of templet. Top drilling to be kept separate - Templet to be used in connection with supplementary instructions.



Scale 1/2" = 1."

Plate 4.

drilling the drillings, instead of coming out on top of the bar, are forced into the cavities, while in bottom-drilling there is comparatively little time for this to occur; the drill goes through the thin top crust from beneath so rapidly that only a small part of the drillings is retained in interstices.

These experimental tests are not to be taken as a quantitative measure of possible error - they serve merely to show that errors, expecially in silver, always occurring in one direction, may be rectified when retention of drillings is prevented.

In sampling the six test lots, 11-B, 11-C, 11-D, 11-E, O-26A and O-26B by the templet method after hammering to close interstices, a new templet was used. It was desired to ascertain how the bevels of the bars differed from the bodies and what effect inclusion or exclusion of bevel borings would have on the templet method. For this reason the bevels were sampled separately, using a 3/8" drill rather than the 17/32" used in sampling the bodies. The smaller drill was used because there is less danger of breaking off outside edges and of unduly "skinning" the outer surfaces on the sides. The templet used is shown in Plate 4.

Since with this templet bevels and bodies were sampled with different sized drills, it was necessary to know the weight ratios of bevels to bodies. Calculated from measurements of 25 Oroya bars, made as carefully as possible by the Refinery, the volume of the bevel is 9% of the whole volume. The volume ratio, however, is not applicable. It is practically impossible in any case to measure, even approximately, the true thickness owing to uneven top and bottom surfaces. The bevels are nearly sound metal while the bodies are full of interstices. Weight ratios must therefore govern in averaging separate assays of bevels and bodies when drillings are taken with different sized drills. To obtain weight ratios, three characteristic bars of a regular shipment were planed to remove the bevels as exactly as possible; the rectangular bodies and the planings were weighed:

	Total Weight Lbs.	Weight Bevel Planings Lbs.	Percent Bevel by wt.
#1.	378	57.	15.08
#2.	380.375	52.375	13.74
#3.	377.375	44.375	11.76
		Average . . .	13.5

In bars #1 and #2, the metal had washed up on the edges in casting. Bar #3 was flat, showing no wash. While the differences shown above may seem large, it will be seen later than an average weight ratio differing by as much as 1% from this average would affect the calculated average assays of the six test lots only by about 0.3 oz. silver per ton, without affecting the gold and copper results at all.

In sampling the six test lots by the new hammered templet, all drillings were weighed to get comparisons with the weights of borings given by other methods.

All assays of the test lot samples have been made by United States Metals Refining Company and also by Messrs. Walker & Whyte, and by ourselves. The averages of all three assays have been taken as more closely representing the real valuable metallic contents than those of one Laboratory.

All silver assays are corrected.

The details of assays are shown in the following tables:

LOT 26-A

COPPER

	L	U.S.M.	W & W	Average
Hammered Top Body	97.30	97.20	97.22	97.24
Hammered Bot.Body	97.31	97.31	97.32	97.31
Bevel	97.34	97.25	97.23	97.27
Av.Body+Bevel 13.5%:				
Top				97.24
Bottom				97.30
336-Hole Templet:				
Top	97.36	97.29	97.30	97.32
Bottom	97.30	97.25	97.28	97.28
Oroya Regular				97.44

SILVER

	L	U.S.M.	W & W	Average
Hammered Top Body	474.1	475.1	476.1	475.10
Hammered Bot.Body	471.7	474.1	473.7	473.17
Bevel	431.1	429.7	431.1	430.63
Av.Body+Bevel 13.5% by wt.				
Top				469.20
Bottom				467.43
336-Hole Templet:				
Top	458.3	457.2	457.8	457.77
Bottom	463.1	462.6	463.6	463.10
Oroya Regular				454.90

GOLD

	L	U.S.M.	W & W	Average
Hammered Top Body	1.13	1.13	1.15	1.137
Hammered Bot.Body	1.13	1.12	1.15	1.133
Bevel	1.08	1.08	1.10	1.087
Body+Bevel 13.5% by wt.				
Top				1.130
Bottom				1.127
336-Hole Templet:				
Top	1.11	1.12	1.13	1.120
Bottom	1.12	1.11	1.13	1.120
Oroya Regular				1.120

LOT 26-B

C O P P E R

	L	U.S.M.	W & W	Average
Hammered Top Body	97.41	97.41	97.35	97.39
Hammered Bot.Body	97.48	97.41	97.34	97.41
Bevel	97.50	97.48	97.44	97.47
Body+Bevel (13.5% wt.)				
Top				97.40
Bottom				97.42
336-Hole Templet:				
Top	97.50	97.50	97.45	97.48
Bottom	97.51	97.53	97.45	97.50
Oroya Regular				97.52

S I L V E R

	L	U.S.M.	W & W	Average
Hammered Top Body	339.0	339.8	339.8	339.53
Hammered Bot.Body	339.7	340.1	341.5	340.43
Bevel	303.1	302.4	303.9	303.13
Body+Bevel 13.5%				
Top				334.62
Bottom				335.28
336-Hole Templet:				
Top	329.5	329.3	329.0	329.27
Bottom	331.1	330.3	332.2	331.20
Oroya Regular				325.8

G O L D

	L	U.S.M.	W & W	Average
Hammered Top Body	1.37	1.34	1.35	1.353
Hammered Bot.Body	1.37	1.35	1.36	1.360
Bevel	1.29	1.27	1.25	1.270
Body+Bevel 13.5%				
Top				1.342
Bottom				1.348
336-Hole Templet:				
Top	1.34	1.33	1.33	1.333
Bottom	1.35	1.33	1.33	1.337
Oroya Regular				1.41

LOT 11-B

C O P P E R:

	L	U.S.M.	W & W	Average
Hammered Top Body	97.53	97.55	97.43	97.50
Hammered Bot.Body	97.57	97.53	97.53	97.54
Bevel	97.30	97.37	97.36	97.34
Av.Body-Bevel 13.5% by wt.				
Top				97.48
Bottom				97.51
Refinery Sampling by 336-Hole Templet:				
Top	97.47	97.60	97.50	97.52
Bottom	97.39	97.27	97.53	97.40
Oroya Regular (from their reports)				97.60

S I L V E R:

	L	U.S.M.	W & W	Average
Hammered Top Body	410.2	408.3	409.0	409.17
Hammered Bot.Body	410.7	410.30	408.2	409.73
Bevel	392.9	393.4	393.4	393.23
Av.Body & Bevel 13.5% by wt.				
Top				407.02
Bottom				407.50
Refinery Sampling by 336-Hole Templet:				
Top	399.8	403.5	400.1	401.13
Bottom	411.2	410.5	410.1	410.6
Oroya Regular				411.1

G O L D:

	L	U.S.M.	W & W	Average
Hammered Top Body	1.03	1.03	1.00	1.020
Hammered Bot.Body	1.04	1.04	1.02	1.033
Bevel	1.02	1.01	1.00	1.010
Av.Body & Bevel 13.5%				
Top				1.019
Bottom				1.030
Refinery Sampling by 336-Hole Templet:				
Top	1.04	1.04	1.04	1.040
Bottom	1.02	1.03	1.04	1.030
Oroya Regular				1.05

LOT 11-C

COPPER:

	L	U.S.M.	W & W	Average
Hammered Top Body	97.56	97.49	97.55	97.53
Hammered Bot.Body	97.59	97.55	97.58	97.57
Bevel	97.54	97.49	97.50	97.51
Av.Body+Bevel 13.5%				
Top				97.53
Bottom				97.56
Refinery Sampling by 336-Hole Templet:				
Top	97.59	97.51	97.65	97.58
Bottom	97.60	97.48	97.59	97.56
Oroya Regular				97.67

SILVER:

	L	U.S.M.	W & W	Average
Hammered Top Body	412.9	413.0	412.7	412.87
Hammered Bot.Body	415.0	414.1	416.5	415.20
Bevel	390.1	391.0	390.8	390.63
Av.Body+Bevel 13.5%				
Top				409.87
Bottom				411.89
Refinery Sampling by 336-Hole Templet:				
Top	403.5	404.1	404.3	403.97
Bottom	407.8	405.5	407.7	407.00
Oroya Regular				413.00

GOLD:

	L	U.S.M.	W & W	Average
Hammered Top Body	1.36	1.36	1.33	1.350
Hammered Bot.Body	1.35	1.35	1.33	1.343
Bevel	1.33	1.35	1.29	1.323
Av.Body+Bevel 13.5%				
Top				1.347
Bottom				1.340
Refinery Sampling by 336-Hole Templet				
Top	1.36	1.37	1.37	1.367
Bottom	1.37	1.35	1.35	1.357
Oroya Regular				1.38

L O T 11-D

C O P P E R:

	L	U.S.M.	W & W	Average
Hammered Top Body	97.65	97.68	97.51	97.61
Hammered Bot.Body	97.60	97.62	97.57	97.60
Bevel	97.40	97.57	97.32	97.42
Av.Body+Bevel 13.5%				
Top				97.58
Bottom				97.58
Refinery Sampling by 336-Hole Templet:				
Top	97.70	97.35 ?	97.60	97.55
Bottom	97.55	97.54	97.55	97.55
Oroya Regular				97.58

S I L V E R:

	L	U.S.M.	W & W	Average
Hammered Top Body	357.9	357.7	357.4	357.67
Hammered Bot.Body	359.5	359.2	359.9	359.53
Bevel	344.3	344.3	344.9	344.50
Av.Body+Bevel 13.5%				
Top				355.89
Bottom				357.50
Refinery Sampling by 336-Hole Templet:				
Top	349.9	351.5	351.4	350.93
Bottom	355.3	356.1	356.5	355.97
Oroya Regular				361.1

G O L D:

	L	U.S.M.	W & W	Average
Hammered Top Body	1.18	1.17	1.15	1.167
Hammered Bot.Body	1.18	1.17	1.16	1.170
Bevel	1.16	1.15	1.12	1.143
Av.Body+Bevel 13.5%				
Top				1.164
Bottom				1.167
Refinery Sampling by 336-Hole Templet:				
Top	1.19	1.20	1.17	1.187
Bottom	1.19	1.22	1.21	1.207
Oroya Regular				1.205

LOT 11-E

C O P P E R:

	L	U.S.M.	N & W	Average
Hammered Top Body	97.75	97.82	97.72	97.76
Hammered Bot.Body	97.78	97.61	97.74	97.71
Bevel	97.74	97.85	97.76	97.78
Av.Body+Bevel 13.5%				
Top				97.76
Bottom				97.72
Refinery Sampling by 336-Hole Templet:				
Top	97.53	97.61	97.72	97.62
Bottom	97.77	97.65	97.74	97.72
Oroya Regular				

S I L V E R:

	L	U.S.M.	N & W	Average
Hammered Top Body	413.9	414.0	415.2	414.37
Hammered Bot.Body	415.9	412.2	415.7	414.60
Bevel	376.7	376.5	376.9	376.70
Av.Body+Bevel 13.5%				
Top				409.29
Bottom				409.48
Refinery Sampling by 336-Hole Templet:				
Top	405.1	405.1	404.8	405.00
Bottom	406.3	405.3	405.0	405.53
Oroya Regular				

G O L D:

	L	U.S.M.	N & W	Average
Hammered Top Body	1.34	1.30	1.33	1.323
Hammered Bot.Body	1.34	1.34	1.33	1.337
Bevel	1.30	1.28	1.28	1.287
Av.Body+Bevel 13.5%				
Top				1.318
Bottom				1.330
Refinery Sampling by 336-Hole Templet:				
Top	1.35	1.36	1.34	1.350
Bottom	1.34	1.37	1.35	1.353
Oroya Regular				1.36

SUMMARY - SIX LOTS BY DIFFERENT SAMPLING METHODS.

		REFINERY - TOP			REFINERY - BOTTOM			HAMMMERED- Top			HAMMERED - Bottom			OROYA REGULAR		
LOT	WEIGHT lbs.	COPPER	SILVER	GOLD	COPPER	SILVER	GOLD	COPPER	SILVER	GOLD	COPPER	SILVER	GOLD	COPPER	SILVER	GOLD
0-26-A	122,050	97.32	457.77	1.120	97.28	463.10	1.120	97.24	469.20	1.130	97.30	467.43	1.127	97.44	454.90	1.120
0-26-B	120,648	97.48	329.27	1.333	97.50	331.20	1.337	97.40	334.62	1.342	97.42	335.28	1.348	97.52	325.80	1.410
0-11-B	119,832	97.52	401.13	1.040	97.40	410.60	1.030	97.47	407.02	1.019	97.51	407.50	1.030	97.65	411.10	1.050
0-11-C	121,831	97.58	403.97	1.367	97.56	407.00	1.357	97.53	409.87	1.347	97.56	411.89	1.340	97.67	413.00	1.380
0-11-D	120,276	97.55	350.93	1.187	97.55	355.97	1.207	97.58	355.89	1.164	97.58	357.50	1.167	97.58	361.10	1.205
0-11-E	112,035	97.62	405.00	1.350	97.72	405.53	1.353	97.76	409.29	1.318	97.72	409.48	1.330	97.70	411.90	1.360
Arithmetical Averages:		97.512	391.345	1.2328	97.502	395.566	1.2340	97.497	397.648	1.220	97.517	398.180	1.2237	97.593	396.30	1.2542
Average by Weight:		97.510	391.341	1.2316	97.498	395.601	1.2328	97.489	397.679	1.2190	97.512	398.212	1.2220	97.591	396.256	1.2531
Comparisons:																
With Hammered Bottom -		-.002	-6.871	+.0090	±.014	-2.611	+.0102	-.023	-.533	-.0036	--	--	--	+.079	-1.956	+.0305
With Hammered Top -		+.021	-6.338	+.0126	+.009	-2.078	+.0138	--	--	--	+.023	+0.533	+.003	+.102	-1.423	+.0341
Comparison-Per cent:		%	%	%	%	%	%	%	%	%				%	%	%
Bot.Hammered 100		.00	-1.72	+0.7	-.014	-0.65	+0.8	1.02	-0.13	-0.3	--	--	--	+.08	±.49	+2.5
Av.Top & Bottom Hammered 100		+.01	-1.66	+0.9	+.00	-0.59	+1.0	--	--	--	--	--	--	+.09	-.43	+2.6
Refinery Avg.TopBot. vs. Hammered TopBot.		.00	-1.12	+0.9												

Inspection of the foregoing figures shows that in the hammered templet method the results agree closely whether drilling is done from the top or from the bottom. Copper, gold and silver assays are a little higher in the samples taken by bottom drilling. Copper and gold differences are within the limits of analytical errors, even on very long averages. The average silver difference is 0.5 oz. per ton. In all the individual assays except one - (Lot 26-A) - the silver in the bottom-drilled samples is higher than in the top. This persistent difference in one direction requires some explanation. It is to be found in the fact that there is a small loss of drillings still retained in small interstices, even after hammering. Inspection of photographs #6 and #7 shows that all holes are not closed by hammering.

The weights of drillings taken by the several methods are as follows:

		Hammered Samples Body Holes			Refinery Method	
Lot	Bars	Top	Bottom	Bevel- 3/8" dr.	Top	Bottom
26-A	332	24490	23775	8435	21818	22160
26-B	336	24100	24177	7934	19791	22438
11-B	336	23430	24470	7996	19068	21792
11-C	336	23630	24210	8608	20657	21792
11-D	336	23500	24560	7878	17706	21224
11-E	336	22261	22782	7923	19068	19522
	2012	141411	143974		118108	128928

All weights in grams.

In Lot 26-A, which shows a lower silver assay in the bottom sample than in the top, the weight of drillings obtained by top-drilling the body is greater than from the bottom.

Since the Bevel holes by hammered templet drilling are taken by a smaller drill than the body holes, they are not considered in the following calculation.

In the refinery templet method there are 72 edge holes in each lot, which include, approximately, two-thirds the volume of the body holes. Six lots drilled contained 432-edge holes, equivalent to 288 body holes. Allowance for this number gives 1872 full templet holes. Lot 26-A consisted of 332 bars, being four bars short, making 1868 full holes. Dividing each of the above total weights by this number gives comparative figures as follows:

Hammered Top	70.284	grams per drill hole
Hammered Bottom	71.558	" " " "
Refinery Top	63.227	" " " "
Refinery Bottom	69.019	" " " "

Taking hammered bottom as 100, the ratios are:

Hammered Top	98.2
Refinery Bottom	96.5
Refinery Top	88.4

The difference between top and bottom drilling after hammering is due to the same cause as when the drilling is done without hammering. Hammering does not close all the deeper-seated holes. This is apparent in photograph #6, which represents a cross-section through fourteen drill holes. The difference in weights of drillings between top and bottom drilling, and the differences between assays are always in the same direction, and confirm the statement previously made that any loss of drillings at the time of drilling will necessarily affect the sample.

While the silver assays in this sampling correspond to expectations based on known factors, gold assays do not. The gold assays average a little lower by sampling after hammering. By vertical segregation tests it was shown that gold varied from top to bottom of the bars more or less in accord with silver; the expectation would be that if the silver assay is increased through preventing entrapment of drillings, gold would be increased also, though not in the same proportion. We believe that the discrepancy shown - which amounts to approximately 1% - may be explained in part by assaying errors. The gold in Oroya bullion is so small in proportion to silver that determinations of gold with the degree of accuracy required to make comparisons on a percentage basis is uncertain on the average of six lots. By referring to Plates #2 and #3, which show vertical segregation tests, it will be seen in Plate 2, that the average gold contained is 0.929 ozs. per Ton, while the top 3/4" averages, all the way across, 1.025 ozs. per Ton. The difference is .096 ozs. Assuming that 10% of the borings are lost in interstices, the average loss of gold would be .0096 oz.

In Plate #3, the average gold is 1.677 ozs. per ton, while the average of the upper 3/4-inch section, all the way across, is 1.870 ozs. The difference is .2 oz. On the assumption that 10% of drillings are lost, the loss in gold would be .02 oz. These are maximum possible differences so far as shown by these segregation tests. The losses are less than 10%. There is nothing to show what lost borings assay in gold except a few experiments on recovered drillings made at the Smelter and at the Refinery. These showed a maximum gold difference between recovered drillings and the general average of 0.1 oz. per ton, and an average difference of only three or four hundredths. The weight of evidence tends to show that gold errors due to lost borings should not exceed .01 oz. per ton. This figure is within the limits of assay differences in an average of six tests.

Copper differences vary in directions that may be expected, but this is only chance. All the differences shown are within the limits of analytical errors.

SAMPLING AT OROYA.

Inspection of sampling at the Smelter by Dr. Edward Keller is covered by his report. Dr. Keller arrived in New York on February 8, 1926. He spent ten days here reviewing available data covering the situation. Sailing for Peru on February 18th, he arrived at Oroya on March 5th, left there March 17th, and arrived in New York on April 1st. He spent five days reviewing the work which was in progress here. Dr. Keller's instructions were to observe, criticise, and make suggestions, but not to embark in an experimental campaign unless some feature of sampling as conducted at the Smelter was evidently so faulty as to require demonstration on the spot. In that case, he was to report to us by cable. Dr. Keller's report follows:

New York, April 5, 1926.

Messrs. Ledoux & Company,
99 John Street,
New York City.

Dear Sirs:

I herewith beg to present to you report of my visit to the Smelter of the Cerro de Pasco Copper Corporation at LaOroya, Peru, with the special purpose of studying their methods of sampling blister copper. Much of the latter is already generally known, yet a complete recount of the facts seems unavoidable. The blister copper bars, which are the objects directly under discussion, are cast from a tilting furnace which is called the mixer. To the mixer are brought, by traveling crane, the blown charges from the several converters, the sum of which may vary greatly. The charge of the mixer is constantly heated by two oil burners, one at each end. The charge has been blown at times, but I am told that the practice has been abandoned entirely. Once the casting of bars is begun, there is no more converter copper added to that charge of the mixer. From the mixer, the copper is poured into a tilting-ladle, and from the latter into the bar-molds. The drop of the stream in the latter pouring may vary from 12"-18". The bar-molds are of blister copper with an iron plate at the point where the stream of copper impinges and are cast at the mixer. They are fastened to a continuous carrier and are 49 in number. The motions of the mixer, the tilting-ladle and the mold-carrier are controlled from one station. The sample is taken from the stream of copper flowing from the tilting-ladle to the bar-molds, which is the proper place, for, in the tilting-ladle, the copper flowing from the mixer undergoes some chilling and the stream from there would not yield a true sample. Time and place of taking the sample are arranged for in the following manner: Molds Nos. 7, 23, and 39 have some flagging signal of wire or tin; Nos. 8, 24, and 40 a mark of paint, and over Molds Nos. 9, 25, and 41 the samples are taken. Thus two of the samples represent sixteen blister bars each, while the third represents seventeen bars. The correct ratio, if thought necessary, could readily be established by discarding one mold. The dimensions of the sample-mold are as follows:

		<u>Length:</u>	
		Bottom,-	9-1/4 in.
<u>Height</u>,	2-1/2 in.	Top,-	10- in.
		<u>Width:</u>	
		Bottom,-	3-3/8 in.
		Top,-	4-in.

cont'd.

The mold is inserted in an iron holder with a 3-4-foot handlebar at either end. At the appointed times, it is lifted on to the bar-molds and swung under the stream of copper issuing from the tilting-ladle. There usually seems to be some splashing and as the mold is heavy and unwieldy, it is difficult for the operator to obtain the desired quantity of copper each time. When there is too much, usually with a quick tilt, he spills some back to the bar-mold. As soon as the copper in the sample-mold has set, the mold is brought to the floor. Here it is found that the copper forms a thin layer over the top edges of the mold which is trimmed off with a chisel. The sample bar is then removed from the mold and is found to have the shape of a trough with outer dimensions the same as those of the mold. It weighs about 5 Kilos. As the blister bars from a mixer charge may vary in number between 145-270 - more or less - so will the sample bars vary accordingly. They are marked with the charge number at the mixer with chalk, then taken to the sawing room, stamped with the charge number and brushed with a steel brush,- the latter giving them about the same surface appearance as that of the blister bars. Heretofore, a tin mold fitting the bottom of the sample bar and having a half-inch slot along the longitudinal center was placed over the bar and along the sides of the slot two lines drawn or scratched on the lower surface of the bar. In sawing the bar, the operator was supposed to stop the saws on the half-way point between the two lines. By my own measurements I found that the error usually was within 1/16-in. However, while I was at the Smelter, a device for a centerline marking was made and put into operation. The sawing machine has nine blades placed equidistant - the distance between the two end blades being 8-5/16th in. The saws work well and produce perfectly untarnished sawings. Those from each sample bar are spread on an oil cloth, chips picked out and steel particles removed with a magnet, then poured into a paper sack. These sacks, representing one mixer charge, are taken to the balance room and from each sach 50 grams of the sawings are weighed and these combined to form the charge sample. There are usually four mixer charges per twenty-four hours, and for these a combination assay sample is prepared in the following manner: Each mixer lot is weighed in Kilograms; these weights are divided by 200,000 and the resulting quotient, expressed in grams, is weighed from the respective saw samples, and the four weights of sawings combined to form the proportioned assay sample of the day's production. No notice is taken in any way of the future 336-bar templet lots of the Refinery.

PERSONAL OPINION AND CRITICISM.

From the foregoing description of the sampling of blister copper at La Oroya, I would not be prepared to pronounce it correct or incorrect. At the same time, it would be impossible for me to consider it a standard method for past or present work

cont'd.

on account of defects in the practical application tending to introduce errors. Foremost of the latter, is the difficulty of incorporating in the sample bar the total stream of molten copper flowing during the given short interval of time from the tilting-ladle. The adequacy or inadequacy of the period between sample bars is dependent upon the homogeneity or heterogeneity of the mixer charge. However, it is important that the periods be regular, or that the signals for taking the samples are always kept in their proper place and promptly answered by the man taking the sample. Spilling of part of the sample from the mold should not be permitted. The shape of the stream of copper from the tilting-ladle could be improved by giving the lip the V-shape, as suggested by Mr. Harper, who is in charge of the Department. The trimmings from the top edges of the sample mold form a very small percentage of the sample bar and could effect but very slightly the assay results. The sawing of the sample bars could be improved by introducing an automatic stop for the saws at the centerline, thus eliminating a personal factor. The objection to sample bars of uneven thickness could be met by sawing them to the centerline from both sides. It remains an open question if the large blister bars and the small sample bars are chemically alike; or, if the difference produced in chemical reactions due to different rates of cooling, produce an appreciable difference in the assays.

There is not the slightest doubt about the best of good will for correct sampling existing at La Oroya. Those in responsible positions, however, generally have many varied duties to perform. To the ordinary workman, who is the actual operator, it may be very difficult to perceive that there is an important difference between a stream of molten copper filling a mold and a stream of water filling a cup. Supervision, in my opinion, of important sampling should at all times be exercised by some one impressed with the facts of segregation and the differences resulting therefrom.

Special Tests...

In the course of our conversations, Mr. Spillsbury asked me what I thought they should do in the way of sampling. I explained to him the idea of producing a full-sized blister bar fit for sampling by sawing, which could be accomplished by producing a number of parallel grooves across the bottom of the bar so that it might readily be broken into small sample-bars,-these to be sawed according to some proper templet. Recognizing that provisions for such a method would require considerable time and expense, I suggested that we make a few tests by pouring sample cakes with a ladle. In my former experiences, I had often handled molten copper in crucibles and had observed that when the latter were sufficiently heated copper could be poured from them leaving them perfectly clean. The same would be true with a ladle. We

con't.

prepared to sample a mixer charge in this way. We found that by holding the ladle closely to the lip of the tilting-ladle, the stream could be caught without splashing; however, during the operation, we lost three ladles in the act of washing them in the stream of molten copper, and thereby missed two sample bars. These bars were much more regular than those poured directly into the sample mold, also practically free of fins, and in surface appearance very much like the blister bars. We decided to disregard this experiment and to prepare for another with crucibles. These were readily fastened with wet clay in a circular holder with handle. A single crucible stood the test for Mixer Lot #273 producing 273 blister bars and 16 sample bars of each of the two sampling methods. With each pouring, the crucible was scrupulously inspected and found to be clean. I have brought a part of the two finished samples with me. The results obtained of them in the La Oroya Laboratory were reported to me as follows:

LaOroya Mixer Lot of Blister Copper #273

	Copper %	Silver Ozs.	Gold Ozs.
Regular Oroya Sample	97.64	362.7	1.72
Crucible Sample	97.45	362.2	1.72

Lot #289 was sampled in the same way, but the assay results were not available at the time of my departure. The sample bars poured with a crucible are considerably lighter than those taken directly from the stream of copper; they weigh about 3 kilograms. As a consequence, considerable time is saved in sawing.

I gave my opinion to the effect that the crucible pouring method, if carried out with all the necessary precautions, would be an improvement over the one now in use.

(signed) Edward Keller.

Dr. Keller's supplementary report is as follows:

New York, April 5, 1926.

Messrs. Ledoux & Company,
99 John Street,
New York City.

Dear Sirs:

In my regular report under this date presented to you, I confined myself to the assigned duty of describing the method of sampling blister copper as practiced at LaOroya Smelter, together with my observations as to its defects. Incidentally, however, I also described a test made there in my presence which was designed to eliminate the most essential defects of the method in use. Upon mature consideration, I would now venture a concrete suggestion as to the adoption of a sampling method of the molten copper at said Smelter, a method which, in my opinion, would eliminate defects now existing, avoid personal factors, and would cause no extra expense of any importance:

The method would imply a sample bar mold as large as possible, producing a sample bar not too large to be sampled by sawing. It would be best to have it fastened directly to the carrier of the blister bar molds, in place of Nos. 9, 25 and 41. This would leave 46 molds for blister bars, and the sample bars would now represent 15,15 and 16 of the former, or, 15, 15, and 15 should one more blister bar mold be eliminated. The sample bars in this arrangement would be dumped at the same place as the blister bars. A less desirable way would be to place an enlarged sample bar mold into the proper blister bar mold in such a way that the tilting-ladle could deliver its stream of molten copper into it without splashing. The mold with the sample bar could be withdrawn on the spot or dumped with the blister bars. In either of the devices, the sample bar would preferably be cast as thin as possible.

(signed) Edward Keller.

Enlarged photographs of two Smelter sample bars, taken with a kodak by Dr. Keller, - one showing the trough-shaped bar cast directly from the pouring stream, and the other showing the flat bars obtained by casting from a crucible are submitted. The pictures are not clear, but they serve to show the difference in shapes obtained by the two methods.

We may supplement this report by some remarks based on discussions with Dr. Keller, upon our own experience, and upon the figures given in the summary of work done here:

While agreeing that the method used at the Smelter is acceptable in principle, Dr. Keller objects to the way it is carried out in that the full stream of molten metal is not always intercepted by the sample mold; that some of the metal is sometimes thrown out of the mold by the operator - if he thinks he has too much,- and that the accuracy of sampling any individual lot depends upon the thoroughness of mixing the several conventer charges in the mixer before casting begins.

The first of these objections is based upon the fact that the metal stream is not homogeneous. Errors occur if the whole stream is not interrupted during the casting of the sample bar. Errors due to this cause would not necessarily be in one direction, but would tend to compensate one another in the long run unless the workmen acquired habits of taking the sample from only one part of the stream.

The second objection would tend to make errors constantly in one direction, toward low silver results, because if any of the metal had set on the cold sides of the mold, the liquid part which is thrown out would be richer in silver than the average, and the sample bar would be correspondingly impoverished. The contrary might be the case if the copper is high in lead and antimony.

The third objection is based upon the supposition that the mixer charge is not homogeneous, especially since blowing has been discontinued recently, and that three sample bars to forty-nine full-sized bars cast may be insufficient to cover variations; at any rate that the sample bars are not taken at perfectly regular intervals, but are supposed to represent 16, 16 and 17 full-sized bars cast. Equal weights of sawings are taken from each sample bar, although the third, which represents 17 bars, must represent a greater weight of bullion. Errors from this source, whether great or small, would tend to conpensate one another in the long run.

That these differences are not great is shown by the following assays of sawings from individual sample bars. These were made by the Smelter at our request, the results being reported by them by cable:

	Sample Bar #	Mixer Charge of 187 Bars, air-blown in Mixer	Mixer Charge 158 Bars No air used.
		Silver (corrected assays)	
1.	9	397.7	372.5
2.	25	386.7	377.9
3.	41	398.6	367.8
4.	58	395.9	371.2
5.	74	391.8	371.4
6.	90	399.4	372.6
7.	107	398.3	376.6
8.	123	387.3	375.5
9.	139	393.0	376.7
10.	156	398.2	369.3
11.	172	396.8	____
	Maximum difference	12.7	10.1

The differences are not great, averaging the first, third, fifth, etc., and comparing this with the averages of the fourth, sixth, eighth, etc. in each column gives:

	187 Bars	158 Bars
Odd	396.0	373.0
Even	393.4	372.3

Evidently the mixer charges are fairly homogeneous whether air is used or not. Nothing would be gained in accuracy by taking more sample bars unless the number taken is very much increased.

A fourth objection is one that pertains to all small casting samples of converter metal. In full-sized bars, reactions proceed for some time after the bar is cast and before complete setting occurs, with loss of both sulphur and oxygen. In small sample bars, reaction does not proceed far because the setting is rapid. There is therefore likely to be a small concentration due to expulsion of sulphur and oxygen in the large bars. This source of error is very small, probably trifling in Oroya practice; it occurs nevertheless.

Taking all these factors into consideration, our opinion of the Smelter method is that the sampling does not accurately represent any one lot but owing to compensating errors over a long series of shipments, it represents the average value of Oroya bullion much more closely than the Refinery method with its constant error in one direction.

Considering the summarized results of the six experimental lots given on page 19, it will be seen that the Smelter assays in two cases - Lots 26-A and 26-B - are much lower in silver than those of the hammered templet method. Lot 26-B is higher in gold. The average silver difference is over ten ounces per ton. In the other four lots, the smelter assays are all higher both in silver and in gold than those of the hammered templet method.

The averages of the six lots, on this account, agree better in silver, but not in gold with those of the hammered templet method.

The hammered templet method checks itself upon repetition, that is, top sampling, after hammering, agrees with bottom sampling after hammering within close limits. The small difference between the two is explained by a perfectly definite cause. Taking either top or bottom drilling after hammering as standard, the Smelter sampling shows variable departures from it in the several lots. This confirms the opinion expressed above that Smelter sampling is likely to be erratic, the errors tending to compensate one another over long averages. The average of six lots is not sufficient to show whether compensations would be exact or not.

To check more completely the Smelter method against the old templet method or an improved templet method, Mr. M. S. Walker has suggested that a composite sample lot may be made by reserving at the Smelter full-size bars cast at the same time the small sample bars are cast, that is, every 9th, 25th, 45th, etc. until 336 bars are cast,- these to be shipped as a lot intact, to be sampled by templet methods and the results compared with those of the Smelter on the small sample bars and with the calculated averages of the assays of the lots they represent as shipped in the usual way. At first this plan seemed excellent, but on further consideration it would require modification. The templet method works by compensation of errors occurring in different directions. The assays of a lot sampled only once by templet and consisting of bars <u>differing widely from one another in silver</u> would not necessarily be correct. This is shown by considering the differences between top and bottom sampling after hammering in the individuals of the six test lots sampled at the Refinery. In these, the bars in each lot were of about the same tenor. To get comparisons by the method suggested, it would be necessary to resample the 336-bar control lot by the templet method several times, at least as many times as would give the same number of drill holes as were made in sampling the whole shipment that the 336-bar test lot is supposed to represent. In resampling, the drill holes would have to be made in sections of each bar different from where they occurred in previous drilling. It seems to us, if the matter requires further comparisons that it would be better to ship, say, sixteen lots, consisting of bars having the usual wide differences from bar to bar, as entities and to compare the final average by hammered templet drilling with the Smelter results.

The details given in the foregoing pages make a complete story of this investigation which warrants the conclusion that Refinery sampling of Oroya blister by the templet method, whether by top or bottom drilling, is erroneous through entrapment of drillings which are always richer in silver than the average silver contents of the drill holes. The reasons for this are explained and the degree of error from this source approximately determined. The copper and gold returns of the Refinery sampling are also subject to errors through retained drillings, yet these are so small as to come within the limits of analytical differences.

A method for sampling Oroya bullion by the templet drilling system has been devised which reduces the possibility of all errors through retained drillings to very small and probably negligible figures.

The Smelter sampling of Oroya bullion is subject to errors in details that require skilled attention. With One exception, that of throwing metal out of the mold after some of it may have solidified, these errors occur in different directions, tending to neutralize one another. All of them are minor compared with the retention of drillings in the Refinery templet method. Long averages of the results of Smelter sampling must be considered as more closely representing the value of Oroya bullion than those of Refinery sampling as heretofore practiced.

Since templet sampling by drilling is the only practical way to sample blister copper in large bars, the method recommended for use at the Refinery is that referred to in this report as the hammered templet method. All drilling, except bevel holes, should be done with the bottoms of the bars up. The 336-hole templet in present use may safely be continued. There is no necessity for separate bevel sampling because the correct proportion of bevel borings on the average will be included in the sample automatically when the same sized drill is used for all holes.

It is recommended that this method be used at the Smelter also.

In closing this report, we wish to express our appreciation of the way in which the operating officers at the Refinery have co-operated in this work. Every facility has been at our disposal and under our control, and every suggestion made has been patiently considered by them.

Very truly yours,

LEDOUX & COMPANY

By (sgd) A. M. Smoot
V.P.

AMS:LGS

May 17, 1926.

Mr. Edward H. Clark,
Cerro de Pasco Copper Corporation,
44 Wall Street,
New York City.

Dear Sir:

We are sending herewith three copies each of the photographs and plates for use in the extra typewritten copies of Report #357103 that you are having made. This is in accordance with conversation with Mr. Addicks changing the request made in your letter of May 11th.

In Plate #4 of the templet used in drilling experimental lots at the Refinery, the drill diameter of the body holes is given as 1" and the edge holes as 1/2". After experiment, the dimensions were changed to 17/32" and 3/8", respectively, but these were not recorded on the tracing from which the plate was taken. The matter is unimportant since the drill dimensions are given in the text. As a matter of record, it should be changed.

Very truly yours,

LEDOUX & COMPANY,

By A. M. Smoot.

AMS:LGS