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WELCOME

Thank you for joining the session. This session will be recorded. Due to the number of participants, all attendees have been muted upon entry. If you have any questions, please use the chat feature and your questions will be addressed at the end of the presentation. Any questions not addressed by the close of the program will be collected and addressed by email.

Thank you!

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Statistics

For ASTM Precision and Bias

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Introduction

- The ability to describe data in various ways has always been important. The need to organize masses of information has led to the development of formalized ways of describing data. The purpose of this presentation is to introduce the viewer to some of the basic tenants of statistics used in ASTM standards.

Determining the precision of a Test Method

- Statistics frequently come up in the calculation of precision. ASTM offers several recommendations for determining the precision of a Test Method. The two most widely referenced practices are:
  - ASTM E691- Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method, and
  - ASTM D6300 – Standard Practice for Determination of Precision and Bias Data for Use in Test Methods for Petroleum Products and Lubricants

Useful concepts that will be covered in this module

- *From E691 and D6300 (but not necessarily specific to these standards)*
  - Average
  - Accuracy
  - Bias
  - Ruggedness Test
  - Interlaboratory Study
  - Observation
  - Standard deviation
  - Variance
  - Precision
  - Repeatability conditions
  - Repeatability limit
  - Reproducibility conditions
  - Reproducibility limit
  - Test result
  - Between-laboratory consistency statistic, h
  - Within-laboratory consistency statistic, k
  - Analysis of Variance (ANOVA)
  - Outlier
  - Random error

Explanation of concepts

- Average
  - Also referred to as Mean.
  - Often used to express the middle of a numerical data set.
  - The sum of all values, divided by the total number of values included in the calculation.
  - The average of a set of values is not always representative of the data set.
    - Average income of bus passengers

- Accuracy
  - The closeness of agreement between a test result and an accepted reference value.

Explanation of concepts

- Bias
  - The difference between the expectation of the test result and an accepted reference value.
    - For example:

    If several labs were each given the opportunity to determine the mass of the famed platinum-iridium kilogram standard, and the average reported result was 0.9998, the average bias would be 0.02% low.

    Some standards allow for bias correction.

- Precision
  - The closeness of agreement between independent test results obtained under stipulated conditions.
    - For example:

    Weighing yourself on your bathroom scale does not always give you the same result, even when you are simply stepping off the scale and right back on. That is because there is variability in the measurement system.

Explanation of concepts

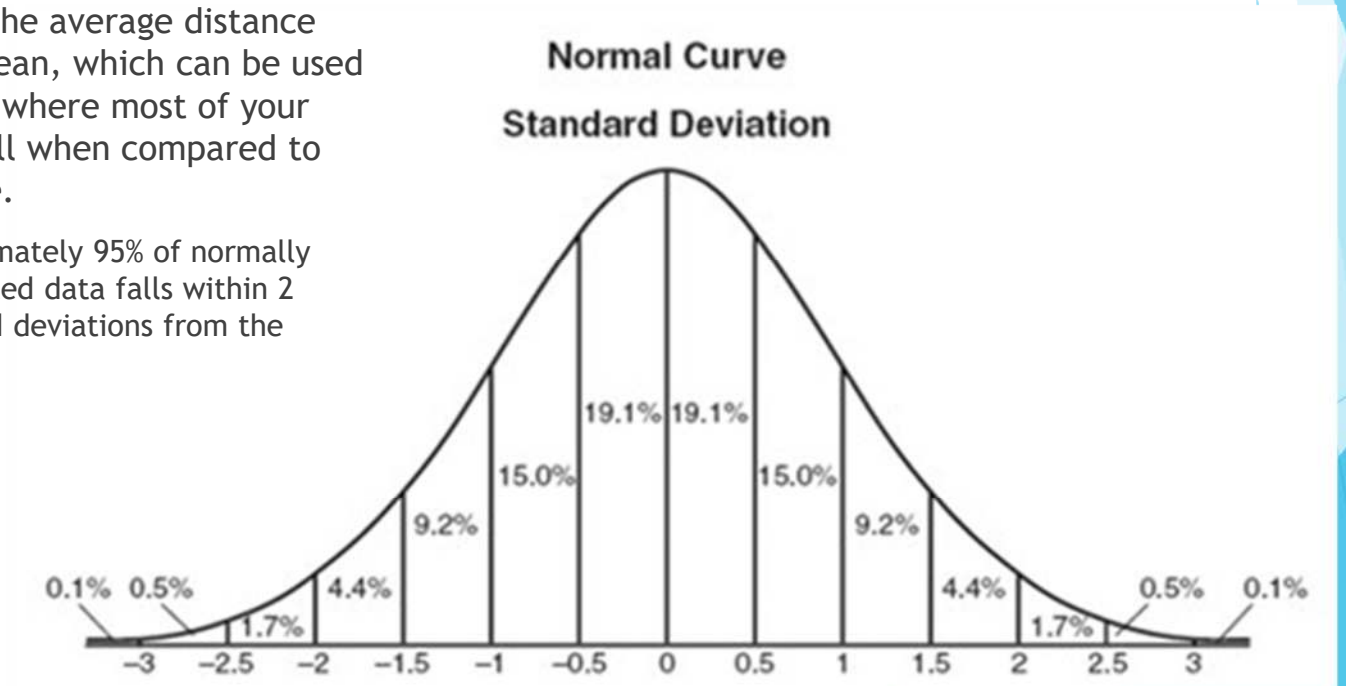
- Ruggedness Test
  - A planned experiment in which environmental factors or test conditions are deliberately varied in order to evaluate the effects of such variation.
    - For example:

    We can help you design a ruggedness test to determine if there is a significant difference whether you run your test method at 25°C or 50°C, or over 2 days vs. 5 days.

- ASTM Interlaboratory Study (ILS)
  - A designed procedure for obtaining a precision statement for a test method, involving multiple laboratories, each generating replicate test results on one or more materials.
  - Interlaboratory Studies in support of ASTM Test Methods are eligible for administrative support provided by ASTM's ILS Program.
    - www.ASTM.org/ILS

Explanation of concepts

- Standard Deviation
  - Generally, the average distance from the mean, which can be used to describe where most of your data will fall when compared to the average.
    - Approximately 95% of normally distributed data falls within 2 standard deviations from the mean.



Explanation of concepts

- Observation
  - The process of obtaining information regarding the presence or absence of an attribute of a test specimen, or of making a reading on a characteristic or dimension of a test specimen.
    - An observation may be a stepping stone in the calculation of a final result.
      - For example:

      You may need to record the temperature of a specimen along with the number of colonies counted and the distance between colonies in order to calculate one test result.

- Test result
  - The value of a characteristic obtained by carrying out a specified test method.
    - The test result is the final reportable value, so if a test method calls for three measurements to be averaged, then only the final averaged value constitutes a Test Result, the intermediate test observations are required, but not reportable.

Explanation of concepts

- Standard deviation
  - Represents the distance from any point in the data set to the center of the data set.

$$\sigma = \sqrt{\frac{\Sigma\ (X - \overline{X})^2}{n - 1}}$$

The larger the standard deviation in a data set, the greater the spread of values around the average.

- For example:

  Data set #1:

  5, 6, 5, 7, 6, 6, 7

  Data set #2:

  9, 2, 3, 7, 8, 1, 12

Both have the same average (6.0), but Data set #2 has a standard deviation 5 times that of Data set #1.

Explanation of concepts

- Repeatability conditions
  - Conditions where independent test results are obtained with the same method, on identical test items, in the same laboratory, by the same operator, using the same equipment, within short intervals of time.
    - When participating in an interlaboratory study (ILS), we try to control some of the most significant variables, while leaving each lab free to choose others, such as brands and manufacturers of necessary reagents and equipment.
- Repeatability Limit
  - The quantitative expression for the random error associated with the difference between two independent test results obtained under repeatability conditions tat would be exceeded with an approximate probability of 5% (just one case in 20 in the long run) in the normal and correct operation of the test method. The value equal to or below which the absolute difference between two single test results on identical material, obtained by the same operator, in the same lab, using the same Test Method, may be expected to lie with a probability of 95%.

Example

1 minute later...

Explanation of concepts

- Reproducibility Conditions
  - Conditions where independent test results are obtained with the same method on identical test items in different laboratories with different operators using different equipment.
    - In order to determine the expected variability between laboratories, we try to ensure that there are certain conditions that are different between participants, such as operator, location, environment, and equipment.
- Reproducibility Limit
  - A quantitative expression for the random error associated with the difference between two independent results obtained under reproducibility conditions that would be exceeded with an approximate probability of 55 (one case in 20 in the long run) in the normal and correct operation of the test method. The value equal to or below which the absolute difference between two single test results on identical material, obtained by operators in different labs, using the same Test Method, may be expected to lie with a probability of 95%.

Explanation of concepts

- Between-laboratory consistency statistic, h
  - The ratio of the cell deviation to the standard deviation of the cell averages.
- Within-laboratory consistency statistic, k
  - The ratio of the cell standard deviation to the repeatability standard deviation.

E691 – 16

TABLE 5 Critical Values of *h* and *k* at the 0.5 % Significance Level

Critical value of *h*	Number of labs *p*	Critical values of *k* Number of replicates per lab, *n*								
		2	3	4	5	6	7	8	9	10
1.15	3	1.72	1.67	1.61	1.56	1.52	1.49	1.47	1.44	1.42
1.49	4	1.95	1.82	1.73	1.66	1.60	1.56	1.53	1.50	1.47
1.74	5	2.11	1.92	1.79	1.71	1.65	1.60	1.56	1.53	1.50
1.92	6	2.22	1.98	1.84	1.75	1.68	1.63	1.59	1.55	1.52
2.05	7	2.30	2.03	1.87	1.77	1.70	1.65	1.60	1.57	1.54
2.15	8	2.36	2.06	1.90	1.79	1.72	1.66	1.62	1.58	1.55
2.23	9	2.41	2.09	1.92	1.81	1.73	1.67	1.62	1.59	1.56
2.29	10	2.45	2.11	1.93	1.82	1.74	1.68	1.63	1.59	1.56
2.34	11	2.49	2.13	1.94	1.83	1.75	1.69	1.64	1.60	1.57
2.38	12	2.51	2.14	1.96	1.84	1.76	1.69	1.64	1.60	1.57
2.41	13	2.54	2.15	1.96	1.84	1.76	1.70	1.65	1.61	1.58
2.44	14	2.56	2.16	1.97	1.85	1.77	1.70	1.65	1.61	1.58
2.47	15	2.57	2.17	1.98	1.86	1.77	1.71	1.66	1.62	1.58
2.49	16	2.59	2.18	1.98	1.86	1.77	1.71	1.66	1.62	1.58
2.51	17	2.60	2.19	1.99	1.86	1.78	1.71	1.66	1.62	1.59
2.53	18	2.61	2.20	1.99	1.87	1.78	1.72	1.66	1.62	1.59
2.54	19	2.62	2.20	2.00	1.87	1.78	1.72	1.67	1.62	1.59
2.56	20	2.63	2.21	2.00	1.87	1.79	1.72	1.67	1.63	1.59
2.57	21	2.64	2.21	2.00	1.88	1.79	1.72	1.67	1.63	1.59
2.58	22	2.65	2.21	2.01	1.88	1.79	1.72	1.67	1.63	1.59
2.59	23	2.66	2.22	2.01	1.88	1.79	1.72	1.67	1.63	1.59
2.60	24	2.66	2.22	2.01	1.88	1.79	1.73	1.67	1.63	1.60
2.61	25	2.67	2.23	2.01	1.88	1.79	1.73	1.67	1.63	1.60
2.62	26	2.67	2.23	2.02	1.89	1.80	1.73	1.68	1.63	1.60
2.62	27	2.68	2.23	2.02	1.89	1.80	1.73	1.68	1.63	1.60
2.63	28	2.68	2.23	2.02	1.89	1.80	1.73	1.68	1.63	1.60
2.64	29	2.69	2.24	2.02	1.89	1.80	1.73	1.68	1.64	1.60
2.64	30	2.69	2.24	2.02	1.89	1.80	1.73	1.68	1.64	1.60

See Section X1.2 for derivations and calculation formulas for calculation of critical values for the *h* and *k* consistency statistics.
For calculation of the *h* critical values see Eq X1.5 in X1.2.2.1.
For calculation of the *k* critical values see Eq X1.13 in X1.2.3.2.

ASTM E691-16 Table 5 (detail)

E691 – 16

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2.34	11	2.49	2.13	1.94	1.83	1.75	1.69	1.64
2.38	12	2.51	2.14	1.96	1.84	1.76	1.69	1.64
2.41	13	2.54	2.15	1.96	1.84	1.76	1.70	1.65
2.44	14	2.56	2.16	1.97	1.85	1.77	1.70	1.65
2.47	15	2.57	2.17	1.98	1.86	1.77	1.71	1.66
2.49	16	2.59	2.18	1.98	1.86	1.77	1.71	1.66
2.51	17	2.60	2.19	1.99	1.86	1.78	1.71	1.66

Explanation of concepts

- Outlier
  - A result far enough in magnitude from other results to be considered not a part of the set.
    - It is always important to note any laboratory specific reasons or justifications for a potential outlier, such as instrument error, technician error, difficulties with a particular sample or material…
    - Studies with a limited number of participants are particularly susceptible to seeing acceptable data points flagged as outliers.
- Random error
  - The chance variation encountered in all test work despite the closest control of variables.
    - There will always be variables that are beyond the control of any study participants. When possible, it can be helpful to segregate this random error.

Explanation of concepts

- Variance
  - A measure of the spread of data in your sample.
  - The sum of the squares of the differences from each data to the sample mean, divided by the number of data points measured, minus one, gives an estimate of the total population variance.
- Analysis of Variance (ANOVA)
  - A technique that enables the total variance of a method to be broken down into its component factors, comparing the means of two or more groups.
    - One-way ANOVA
      - One factor with at least two levels that are independent
    - Sampling distribution of means must be normally distributed.
    - Outliers should be removed before comparisons are made.

Questions?

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