TBCC Copper Assay Data

A Statistical Review

The Chemical Structure of TBCC

TBCC is a manufactured form of a natural mineral substance with the empirical formula - $Cu_2(OH)_3Cl$ - and a theoretical copper concentration of 59.5%. Strict chemical nomenclature for this compound is dicopper chloride trihydroxide, but a somewhat less cumbersome common name is tribasic copper chloride. In nature, under differing geologic conditions, various crystal structures of this chemical compound were formed. They have the same elemental make-up and general behavior in chemical reactions, but differ slightly in the geometric structure of the crystal lattice (angles and lengths of bonds between elements). Three such forms occur frequently enough in nature to have been thoroughly defined by crystallographers and assigned standard x-ray diffraction patterns – atacamite, paratacamite and botallackite. Botallackite has one extra water molecule incorporated into the crystal structure - $Cu_2(OH)_3Cl \cdot H_2O$ - and therefore has a lower theoretical assay of 54.5%.

As shown in the product specification sheet, TBCC is very low in impurities. The primary factor affecting the copper assay of the product is the amount of water bound in the structure. In manufacturing TBCC, the conditions in the crystallizer produce a product with the predominant structure of atacamite, but the assay is influenced by the presence of minor amounts of botallackite. The guaranteed minimum copper concentration is 57%, but mean of the statistical distribution of actual results is 58%, which is the level that should be used for calculating dietary formulations. The following discussion explains the assay variation that may be observed in the product.

The Data Base

Statistical evaluations were performed on two sets of data – one covering over four years of analyses performed from March, 1996 through June, 2000 and the other covering a recent twelve month period from July, 1999 through July, 2000. The tighter distribution of the more recent results reflects Micronutrients' continuous improvement efforts. Included in each set are three different ways of analyzing the available data. The first (labeled ALL) includes data from all sources. The second (called MICRO) is the analyses done internally at the Micronutrients lab. The third is a separate view of the data from the various external labs that have been used as a quality check on the internal lab work.

While both databases include all material produced by the manufacturing process, Micronutrients rigorously adheres to a policy of not shipping material to customers which has an assay below the guarantee level of 57%. Removing the data on rejected lots from the databases would slightly shift the statistical results. However, as indicated by the histograms, the impact would be small.

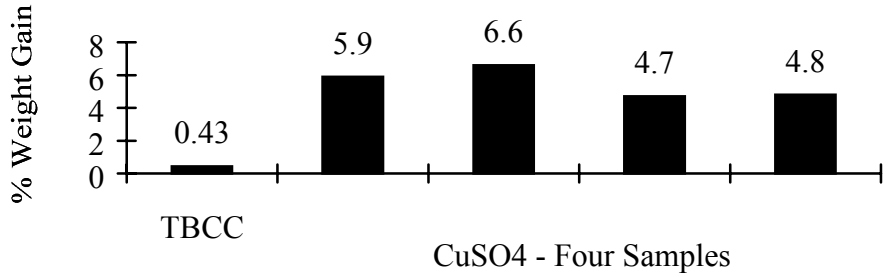
Comments

- In addition to inherent variation in a particular product, there is also an uncertainty (or confidence interval) associated with every laboratory analytical result. The scatter in a set of data is a combination of the two.

- The inherent precision in the lab result is often evaluated by analyzing "splits" or replicates of a given product sample. We have done this on various occasions with both our internal and external labs. By submitting blind splits, this approach tests both the precision of the final analytical technique as well as the entire system including sample prep. Typically we find our internal capability to be in the range of ± 0.5%, while the same sample sent to multiple labs will give results varying ± 3-5%. This phenomenon explains the unusual statistical distributions (see histograms) for the external lab results.

- The same issues affect analysis of any copper source. An analytical result for copper sulfate of 25%, with a confidence interval of ± 1% means that it is somewhere between 24.75% and 25.25%. The same uncertainty on a TBCC sample at 58% puts it between 57.4 and 58.6%. Superficially, the range on TBCC seems to be 2.4 times as large, but the impact for feed formulation purposes is identical.

- As shown below, the hygroscopicity of copper sulfate is much higher than TBCC. Thus, the *true copper concentration* of a given sample of copper sulfate can change by as much as 5% depending on whether it was taken on a humid August day or a relatively dry day. Aside from the impact on lab analyses, this issue also affects how much copper gets added in a mill depending on the day's humidity.



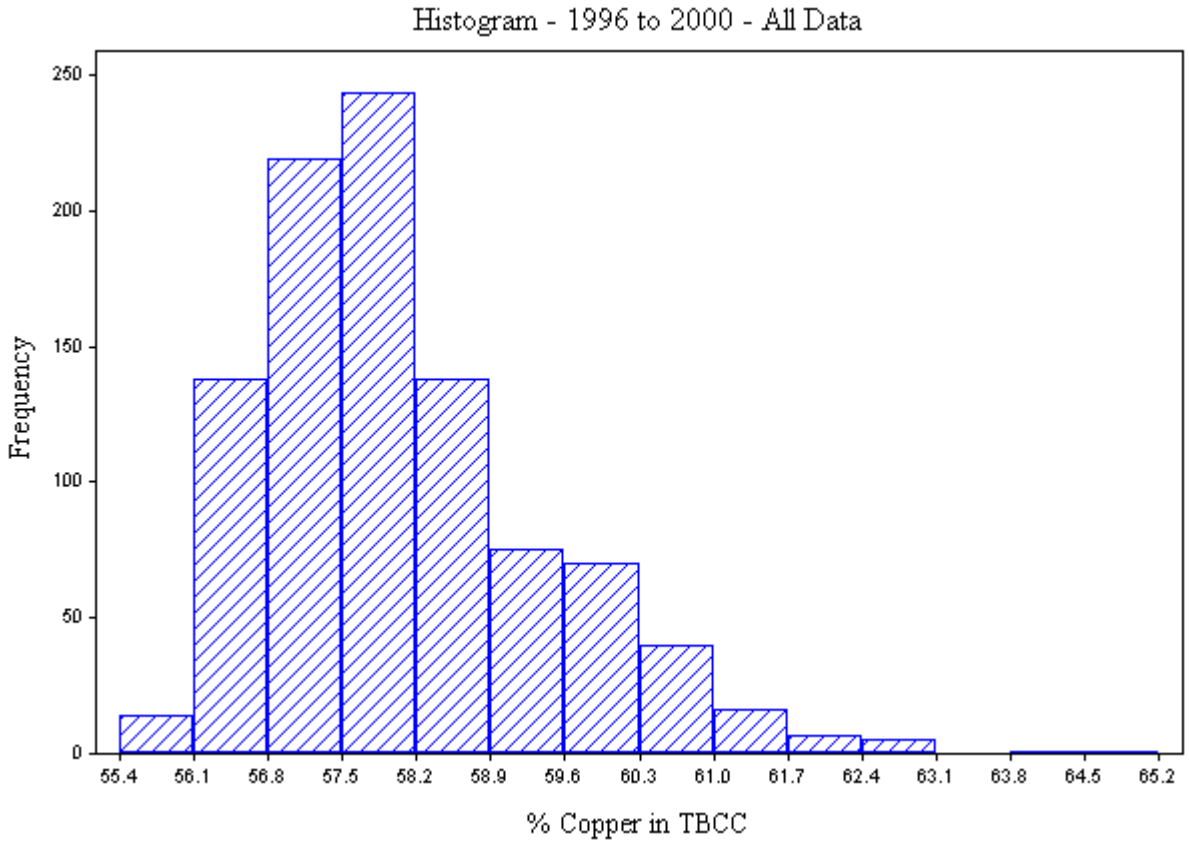
Method: All samples dried in silica gel desiccator for 24 hours, weighed, then placed in 90% relative humidity chamber for 24 hours and reweighed.

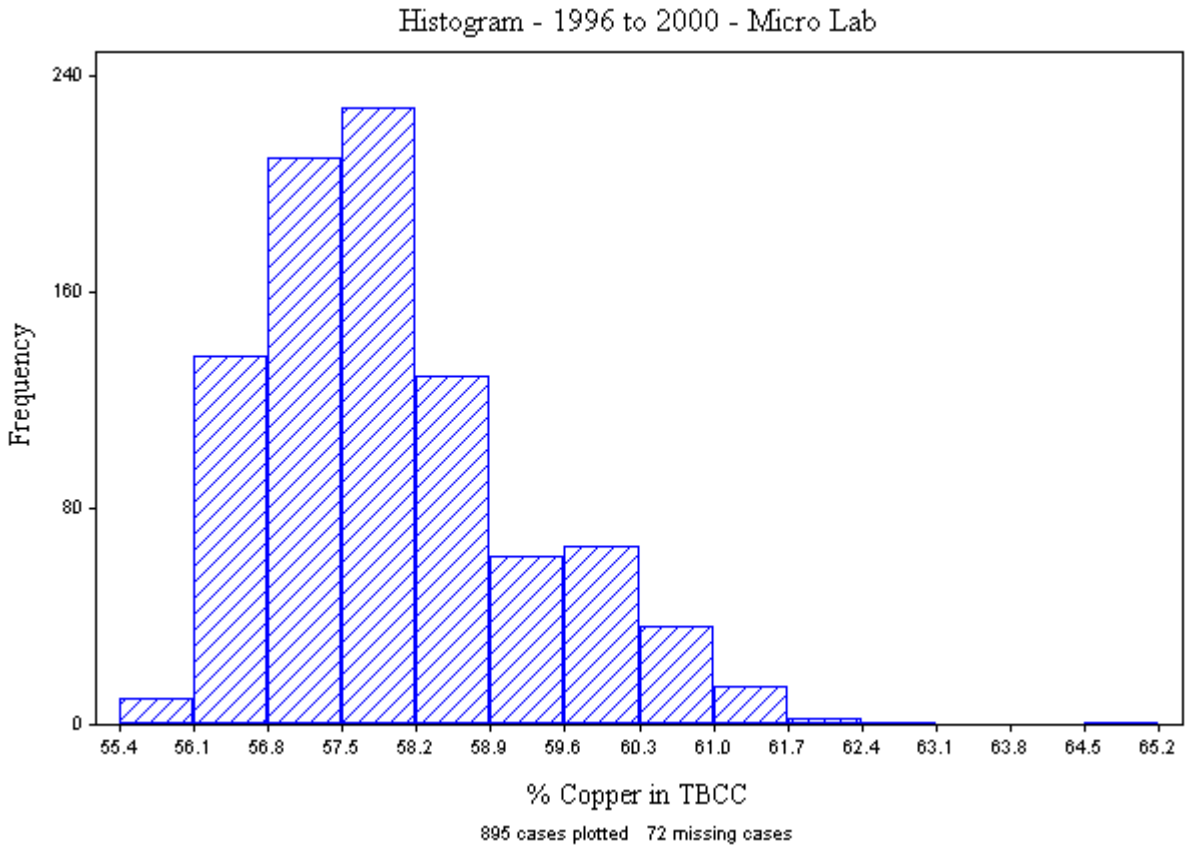
Copper Assay Data Analysis on *Micronutrients TBCC*™

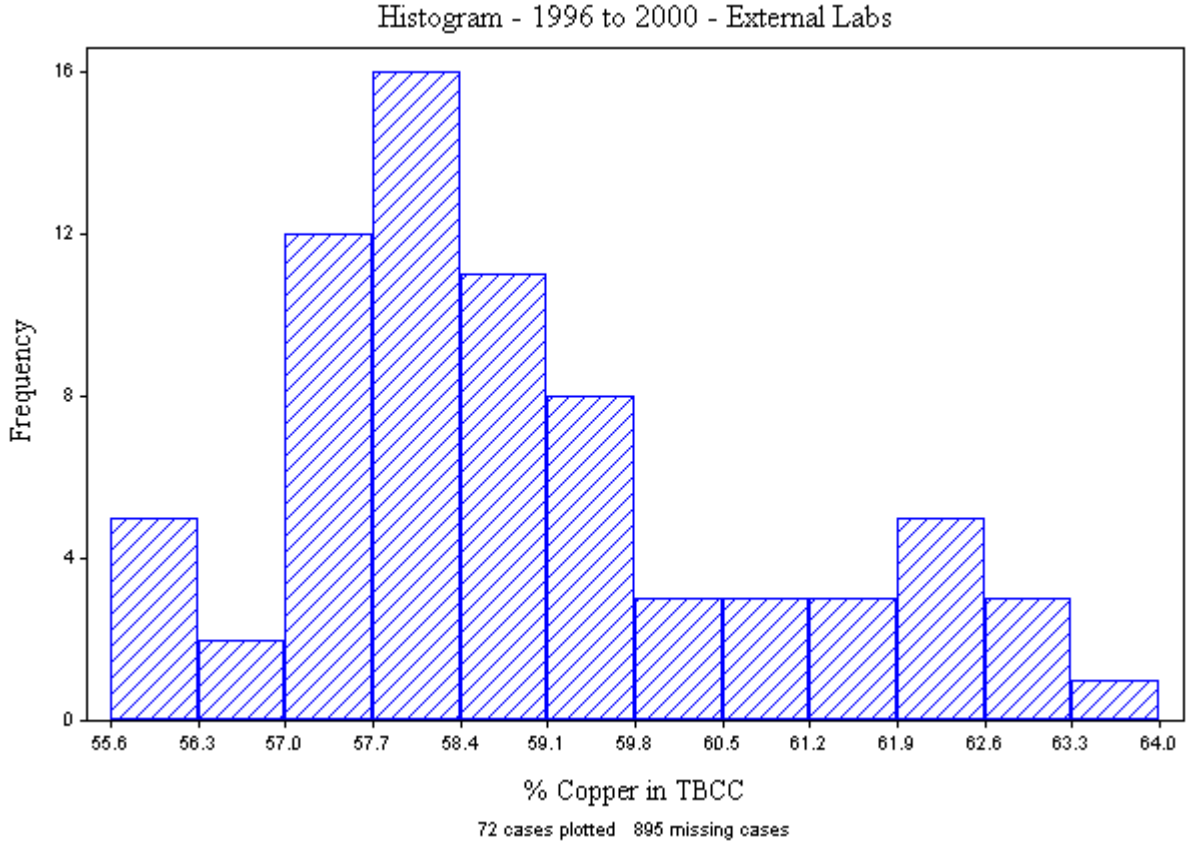
March, 1996 through June, 2000

DESCRIPTIVE STATISTICS

	ALL DATA	MICRO	EXTERNAL
N	**967**	**895**	**72**
MEAN	**58.006**	**57.931**	**58.937**
SD	**1.3417**	**1.2561**	**1.9175**
SE MEAN	**0.0431**	**0.0420**	**0.2260**
C.V.	**2.3130**	**2.1682**	**3.2535**
MINIMUM	**55.500**	**55.500**	**55.610**
MAXIMUM	**65.100**	**65.100**	**63.960**




Histogram - 1996 to 2000 - Micro Lab
Frequency
240
160
80
0
55.4
56.1
56.8
57.5
58.2
58.9
59.6
60.3
61.0
61.7
62.4
63.1
63.8
64.5
65.2
% Copper in TBCC
895 cases plotted 72 missing cases

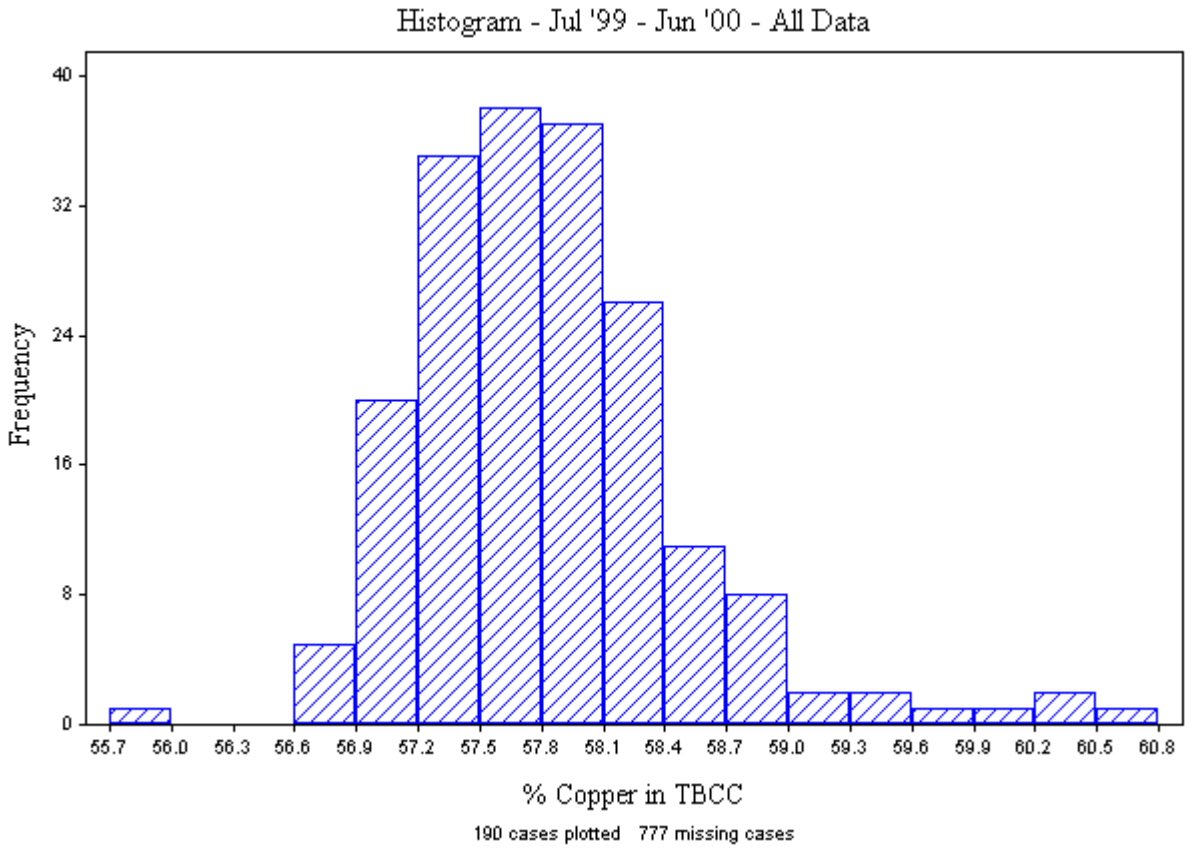

Histogram - 1996 to 2000 - External Labs
Frequency
16
12
8
4
0
55.6
56.3
57.0
57.7
58.4
59.1
59.8
60.5
61.2
61.9
62.6
63.3
64.0
% Copper in TBCC
72 cases plotted 895 missing cases

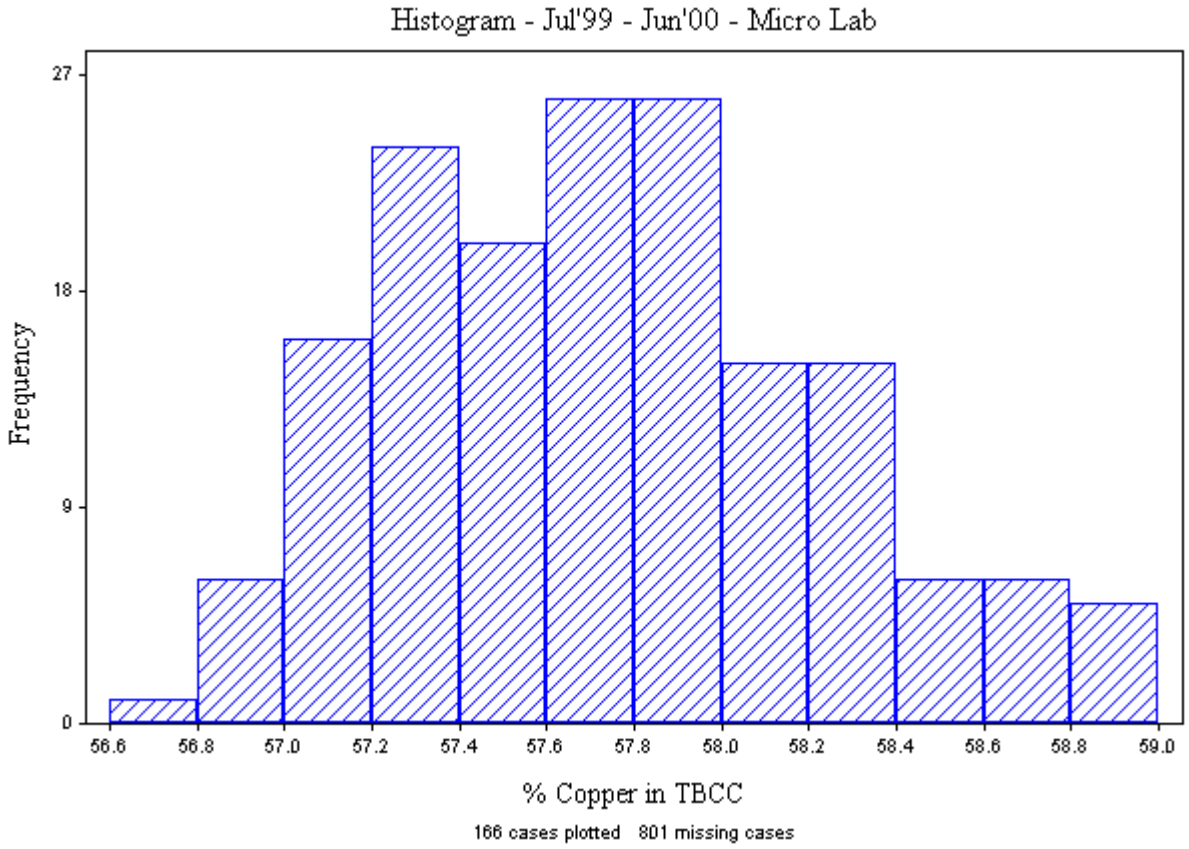
Copper Assay Data Analysis on *Micronutrients TBCC*™

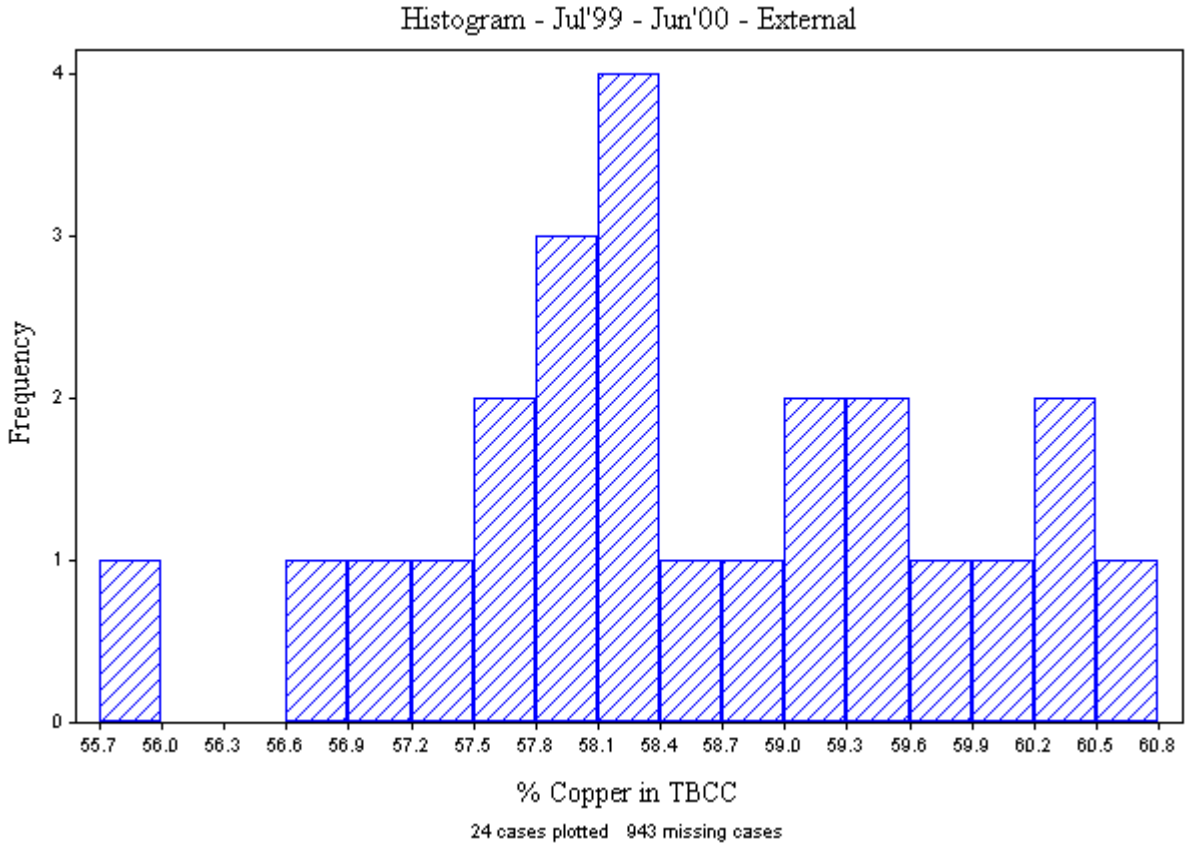
July, 1999 through June, 2000

DESCRIPTIVE STATISTICS

	ALL DATA	MICRO	EXTERNAL
N	190	166	24
MEAN	57.817	57.716	58.516
SD	0.6914	0.4989	1.2491
SE MEAN	0.0502	0.0387	0.2550
C.V.	1.1959	0.8644	2.1347
MINIMUM	55.800	56.700	55.800
MAXIMUM	60.760	58.990	60.760




Histogram - Jul'99 - Jun'00 - Micro Lab
Frequency
27
18
9
0
56.6
56.8
57.0
57.2
57.4
57.6
57.8
58.0
58.2
58.4
58.6
58.8
59.0
% Copper in TBCC
166 cases plotted 801 missing cases


Histogram - Jul'99 - Jun'00 - External
Frequency
4
3
2
1
0
55.7
56.0
56.3
56.6
56.9
57.2
57.5
57.8
58.1
58.4
58.7
59.0
59.3
59.6
59.9
60.2
60.5
60.8
% Copper in TBCC
24 cases plotted 943 missing cases