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LIEBHERR

A. General Report Information

In-Line (in-situ) moisture measurements in aluminum oxide (Al_2O_3) or other materials can be a very advantageous part of the manufacturing process, if utilized. This report shows the results of our in-house testing on Al_2O_3 pellets varying in size from 1.0 - 2.5 mm in diameter and 5-12 mm in length.

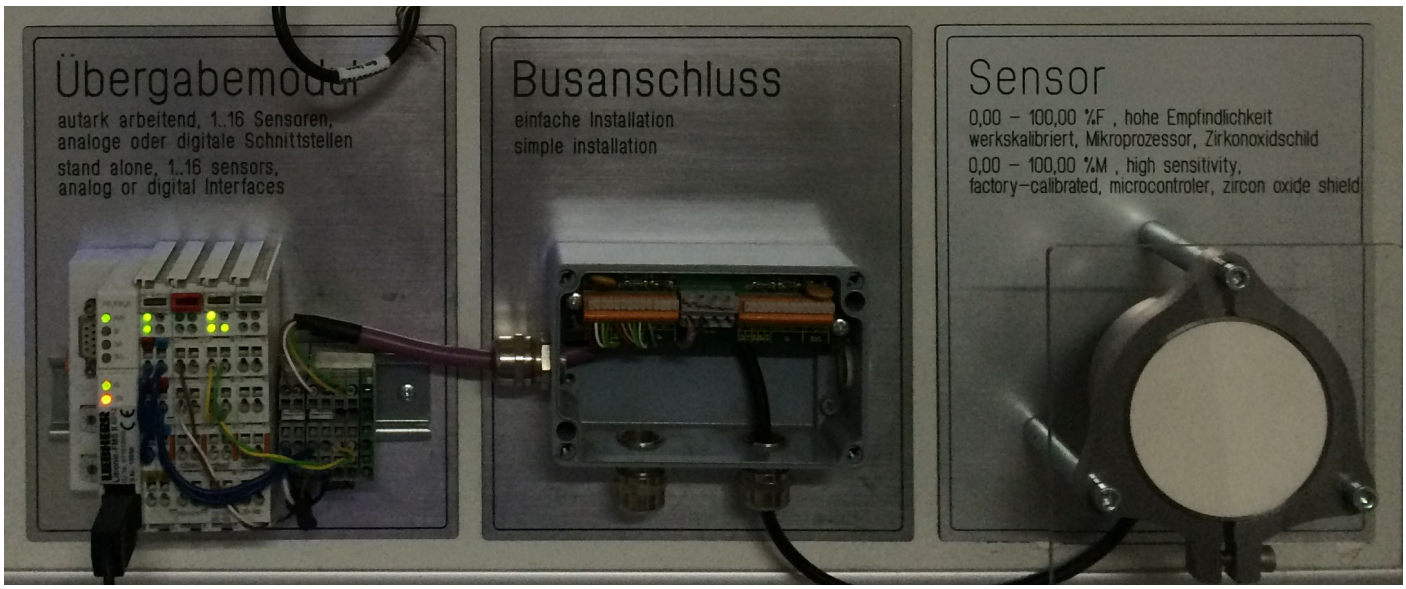
Test conditions and system type: A production in-line analyzer was used in an "at-line" configuration testing both the optional SST **P30** (1.1" diameter) and **P78** (3" diameter) sensor heads.

The Instrument: The ***Liebherr FMS-II Litronic*** is an industrial, robust and patented in-line or lab analyzer used to measure moisture and other constituents in food, beverage, petro-chem, aggregates and other "flow-able" or static products. It can be installed into pipes, conveyors, chutes, web belts or other locations to provide "real-time" measurements used for automated control and/or manual process monitoring.

The analyzer consists of **a)**, up to 16 optional "intelligent" sensor heads connected via RS485 to **b)**, an optional sensor buss to **c)**, a separate micro-controller that can then be connected to a customer interface/PLC/SCADA via RS232/Ethernet, 4-20mA, 0-10V analog, WLAN or Bluetooth.

There are no moving parts and the interface options are food grade PEEK® (polyetheretherketone) or industrial grade Zirconium Alumina Oxide (ZrO_2 - Al_2O_3). Explosion and Dust Proof versions are also available and with over 10,000 sensor heads installed over the last 35 + years, reliability is ensured.

c. **b.** **a.**



B. Objectives, Test Highlights & Preliminary Summary

Objectives:

1. To determine the feasibility of this application.
2. To determine instrument parameters for the measurement with regards to this product.
3. To get a preliminary indication of the sensitivity and precision of the instrument measuring representative test product.

Test highlights:

1. The instrument shows excellent sensitivity to varying moisture content in aluminum oxide pellets.
2. There is high correlation between the Liebherr predicted & measured validation results and the prepared lab samples. An **r2** correlation coefficient of 0.998 was measured with the P78 and 0.995 with the P30.
3. The measurement accuracy, based on the standard lab values was also excellent. A Standard Error of +/- 0.200% moisture was achieved for the P78 and +/- 0.337% for the smaller P30 sensor, both at 95% confidence level.

Preliminary Summary:

Based on the test results of this report, moisture measurements using the Liebherr instrument on these types of product would be an excellent application for this technology and will yield very good in-line or lab measurements.

C. Test environment, Procedure & Sample Presentation

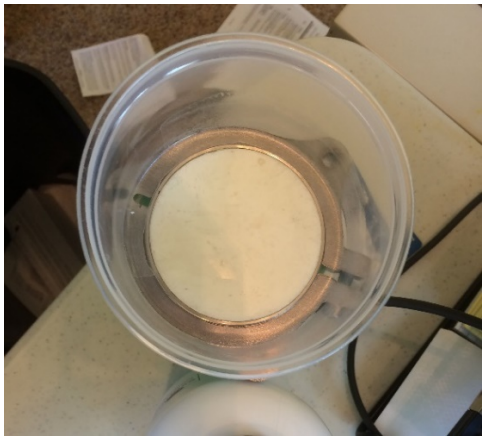
1. The FMS-II Liebherr in-line analyzer was set up using an “at-line” configuration while at ambient room temperature, pressure and humidity.

2. 15 test samples of varying moisture over a range of ~ 1% to 12% were analyzed with the P30 sensor then the P78 without any physical or vibrational packing. The containers were rotated a few times to redistribute the pellets. During this procedure three “blind” samples were also measured and raw information recorded for later moisture value extrapolation.

NOTE: The blind samples had both larger and smaller particle sizes than the calibration samples. This is not an ideal validation test since none of the calibration samples were of this size. The unit can store many curves so a customer may add as many “recipes” (particle sizes) as necessary.

3. The samples were presented to the sensors as shown in a) and b) below:
   a) The **P30** sensor was placed on top of the sample and slightly “wiggled” so its own gravity would provide full surface contact.

b) Using the **P78** sensor, samples were poured into the plastic sample cup that was attached directly in front of the sensor head. Because the sensor averages 40 readings a second, any packing or flow variations can be mitigated by signal smoothing using the Liebherr controller or an end users PLC.

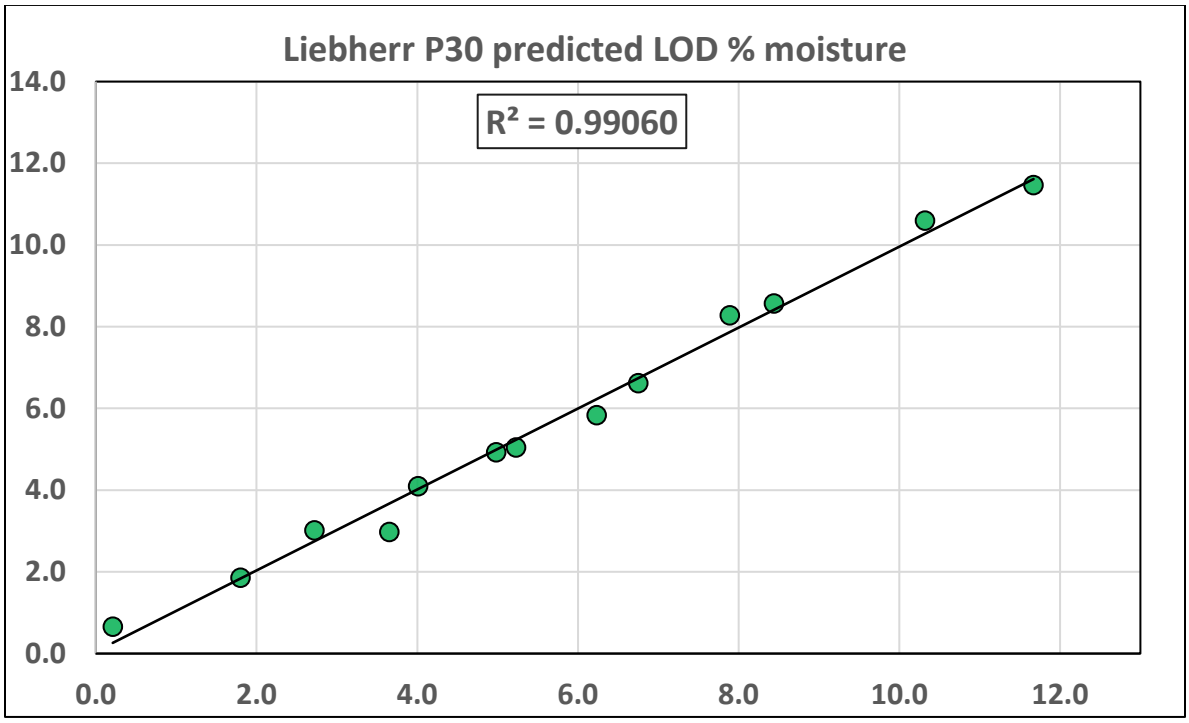


4. The samples were scanned, recorded and analyzed using linear-regression to evaluate the accuracy of the measurement and, to generate coefficients that were then installed into the controller for validation testing.

NOTE: For this test loss in weight, *LOD* lab moisture analysis was performed at 120C while *LOI* moisture analysis was performed at 1,200C

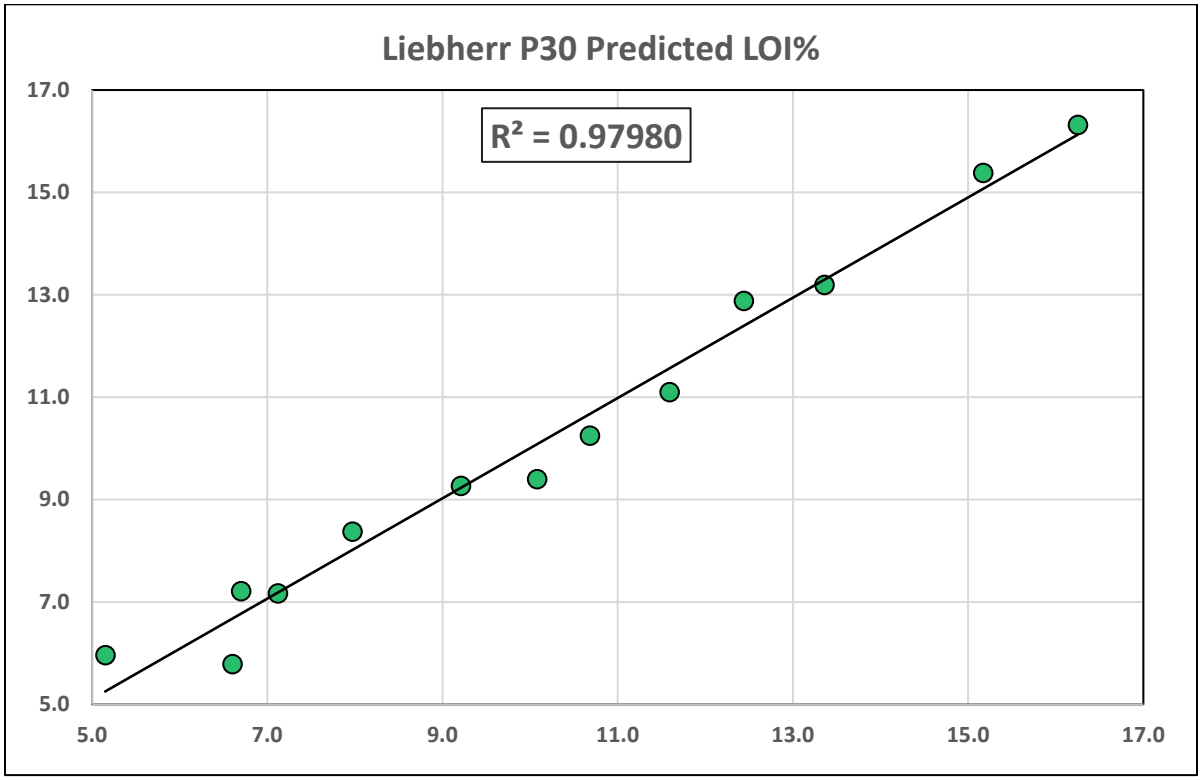
D1. Test Results, P30 sensor head % LOD

Correlation Coefficient: 0.990 **Standard Error:** 0.337%



D2: Test Results, P30 sensor head % LOI

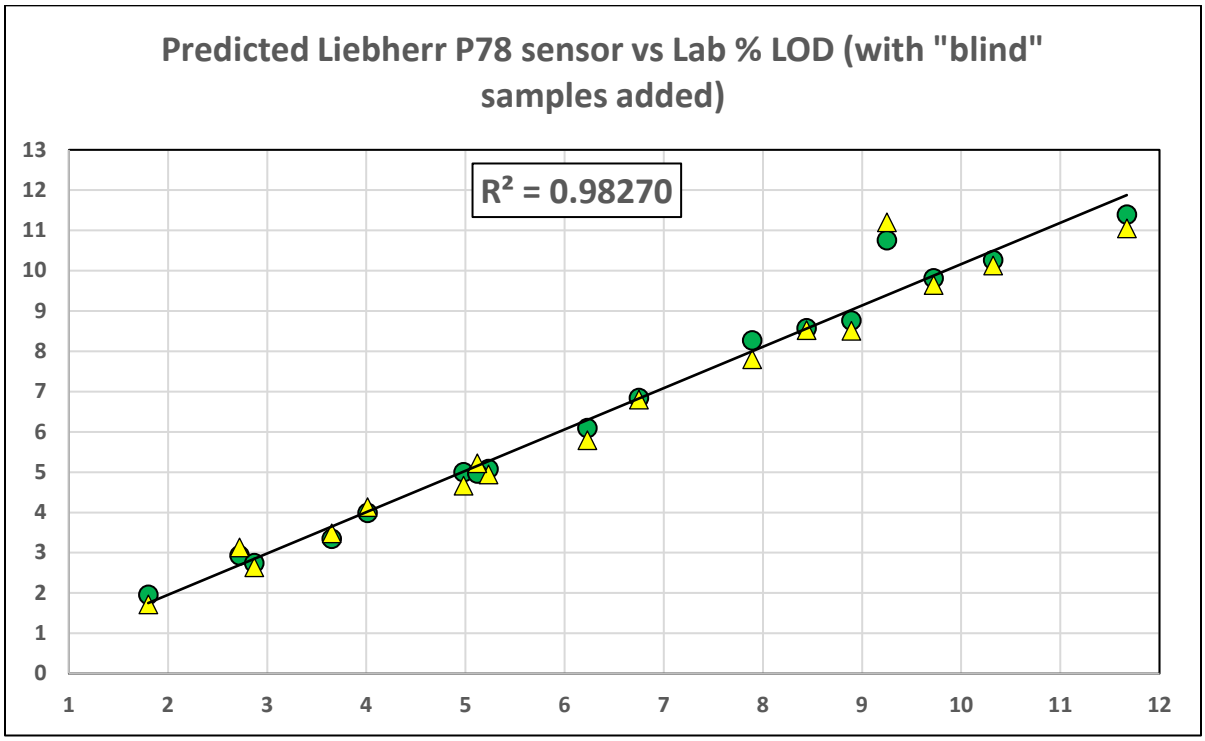
Correlation Coefficient: 0.980 **Standard Error:** 0.515%



D3. Test Results, P78 sensor head % LOD

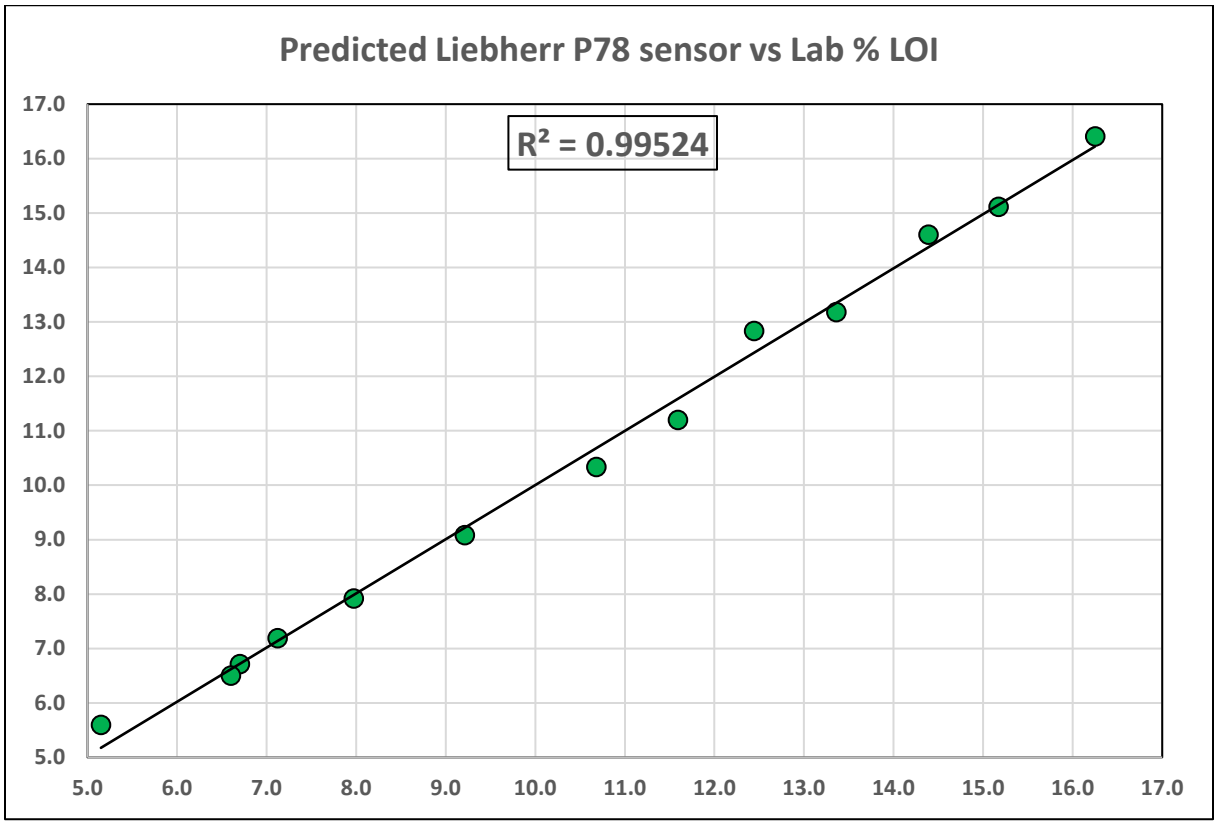
Correlation Coefficient: 0.983 **Standard Error:** 0.200%

In the graph below validation samples (actually measured, post calibration) are shown in yellow markers versus the green predicted value markers.



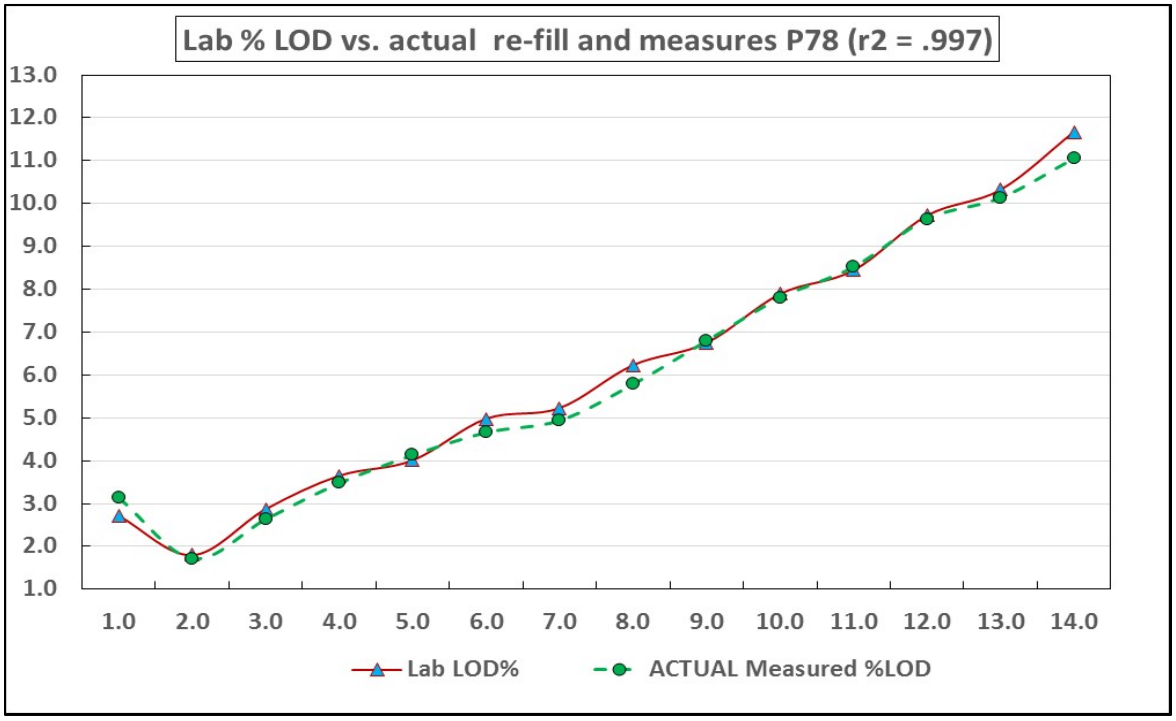
D4. Test Results, P78 sensor head % LOI

Correlation Coefficient: 0.995 **Standard Error:** 0.264%



E1. Calibration Sample Validation

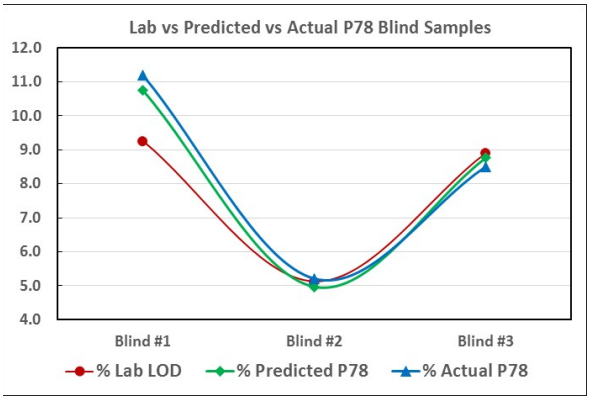
Once the calibration was installed and using the P78 head only, the samples were then re-measured with the results below. The P30 was not validated at this time.



E2. “Blind” Sample Validation

Blind sample results showed excellent % LOD correlation (LOI was almost identical). As previously stated calibration curves would be added for each different particle size yielding better results.

ID	% Lab LOD	% Predicted P78	% Actual P78
Blind #1	9.25	10.75	11.20
Blind #2	5.12	4.96	5.22
Blind #3	8.89	8.76	8.51



F. Discussion, Definitions & Conclusion

The preceding information constitutes a preliminary report for review. The statistical values presented are based on data generated in our laboratory versus a limited quantity of material samples. Accuracy may differ somewhat from these results, depending on variations in material and actual process line conditions. In addition, poor sampling and lab analysis technique will add to instrument error. For these reasons, any study or statistical evaluation for any in-line measurement should be done with the sensor installed in the optimal production location.

Inconsistent voids or gaps in front of the sensor will cause variations in the instrument readings however, using various analyzer settings these false readings can be ignored. Consistent presentation of the product will improve the measurement for any in-line system and oftentimes, have less error than the lab or at-line system based on the infinitely large number of readings on all the material.

R-Squared (r2)
The correlation coefficient, r2 is a mathematical expression of the randomness of the data points around a linear regression line. It is a function of both the accuracy of the measurement and the range of moisture values in the calibration sample standards. A value of 1 is perfect but for most in-line applications > .90 is a minimum.

Standard Error:
The standard error is the variability between samples that you would obtain if you took multiple samples in the same data set. It is also a function of the scatter of data points around the linear regression line and is an indication of how closely the regression line predicts the measured test values with a value of 0 being perfect. In theory, 68% of calibrated instrument readings will be within +/- one standard error of the real moisture value while approximately 95% of calibrated values fall between +/- two standard error values.

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