# Operation of the SmartScope FOV Video Measurement System

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## 1 Introduction

The SmartScope FOV (Optical Gaging Products, Inc.) is a video measuring microscope system that uses calibrated optics and a high precision linear translation table to produce non-contact, dimensional measurements of objects. The instrument produces measurements in three dimensions that are both more accurate and more precise than those obtainable using standard mechanical devices such as micrometers and calipers.

## 2 Scope

This document applies to case working personnel using the associated instrument in support of metallurgy examinations.

The SmartScope FOV video measurement system is used for measuring physical dimensions and surface features of a wide variety of objects.

## 3 Principle

The SmartScope instrument determines planar dimensions by reference to a highly accurate and precise linear translating stage on which the object being measured is placed, and depth (by height differential) from differences in focal distance. Calibrated lenses and instrument-specific software algorithms permit accurate measurement of planar spacing and height differential between selected points or features. Illumination options provide the user the ability to control the intensity, direction, and incidence angle of light and optimize the image for measurement.

Although lenses of various magnifying capacity are available to provide different image areas (fields of view), the selected points to be measured do not have to be within a single field of view (FOV). The software algorithms use the calibrated magnification factors to determine the size of the region within the instrument FOV at a given magnification. Physical measurements are made by selecting two or more points on a feature of interest and comparing the relative distance between them to the known dimensions of the FOV and the difference in lens height at optimal focus. Distances greater than the FOV are determined by reference to it and to the stage displacement. Edge detection and automated focusing routines permit highly reproducible feature selection.

## 4 Specimens

Imageable features of solid objects that are small enough to fit between the sample stage and lens apparatus can be analyzed by this method. The features to be measured must be perpendicular to the optical axis. Rough surfaces and irregular edges can affect measurement accuracy. Specimens should be free of any loose debris where in contact with the stage and at all measurement points.

## 5 Equipment

- SmartScope FOV instrument with control and measurement software
- Certified reference materials (CRMs):

- Calibrated microrule
- Calibrated Grade B (or better) [1] gage block set

## 6 STANDARDS AND CONTROLS

The instrument contains a built-in, NIST (National Institute of Standards and Technology) traceable, optical reference filar. The instrument determines its magnification factor automatically by reference to this filar. This internal calibration process is verified by reference to measurements made on a certified microrule and/or gage blocks.

## 7 PROCEDURE

### 7.1 Select Analysis Range

Select the appropriate lens and adjust the magnification to distinguish the evidentiary feature of interest (FOI) to be measured. Observe the approximate range of travel required to measure the feature along the X, Y, and Z axes. Performance must be verified on a certified microrule and/or gage blocks with the same lens at approximately the same magnification, and over a range at least as large as the evidentiary measurements.

### 7.2 Verify Instrument Performance

A. For X-Y table translation, X- and Y- axes are verified separately. For each axis, select a range of the microrule that is at least as large as the maximum translation that will be performed on the evidence.

   1. Align the microrule along the X-axis. Set the zero at one end of the selected range and translate the stage to the other end of the range and record the measurement. Use the software to return to zero and record any deviation from the initial filar position. Repeat for a total of at least five measurement cycles.

   2. Repeat the measurement and zero-return sequence for the Y-axis.

B. For Z-height, select a gage block at least as large as the thickness of interest on the evidence. Set the Z-axis zero with the stage surface in focus. Translate to the gage block, autofocus on the top of the block, and record the measurement. Return to zero, refocus the table surface, and record any deviation from the initial focus position. Repeat for a total of at least five measurement cycles.

C. The instrument is considered to be functioning correctly if the mean value of five or more measurements generated on a standard gage block falls within the 99.7% confidence interval for its certified value or 0.0001 inches, whichever is larger. If the measured values do not agree adequately, a second series of five measurements will be taken. If these also do not agree within the specified tolerance, the instrument will

[1] Per historical Federal Specification GGG-G-15C

be serviced and recalibrated by a service provider that meets the FBI Laboratory requirements.

D. Record the selected CRMs, the verification measurements, their mean values, and the verification result (pass/fail) in the instrument logbook. Record the verification results in the case notes.

### 7.3 Feature Measurement

A. Adjust the lighting to optimize the image using the appropriate light source. Available light sources include coaxial lighting from above, a ring light with selectable lighting directions and incidence angles, or transmitted light from below. The one which gives the best FOI image should be used in a given situation. Adequate brightness and contrast can typically be achieved by adjusting the light level to approximately 40 - 65%.

B. Focus the image.

C. Set the stage reference position. Move an appropriate point of the FOI to the screen centerline, focus, then zero the X, Y, and Z values.

D. Select the measurement mode and a measurement tool from the Toolbox icons.

E. Move the stage to the first point to be recorded. (The software contains edge finder functions which allow optimal selection of the feature edge being measured). Record the point using the “Enter” button on the joystick platform. Relocate the stage to the next point of interest and record the next point until the feature is represented.

F. When the correct number of points has been entered, the software will automatically display the result. For example, if three points are entered along the edge of a circle, the software will fit a curve through the points and generate a diameter measurement. To collect an additional measurement of the same FOI, select “Again”.

G. For measurements that include a Z-axis component, use the autofocus function to focus on the surface at each height of interest.

H. Record the measurement values in the case notes.

## 8 CALCULATIONS

### 8.1 Quantitative Analysis

A. Feature characteristics (such as diameter, line length, or radius of curvature) are automatically calculated by the instrument software from the position of the stage and lens at each of the points entered for that feature. These readings, and their associated measurement uncertainty, may be used to report a range or series of measurements.

B. To report averaged measurements, collect at least five values. Calculate and report the mean and expanded measurement uncertainty.

Mean is calculated as: $\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$, where $\sum_{i=1}^{n} x_i$ is the sum of the measurements, $n$ is the number of measurements and $\bar{x}$ is the mean dimension.

C. Estimate measurement uncertainty as detailed in CHEM-100.

### 8.2 Comparative Analysis

Where quantitative data from two specimens are being compared, a pooled, two-tailed Student's t-test statistic of the sample means will be used for the comparison, as detailed in METAL-210 (Calculations section.)

## 9 Measurement Uncertainty

Quantitative data from this procedure are often used for comparative purposes. Expanded uncertainty should not be used for these inter-comparisons because it increases the probability two samples will appear to be analytically indistinguishable and therefore increases the likelihood of type II errors (false inclusion).

When quantitative data are compared to a particular specification or when quantitative measurements are reported, the estimated measurement uncertainty will be calculated in accordance with CHEM-100. Measurement uncertainty is expected to be significantly influenced by the repeatability of locating feature edges. Since this repeatability is specimen dependent, the measurement uncertainty will be calculated on a case-by-case basis.

## 10 Acceptance Criteria

### 10.1 Calibration

The system is calibrated annually by a service provider that meets the FBI Laboratory certification requirements. During normal operation, the lens magnification is auto-calibrated by the instrument within its measurement routine.

### 10.2 Performance Check

Daily instrument verification criteria are detailed in section 7.2 Verify Instrument Performance.

## 11 Limitations

A. Since measurement relies on imaging the specimen, the instrument cannot measure internal cavities.

B. In order for a feature to be measured accurately, it must be perpendicular to the objective lens.

C. Accurate height/depth (Z) measurements require surfaces that respond well to the instrument's autofocus routine.

## 12 SAFETY

A. The motorized stage is computer-driven. Ties and other loose clothing should not be worn when operating it, and long hair should be tied back. If entanglement occurs, a red panic button labeled "STOP" can be used to interrupt the instrument power and halt the stage motion.

B. The halogen sample illumination lamps are extremely hot when operating and should never be touched unless adequate time has been allowed for cooling. Use gloves when handling halogen lamps to prevent bulb degradation.

## 13 REFERENCES


- CHEM-100, Quality Assurance and Operations Manual, FBI Laboratory, Chemistry Unit
- METAL-210, Examinations for Association or Origin, Chemistry Unit
- Federal Specification GGG-G-15C: Gage Blocks and Accessories (20 Mar 1975)


## 14 REVISION HISTORY

| Revision | Issued | Changes |
|---|---|---|
| 06 | 09/30/2022 | Revised to comply with new formatting requirements. Distributed information from previous Instrumental Conditions and Decision Criteria sections into Acceptance Criteria and Procedure sections. Removed informational references. Clarified 3-D as v3-D. Added gage block grade source. |