Chapter 1.General Information

1.1Scope

Routine verification of the net contents of packages is an important part of any weights and measures program to facilitate value comparison and fair competition. Consumers have the right to expect packages to bear accurate net content information. Those manufacturers whose products are sold in such packages have the right to expect that their competitors will be required to adhere to the same standards.

The procedures in this handbook are recommended for use to verify the net quantity of contents of packages kept, offered, or exposed for sale, or sold by weight, measure (including volume, and dimensions), or count at any location (e.g., at the point-of-pack, in storage warehouses, retail stores, and wholesale outlets).

When and where to use these procedures?

An effective program will typically include testing at each of the following levels.

*Point-of-pack*

Testing packages at the “point-of-pack” has an immediate impact on the packaging process.  Usually, a large number of packages of a single product are available for testing at one place. This allows the inspector to verify that the packer is following current good packaging practices. Inspection at the point-of-pack also provides the opportunity to educate the packer about the legal requirements that products must meet and may permit resolution of any net content issues or other problems that arise during the testing. Point-of-pack testing is not always possible because packing locations can be in other States or countries. Work with other State, county, and city jurisdictions to encourage point-of-pack inspection on products manufactured in their geographic jurisdictions. Point-of-pack inspections cannot entirely replace testing at wholesale or retail outlets, because point-of-pack inspections do not include imported products or the possible effects of product distribution and moisture loss. Point-of-pack inspections only examine the manufacturing process. Therefore, an effective testing program will also include testing at wholesale and retail outlets.

*Wholesale*

Testing packages at a distribution warehouse is an alternative to testing at the point-of-pack with respect to being able to test large quantities of and a variety of products. Wholesale testing is a very good way to monitor products imported from other countries and to follow up on products suspected of being underfilled based on consumer complaints or findings made during other inspections, including those done at retail outlets.

*Retail*

Testing packages at retail outlets evaluates the soundness of the manufacturing, distributing, and retailing processes of the widest variety of goods at a single location. It is an easily accessible, practical means for State, county and city jurisdictions to monitor packaging procedures and to detect present or potential problems. Generally, retail package testing is not conducive to checking large quantities of individual products of any single production lot. Therefore, follow-up inspections of a particular brand or lot code number at a number of retail and wholesale outlets, and ultimately at the point-of-pack are extremely important aspects in any package-checking scheme. After the evaluation of an inspection lot is completed, the jurisdiction should consider what, if any, further investigation or follow-up is warranted. At the point-of-sale, a large number of processes may affect the quality or quantity of the product. Therefore, there may be many reasons for any inspection lot being out of compliance. A shortage in weight or measure may result from mishandling the product in the store, or the retailer’s failure to rotate stock. Shortages may also be caused through mishandling by a distributor, or failure of some part of the packaging process. Shortages may also be caused by moisture loss (desiccation) if the product is packaged in permeable media. Therefore, being able to determine the cause of an error in order to correct defects is more difficult when retail testing is used.

(Amended 2002)

***What products can be tested?***

Any commodity sold by weight, measure, or count may be tested. The product to be tested may be chosen in several ways. The decision may be based on different factors, such as (1) marketplace surveys (e.g., jurisdiction-wide surveys of all soft drinks or breads), (2) surveys based on sales volume, or (3) audit testing (see Section 1.3) to cover as large a product variety as possible at food, farm, drug, hardware stores, or specialty outlets, discount and department stores. Follow-up of possible problems detected in audit testing or in review of past performance tends to concentrate inspection resources on particular commodity types, brand names, retail or wholesale locations, or even particular neighborhoods. The expected benefits for the public must be balanced against the cost of testing.  Expensive products should be tested because of their cost per unit. However, inexpensive items should also be tested because the overall cost to individual purchasers may be considerable over an extended period.  Store packaged items, which are usually perishable and not subject to other official monitoring, should be routinely tested because they are offered for sale where they are packed. Products on sale and special products produced for local consumption should not be overlooked because these items sell quickly in large amounts.

Regardless of where the test occurs, remember that it is the inspector's presence in the marketplace through routine unannounced testing that ensures equity and fair competition in the manufacturing and distribution process. Finally, always follow up on testing to ensure that the problems are corrected; otherwise, the initial testing may be ineffective.

1.2Package Requirements

The net quantity of content statement must be “accurate,” but reasonable variations are permitted. Variations in package contents may be a result of deviations in filling. The limits for acceptable variation are based on current good manufacturing practices in the weighing, measuring, and packaging process. The first requirement is that accuracy is applied to the average net contents of the packages in the lot. The second requirement is applied to negative errors in individual packages. These requirements apply simultaneously to the inspection of all lots of packages except as specified in “Exceptions to the Average and Individual Package Requirements” in this section.

*Inspection Lot*

An “inspection lot”  (called a “lot” in this handbook) is defined as a collection of identically labeled (except for quantity or identity in the case of random packages) packages available for inspection at one time.  The collection of packages will pass or fail as a whole based on the results of tests on a sample drawn from this collection. This handbook describes procedures to determine if the packages in an “inspection lot” contain the declared net quantity of contents and if the individual packages variations are within acceptable limits.

*Average Requirement*

In general, the average net quantity of contents of packages in a lot must at least equal the net quantity of contents declared on the label. Plus or minus variations from the declared net weight, measure, or count are permitted when they are caused by unavoidable variations in weighing, measuring, or counting the contents of individual packages that occur in current good manufacturing practice. Such variations must not be permitted to the extent that the average of the quantities in the packages of a particular commodity or a lot of the commodity that is kept, offered, exposed for sale, or sold, is below the stated quantity. (See Section 3.7, “Pressed and Blown Glass Tumblers and Stemware” and Section 4.3, “Packages Labeled by Count of 50 Items or Less” for exceptions to this requirement.)

*Individual Package Requirement*

The variation of individual package contents from the labeled quantity must not be “unreasonably large.” In this handbook, packages that are underfilled by more than the Maximum Allowable Variation specified for the package are considered unreasonable errors. Unreasonable shortages are not generally permitted, even when overages in other packages in the same lot, shipment or delivery compensate for such shortage. This handbook does not specify limits of overfilling, which is usually controlled by the packer.

*Maximum Allowable Variation*

The limit of “reasonable variation” for an individual package is called a “Maximum Allowable Variation” (MAV). An MAV is a deviation from the labeled weight, measure, or count of an individual package beyond which the deficiency is considered unreasonable. Each sampling plan limits the number of negative package errors permitted to be greater than the MAV.

*Deviations Caused by Moisture Loss or Gain*

Deviations from the net quantity of contents caused by the loss or gain of moisture from the package are permitted when they are caused by ordinary and customary exposure to conditions that normally occur in good distribution practice and that unavoidably result in change of weight or measure. According to regulations adopted by the U.S. Environmental Protection Agency, no moisture loss is recognized on pesticides. (See Code of Federal Regulations 40 CFR 156.10.)

Why do we allow for moisture loss or gain?

Some packaged products may lose or gain moisture and, therefore, lose or gain weight or volume after packaging. The amount of lost moisture depends upon the nature of the product, the packaging material, the length of time it is in distribution, environmental conditions, and other factors. Moisture loss may occur even when manufacturers follow good distribution practices. Loss of weight “due to exposure” may include solvent evaporation, not just loss of water. For loss or gain of moisture, apply the moisture allowances to both the maximum allowable variations permitted for individual packages and the average net quantity of contents before determining the conformance of a lot.

This handbook provides “moisture allowances” for some meat and poultry products, flour, and dry pet food. (See “Moisture Allowances” in Chapter 2.) These allowances are based on the premise that when the average net weight of a sample is found to be less than the labeled weight, but not by an amount that exceeds the allowable limit, either the lot is declared to be within the moisture allowance, or more information must be collected before deciding lot compliance or noncompliance.

Test procedures for flour, some meat, and poultry are based on the concept of a “moisture allowance” also known as a “gray area” or “no decision” area. (See Section 2.3, Basic Test Procedure, Calculations, “How is the Maximum Allowable Variation corrected for the Moisture Allowance/How is the Average Error for Moisture Allowance corrected?”) When the average net weight of a sample is found to be less than the labeled weight, but not more than the boundary of the “gray area,” the lot is said to be in the “gray” or “no decision area.” The gray area is not a tolerance. More information must be collected before lot compliance or noncompliance can be decided. Appropriate enforcement should be taken on packages found short weight and outside of the “moisture allowance” or “gray area.”

(Amended 2002)

*Exceptions to the Average and Individual Package Requirements*

There is an exemption from the average requirement for packages labeled by count of 50 or fewer items. The reason for this exemption is that the package count does not follow a “normal” distribution even if the package is designed to hold the maximum count indicated by the label declaration (e.g., egg cartons and packages of chewing gum). Another exception permits an “allowable difference” in the capacity of glass tumblers and stemware because mold capacity doesn’t follow a normal distribution.

1.3Sampling Plans

This handbook contains two sampling plans to use to inspect packages: **Category A** and **Category B**. Use the **Category B** Sampling Plans to test meat and poultry products at point-of-pack locations that are subject to U. S. Department of Agriculture Food Safety and Inspection Service (FSIS) requirements. When testing all other packages, use the **Category A** Sampling Plan.

***Why is sampling used to test packages?***

Inspections by weights and measures officials must provide the public with the greatest benefit at the lowest possible cost. Sampling reduces the time to inspect a lot of packages, so a greater number of items can be inspected. Net content inspection, using sampling plans for marketplace surveillance, protects consumers who cannot verify the net quantity of contents. This ensures fair trade practices and maintains a competitive marketplace. It also encourages manufacturers, distributors, and retailers to follow good manufacturing and distribution practices.

Why is the test acceptance criteria statistically corrected, and what are the confidence levels of the sampling plans?

Testing a “sample” of packages from a lot instead of every package is efficient, but the test results have a “sampling variability” that must be corrected before determining if the lot passes or fails. The Category A sampling plans give acceptable lots a 97 % or better probability of passing. An “acceptable” lot is defined as one in which the “average” net quantity of contents of the packages equals or exceeds the labeled quantity. The Category B sampling plans give acceptable lots at least a 50 % probability of passing. The sampling plans used in this handbook are statistically valid. That means the test acceptance criteria are statistically adjusted, so they are both valid and legally defensible. This handbook does not discuss the statistical basis, risk factors, or provide the operating characteristic curves for the sampling plans. For information on these subjects, see explanations on “acceptance sampling” in statistical reference books.

Why random samples?

A randomly selected sample is necessary to ensure statistical validity and reliable data. This is accomplished by using random numbers to determine which packages are chosen for inspection. Improper collection of sample packages can lead to bias and unreliable results.

May audit tests and other shortcuts be used to identify potentially violative lots?

Shortcuts may be used to speed the process of detecting possible net content violations. These audit procedures may include the following: using smaller sample sizes, spot checks using tare lists provided by manufacturers, selecting samples without collecting a random sample. These and other shortcuts allow spot checking of more products than is possible with the more structured techniques, but do not take the place of Category A or B testing.

Can audit tests and other shortcuts be used to take enforcement action?

No. Do not take enforcement action using audit test results.

If, after an audit test, there is suspicion that a lot of packages is not in compliance, use the appropriate Category A or Category B sampling plan to determine if the lot complies with the package requirements.

1.4Other Regulatory Agencies Responsible for Package Regulations and Applicable Requirements

In the United States, several Federal agencies issue regulations regarding package labeling and net contents. The U.S. Department of Agriculture regulates meat and poultry. The Food and Drug Administration regulates food, drugs, cosmetic products, and medical devices under the Food, Drug, and Cosmetic Act (FDCA) and the Fair Packaging and Labeling Act (FPLA). The Federal Trade Commission regulates most non-food consumer packaged products as part of the agency's responsibility under the FPLA. The Environmental Protection Agency regulates pesticides.  The Bureau of Alcohol, Tobacco, and Firearms in the U.S. Department of the Treasury promulgates regulations for packaged tobacco and alcoholic beverages as part of its responsibility under the Federal Alcohol Administration Act.

Packaged goods produced for distribution and sale also come under the jurisdiction of State and local weights and measures agencies that adopt their own legal requirements for packaged goods. Federal statutes set requirements that pre-empt State and local regulations that are or may be less stringent or not identical to Federal regulation depending on the Federal law that authorizes the Federal regulation. The application of Handbook 133 procedures occurs in the context of the concurrent jurisdiction among Federal, State, and local authorities. Therefore, all agencies using this handbook should keep abreast of the revisions to Federal agency regulations that may contain sampling or testing information not in the regulations at the time of publication of this handbook. See Table 1-1. in Appendix A for information on the responsible agencies for package regulations and the requirements of this handbook that must be used when testing products concurrently subject to pre-emptive federal regulations.

1.5Assistance in Testing Operations

If the storage, display, or location of any lot of packages requires special equipment or an abnormal amount of labor for inspection, the owner or the operator of the business must supply the equipment and/or labor as required by the weights and measures official.

1.6Health and Safety

This handbook cannot address all of the health and safety issues associated with its use. The inspector is responsible for determining the appropriate safety and health practices and procedures before starting an inspection (e.g., contact the establishment's health and safety official). Comply with all handling, health, and safety warnings on package labels and those contained in any associated material safety data sheets. The inspector must also comply with Federal, State, or local health and safety laws or other appropriate requirements in effect at the time and location of the inspection. Contact your supervisor to obtain information regarding your agencies safety and health policies and to obtain appropriate safety equipment.

1.7Good Measurement Practices

The procedures in this handbook are designed to be technically sound and represent good measurement practices. To assist in documenting tests, we have included “model” inspection report forms designed to record the information.

*Traceability Requirements for Measurement Standards and Test Equipment*

Each test procedure presented in this handbook includes a list of the equipment needed to perform the inspection. The scales and other measurement standards used (e.g., balances, mass standards, volumetric, and linear measures) to conduct any test must be traceable to the National Institute of Standards and Technology (NIST). Standards must be used in the manner in which they were designed and calibrated for use.

*Certification Requirements for Standards and Test Equipment*

All measurement standards and test equipment identified in this handbook or associated with the test procedures must be calibrated or standardized before initial use. This must be done according to the instructions found in NIST Handbook 145, “Handbook for the Quality Assurance of Metrological Measurements,” or other recognized procedures (e.g., those adopted for use by a State weights and measures laboratory). After initial certification, the standards must be routinely recertified according to your agency’s measurement assurance policies.

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Chapter 2.Basic Test Procedure – Gravimetric Testing

2.1Gravimetric Test Procedure for Checking the Net Contents of Packaged Goods

The gravimetric test method uses weight measurement to determine the net quantity of contents of packaged goods. This handbook includes general test methods to determine the net quantity of contents of packages labeled in terms of weight and special test methods for packages labeled in terms of fluid measure or count. Gravimetric testing is the preferred method of testing most products because it reduces destructive testing while maximizing inspection resources.

2.2Measurement Standards and Test Equipment

***What type of scale is required to perform the gravimetric test method?***

Use a scale (for this handbook the term scale includes balances) that has at least 100 scale divisions. It must have a load-receiving element of sufficient size and capacity to hold the packages during weighing. It also requires a scale division no larger than 1/6 of the Maximum Allowable Variation (MAV) for the package size being weighed. The MAV/6 requirement is crucial to ensure that the scale has adequate resolution to determine the net contents of the packages. Subsequent references to product test criteria agreeing within one scale division are based on scale divisions that are equal to or only slightly smaller than the MAV/6.

**Example:** The MAV for packages labeled 113 g (0.25 lb) is 7.2 g (0.016 lb)

(See Table 2.5.) MAV/6 is 1.2 g (0.002 lb).  In this example, a 1 g (0.002 lb) scale division would be the largest unit of measure appropriate for weighing these packages.

***How often should I verify the accuracy of a scale?***

Verify the accuracy of a scale before each initial daily use, each use at a new location, or when there is any indication of abnormal equipment performance (e.g., erratic indications). Recheck the scale accuracy if it is found that the lot does not pass, so there can be confidence that the test equipment is not at fault.

***Which accuracy requirements apply?***

Scales used to check packages must meet the acceptance tolerances specified for their accuracy class in the current edition of NIST Handbook 44, “Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices” (NIST HB 44). The tolerances for Class II and Class III digital scales are presented in Section 2.20, Scales, NIST HB 44.

**Note:** If the package checking scale is not marked with a “class” designation, use NIST HB 44 Table 1-1. to determine the applicable tolerance.

***What considerations affect measurement accuracy?***

Always use good weighing and measuring practices. For example, be sure to use weighing and measuring equipment according to the manufacturer’s instructions and make sure the environment is suitable. Place scales and other measuring equipment (e.g., flasks and volumetric measures) on a rigid support and maintain them in a level condition if being level is a requirement to ensure accuracy.

***In testing, which tolerances apply to the scale?***

Do not use a scale if it has an error that exceeds the specified tolerance in any of the performance tests described in the following section.

Determine the total number of divisions (i.e., the minimum increment or graduation indicated by the scale) of the scale by dividing the scale’s capacity by the minimum division.

**Example:**  A scale with a capacity of 5 000 g and a minimum division of 0.1 g has 50 000 divisions.

From Table 1-1. determine the class of the scale using the minimum scale division and the total number of scale divisions.

**Example:**  On a scale with a minimum division of 0.1 g and 50 000 total scale divisions the appropriate class of scale is “II.”

**Note:** If a scale is used where the number of scale divisions is between 5 001 and 10 000 and the division size is 0.1 g or greater and is not marked with an accuracy Class II marking, Class III scale tolerances apply.

Determine the tolerance from Table 1-2. in divisions appropriate for the test load and class of scale.

**Example:**  Determine the number of divisions for any test load by dividing the value of the mass standard being applied by the minimum division indicated by the scale. For example, if the scale has a minimum division of 0.1 g and a 1 500 g mass standard is applied, the test load is equal to 15 000 divisions (1 500/0.1). On a Class II scale with a test load between 10 000 and 20 000 divisions, Table 1-2. indicates the tolerance is plus or minus one division.

***Which performance tests should be conducted to ensure the accuracy of a scale?***

Use the following procedures to verify the scale. The following procedures, based on those required in NIST Handbook 44, have been modified to reduce the amount of time required for testing scales in field situations.

*Increasing-Load Test*

Use certified mass standards to conduct an “increasing-load test” with all test loads centered on the load-receiving element. Start the test with the device on zero and progress with increasing test loads to a “maximum test load” of at least 10 percent more than the gross weight of the packages to be tested. Use at least three different test loads of approximately equal value to test the device up to the “maximum test load.” Verify the accuracy of the device at each test load. Include the package tare weight as one of the test points.

*Decreasing-Load Test*

For all types of scales, other than one with a beam indicator or equal-arm balance, conduct a “decreasing-load test” with all test loads centered on the load-receiving element. Use the same test loads used in the “increasing-load test” of this section, and start at the “maximum test load.” Remove the test loads in the reverse order of the increasing-load test until all test loads are removed. Verify the accuracy of the scale at each test load.

*Shift Test*

Use a test load equal to one-half of the “maximum test load” used for the “increasing-load test.” For bench scales (see Diagram 1) place the test load in the center of four separate quadrants, equidistant between the center and edge of the load-receiving element and determine the accuracy in each quadrant for equal-arm balances. For example, where the load-receiving element is a rectangular or circular shape, place the test load in the center of the area represented by the shaded boxes in the following diagrams.

**Diagram 1. Bench ScalesDiagram 2. Equal-Arm Balance**

*Return to Zero*

Conduct the return to zero test whenever all the test weights from the scale are removed, check to ensure that it returns to a zero indication.

***Which standards apply to other test equipment?***

Specifications, tolerances, and other technical requirements for the other measurement standards and test equipment cited in this handbook are specified in the following NIST publications. These publications may be obtained from the Office of Weights and Measures or the U.S. Government Printing Office.

Mass Standards *-* Use NIST Handbook 105-1, “Specifications and Tolerances for Reference Standards and Field Standard Weights and Measures-Field Standard Weights (NIST Class F)” (1990)

Volumetric Flasks and Cylinders *-* Use NIST Handbook 105-2, “Specifications and Tolerances for Reference Standards and Field Standard Weights and Measures-Field Standard Measuring Flasks” (1996)

Stopwatches - Use NIST Handbook 105-5, “Specifications and Tolerances for Reference Standards and Field Standard Weights and Measures-Field Standard Stopwatches” (1997)

Thermometers - Use NIST Handbook 105-6, “Specifications and Tolerances for Reference Standards and Field Standard Weights and Measures-Specifications and Tolerances for Thermometers” (1997)

2.3Basic Test Procedure

The following steps apply when gravimetrically testing any type of packaged product except Borax and glazed or frozen foods. If the tested products contain Borax, refer to Section 2.4, Borax. If glazed or frozen food is tested, refer to Section 2.6, Drained Weight for Glazed or Frozen Foods.

**The Basic Test Procedure:**

**Identify and define the inspection lot.**

**Select the sampling plan.**

**Select the random sample.**

**Measure the net contents of the packages in the sample.**

**Evaluate compliance with the Maximum Allowable Variation (MAV) requirement.**

**6. Evaluate compliance with the average requirement.**

**Define the Inspection Lot**

The official defines which packages are to be tested and the size of the inspection lot. The lot may be smaller or larger than the production lot defined by the packer. Only take action on the packages contained in the lot that has been defined.

**Note:** Normally, there will never be access to the entire “production lot” from a manufacturer. The “inspection lot” is selected from packages that are available for inspection/test at any location in the distribution chain.

**Example:** An inspection lot should consist of all of the cans of a single brand of peach halves, labeled with a net quantity of 453 g (1 lb). When packages are tested in retail stores, it is not necessary to sort by lot code. If lot codes are mixed during retail testing, be sure to record the lot codes for all of the packages included in the sample so that the inspector and other interested parties can follow up on the information. For special reasons, such as a large number of packages or the prior history of problems with the product or store, the inspector may choose to define a lot as only one type of packaged product (e.g., ground beef). Another reason to narrowly define the lot is if the results of an audit test indicate the possibility of a shortage in one particular lot code within a particular product.

***What is the difference between standard and random weight packages?***

Standard packages are those with identical net content declarations such as containers of soda in 2 L bottles and 2.26 kg (5 lb) packages of flour. “Random packages” are those with differing or no fixed patterns of weight, such as packages of meat, poultry, fish, or cheese.

**Sampling Plans**

***Where are sampling plans located for Category A inspections?***

Use Table 2-1., Sampling Plans for Category A, in Appendix A to conduct Category A inspections.

***Where are sampling plans located for Category B inspections?***

Use Table 2-2., Sampling Plans for Category B, in Appendix A to conduct Category B inspections.

**Basic Inspection Procedure and Record Keeping**

***How are the specific steps of the Basic Test Procedure documented?***

Use an official inspection report to record the inspection information. Attach additional worksheets, test notes, and other information as needed. This handbook provides random and standard packaged products model inspection report forms in Appendix E. The references to box numbers in these instructions refer to the random and standard package reports in Appendix E. Modify the model reports and the box numbers to meet your agency's needs. Other formats that contain more or less information may be acceptable.

**Note:** Inspection reports should be legible and complete. Good record keeping practices typically include record retention for a specified period of time (e.g., 1 to 3 years).

Record the product identity, packaging description, lot code, location of test, and other pertinent data.

Record the labeled net quantity of contents in box 1. Record both metric and inch-pound declarations if they are provided on the package label.

**Example:** If the labeled weight is 453 g (1 lb), record this in box 1.

When the declaration of net quantity on the package includes both the International System of Units (SI) (metric) and inch-pound units, the larger of the two declarations must be verified. The rounding rules in the Uniform Packaging and Labeling Regulation in NIST Handbook 130 permit packers to round declarations up or down based on their knowledge of their package filling targets and the accuracy of packaging equipment.

Determine the larger of the values by converting the SI declaration to inch-pound units, or vice versa, using conversion factors that are accurate to at least six places. Compare the values, and use the larger value in computing the nominal gross weight (see later steps). Indicate on the report which of the declarations are being verified when packages labeled with two units of measure are encountered.

**Example:** If the net weight declared on a package is 1 lb, the metric equivalent (accurate to six significant digits) is 453.592 g. Do not round down or truncate values in the calculations until the nominal gross weight is determined and recorded. If the package is also labeled 454 g, then the metric declaration is larger than the inch-pound declaration and should be used to verify the net contents of the package. The Basic Test Procedure does not prohibit the use of units of weight instead of dimensionless units when recording package errors, nor does it prohibit the use of net content computer programs to determine product compliance. Record the unit of measure in box 2. The unit of measure is the minimum division of the unit of measurement used to conduct the test. If a scale is used that reads to thousandths of a pound, the unit of measure is 0.001 lb even if the scale division is 0.002 lb or 0.005 lb.

**Example:** If the scale has a scale division of 0.5 g, the unit of measure is 0.1 g. If a weighed package that has an error of “- 0.5 g,” record the error as “- 5” using “dimensionless units.” If the scale indicates in increments of 0.002 lb, the unit of measure is 0.001 lb. If a weighed package has an error of “+ 0.016,” record the error as “+ 16” using “dimensionless units.” When using dimensionless units, multiply package errors by the unit of measure to obtain the package error in weight.

Enter the appropriate MAV value in box 3 for the type of package (weight, volume, etc.), the labeled net contents, and the unit of measure.

***Where are Maximum Allowable Variations found?***

Find the MAV values for packages labeled by weight, volume, count, and measure in the tables listed below in Appendix A.

packages labeled by weight **See Table 2-5.**

packages labeled by volume liquid or dry**See Table 2-6.**

packages labeled by count**See Table 2-7.**

packages labeled by length, (width), or area**See Table 2-8.**

packages bearing a USDA seal of inspection – Meat and Poultry

textiles, polyethylene sheeting and film, mulch and soil labeled by volume,**See Table 2-10.**

packaged firewood, and packages labeled by count with less than 50 items

***How is the value of an MAV found?***

Refer to the appropriate table of MAVs and locate the declared quantity that is on the package label in the column marked “Labeled Quantity.” Read across the table to find the value in the column titled “Maximum Allowable Variation.” Record this number in box 3. Determine the MAV in dimensionless units and record in box 4 on the Standard Package Report Form (a dimensionless unit is obtained by dividing the MAV recorded in box 3 by the unit of measure recorded in box 2). Refer to Appendix C, “The Glossary,” for the definition of dimensionless units.

***How many MAVs are permitted in a sample?***

To find out how many minus package errors are permitted to exceed the MAV, see Column 4 in either Table 2-1. (Category A) or Table 2-2. (Category B). Record this number in box 8.

**Random Sample Selection**

***How are the sample packages selected?***

Randomly select a sample from the inspection lot. Random number tables (see Appendix B) or a calculator that is able to generate random numbers may be used to identify the sample. If the packages for the sample are not randomly selected, the test results may not be statistically valid.

**Note:** If the inspector and the party that is ultimately responsible for the packing and declaration of net weight for the product agree to an alternative method of sample selection, document how the sample packages were selected as part of the inspection record.

***How is the size of the “Lot" determined?***

Count the number of packages comprising the inspection lot or estimate the size to within 5 % and record the inspection lot size in box 5.

***How is the sample size determined?***

Refer to Table 2-1. or Table 2-2. to determine the sample size. In Column 1, find the size of the inspection lot (the number recorded in box 5 of the report form). Read across from Column 1 to find the appropriate sample size in Column 2 and record this number in box 6 of the report form.

**Tare Procedures**

***What types of tare may be used to determine the net weight of package goods?***

This handbook defines three types of tare for the inspection of packaged goods. The tare weight may vary considerably from package to package as compared with the variability of the package net contents, even for packages in the same production lot. Although this is not common for most packaging, the basic test procedure in this handbook considers the variation for all tare materials.

*Used Dry Tare*

Used Dry Tare is defined as follows: Used tare material that has been air dried, or dried in some manner to simulate the unused tare weight. It includes all packaging materials that can be separated from the packaged product, either readily (e.g., by shaking) or by washing, scraping, ambient air drying, or other techniques involving more than “normal” household recovery procedures, but not including laboratory procedures like oven drying. Labels, wire closures, staples, prizes, decorations, and such are considered tare. Used Dry Tare is available regardless of where the packages are tested. The net content procedures described in this handbook reference Used Dry Tare.

*Unused Dry Tare*

If testing packages in retail store locations where they are packaged, and sold in small quantities to the ultimate consumers, the basic test procedure may be modified by using samples of the packaging material available in the store. Unused dry tare is defined as:

All unused packaging materials (including glue, labels, ties, etc.) that contain or enclose a product. It includes prizes, gifts, coupons, or decorations that are not part of the product.

*Wet Tare*

If the jurisdiction uses wet tare to determine net weight, follow the procedures described below that reference Used Dry Tare, except make no effort to dry the tare material. If Wet Tare is used to verify the net weight of packages of fresh poultry, hot dogs, and franks that are subject to the USDA regulations, the inspector must allow for moisture loss. Wet Tare is defined as: Used tare material where no effort is made to dry the tare material. Free-flowing liquids are considered part of the tare weight.

***How is a tare weight determined?***

Except in the instance of applying unused dry tare, select the packages for the initial tare sample from the sample packages. Mark the first two (three or five) packages in the order the random numbers were selected; these packages provide the initial tare sample. Determine the gross weight of each package and record it in block a, “Gross Wt,” under the headings “Pkg. 1,” “Pkg. 2,” “Pkg. 3,” etc. on the report form. Except for aerosol or other pressurized packages, open the sample packages, empty, clean, and dry them as appropriate for the packaging material.

***Does the inspection of aerosol containers require special procedures?***

Yes, aerosol containers are handled differently for two reasons. First, regulations under the Uniform Packaging and Labeling Regulation in NIST HB 130 require that packages designed “to deliver” the product under pressure, “must state the net quantity of the contents that will be expelled when the instructions for use as shown on the container are followed.” This means that any product retained in aerosol containers after full dispersion is included in the tare weight. Second, aerosol containers must not be opened because they are pressurized; for safety reasons they should not be punctured or opened. When emptying aerosol containers to determine a tare weight, exhaust them in a well-ventilated area (e.g., under an exhaust hood or outdoors) at least 15 m (50 ft) from any source of open flame or spark.

To ensure that the container properly dispenses the product, read and follow any dispensing instructions on the package. If shaking during use is specified in the instructions, periodically shake (at least two or three times during expulsion of the product).  If directions are not given, shake the container five times with a brisk wrist twisting motion. If the container has a ball agitator, continue the shaking procedure for one minute after the ball has shaken loose.

***How is the tare of vacuum-packed coffee determined?***

The gross weight of a can of vacuum-packed coffee will be more after the seal is broken and air enters the can. In the procedure to determine the tare weight of the packaging material, correct the gross weight determined for unopened cans as follows. Use the initial tare sample packages, weigh, and record the gross weight of the product-filled cans before and after breaking the vacuum seal. Compute the average gross weight difference (open weight minus sealed weight) and record this in box 13a of the report form. The nominal gross weight equals the average tare weight minus the average difference in gross weights plus the labeled weight (box 14): box 13 - box 13a + box 1.

***How is it determined how many packages to select for the initial tare sample?***

For the initial tare sample size, see Column 5 under initial tare sample size in Table 2-1., or Column 3 under initial tare sample size in Table 2-2. Record the initial tare sample size in box 7 on the report form.

**Note:** The initial tare sample size is considered the total tare sample size when the sample size is less than 12.

***How are the tare sample and tare weight of the packaging material determined?***

Except for unused dry tare at the point-of-pack, first determine the tare weight for each package in the initial tare sample and record the value in row b, “Tare Wt.” under the appropriate package number column.

For sample sizes of 12 or more, subtract the individual tare weights from the gross weights (block a, minus block b, on the report form) to obtain the net weight for each package and record these values in block c, “Net Wt,” on the report form.

Determine and record the “range of package errors” (called Rc) for the initial tare sample in box 9 on the report form.  (The range is the difference between the package errors.)

(Amended 2002)

Determine and record the “range of tare weights” (called Rt) in box 10.

Compute the ratio Rc/Rt by dividing the value in box 9 by the value in box 10. Record the resulting value in box 11. (Rc and Rt must both be in the same unit of measure or both in dimensionless units.)

Determine and record in box 12 the total number of packages to be opened for the tare determination from either Table 2-3., for a Category A test or Table 2-4., for a Category B test.

In the first column (titled Ratio of Rc/Rt), locate the range in which the computed Rc/Rt falls. Then, read across to the column headed with the appropriate sample size.

If the total number of packages to open equals the number already opened go to Step 6.

If the total number of packages to open is greater than the number of packages already opened, compute the number of additional packages to open for the tare determination and go to Step 6. Enter the total number of tare samples in box 12.

Determine the average tare weight using the tare weight values for all the packages opened and record the average tare weight in box 13.

***When and where is unused dry tare used, and how is it used to determine an average tare weight?***

You may determine the average tare weight using samples of unused dry tarewhen testing meat, poultry, or any other products that are not subject to regulation of the Food and Drug Administration (FDA). You may use unused dry tare samples when conducting inspections at locations where the point-of-pack and sale are identical (e.g., store-packed products in a supermarket meat case). To determine unused dry tare at the point-of-sale, randomly select two (2) samples of unused dry tare, and weigh each separately. If there is no measurable variation in weight between the samples, proceed with the test using the weight of one of the samples. If the weight of the two (2) initial samples vary, randomly select three (3) additional tare samples and determine the average weight of all five (5) samples. Use this value as the average tare weight.

(Amended 2002)

**Determine Nominal Gross Weight and Package Errors for Tare Sample**

***What is a nominal gross weight?***

A nominal gross weight is used to simplify the calculation of package errors. To compute the nominal gross weight, add the average tare weight (recorded in box 13) to the labeled weight (recorded in box 1). To obtain the package error, subtract a package’s gross weight from the nominal gross weight. The nominal gross weight is represented by the formula:

Nominal gross weight = average tare + labeled weight

***How are individual package errors determined for the tare sample packages?***

Determine the errors of the packages opened for tare by subtracting the nominal gross weight recorded in box 14 from the individual package gross weights recorded for each package (“Pkg 1,” “Pkg 2,” etc.) in block a, “Gross Wt.” The nominal gross weight must be used, rather than the actual net weight, for each package to determine the package error. This ensures that the same average tare weight is used to determine

the error for every package in the sample, not just the unopened packages.

For standard packages, record the package error in the appropriate plus or minus column on the report form for each package opened for tare.

For random packages, determine the package error for the tare sample using a nominal gross weight for each package so that all of the package errors are determined with the same tare weight value. Record the package error on the Random Package Report Form in the appropriate plus or minus column under Package Errors.

**Note:** Converting the package error to dimensionless units allows the inspector to record the package errors as whole numbers disregarding decimal points and zeroes in front and unit of measure after the number.

**Example:** If weighing in 0.001 lb increments, the unit of measure is also 0.001 lb. If the package error for the first package opened for tare is + 0.008 lb, instead of recording 0.008 lb in the plus column, record the error as “8” in the plus column. If the second package error is + 0.060 lb, record the package error as “60” in the plus column, and so on. (This section does not prohibit the use of units of weight or computer programs instead of dimensionless units.)

***How are individual package errors determined for the other packages in the sample?***

Compare the gross weight of each of the unopened sample packages with the nominal gross weight (box 14). Record the package errors in the “Package Errors” section of the report form using either units of weight (lb or g) or dimensionless units.

***How is the total package error computed?***

Add all the package errors for the packages in the sample. Be sure to subtract the minus package errors from the plus package errors and to record the total net error in box 15.

**Evaluating Results**

***How is it determined if a sample passes or fails****?*

The following steps lead the inspector through the process to determine if a sample passes or fails. If the product is subject to moisture allowance, follow the procedures under “Moisture Allowances” in this chapter to correct the MAV.

***How is it determined if packages exceed the Maximum Allowable Variation?***

Compare each minus package error with the MAV recorded in box 3 or box 4 (if using dimensionless units). Circle the package errors that exceed the MAV. These are “unreasonable errors.” Record the number of unreasonable minus errors found in the sample in box 16.

***How is it determined if the negative package errors in the sample exceed the number of MAVs allowed for the sample?***

Compare the number in box 16 with the number of unreasonable errors allowed (recorded in box 8.) If the number found exceeds the allowed number, the lot fails. Record in box 17 whether the number of unreasonable errors found is less or more than allowed.

**Note**: If the total error recorded in box 15 is a plus value and box 17 is “No”, then the number of unreasonable errors is equal to or less than the number allowed (recorded in box 8) and the lot passes.

***How is the average error of the sample determined and does the inspected lot pass or fail the average requirement?***

Determine the average error by dividing the total error recorded in box 15 by the sample size recorded in box 6. Record the average error in box 18 if using dimensionless units or in box 19 if using units of weight. Compute the average error in terms of weight (if working in dimensionless units up to this time) by multiplying the average error in dimensionless units by the unit of measure and record the value in box 19.

If the average error is positive, the inspection lot passes the average requirement.

If the average error is negative, the inspection lot fails under a Category B test. Record in box 20.

If the average error is a negative value when testing under the Sampling Plans for Category A, compute the Sample Error Limit (SEL) as follows:

Compute the Sample Standard Deviation and record it in box 21.

Obtain the Sample Correction Factor from Column 3 of Table 2-1. For Category A test. Record this value in box 22.

Compute the Sample Error Limit using the formula:

Sample Error Limit (box 23) = Sample Standard Deviation (box 21) x

Sample Correction Factor (box 22)

Compliance Evaluation of the Average Error:

If the value of the Average Error (box 18) is smaller than the SEL (box 23), the inspection lot passes.

If the value of the Average Error (disregarding the sign) (box 18) is larger than the SEL (box 23) the inspection lot fails. However, if the product is subject to moisture loss, the lot does not necessarily fail. Follow the procedures under “Moisture Allowances” in this chapter.

**Moisture Allowances**

***How is reasonable moisture loss allowed?***

If the product tested is subject to moisture loss, provide for the moisture allowance by following the steps listed below.

Determine the value of the moisture allowance if the product is listed below.

***What is the moisture allowance for flour and dry pet food?***

The moisture allowance for flour and dry pet food is 3 % of the labeled net weight.

**Note:** Dry pet food means all extruded dog and cat foods and baked treat products packaged in kraft paper bags and/or cardboard boxes with a moisture content of 13 % or less at the time of pack.

***What moisture allowance is used with Used Dry Tare when testing packages that bear a USDA Seal of Inspection?***

There is no moisture allowance when inspecting meat and poultry from a USDA inspected plant when Used Dry Tare and a Category A sampling plan are used.

***What moisture allowance is used with wet tare when testing packages bearing a USDA seal of inspection?***

Use the following guideline when testing meat and poultry from any USDA inspected plant using Wet Tare and a Category A sampling plan.

For packages of fresh poultry that bear a USDA seal of inspection, the moisture allowance is

3 5 of the labeled net weight. For net weight determinations, only, fresh poultry is defined as poultry above –3 ºC (26 ºF). This is a product that yields or gives when push with the thumb.

For packages of franks or hotdogs that bear an USDA seal of inspection, the moisture allowance is 2.5 % of the labeled net weight.

For packages of bacon, fresh sausage, and luncheon meats that bear a USDA seal of inspection, there is no moisture allowance if there is no free-flowing liquid or absorbent materials in contact with the product and the package is cleaned of clinging material. Luncheon meats are any cooked sausage product, loaves, jellied products, cured products, and any sliced sandwich style meat. This does not include whole hams, briskets, roasts, turkeys, or chickens requiring further preparation to be made into ready-to-eat sliced product. When there is no free-flowing liquid inside the package and there are no absorbent materials in contact with the product, Wet Tare and Dried Used Tare are equivalent.

When there is free flowing liquid or absorbent packaging materials in contact with the product, all free liquid is part of the wet tare.

**Calculations**

***How is moisture allowance computed and applied to the average error?***

To compute moisture allowance, multiply the labeled quantity by the decimal percent value of the allowance.

**Example:** Labeled net quantity of flour is 907 g (2 lb)

Moisture Allowance is 3 % (0.03)

Moisture Allowance = 907 g (2 lb) x 0.03 = 27 g (0.06 lb) record this value in box 13a.

***How is the Maximum Allowable Variation corrected for the moisture allowance?***

Adjust the MAV by adding the moisture allowance to the MAV.

**Example:** 907 g (2 lb) package of flour: moisture allowance added to the MAV = 31.7 g (0.07 lb) (MAV for 907 g [2 lb] package) + 27 g (0.06 lb) moisture allowance = a corrected MAV of 58.7 g (0.13 lb)

Correct MAV in dimensionless units by converting the moisture allowance to dimensionless units = 0.06 lb ÷ 0.001 lb = 60. Go to box 4 and add the moisture allowance in dimensionless units to the MAV in dimensionless units.

**Example:** MAV = 70 (MAV for 2 lb where the unit of measure = 0.001 lb) + 60 (moisture allowance in dimensionless units) = 130. Minus package errors must exceed the MAV + gray area before they are declared “unreasonable errors.”

If the number of unreasonable errors exceeds the allowed number (recorded in box 8) the inspection lot fails.

***How is the average error for the moisture allowance corrected?***

If the minus average error (box 18) is larger (disregarding the sign) than the SEL (box 23) and moisture loss applies, compare the difference between box 18 and box 23 with the moisture allowance recorded in box 13a. (Make sure that all the values are in units of weight or in dimensionless units before making this comparison.) If box 13a is larger than the difference between box 18 and 23, then the lot is considered to be in the gray area.

**Example:** Box 13a for 2 lb flour is 60 (dimensionless units); box 18 is 2 (dimensionless units); box 23 is 0.550 (dimensionless units). The difference between box 18 and box 23 is 1.450 (dimensionless units). Since box 13a is 60 (dimensionless units), 13a is larger than the difference between box 18 and box 23, the lot is considered to be in the gray area and further investigation is necessary before ruling out moisture loss as the reason for shortweight.

When the average error of a lot of fresh poultry, franks, or hot dogs from a USDA-inspected plant is minus, but does not exceed the established “moisture allowance” or “gray area,” contact the appropriate USDA official and/or plant management personnel to determine what information is available on the lot in question. Questions to the USDA official and/or plant management representative may include:

Is a quality control program in place?

What information is available concerning the lot in question?

If net weight checks were completed, what were the results of those checks?

What adjustments, if any, were made to the target weight?

**Note:** If USDA or plant management has data on the lot, such data may help to substantiate that the "lot" met net content requirements at the point of manufacture.

This handbook provides "moisture allowances" for some meat and poultry products, flour, and dry pet food. These allowances are based on the premise that when the average net weight of a sample is found to be less than the labeled weight, but not by an amount that exceeds the allowable limit, either the lot is declared to be within the moisture allowance or further investigation can be conducted.

Deviations from net quantity of contents caused by the loss or gain of moisture from the package are permitted when caused by ordinary and customary exposure to conditions that occur under good distribution practices. If evidence is obtained and documented to prove that the lot was shipped from the packaging plant in a shortweght condition or was distributed under inappropriate or damaging distribution practices, appropriate enforcement action should be taken.

(Amended 2002)

2.4Borax

***How is it determined if the net weight labeled on packages of borax is accurate?***

Use the following procedures to determine if packages of borax are labeled correctly. This procedure applies to packages of powdered or granular products consisting predominantly (more than 50 %) of borax. Such commodities are labeled by weight, but borax can lose more than 23 % of its weight due to moisture loss. However, it does not lose volume upon moisture loss, and this property makes possible a method of volume testing based on a density determination in the event that the net weight of the product does not meet the average or individual package requirements. This method may be used for audit testing to identify possible short-filling by weight at point-of-pack. Since the density of these commodities can vary at point-of-pack, further investigation is required to determine whether, such short filling has occurred.

**Test Equipment**

Metal density cup with a capacity of 550.6 mL or (1 dry pt).

Metal density funnel with slide-gate and stand.

Scale or balance having a scale division not larger than 1 g or ( 0.002 lb).

Rigid straightedge or ruler

Pan suitable for holding overflow of density cup

**Test Procedure**

Follow Chapter 2, Section 2.3, Basic Test Procedures. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then use the following test procedure to determine product compliance.

If the lot does not comply by weight with the sampling plan requirements (either the average or individual package requirements), select the lightest package and record the net weight of this package.

Determine the weight of the density cup.

Place the density cup in the pan and put the funnel on top of the density cup. Close the funnel slide-gate.

Pour sufficient commodity into the funnel so that the density cup can be filled to overflowing.

Quickly remove the slide-gate from the funnel, allowing the commodity to flow into the density cup.

Carefully, without agitating the density cup, remove the funnel and level off the commodity with the ruler or straight edge. Hold the ruler or straight edge at a right angle to the rim of the cup, and carefully draw it back across the top of the density cup to leave an even surface.

Weigh the filled density cup. Subtract the weight of the density cup from the gross weight of the commodity plus the density cup to obtain the net weight of commodity in the cup.

***How is the volume determined?***

Multiply the net weight (in pounds) as found for the package under test by 550.6.

Divide the answer just obtained by the weight of the commodity in the density cup, step (7). The result is the net volume of commodity in the package in milliliters.

Compare the net volume of the commodity in the package with the volume declared on the package. The volume declaration is not located on the principal display panel. The following example is how the declaration of volume should appear.

**Volume 2530 cm3 per NIST**

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**Note. (1 mL = 1 cm3)**

**What action can be taken based on the results of the density test**?

If the net volume of commodity in the lightest package equals or exceeds the declared volume on the package, treat the lot as being in compliance based on volume and take no further action. If the net volume of borax in the lightest package is less than the declared volume on the package, further compliance testing will be necessary. Take further steps to determine if the lot was in compliance with net weight requirements at point-of-pack or was short-filled by weight. To determine this, perform a laboratory moisture loss analysis to ascertain the weight of the original borax product when it was fully hydrated; obtain additional data at the location of the packager; and/or investigate the problem with the packager of the commodity.

2.5The Determination of Drained Weight

Since the weight per unit volume of a drained product is of the same order of magnitude as that of the packaging liquid that is drained off, an “average nominal gross weight” cannot be used in checking packages of this type. The entire sample must be opened. The procedure is based upon a test method accepted by the U.S. Food and Drug Administration.

A tare sample is not needed because all the packages in the sample will be opened and measured.

The weight of the container plus drained-away liquid is determined. This weight is then subtracted from the gross weight to determine the package error.

**Equipment**

Scales and weights recommended in Section 2.2 are suitable for the determination of drained weight.

Sieves

For drained weight of 1.36 kg or (3 lb) or less, one 20 cm or (8 in) No. 8 mesh U.S. Standard Series Sieve, receiving pan, and cover

For drained weight greater than 1.36 kg or (3 lb), one 30 cm or (12 in) sieve, with same specifications as above

Stopwatch

**Test Procedure**

Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A or a Category B sampling plan in the inspection (depending on the location of test); select a random sample; then use the following test procedure to determine lot compliance.

Fill out boxes 1 through 8 on the standard pack report form on page E-4. Select the random sample. Determine and record on a worksheet the weight of the receiving pan.

Determine and record on a worksheet the gross weight of each individual package comprising the sample.

Pour the contents of the first package into the dry sieve with the receiving pan beneath it, incline sieve to an angle between 17o to 20o from horizontal to facilitate drainage, and allow the liquid from the product to drain into receiving pan for 2 minutes [Do not shake or shift material on the sieve.] Remove sieve and product.

Weigh the receiving pan, liquid, wet container, and any other tare material. [Do not include sieve and product.] Record this weight as tare and receiving pan.

Subtract the weight of the receiving pan, determined in step 1, from the weight obtained in step 4 to obtain the package tare weight (which includes the weight of the liquid).

Subtract the tare weight, found in step 5, from the correspondThe Astrobiology Field LaboratorySeptember 26, 2006Final report of the MEPAG Astrobiology Field Laboratory Science Steering Group (AFL-SSG)SSG Members: Andrew Steele and David Beaty (co-chairs), , Jan Amend, Bob Anderson, Luther Beegle, Liane Benning, Janok Bhattacharya, David Blake, Will Brinckerhoff, Jennifer Biddle, Sherry Cady, Pan Conrad, John Lindsay, Rocco Mancinelli, Greg Mungas, Jack Mustard, Knut Oxnevad Jan Toporski, Hunter Waite(For correspondence, please contact a.steele@gl.ciw.edu 202-478-8974, or David.Beaty@jpl.nasa.gov, 818-354-7968)This report has been approved for public release by JPL Document Review Services (Reference Ref. # CL#06-3307), and may be freely circulated. Suggested bibliographic citation:Steele, A., Beaty, D.W., Amend, J., Anderson, R., Beegle, L, Benning, L, Bhattacharya, J., Blake, D., Brinckerhoff, W., Biddle, J., Cady, S., Conrad, P., Lindsay, J., Mancinelli, R., Mungas, G., Mustard, J., Oxnevad, K., Toporski, J., and Waite, H. (2005). The Astrobiology Field Laboratory. Unpublished white paper, 72 p, posted Dec., 2005 by the Mars Exploration Program Analysis Group (MEPAG) at http://mepag.jpl.nasa.gov/reports/index.html.Table of ContentsTable of Contents2Membership41.0EXECUTIVE SUMMARY52.0AFL CHARTER82.0DEFINTIONS104.0INTRODUCTION125.0SCIENCE GOALS135.1 Assumptions135.2 Objectives165.2.1 Habitability165.2.2 Extinct or Extant Life. Abiotic or Prebiotic Material175.2.2.1 What techniques have been used to detect and characterize terrestrial and meteoritic biosignatures?225.2.2.2 What are the challenges for AFL in the search for biosignatures on Mars?235.3 Preservation Potential256.0Precursor Discoveries257.0Mission Site Selection267.1 Sediments277.2 Hydrothermal297.3 Ice337.4 Water388.0Core Mission Components398.1 Payload strategy408.2 Core Measurements and Instrumentation418.3 Sampling and Precision Sub sampling468.3.1 Obtaining a sample478.3.2 Sedimentary deposits:488.3.3 Precision sampling of a core488.3.4 Ice Samples498.3.5 Liquid and Heat extraction of organics498.3.6 Contamination concerns528.4. Time resolved Measurements529.0Engineering analysis of AFL core5310.0Planetary Protection5611.0Relationship between AFL and MSL5712.0The Future of AFL5713.0References5914.0Appendix 1. Discoveries AFL must respond to.6615.0Appendix 2 - Instrument descriptions and capabilities67MembershipDuring the course of the SSG several breakout groups were formed to answer specific issues related to our discussions. These are as follows;AFL subcommitteesSedimentary sub-team. Pan Conrad, leader.Hydrothermal sub-team. David Blake, leaderIce sub-team. Luther Beegle, leaderSample preparation sub-team. Jan Toporski, leaderDefinitions sub-team. Pan Conrad, leaderInstruments sub team. Will Brinkerhoff leaderWater sub-team. Jan Amend, leaderEXECUTIVE SUMMARYThe AFL SSG was asked to develop an analysis of a possible future mission called the Astrobiology Field Lab. This mission is a generic concept, consisting of a lander equipped with a major in-situ laboratory capable of making significant advancements towards MEPAG’s Goal I (“Determine if life ever arose on Mars”). In essence, the purpose of this analysis was to evaluate the question, “what is the most that can be accomplished in this area by in situ means?” In order to give the analysis team room to work, financial and timing constraints were very loose. Although at the time of convening this exercise 2013 was the closest discussed deadline and so considerations were given to what technically could be accomplished for this deadline. The AFL SSG considered the problem at several levels:What overall programmatic exploration strategies are needed to achieve Goal I? Results from many missions will contribute to these strategies, and a mixture of ambiguous and definitive outcomes will need to be accommodated.What result would AFL need to deliver to make a meaningful contribution to this strategy?What are the engineering options for configuring a landed mission that would make such a contribution?Programmatic exploration strategiesIn order to plan missions during the period 2013-1018, it is necessary to predict the state of human knowledge at that time. Although this is hard to do in detail, it is possible to reach some important generalities. First of all, habitability is the potential of an environment (and applied to either the past or the present) to sustain life. By this definition, habitability will be the integrated and accumulated knowledge of many missions and many different kinds of scientific investigations. However, as with any other potential, it will not be possible to achieve certainty unless life itself is discovered. Habitation, on the other hand, is a simple yes-no question. A key planning question, therefore, is when has the habitability potential risen high enough that a habitation test can be justified? Although it has been generally assumed in the past that these two objectives need to be pursued sequentially, the AFL SSG has concluded that organisms and their environment together constitute a system, and each produces an effect on the other. Many kinds of investigations of this system can simultaneously provide information about both. This implies that habitability and habitation can be investigated together. This expands significantly on the current mission concept for MSL, with AFL having an expanded instrument suite dedicated more towards life detection and precision sample handling than MSL. Moreover, the process of life detection on Mars involves two sequential steps: 1). Proposing that a set of phenomenon are, or could be, biosignatures. This will constitute a working hypothesis that life is or was present. 2). Establishing that at least one of these biosignatures is definitive. This requires extensive effort and careful planning and a number measurements mutually confirming each other. Finally, we know that some kinds of scientific investigations will measure signs of both extinct and extant life without needing to distinguish between these two possibilities before launch. Given the expected state of our knowledge about Mars during the period 2013-2018, the AFL SSG has reached three conclusions: It is both possible and reasonable to do life detection first, then determine whether it is extinct or extant on the basis of a positive result.Missions during this period can reasonably begin the process of life detection by characterizing potential biosignatures.It is reasonable to set mission objectives that relate to both habitability AND habitation. It is not necessary to choose one at the expense of the other.Finally if a definitive biosignature is located by AFL instrumentation and missions must be configured to definitively characterize that life signature. It is only by thorough study of a positive signal will skepticism be kept to a minimum and the maximum understanding of how this relates to the formation of life on earth be understood.Engineering optionsThe AFL SSG has concluded that the following overall scientific objective is both achievable by AFL as early as 2013 (although 2018 was also postulated as a target from the pathways document, Figure 1), and is a significant extension of currently planned missions: For at least one Martian environment of high habitability potential, quantitatively investigate the geological and geochemical context, the presence of the chemical precursors of life, and the preservation potential for biosignatures, and begin/continue the process of life detection.By targeting an environment of high habitability potential, a response to prior discoveries is implied. Investigating the context is a reflection of the reality that our understanding of habitability will not be complete by 2013 we need to plan for more work. Understanding prebiotic chemistry is necessary to allow planetary-scale life-related predictions, especially in the contingency that life is not found in a specific experiment. Understanding preservation is key to interpreting the results of biosignature investigations, and is also critical feed-forward to future missions. Finally, life detection, as AFL SSG defines it, is a process that will take time. It is reasonable to expect that missions like AFL will play a significant role in this process, but unreasonable to expect that they will bring it to a conclusion.Engineering options for an AFL missionThe AFL SSG has defined a landed mission that can achieve the above objective. There are multiple possible variations of what could be called “AFL”, and different scientists see these variations in different context, and with different systems of priority. However, it is possible to define an invariant base that is common to most versions, along with a discovery-responsive and competition-responsive cap. The basic landed system needs to be able to accomplish four things:Acquire the right samples (access a place with high general habitability potential, understand preservation potential, have a high ability for scientific sample selection, capable sample acquisition system)Know the context (Setting, mineralogy, chemistry, relationships)ID best place on the sample (Mid-scale observations.Precision sub-sampling (down to mm scale) for investigation by analytical suite)At least 3 mutually confirming A/B measurements (Suites of observations by different means of the same or related phenomena will be necessary to reach definitive conclusions).Initial engineering concepts for this mission place AFL as a COSPAR level 4B mission.2.0AFL CHARTERThe AFL SSG was given the following charter. IntroductionThe Mars Program Office at NASA HQ (Code S) requests a study of the preliminary scientific options and engineering characteristics of the AFL mission. This mission was identified in the final report of the MSPSG (Mars Science Program Synthesis Group).Starting assumptions (to be refined)Assumptions for each mission need to be compiled separately.Assume TBD mission must be ready to launch as early as TBD.Science priorities will be derived from the MEPAG Goals document.Requested Tasks:Develop a set of candidate whole mission concepts. For each:Define preliminary general science objectives, and science floor (the level below which the mission is not worth flying).Identify and evaluate the primary science tradesDetermine whether instruments capable of addressing the science objectives are likely to be available in time.Landing site accessibility: Propose the size of the latitude band which needs to be held open for this mission, the landing precision, and required ability to land in rough terrainIdentify possible facility subsystems related to sample acquisition and sample preparation. Describe the essential engineering constraints on the missionDetermine if positioning in the pathways makes a difference to the science/engineering of the mission.Describe how the mission fits into NASA’s long-range strategic framework for the exploration of MarsBased on the above analysis, present a prioritized set of preliminary options for consideration by NASA HQ. MethodsThe SSG is asked to conduct its business primarily by telecons, e-mail, and or web-based processes. There is enough budget to convene 1 or 2 face-to-face meetings.Logistical support will be provided by the Mars Program Science Office.TimingIt is expected that the team will be ready to start its deliberations in mid-November.A mid-term telecon status check by Jim Garvin, Dan McCleese, and Bruce Jakosky is requested after the new year.The near-final report of the AFL SSG is requested by Feb. 28, 2004.It is expected that the results of this study will be presented to MEPAG at its June, 2004 meeting. Feedback from this discussion will be incorporated in the final report, which will be due July 31, 2004.Report FormatIt is requested that the results be presented in the form of both a PowerPoint presentation and a white paper. Additional supporting documents can be prepared as needed. After the white paper has been accepted by program management (including the MEPAG executive committee), it will be posted on a publicly accessible web site.The report should not include any material that is a concern for ITAR (as is true of everything done by MEPAG).Note, the bulk of this work and the draft white paper was completed by September 2004. There have been unavoidable delays to its publication. In the meantime thinking about AFL has progressed. This document reflects the thinking in September 2004. Whilst engineering and programmatic changes have occurred since then, the strength of this document lies in the science definition for the mission.DEFINTIONSDuring the course of the AFL-SSG discussions several questions related to the MSPSG statement arose. Specifically these questions relate to the definitions of, for example, the terms habitability (or what constitutes a habitat) and biosignature. Critical questioning by the group resulted in the formation of a definitions subgroupThe following definitions were decided upon by that group. These definitions are consistent through this document and although we cannot suggest the wider community adopt these definitions it is suggested that some consensus within the MEPAG members is reached to prevent numerous iterations of this process in other reports. Abiotic Chemistry Mainly carbon based chemistry the speciation and composition of which has remained simple with the production of all different isomeric possibilities and show no chiral or species preferences. In this scenario complex molecules may only be kerrogenous in nature (type iv) and similar to that found in meteorites. Biosignature Any phenomenon produced by life (either modern or ancient). Two sub-definitions: Definitive Biosignature: A phenomenon produced exclusively by life.  Due to its unique biogenic characteristics, a definitive biosignature can be interpreted without question as having been produced by life. Potential Biosignature: A phenomenon that may have been produced by life, but for which alternate abiotic origins may also be possible.Extant lifeGeneral reference to living or recently dead organisms which may also possess a fossil record. Extinct life General reference to past life (and no longer present on the planet). If evidence remains, it is ONLY fossil. Habitability A general term referring to the potential of an environment (past or present) to support life of any kind. In the context of planetary exploration, two further concepts are important: Indigenous habitability is the potential of a planetary environment to support life that originated on that planet, and exogenous habitability is the potential of a planetary environment to support life that originated on another planet. HabitatAn environment (defined in time and space) that is or was occupied by life.Life detectionThe process of investigating the presence of biosignatures (including potential biosignatures). Life detection can apply to either past or present life.Micro BioSensors (not to exclude organic chemical detection)Miniaturized instruments or instrument suites that are developed from technology such as Micro Electronic Machine Systems (MEMS), Micro electronic optic systems (MEOS), Microfluidics, Micro Total Analytical Systems (uTAS) or Lab-on-a-Chip (LOC).Prebiotic Chemistry Mainly carbon based chemistry the speciation and composition of which has a complexity and has produced a number of polymeric systems that could be used for structural, metabolic processes and information storage and retrieval.Present life investigation One that specifically targets living or recently dead organisms. Time resolved studies on seasonal and daily (with perhaps higher frequency) time scales may be required to confirm observations that a biosignature of present life has been detected.Preservation PotentialThe potential for a particular biosignature to survive and therefore be detected in a particular habitat.Primary Sample Geological material (e.g. rock, regolith, dust, atmosphere, ice) acquired from its natural setting on Mars.  Note: specific locations where data are collected by contact instruments are referred to as "targets", not samples.Secondary Sample Any sample derived from the primary, including splits, extracts, sub-samples, etc.4.0INTRODUCTION The primary science driver for the mission concept was to define the first Mars mission to concentrate fully on Astrobiology science goals (as defined within the recently updated Astrobiology roadmap). Therefore, to define the preliminary general science objectives, and the science floor, the level below which the mission is not worth flying. The Astrobiology Field Lab was created as a concept by the Mars Science Program Synthesis Group (MSPSG) during their Pathways planning discussions in 2002-03 and can be paraphrased as; Astrobiology Field Laboratory. “This mission would land on and explore a site thought to be a habitat. Examples of such sites are an active or extinct hydrothermal deposit or a site confirmed by MSL to be of high astrobiological interest, such as a lake or marine deposits or a specific polar site. The investigations would be designed to explore the site and to search for evidence of past or present life. The mission will require a rover with “go to” capability to gather “fresh” samples for a variety of detailed in situ analyses appropriate to the site. In situ life detection would be required in many cases.” (From MSPSG (2003)However, MSPSG deferred to a successor team (AFL-SSG) the definition of AFL’s specific scientific and engineering constraints, possibilities, and priorities. The AFLSSG team was initially convened in October 2003 and operated through a number of telecons and one face to face meeting. Therefore this team was asked to plan during a constantly shifting science focus and have constantly endeavored to keep abreast of the Mars Exploration Rover findings and review the goals and outcomes of the SSG accordingly. Undertaking this activity at a time when 3 new space craft have started to explore Mars has been exciting, inspiring and already produced new evidence to which we have responded. Many notions of how to perform this mission have therefore been updated from preconceived notions held before specifically, the MER data was returned. We hope that these changes reflect a renewed sense of optimism and realization of the location of interesting samples to interrogate with instrumentation currently under development.5.0SCIENCE GOALS5.1 Assumptions To undertake this task the AFL-SSG was asked to consider the following assumptions; Assume AFL will need to be ready to launch as early as the 2013 opportunityAssume all missions scheduled before 2013 are successful.The MSL entry-descent-landing (EDL) system has successfully been demonstrated, and the engineering heritage can be used on AFL.Assume the primary goal of AFL is to make a major advance in astrobiology. Assume a cost cap approximately equal to that of Ground Breaking Mars Sample Return.These assumptions are based on the timeline suggested by the Pathways SSG, summarized in Figure 1.Figure 1. A summary diagram of the pathways proposed by MSPSG.From Figure 1 it can be seen that the pathways leading to AFL are propelled by the discoveries of hydrothermal habitats and the search for evidence of past life. During the course of the AFL-SSG discussions several questions related to the MSPSG statement arose. Specifically these questions relate to the definitions of, for example, the terms habitability (or what constitutes a habitat) and biosignature. Critical questioning by he group resulted in the formation of a definitions subgroup the results of which are shown in Section 2. Responses to discoveries other than pathway to discover hydrothermal habitats as shown in Figure 1 were deemed necessary and led to the formation of the hydrothermal, ice, sedimentary and water subgroups. Through these discussions the parallel nature of exploration and engineering goals in different environments was explored and a “core” of similar themes and objectives arrived at that included life detection philosophy, measurements, rover capabilities and sample preparation. This notion is explored further in section 8.1.2. Other questions arising from the MSPSG guidelines and our discussions related to “the capability to gather fresh samples” which led to the formation of the sample preparation subgroup. The mention of in-situ life detection led to the Instrument subgroup surveying and documenting the current instruments in development.Several assertions for the completion of these science goals were formulated and are as follows:1.By 2013 a full model of the potential habitability of Mars, organized by environment, and applicable to both the present and geological past will be partially understood. Therefore the Mars program will have to choose to either; select one environment with a high habitability potential and test for habitation or continue to refine the habitability models to allow better targeting of a subsequent habitation mission.Therefore we forecast one of two conditions will be true in 2013:•More likely: Models of habitability require either further definition or further confirmation before a specific test for habitation should be attempted.•Less likely: At least one environment (past or present) with high habitability and preservation potential has been identified, and a habitation test is justified.We therefore questioned whether AFL would be effective in both scenarios. Which further reinforced the concept of defining a core set of mission parameters (Section 8).2.Organisms and their environment together constitute a system. Each produces an effect on the other. Some kinds of investigations can simultaneously provide information about both the environment (e.g. habitability potential) and associated life forms (habitation).3.Traditional Mars mission planning has involved choosing scientific objectives and investigations for EITHER prebiotic chemistry, extinct OR extant life. (PP policy is structured the same way.) However, some kinds of scientific investigations will detect all of the above categories and potentially measure the signs of life without prior need to assume search parameters that will pre-categorize whether it is extant or extinct. 4.As our exploration of Mars (through robotic and sample return missions and terrestrial studies on Martian meteorites) proceeds, anomalous features will be discovered that are POSSIBLE biosignatures for Martian life forms. It is important that this Observation of POSSIBLE biosignatures can be made by relatively simple observations (e.g. geological, textural, geochemical). Such features would constitute a working hypothesis, NOT confirmation that life exists and has been detected.Concluding that evidence of a Martian life form (past or present) has been discovered requires proving that a POSSIBLE biosignature was produced by the activities or remains of Martian life. Unless a POSSIBLE biosignature is proven to be a DEFINITIVE biosignature – an object or phenomenon that could only have been produced by life – it may not possible to prove the presence or former presence of life on Mars using AFL alone. However, the AFL mission has been configured so that it will not miss POSSIBLE biosignatures if they occur in a similar habitat and with similar character to those found on Earth and may indeed detect those non-earth centric signatures that would, without prior knowledge of the state of an unknown biochemistry, appear to be reasonably measurable.Once several POSSIBLE biosignatures are identified, additional efforts will need to be made to prove that they definitively represent extant life or former life, or determine whether the group of POSSIBLE biosignatures is CONSISTENT with the hypothesis that life exists or once existed on Mars.The current MEPAG goals document highlights the following strategy for Goal 1 “The search for Life” Determining if life ever arose on Mars is a challenging goal. The essence of this goal is to establish that life is or was present on Mars, or if life never was present to understand the reasons why Mars did not ever support its own biology. A comprehensive conclusion will necessitate understanding the planetary evolution of Mars and whether Mars is or could have been habitable and will need to be based in multi-disciplinary scientific exploration at scales ranging from planetary to microscopic. The strategy we have adopted to pursue this goal has two sequential aspects: Assess the habitability of Mars (which needs to be undertaken environment by environment), and in environments which can be shown to have high habitability potential, to test for prebiotic processes, past or present life. These constitute two high-level scientific objectives. A critical means to achieve both of these objectives is to characterize Martian carbon chemistry and carbon cycling. The science associated with carbon chemistry is so fundamental to the overall life goal that we have established it as a third primary science objective. To some degree, these overarching scientific objectives can be addressed simultaneously, as each requires basic knowledge of the distributions of water and carbon on Mars and an understanding of the processes that govern their interactions. Importantly this statement points out that the seemingly differing goals, habitability, Carbon chemistry and the search for biosignatures, overlap and can therefore be addressed to a significant degree by the interpretation of measurements undertaken by certain instruments. Examples, habitability demands the presence of Carbon, biosignatures are often Carbon based etc. Amino acid analysis, n alkane distributions, selection of informational and catalytic polymers based on a narrow range of particular molecules and isomers of a particular molecular group. For example nucleic acids contain ACTGU on earth, but may contain LMNOP on Mars, it is the presence of a narrow range of the possible purines and pyrimidines available through abiotic processes that would constitute a biosignature. This could be true of any potential novel biomolecule and it may be that upon detecting a small range of the possible isomers of a particular compound speculation as to their informational or catalytic roles can begin. Therefore AFL can reasonably begin the process of life detection by characterizing potential biosignatures.5.2 ObjectivesProposed overall scientific objective of AFL: For at least one Martian environment of high habitability potential, further investigate the potential for habitability, the potential presence of the chemical precursors of life, the potential for preservation of biosignatures, and possible signs of life. This objective must balance the need to be a significant extension beyond currently planned missions, yet not an unrealistic extension of current technology. The detailed objectives proposed include (in no order of importance); 1.Within the region of Martian surface operations, identify and classify Martian environments (past or present) with different habitability potential, and characterize their geologic context.2.Quantitatively assess habitability potential.Measure isotopic, chemical, mineralogical, and structural characteristics of samples, including the distribution and molecular complexity of carbon compounds. Assess biologically available sources of energy, including chemical and thermal equilibria/disequilibria.Determine the role of water (past or present) in the geological processes at the landing site3.Investigate the factors that will affect the preservation of potential signs of life (past or present) on Mars 4.Investigate the possibility of prebiotic chemistry on Mars (including non-carbon chemistry)5.Document any anomalous features that can be hypothesized as POSSIBLE Martian biosignatures. This will constitute a set of working hypotheses, which will need refinement and further testing on Mars or in return samples. 5.2.1 Habitability A definition for habitability is contained in section 2. From the first assumption above the following recommendation was made: Habitability models have the potential to integrate many different classes of information that have been made recently and will be acquired over the next decade. However, they will be most effective if placed on a semi-quantitative footing (see Appendix II for an example). This question was then followed up in discussions within the definitions subgroup and illustrated by Figure 2.Habitability should be described by measurable parameters that index the potential of an environment to support life. Only in this way can the scientific community achieve consensus regarding whether or not a given environment is habitable, either for Martian or Earthly life. For any living system, certainly there will be a range of environmental requirements, outside of which life will be unsupportable. Even though we have no information on potential Martian biological requirements, we can learn from universal Earthly life requirements. The AFL study group has agreed that Earth life requires water and certain chemical raw materials such as carbon, hydrogen, nitrogen, phosphorus and a few others in trace amounts (Williams and Fraústo da Silva, 1996). We also know that life makes products from these raw materials with the additional requirement for an energy source, so sufficient habitat space must be available for the products to be mobilized or diffuse away, otherwise metabolic reactions would run to equilibrium, or possibly reverse. On Earth, the chemistry of life involves oxidation-reduction reactions, and metabolism from the archaea to some highly-evolved eukarya requires electron donor/receptor pairs. The spatial distribution of both oxidized and reduced forms of ions involved in respiration may be as important as their concentration in the context of biological requirements.We assume that the astrobiology community will have made progress toward consensus regarding the indexing of habitability before the launch of an AFL mission, as the concept of habitability will have an impact on missions with the scope of Terrestrial Planet Finder to SSE missions in search of present or past Martian habitable environments. One approach toward such progress may lie in development of terms that lead to a probabilistic evaluation—a scale of habitability based upon measurements of agreed-upon parameters such as threshold concentrations of water and other raw materials, energy, etc. 5.2.2 Extinct or Extant Life. Abiotic or Prebiotic Material It is important to recall that life on Mars may be composed of many molecules that differ from those of Earth life. However, most current hypotheses on extraterrestrial life maintain that Martian life, if it exists or once existed, will resemble life on Earth in that it will be: 1) composed of carbon, 2) based on a ‘nucleic acid like’ replication mechanism and 3) packaged in cellular compartments. Measuring the distribution, isomerization and quantities of carbon species limits the search to life based on carbon chemistry, an appropriate goal that reflects the strategies used to locate the biosignatures of ancient carbon-based life forms on Earth. Potential organic carbon species that would need to be distinguished by AFL are given in Table 2.In the search for biosignatures on Mars the interpretation of measurements will determine whether a particular results indicates the category to which a particular a/biosignature should be placed i.e. pre/abiotic extinct or extant. The important issue is to make the correct measurements to ensure the sensitive detection of molecules of interest can be undertaken.Figure 2 Illustrated the cross cutting relationships between the searches for habitability in comparison with the search for evidence of past or present habitation. From assertions 2 and 3 and illustrated by Figure 2 the implications are that: The distinctions between investigations of habitability potential, habitation, extinct life, and extant life are blurred. It is possible to configure a mission that has relevance to ALL of these subjects.Without evidence of liquid water on Mars, the potential to locate extant Martian life is less, as all conceivable life forms require liquid water. Hence the focus of upcoming missions on determining whether liquid water is available. Until this information is known, an AFL mission will need to be prepared to detect both extinct and extant life, as well as be able to distinguish abiotic and prebiotic material. We assume that the investigation of abiotic and prebiotic chemistry will be useful in evaluating the postulated meteoritic and cometary delivery of exogenous organics to the lithosphere and the formation of organic material by indigenous hydrothermal processes. The current MER information that Mars harbors environments that contained liquid water in the past indicates that the possibility of discovering extinct life has increased.All information gained from AFL will be useful with regard to either describing what kind of life exists/existed on Mars or describing conditions found on Mars and determine why life evolved on Earth and not Mars (assuming the conditions on Mars are similar to those on Earth). The search for the signatures of prebiotic chemicals or components of life–past or present will provide important information that will advance the field of astrobiology and the understanding of our own planet. In addition, there is now considerable evidence pointing to the presence of methane in the atmosphere on Mars (Kerr 2004a.b commentary). This implies that geological processes on Mars could provide a chemical potential and carbon source that could be used by microorganisms and may indicate the presence of hydrothermal sites and liquid water. The generation and fate of atmospheric methane on Mars would be a significant goal for missions that fly prior to AFL. Such measurements would significantly improve our understanding of habitability.Investigating early planetary surface chemical processes on Mars is important to understanding two possible program-level exploration outcomes:If life is not present at a specific test site, can we predict that it might exist elsewhere? If life never formed on Mars, WHY?Studying such issues will also address specific goals, issues:Understand planetary evolution through elucidating organic chemical input i.e. meteoritic versus abiogenic synthesis reactions.Mars may give clues to the prebiotic evolution of the Earth. On Earth an unaltered geologic record of early planetary evolution (4.5-3.8 Ga) does not exist. Allow conjecture as to why life did not start on Mars (should that be the outcome). Were the chemical processes and building blocks present there as on Earth?By definition, a biosignature is an indicator of life or biological activity. Therefore, by definition, the discovery of even one biosignature on Mars would indicate that life once existed on the red planet. However, discoveries of ancient POSSIBLE biosignatures on Earth and Mars have shown that it can be extremely difficult, if not impossible, to prove their biogenic origin. Our inability to prove an object or phenomenon’s biogenic origin (i.e., biogenicity) is hampered by the fact that inorganic processes can produce abiotic mimics of biosignatures. Hence the need to make a distinction between a POSSIBLE biosignature and a DEFINITIVE biosignature.A DEFINITIVE biosignature is one that has attributes that can ONLY be produced by life or biological activity. Until such time that a POSSIBLE biosignature is proven to be a DEFINITIVE biosignature, the former constitutes a working hypothesis that requires additional characterization. AFL will contain the necessary equipment to detect POSSIBLE biosignatures (e.g., microfossils, biofabrics, biominerals, biomarkers, biomolecules isotopes, etc.). However, short of locating a living or perfectly preserved cell that displays the structural complexity indicative of biosynthesis, establishing that a POSSIBLE biosignature is DEFINITIVE evidence for life will require further testing. It will also be necessary to prove that a biosignature is indigenous to Mars and not a contaminant, regardless of whether we discover it on Mars or in rocks or sediment returned to Earth from a future sample return mission from Mars. These considerations underscore the need to distinguish a DEFINITIVE biosignature from a POSSIBLE biosignature. This underscored the goal of the definitions sub group that postulated that only by producing several mutually supporting lines of evidence (i.e. possible biosignatures) could a definitive biosignatures be postulated.The lack of a conclusive set of criteria for life detection and preservation has been illustrated recently by two debates; the search for the oldest evidence of life on Earth and the raging debate on the claims for life in ALH84001 (McKay, 1996). The scientific controversies over the former debate, that of the earliest evidence of life on Earth, have recently intensified but are still unresolved (Schidlowski, 1988; Schopf, 1993; Mojzsis et al., 1996; Rosing, 1999; Mojzsis and Harrison, 2000; Brasier et al., 2002; Fedo and Whitehouse, 2002, Pasteris and Wopenka, 2003, Furness 2004). The common denominator in both of these debates is the underlying difficulty, or inability to demonstrate conclusively the biological origin of the respective evidence, which in either of the above cases would have to be seen as conclusively proving the presences of fossil microbial life. However, a consensus that has emerged from these discussions, and is now seen as a critical requirement, is the demand for further lines of evidence in addition to any morphological data that supports such extraordinary claims. Since the inception of the second debate, that of life in Martian meteorite ALH84001, it has become evident that there is no consensus on the nature of life in extraterrestrial materials. Indeed techniques supposed to detect life failed, for whatever reason, to conclusively detect the presence of terrestrial organisms within this meteorite (Steele et al., 1999, 2000, Toporski, 2000). Recent studies suggest that the mass spectrometry experiments on the Viking lander would have missed 3x107 bacteria per gram of Martian regolith (Glavin et al., 2001). These examples are beginning to show that only by means of a multi-disciplinary, multi-instrument scientific approach, will the above questions be answered. It is clear that a great deal of additional systematic experimentation and testing must be undertaken in terrestrial environments to better determine the criteria by which biogenicity and therefore preserved biosignatures can be quantified.Though there are a number of ways of categorizing biosignatures, microbial biosignatures found in ancient Earth rocks can be organized into three categories: bona fide microfossils, microbially influenced structures, and chemical fossils, also known as chemofossils (Cady et al., 2003). Bona fide microfossils, which may include cellular and/or extracellular remains (e.g., carbonaceous microfossils), display structural and chemical characteristics that confirm their biological origin. Microbially influenced sedimentary structures (e.g., biogenic stromatolites and microbialites), display biofabrics and morphologies known to have been produced by the presence and/or activity of biofilms or microbial mats. Chemofossils (e.g., biomarkers and biominerals), display chemical, isotopic, and structural characteristics indicative of biological activity. Among the chemical biosignatures that have been identified as applicable to past and present biological activity on Earth are the biominerals, that is, minerals formed by biotic processes, either directly, or indirectly. Biominerals have been found in the fossil record that date back to the Precambrian. It has been suggested that biominerals could be important indicators of life and thus could play an important role in the search for past or present life on Mars (Schwartz et al., 1992, Cady et al 2003). Furthermore, organic components (biomarkers) that are often associated with biominerals are believed to play crucial roles in both pre-biotic and biotic reactions. For measurements carried out on Mars, a crucial step will be the in situ quantification of the nature, structure and concentration of biosignatures as a function of depth and time. The search for biosignatures requires an extensive knowledge of the context in which they are found. The types of rocks and paleoenvironments that have the highest potential to trap and preserve biosignatures on Earth and Mars include: mineralized sinters, evaporite basins, mineralized soils, subsurface sedimentary systems, permafrost and ground-ice (Farmer and Des Marais, 1999). Recent data from the Mars orbiter, which suggests the presence of reduced gases of biological or volcanic origin, indicate that gas seeps in any type of terrain should also be targeted for possible biosignatures. On Earth, additional criteria such as tectonic setting and alteration history are taken in consideration when looking for biosignatures. The amount of alteration a deposit has experienced since its time of formation is particularly important for assessing the preservation potential of a deposit (see next section).Typical lithologies for searching for biosignatures of past life in ancient terrestrial settings are similar to the ones we hope to find on Mars. Interestingly the haematite rich sites like those found by the MER rovers at Meridiani and Gusev may not be the ideal sites to search for Carbon signatures due to the poor preservation of organic material in haematite (Sumner 2004). Settings with a higher preservation potential include aqueously deposited chemical sediments, such as cherts, carbonates, or phosphates, which are known to be effective at preserving biosignatures on Earth. Because the spatial scale or distribution of such deposits on Mars is presently unknown, and because of the difficulty of resolving mineral mixtures using available or recently acquired remote spectral data (i.e., TES, THEMIS or CRISM), the acquisition of data at high spatial resolution (30-100m/pixel) from selected locations is considered a crucial precursor to defining an adequate landing site for the AFL mission.A critical component for identifying biosignatures on any planetary body is the ability to assess in-situ the potential for an aqueous geochemical environment to create and support life. As an example for Mars, in-situ characterization could provide evidence as to whether the chemical composition of the evaporites located in suspected ancient water bodies were biologically influenced or possessed the chemical parameters within which life may have existed, or may still exist.It is almost certain to be the case that any life signature found on Mars will become the basis for intense debate and necessary follow up investigations. These investigations must be targeted at characterization of any positive signal.If investigations prove negative for all forms of carbon / biosignatures then spatially resolved measurements must be undertaken to different sites to ensure all reasonable target areas have been explored. Table 2. Possible sources of organic carbon that need to be distinguished in Martian samples. 5.2.2.1 What techniques have been used to detect and characterize terrestrial and meteoritic biosignatures?1. Morphological observation using microscopic tools (Light, SEM, TEM, AFM, Fluorescence). The controversy mentioned earlier regarding the oldest fossils on Earth illustrate that it is difficult using all available analytical tools in a laboratory to unambiguously determine if something is truly of biological origin. Recognizing a fossil using the criterion of shape alone poses some challenges, particularly without actually being on the surface of Mars and knowing a priori whether it has a fossil record. In contrast, observing movement in extant life is easy. However, not all extant life moves, especially microbes, therefore making it difficult to determine if it is alive by shape alone. Interdisciplinary multi-instrument approaches have been shown to be effective for studies on deep subsurface ecosystems on Earth (e.g., Fisk et al., 2003; Steele et al., 2002; Toporski et al., 2002; Steele).2. Biochemical analyses. A range of analyses based on either pure chemical or biochemical methods have proven to be useful on Earth in determining if a sample is of biological origin. However, in difficult cases it has usually taken several different methods of analyses to determine if a sample is unequivocally of biological origin. Carbon isotopes have successfully been correlated with individual Proterozoic microfossils (House et al., 2000) and FT-RAMAN spectra were obtained on presumed Proterozoic microfossils (Schopf et al., 2002). Furthermore, fossil and modern bacterial biofilms have been classified using a combination of bulk and spatially resolved measurements including XPS, EDX, XRD, Time of Flight – Secondary Ion Mass Spectroscopy (ToF-SIMS), pyrolysis GCMS, GCMS, GC-IRMS confocal laser microscopy and Raman and infrared microspectroscopy (Steele et al., 2001; Toporski, 2001; Toporski 2002; Toporski 2004, Hall-Stoodley et al, 2004; Benning et al 2004). Only the combination of a multiple-set of instruments lead to a unequivocal determination of the specific characteristics of biofilms. 5.2.2.2 What are the challenges for AFL in the search for biosignatures on Mars?1. Tested Technologies. Of the techniques listed in table 1 those that have been shown to be successful during space missions include: gas chromatography, mass spectrometry, simple thermal analysis, Mossbauer and some types of interactive chemical techniques (e.g., the Viking biology experiments (see Mancinelli 1998 for review).For Mars applications, it is necessary for the detector to be sensitive to the picogram level and capable of responding to a broad variety of compounds, i.e., have universal response. A flight proven detector that is both universal and sufficiently sensitive is the metastable ionization detector. The primary disadvantage of gas chromatography is the small margin of error associated with the column retention times for definitive identification of compounds, which can lead to mis-identification of compounds with similar retention times. This disadvantage should be minimized by use of multiple columns with different separation capabilities (i.e., different column coatings or packings) and calibration standards. A GC/MS has been used successfully on space missions, including the Viking mission The disadvantages are that the MS cannot be simultaneously tuned to be sensitive for the analysis of low and high molecular weight substances at the same time, and it is a bulky and heavy instrument. Various types of analytical instruments equipped with different pyrolytic devices have been used during space missions. These ranged from simple pyrolysis (combustion) to step-wise heating of samples and measuring the power input and temperature. Step-wise heating is usually followed by collecting any volatiles evolved from the sample during heating, and identifying and quantifying them by GC, or GC/MS. For example, heating samples of soil from earth in a step-wise fashion would first volatilize adsorbed water and gases (e.g., CO2, and lower molecular weight organic compounds) at the lower temperatures. At higher temperatures, water from mineral hydration, CO2 from carbonate decomposition, and volatiles from pyrolysis of higher molecular weight organics would be released. Although this technique allows one to analyze the evolved gases, it does not yield any direct information regarding the nature of the sample (e.g. clays vs. hydrated silicates). Mossbauer spectroscopy provides information on the valence state of specific elements (i.e., Fe, Sn, Sb, Ru, and Au), how these elements are combined in the structure of a compound, and the magnetic properties of the sample. Mossbauer spectroscopy can provide information about H2O only if it is associated with the elements Fe, Sn, Sb, Ru, or Au. This again is an area where micro total analytical systems and micromachining may allow significant weight and energy savings.2. Non-tested technologies. Scanning electron microscopy-energy dispersive X-ray spectrometry (SEM-EDS), which maps electron intensities for identification of elements with atomic numbers greater than sodium, although windowless detection allows all elements heavier than boron to be detected. Electron spectroscopy for chemical analyses (ESCA) quantitatively determines the valence states and bonding energies of most naturally occurring elements (excluding hydrogen and helium). This technique is limited to analysis of the top 1-10 monolayers of the sample. X-ray diffraction (XRD) analysis directly and nondestructively probes atomic scale structural correlations of mineral samples yielding sample mineralogy along with information about the presence of H2O. X-ray fluorescence (XRF) analysis non-destructively provides information on the elemental composition of a sample for elements having atomic numbers greater than that of boron. However, no information is given about how those elements are combined in the sample. Rutherford backscattering spectrometry (RBS) maps the elemental composition and distribution measured on sample surfaces (the top 0.5 – 3 microns). Elements that can be analyzed by this non-destructive technique range from Li to U. Secondary ion mass spectrometry (SIMS) analysis has a very high sensitivity and can identify all elements including hydrogen and deuterium. A mass spectrometer (MS) provides information on elemental and molecular composition, including that of H2O, and the isotopic abundances found in a sample. Differential scanning calorimetry (DSC), in which the amount of heat required to maintain isothermal conditions between the sample and an inert reference placed in a continuously heating oven, is recorded, and the enthalpy provided directly. Sample identification is made by examination of the patterns of exotherms and endotherms along a temperature scale. The DSC provides quantitative data to ~700°C. For temperatures >700°C the signal-to-noise ratio becomes too great. Differential thermal analysis (DTA) is similar to DSC in that the sample and an inert reference are heated at the same rate, but to ~1200°C. The temperature of the sample and reference are monitored simultaneously. It differs from DSC in that when endothermic and exothermic events occur in the sample, no attempt is made to keep the sample and reference isothermal to each other. In DTA, the temperature difference between the sample and the reference is recorded as a function of oven temperature and provide the information for sample identification. The thermogram obtained from a DTA or DSC analysis provides information on the mineralogy and chemical composition of the sample. Where the DTA or DSC is coupled to a gas chromatograph (GC), the GC collects and analyzes the volatiles (including H2O) evolved from the sample as it is heated. Specifically for extant life detection interactive chemical methods were performed as part of the Viking mission. This approach is fraught with problems. It assumes prior knowledge of Martian organism metabolism. Using these culturing methods only detect 1-2% of the microbes in earth soil can be detected. A distribution mass peaks obtained by a mass spectrometer of alkanes showing a decrease in concentration with increasing carbon number would indicate abiotic processes. Similarly a predominance of biogenic amino acids with an excess of the L isomer would indicate extant or recently extinct life. Whereas, a suite of racemized biogenic amino acids may indicate fossil life. Detection of hopanes by Time of Flight Mass Spectrometry may also be indicative of life. Field ATP luminometry measurements of the cryptoendolithic communities may provides a rapid method of detecting relative amounts of metabolic turnover in microbial communities. None of these techniques would provide definitive evidence of life during the MSL mission. Clearly, multiple approaches need to be done on samples to determine if they contain viable extant organisms. For example, if organic mass gas chromatography spectrometry analyses combined with deep UV florescence, SEM and RAMAN all point toward life, then there is a high probability that the sample may contain life.5.3 Preservation PotentialA biosignature preservation model, guided by data from AFL, will be critical to long term Martian life detection strategy. That is to say that AFL in detecting carbon chemistry in various sites of possible habitability (see definition) can indicate whether such niche areas could preserve clues of Martian life. This must be modeled by suitable experimentation in laboratories before suitable interpretation of any data can be undertaken. We still do not know the exact composition of the mysterious Martian oxidant postulated in the Viking experiments.Long-range Astrobiological exploration of Mars will require an understanding of the preservation potential of biosignatures. This is an important part of the scientific logic of going from possible biosignature to confirmed biosignature.Lessons from Earth•Life processes produce a range of biosignatures, and geological processes progressively alter and ultimately destroy them.•Understanding the potential for preservation has been a key part of biosignature interpretation. Application to Mars•We don’t know the biosignatures of Martian life forms (if they exist).•However, with appropriate data, it should be possible to postulate a preservation model relating biosignatures as we understand them on Earth to various Martian geologic environments. This model will likely have important predictive value in guiding future search strategy. Models predict that biomolecules and organisms can survive in simulated conditions such models need refinement and to address diagenetic processes in predicted conditions (Scheurger et al., 2003).6.0Precursor DiscoveriesRelevant data may already be available but two major classes of discovery would be of essential relevance to AFL mission planning:MRO•Sending AFL to a hydrothermal site is impossible with present knowledge, because none are known. However, the CRISM spectrometer on MRO is very powerful, and it has potential to discover the mineralogic expression of hydrothermal zones. Phoenix•Phoenix will be the first lander designed to acquire and analyze ice-bearing samples.•It will collect data of relevance to each of the three primary components of habitability (water, carbon, energy), and thus is capable of returning a result which significantly improves or reduces our interest in sending AFL to an ice-related site. Table 3 A summary of types and amounts of biomolecules present in a single bacterial cell and compared to known preservation potential for such molecules.? – debate over the data. Total mass of the organic inventory is based on the assumption that most terrestrial prokaryotes contain approximately 10-13 g of carbon per cell. 7.0Mission Site SelectionFour subgroups were founded to begin to address the need for AFL to respond to the discoveries and requirements for as yet to be determined site. Through this process a core mission concept was arrived at and presented to the engineers for costing.There are four obvious general types of site in which the overall scientific goal of AFL (major advance in A/B) can be pursued:•The sedimentary record.•Fossil (inactive) hydrothermal systems•Sites with ice •Sites where it may be possible to sample liquid waterWe do not have enough information as of this writing to know how these four options would be prioritized by a future SDT. Future discoveries could have a major effect on planning. At the time of writing this document all of the above sites may be postulated to currently exist on Mars. The sedimentary record has been explored by at Gusev and Meridiani by Spirit and Opportunity respectively (Squyres et al., 2004; Grant et al., 2004; Morris et al., 2004; Kerr 2004c (commentary); Arvidson et al., 2004; Bertelsen et al., 2004; Herkenhoff et al., 2004; Gellert et al., 2004). Fossil (slightly active) hydrothermal systems may be concluded from initial papers outlining the concurrence of water vapour, shallow ground ice and methane at Arabia Terra, Elysium Planum and Arcadia Memnoma, (See Kerr 2004a,b and c for commentary). Sites with ice and the obvious poles or shallow “dirty” ice sites such as Phoenix proposes to explore. Sites with possible hydrothermal activity represent a chance to sample liquid water, although this may be at some distance below the surface. To remain flexible to current and future discoveries we Figure 3 Shows the antecedent discoveries that will impact and guide the choice of sites and final payload of the AFL mission 7.1 SedimentsHere we present a mission concept with the overall goal of finding evidence for past or present life in the Martian stratigraphic record in an environment that is highly likely to have formed from the subaqueous deposition of sediment in a shallow marine or lacustrine environment such as exposed in craters at both the Spirit and Opportunity sites (Squyres et al., 2004; commentary by Kerr 2004c). ObjectivesSpecific supporting objectives that support this goal are to:Assess spatially resolved changes in mineralogy with depth on a scale consistent with the depth of individual strata.Determine the abundance and nature of organic chemicals at the same scales as above.Seek information regarding water cycling from the strata, eg. is there free or bound water in any of the layers? Ice? Hydrous mineral phases?Confirm the depositional environment. Determine provenance of the sedimentAssess the fossil preservation potential of the environment. Factors which might be considered are temperature, rock type, local weather, UV flux, depositional regime as suggested by sedimentary structuresApproachCentral to this mission is the selection of a landing site that possesses multiple outcrops of layered sedimentary rock. We would use remote sensing methods that possess sufficient spatial resolution to resolve individual layers to acquire information from several outcrops. Subsequently, a rover would visit at least one 3D outcrop of layered sedimentary rock, measuring variation in chemistry, mineralogy and texture of the strata for at least 100 meters along the strike and ten meters in the dip of the outcrop. Subsurface penetration would be an important feature of this mission for the acquisition of subsurface samples that are from depths great enough to extend beyond the level of surface oxidation. This may mean accessing a depth of one meter in a horizontal area, though it would be desirable to penetrate the exposed bedding along the slope of an outcrop in a larger feature such as the wall of a crater. Examining the subsurface of such beds would only require a relatively shallow penetration (perhaps a few centimeters), and we would then have access to the primary sediment without having to go through the more recent Aeolian deposits.Required measurements for meeting the scientific objectives must be conducted at multiple spatial scales, and we recommend three suites of instruments that can provide integrated measurements a la the remote sensing, non-contact/contact and analytical suite designations originally suggested by the MEPAG PSIG for the MSL mission. Both spectroscopy and imaging will be key to an integrated science package, and we assume technical progress in science autonomy before the launch of AFL that optimizes science operations on the Martian surface. There are several engineering /science trade issues associated with taking a large number of measurements from a large outcrop in three dimensions. Some of them are:“Go to” mobility is required. The degree of mobility will be complementary to the degree of precision of the landing.The ability to land in a terrain which is rougher than previous targets would be valuable. A priority should be given to precision targeting and hazard tolerance.Fresh material should be exposed with a RAT or its descendent. Surface penetration is also required to a level below any weathering layers, a few cm to perhaps a meter.Sample acquisition and some processing, at least to the level of crushing will be required.There will be a requirement for positioning—perhaps a laser range finder. Autonomy should be plentiful—not just for the rover, but for some of the scientific operations in order to maximize efficient use of resources.Landing Site SelectionOne of the primary assumptions of this mission concept is that we will have advanced in our ability to assess habitability for a range of potential landing sites by the missions that are to precede AFL. For example, recent inferences made regarding the environment of deposition for the MER B landing site, Meridiani Planum would suggest that it is an excellent candidate site for an astrobiology follow-up mission. However, as of the time of this writing, there are few exposed examples of the cross-bedded rock from which the shallow marine inferences were drawn at that site. Much of the Martian surface will be mapped in exquisite detail by the time the AFL mission site selection is made, and there are likely to be other candidate target areas that demonstrate appropriate geomorphological and mineralogical character to suggest deposition in a standing body of water. For example Northeast Holden crater, may be a good candidate; geomorphological evidence strongly suggests classical deltaic deposition (Bhattacharya, in prep):Figure 4 Holden crater 7.2 HydrothermalScience theme: Assess past Martian Astrobiology in an inactive hydrothermal system.The apparent harsh climate at the surface of Mars suggests that, should life exist on Mars, the most likely energy source would be subsurface / chemosynthetic rather than surface / photosynthetic. Hydrothermal systems are attractive sites for Astrobiological exploration because they contain all of the requisites for the origin and maintenance of a biosphere and the subsequent preservation of its biosignatures. In such systems, water is typically present in the liquid state in a near-surface environment. Both thermal and chemical energy are made available for use by chemosynthetic organisms as a result of water-rock interactions. Common reactions between mafic/ultramafic minerals, water and volcanic gases such as CO2 lead to the formation of reduced carbon compounds that could have been the building blocks of early life. Secondary mineralization of hydrothermal deposits by carbonate, silica, and other hydrothermal precipitates can preserve evidence of prebiotic carbon chemistry as well as evidence of life. Finally, while the bulk of a hydrothermal system is quite likely to be beyond detection in the subsurface, surface expressions of such systems should be morphologically and mineralogically identifiable from space. However, even when surface expressions of hydrothermal systems are missing or cryptic, impact gardening, mass wasting and simple erosion by wind or water will dissect and expose such systems over geologic time. The detection of the correlation between the concurrence of water vapour, shallow ground ice and methane at Arabia Terra, Elysium Planum and Arcadia Memnoma, may indicate such a system exists in these areas (See Kerr 2004a,b and c for commentary).Finding hydrothermal areas:At present, we know of no bona fide hydrothermal zones or regions on Mars. However, the apparent association of fluvial features with volcanic terrains in many places on Mars suggests that such areas must be common. One can deduce from the young crystallization age of most Martian meteorites (which appear to post-date major fluvial/lacustrine features on the planet) that volcanism and (presumed) associated hydrothermal activity persisted throughout Mars history. Indeed, a number of Mars meteorites (including the famous meteorite ALH84001) contain carbonates or minor hydrous phases suggestive of a hydrothermal setting (Treiman et al 2002). Clues to the presence of fossil (inactive) hydrothermal zones include morphological, mineralogical and chemical features. A morphological feature could consist, for example, of a spring mound (positive topographic feature) associated with evidence of water flow. A mineralogical feature could consist of surface deposits of carbonates, silica, etc. Global surveys of hydrogen in the near-subsurface, discussed largely in the context of near-surface water, could in some cases represent hydrated mineral phases associated with hydrothermal features.Future missions will provide clues, perhaps even compelling evidence of past hydrothermal activity. The Mars Reconnaissance Orbiter will have a high-resolution camera from which morphological data will be obtained. CRISM will provide high resolution chemical or mineralogical maps of surface features. Orbital or landed neutron detectors and radar sounding devices could provide maps of near-surface water over large areas of the Mars surface. The ’07 Phoenix Scout mission, as well as Mars ’09 MSL will provide in-situ information on both morphology and mineralogy at the sub-meter to sub-millimeter scale. Five possible landing site hydrothermal geologic settings are envisioned: Point source hydrothermal zones (igneous-driven convection systems). Point source hydrothermal zones are well known on the Earth – as for example those present in Yellowstone National Park (a continental-type environment) (e.g., Walter and Des Marais, 1993) or at the mid-ocean ridges (oceanic-type “black smokers”) (e.g., Kelly et al., 2001). These features should be identifiable by their morphology and their mineralogy/chemistry (Farmer, 1998). High-resolution mineralogical data should allow the identification of systems such as these, which may vary in size from kilometers (Grand Prismatic hot spring, the largest hot spring on Earth, is ~1 km in size) to meters in size. Mineralogical signatures of these systems range from monomineralic deposits (silica, carbonate, sulfide, oxide) to polymineralic assemblages. In general, the areal extent of hot springs, which are the surficial expression of point-source hydrothermal zones, are dwarfed when compared to the volume of hydrothermally altered rock in which chemosynthetic life could live in the subsurface (Cady et al., 1997). As a result, even without a large surface expression of hydrothermal activity, one could search for hydrothermal alteration minerals similar to those found around ore deposits on Earth (Horn, 1996). Surface and near-surface deposits of hydrothermal systems will contain a variety of alteration minerals that vary as a function of the underlying mineralogy of the system (e.g., oxides, carbonates, sulfates, hydrated minerals, etc).Impact-generated hydrothermal systems (craters). Newsom et al. (2001) reviewed many of the key concepts that support a search strategy for life on Mars in aqueous and hydrothermal deposits associated with Martian impact craters. For example, impact craters on Earth (e.g., the Sudbury impact crater, 1.85 Ga ; ~250 km diameter in Sudbury, Ontario) contain extensive evidence of post-impact hydrothermal activity. Impact melt and uplifted basement heat sources could sustain hydrothermal activity and keep crater lakes from freezing for thousands of years, even under cold climatic conditions (Newsom et al., 1996). Post-impact fluids could result from dewatering of deeply buried hydrated materials, and the breach of local aquifers or regional cryospheres. The lifetimes of impact-generated hydrothermal systems depend on the size and cooling rate of the heat source, the permeability and depth of the disturbed zone, the presence of deeply buried water or hydrated materials, and the rate of burial of the impact melt (e.g., Newsom et al., 2001). The lifetime of hydrothermal systems, which is perhaps long enough to create or sustain a biota, has been estimated as 104 – 105 years for terrestrial craters 100 km in diameter, and up to 106 years for 180-km diameter craters. Impact-generated hydrothermal zones may be quite common in areas of subsurface water or permafrost, such as those areas present in the high latitudes. The surface manifestation of such a system could be mineralogical or morphological, but would be co-located with an identifiable impact structure from which it was generated. Serpentinizing terranes. The single most widespread environment of chemical disequilibrium on present-day Earth is the oceanic crust (Deming and Baross, 1995; McCollom and Shock, 1997). The composition of the modern lower crust and upper mantle of the Earth is essentially the same as that of the early Earth and Mars (Nisbet, 1987; Longhi et al., 1992), and the early histories of these two planets are similar. It follows that an understanding of these zones of chemical disequilibria on Earth would be of great value in devising a search strategy for similar regions on Mars.In addition to being potential sites for the genesis of life, hydrothermal systems associated with serpentinization are also excellent candidate sites for the study of prebiotic biogeochemistry. On Earth there is abundant evidence for the formation of abiotic organic compounds along the modern mid-ocean ridge system where it has been linked to serpentinization (H2 source) and hydrothermal activity (Rona et al., 1992; Bougault et al., 1993; Charlou and Donval, 1993; Holm and Charlou, 2001; Schroeder et al., 2002; Kelley and Fruh-Green, 1991; 2001). Serpentinization has also been linked to hydrogen and methane generation onshore in association with ophiolites (Neal and Stanger, 1983; Abrajano et al., 1988). This may also be an explanation of the observations of methane in the Martian atmosphere (Kerr 2004a,b)An excellent example of subsurface life on Earth is associated with the “Lost City hydrothermal complex” located in an off-axis area of the mid-Atlantic ridge hydrothermal system (Kelley, et al. 2001). Similar sites have been described elsewhere (Chapelle et al, 2002; Stevens and McKinley, 1995; Mottl et al., 2003). In locations such as this, ultramafic rocks from the oceanic crust react with water to form secondary minerals such as serpentine. The process is exothermic, and yields a volume increase of nearly 60%. This type of hydrothermal activity is distinct from all others in that no external source of heat is required (the heat generated by the reaction is sufficient to initiate or perpetuate the system), and the volume increase produced by the reaction results in a self-perpetuating system in which cracks formed in freshly altered material create pathways for water to react with fresh ultramafic rock. The process of serpentinization, through which olivine and pyroxene are altered into serpentine minerals, can be generally described as:olivine + H2O = serpentine + brucite + magnetite + H2(1)andolivine + pyroxene + H2O = serpentine.(2)Reaction (1) could provide a biological energy source through the production of H2, the basis for many chemoautotrophic biochemical processes, including methanogenesis (CO2 + 4H2 = CH4 + 2H2O).The serpentinization process should be relevant to present-day Mars, which lacks plate tectonic processes, and even to an ancient Mars that never developed standing oceans or large-scale plate tectonics. The apparent widespread distribution of olivine-rich basalts at the surface of Mars as well as reported outcrops of olivine on the Mars surface (Hoefen et al., 2003) suggest that interactions of ultramafic rocks with water might have been commonplace in the past.4.Meridiani type areas – hematite or water-associated mineralogy. Prior to the MER missions, remote and spectroscopic images of Sinus Meridiani suggested an ancient (~4 Ga,) wind-eroded subarial or subaqueous sedimentary comprised of 10-15% hematite. As reviewed by Christensen et al. (2000), five possible mechanisms that involve water could explain the formation of the hematite deposit at Sinus Meridiani: (1) direct precipitation from standing, oxygenated Fe-rich water; (2) precipitation from Fe-rich hydrothermal fluids; (3) low-temperature dissolution and precipitation through mobile ground-water leaching; (4) surface weathering and coatings; and (5) thermal oxidation of magnetite-rich lavas. Allen et al., (2001) discussed, on the basis of terrestrial examples, the possibility that a Martian hematite deposit could be associated with microbial mediation and discussed: (1) four possible mechanisms for producing banded iron formations; (2) the accumulation of iron oxides in hydrothermal deposits; (3) formation mechanisms for iron-rich laterite and ferricrete soils; and (4) the association of bacteria that can oxidize ferrous to ferric iron at neutral pH in rock varnish. It is clear from the recent discovery of buried and exhumed hematite concretions and impact ejected hematite-rich rock near the MER landing site that the area exposed to iron-rich fluid is quite extensive, and much remains to be learned about its origin (Squyres et al., 2004, Kerr 2004c commentary). Such sites are important not only for elucidating the history of water on Mars but also because aqueous mineral precipitates could preserve evidence of an early biota, prebiotic chemistry, or exogenous delivery of organics to the planetary surface during the heavy bombardment period.Sub-ice VolcanosA distinctive source of hydrothermal fluids and water-rock interaction is volcanic eruptions into ice or icy regolith. These eruptions necessarily involve heat, liquid water, and reactive rock (fresh lava), on which a biota could thrive. Evidence of “catastrophic outflows” of water from beneath polar caps is reminiscent of similar environments in Iceland and elsewhere, where sub-ice volcanism might create habitats for life. Evidence of habitable under-ice environments might reside within frozen outflows that extend outward from the margins of the polar caps.The advantages of seeking sub-ice volcanos on Mars are: [1] Volcanos, ground ice, and surface ice are known to be present, and [2] Sub-ice volcanos produce distinctive landforms, easily recognized from orbital imagery. Point eruptions beneath ice produce a characteristic landform, a tuya – a sharply bounded mesa, capped by lava flows, and commonly with volcanic cones and flows visible on its top (Allen, 1979; Hodges and Moore, 1979). Fissure eruptions beneath ice produce distinctive, parallel Moberg ridges (Allen, 1979). Many hills in Mars’ northern plains resemble tuyas, at least in Viking imagery (Allen, 1979; Hodges and Moore, 1979), and the Valles Marineris interior deposits have been similarly interpreted as tuyas (Chapman et al., 2003). 7.3 Ice Science Theme: Assess the potential for Habitation in Icey samplesAll life on the Earth is constructed from 2 major ingredients: Water and organic carbon. One of the basic investigation AFL will perform is the identification and inventory of organic carbon species on the Martian surface. The understanding of the nature and chemistry of carbon on Mars can help elucidate astrobiology principals and help us understand the potential of Mars as an enclave of life. The other key ingredient of life, water, has been shown to be present in the polar caps as well as mixed in the regolith at higher latitudes. Therefore a search strategy including exploring a sites that contains a significant amount of H2O (i.e. follow the water) is a possible mission scenario for AFL. Orbital data has indicated that there exists sub surface water ice in large quantities, as well as making up the majority of the northern polar caps. Mars Odyssey has detected large amounts of subsurface Hydrogen, especially accessible in the northern plans indicating that there exists a reservoir of subsurface H2O (Feldman et al. 2002, Anfimov et al. 2002). This water has been systematically moved from the low latitudes where geologic features indicate there was water present at one time and redistributed in the higher latitudes region (Mellon and Jakosky 1995, Crisp et al. 2000).These permafrost like regions constitute a mixture of regolith and H2O that is accessible in the upper few meters and is accessible by a rover. The current orbit Mars Express orbiter will be deploying the MARSIS orbital radar to better map the subsurface water distribution, and the up coming SHARAD instrument on the Mars Resonance Orbiter, will be able to produce maps of subsurface water to a better resolution and sensitivity then is possible from the Odyssey data. This mapping of the subsurface H2O will enable a determination of the accessibility from a rover type platform, and hence its likelihood of exploration by AFL.While the current temperature and pressure conditions on Mars does not allow for stable liquid water on the surface, it potentially can exist in a meta stable state in some specific environments (Hecht 2002). Additionally, it has exited in the geologic past when Mars possessed different orbital and atmospheric conditions which allowed liquid water in at least transient states (Malin and Edgett 2003). This can be demonstrated by numerous geomorphoicial features, photographed from orbit, which were created by large amounts of liquid water as well recent evidence found by the MER rovers of evaporative deposits from standing water (Squyres et al. 2004). If life formed on Mars it may still exist in an environment where it has access to H2O and energy to sustain itself. If life never started, discovering the differences between Mars and Earth is vital for the determination of how prevalent life is in the universe. Visiting a site with ice can help us understand both possibilities. Life also has the ability to exist in terrestrial environments where the temperature is below 0°C for a vast majority of the time. These organisms can exists in environments where only occasionally does the temperature rise above freezing, (Nienow, et al. 1988; Friedmann, et al. 1993), in regions where it reduces the freezing point of water by existing in either brine solutions or excreting chemicals to lower the freezing points of the water (Junge, et al. 2004) and by potentially becoming dormant only to repaired itself in intervening thaw periods (Thomas, et al. 2000; Bakermans, et al. 2003; Gilichinsky, et al. 2003). These vastly different terrestrial settings all have analogies on present day Mars which makes them interesting targets for Astrobiology in situ science. Finally, there is the exciting possibility that a preceding Mars lander mission making a compelling discovery and having AFL return to that same location. By visiting the same site that a previous mission has explored, at least some of the preliminary reconnaissance of that region, can be accomplished. For example, the Phoenix 2007 scout lander will be performing investigations of the chemical compositions of the soil including bulk constituents and mineralogy (TEGA with MS) and astrobiologically important characteristics (MECA) such as Redox potential, pH, and trace metal content, among others, in a region of the Northern permafrost regions. If compelling science discovery is made at this landing site, a follow up mission will be able to expand upon the discoveries. This can be thought of as being analogous to the early practice of planetary flybys followed by orbiters, and then eventually a lander or two. There are also possible discovery driven missions in response to MSL in 2009, and a scout mission in 2011 which an 2018 AFL can capitalize on.Proposed Landing Site Geologic SettingRecent orbital data from Mars Odyssey has located potential water ice that can be accessible to a rover with access to the near subsurface (up to 2 meters) (Boynton, et al. 2002; Mitrofanov, et al. 2002) in vastly different geological settings of high latitudes. We have identified several of those sites as potential sites for exploration by the AFL to include but not be limited to:Northern Polar CapsNorthern Polar Layered DepositsNorthern Permafrost regionsSite with recent evidence of ground meltThe northern and southern polar caps are different both in composition and geologic setting (Thomas, et al. 2000). This includes the age of the deposits in which the southern cap can be 2 orders of magnitude older then the northern one (Herkenhoff 2000; Thomas, et al. 2000) The northern polar caps offer a better target for AFL exploration then the southern cap due to H2O (Vs CO2) and geological formations including layered deposits which can have a record of part geologic and climatologic activity (Thomas, et al. 2000). These polar layered deposits can be created by Aeolian processes which can strip material from the base of the scarp. A mission to the polar caps would obtain and analyze ice cores for remnants of biological activity. Orbital data indicates that recent activity Martian gullies has taken place, and that this can be a result accompanied by submission and ablation (Howard 2000; Edgett, et al. 2003) of ground melt (Malin and Edgett 2000). This indicates that there is some cycling of material in the near surface ground which has potentially huge astrobiology relevance. Proposed science objectives and requirementsThe science objectives for the mission to an ice rich environment include the search for both extinct and extant traces of life. Due to the different types of sites that can be visited, these science investigations require different payload accommodations which would need to be made when the instruments are selected to fully maximize the science return for the AFL. The universal science objectives for any exploration of ice rich environments include:Detect the geo-chemical remains of extinct life.Determine the potential for extant life in an environment where H2O is present. Detect of dormant organisms in an environment which can periodically contain liquid water.Determine if extant life is in contact with the Martian atmosphere elsewhere on the Martian surface. Understanding the long term climate and geological evolution to determine if Mars could have been habitable in the past.One underling theme of astrobiology is the differences in planetary evolution and how that relates to habitability of planets. If Venus, Earth and Mars all formed in the “Habitable zone” of the sun why is Earth the only one to be teaming with life? An AFL mission to high northern latitudes can help elucidate this concept, by helping to understand both geologic and climate changes on Mars over it’s history. Ice exists on Mars in vastly different geologic settings and therefore there are several major differences in the science requirements both with respect to ice bearing regions as well as other Martian regions (i.e. sedimentary and hydrothermal environments). Here we will discuss science requirements that span the different geologic settings, above and beyond what the core AFL science requirements. As mentioned previously life can exist in these locations by either becoming dormant until conditions exist where the temperature is above freezing point of water, or by creating pockets of liquid water by lowering the freezing point of water. Determining if an acquired sample contains liquid water requires the collection of sample without raising the temperature above the local melting point of water (keeping in mind that the concentration of brines in the sample can dramatically lower the melting point below 0°C). The determination of liquid water in a sample is not necessarily a measurement of life, because liquid water can exist in meta stable state in some Martian environments without being associated with life (Hecht 2002). However, samples containing liquid water would be a priority target to be analyzed by the analytical laboratory instruments. In the Northern polar layered deposits the measurement of strata of layered terrain to see potential differences in layering and effects due to Aeolian processes. This would require imaging at several spatial scales.A determination of the yearly cycling of CO2 and H2O will not only lead to a better understanding both current and past atmospheric dynamics (Clifford, Crisp et al. 2000) it can potentially identify if a biosphere is in contact with the surface elsewhere on the surface. Recent discovery of methane in the atmosphere from both ground based observations and from the Planetary Fourier Spectrometer (PFS) onboard the ESA’s Mars Express, although most likely not from biologic process, demonstrates that a better understanding of atmospheric process are needed (Kerr 2004a,b). If biology is in contact with the atmosphere, this maybe detectable from orbit (i.e the recent measurements of methane) but whether life produced these gases can only be ascertained by painstaking surface measurements. Science TradesBecause potential ice missions have different geologic regions there are several science trades that can be made so as to maximize the science return of the mission. The first science trade that can be made is the level of mobility requirement. For missions to the permafrost regions and on the polar caps potentially require very little mobility (only 10’s to 100’s of meters) depending on high resolution orbital mapping by Mars express and Mars Reconnaissance Orbiter. Current orbital data on those scales indicate not much difference in geologic setting over km distances. Therefore large surface mobility could be not as scientifically important as it is for other regions. There would be, however, a need for greater subsurface access including drilling well below 1 meter to increased ice concentrations. Therefore a potential trade of horizontal distances vs. depth, would need to be madeOn the other end of mobility spectra is the recent ground water site which can require large “goto” capability of at least the level of the landing precessions if of a landing ellipse can be placed near that site. This may require mobility in the 10’s of km, similar to what would be required in the sedimentary region.The nature of high latitude northern sites indicate that for extended missions nuclear power is most likely the only feasible alternative for mission power generation as Mars progresses through its year. However, for more equatorial missions solar power can be a feasible alternative especially given the projected longer lifetimes that the on going MER missions are demonstrating. This trade will depend on the expected duration of the mission and ground operations and ability to land at high latitudes as set forth in the science requirements.Site Specific Measurements and sample handing and preparation requirementsMeasurement requirements are dependent on location. The measurements that are required for ice missions resemble the instrument complement for the other missions scenarios postulated (hydrothermal, and sedimentary deposits) and the measurements requirements can be found in section 8.2. Here we discuss measurement requirements specific to ice regions. Remote instrumentsMast based instruments must be able to do visual site reconnaissance at a level at least as well as PanCam on MER. Identifying potential targets from the distance of a daily traverse should be a requirement so that interesting samples can be targeted. Remote mineralogy of potential samples from a distance of 10 meters so that samples can be identified. The remote mineralogy instruments may have to account for ground frost when choosing a spectral range for a mast-based instrument. These requirements are virtually the same regardless of the environment AFL explores. In addition, if AFL is going to perform subsurface sample acquisitions in a high H2O environment, some subsurface reconnaissance must be done, especially if H2O varies dramatically in depth over 1 meter scales. A body-mounted detector capable of reconnaissance styled elemental abundances would also be desirable measurement if feasible and kept within the cost cap of the mission. This measurement could detect high potential astrobiological sites, as well as ground truthing orbital data. Finally, for polar cap missions, the cycling of H2O and CO2 and the interaction of those molecules from the surface to the atmosphere needs to be determined. The Martian atmospheric dynamics is not currently in equilibrium (Clifford, Crisp et al. 2000) (i.e. Aeolian processes, ablation and sublimation) Determining the atmospheric polar properties can help put a constraints on atmosphere compositions and help determine if a biosphere presently exists, as well as long term possibilities that a more favorable climate once existed. This is especially true given the recent detection of methane in the atmosphere at trace levels by both ground and orbital observations. Contact Instrumentation:The instrument delta between AFL ice and other AFL missions is that direct detection of liquid water present in a sample needs to be made. The Phoenix lander is attempting to make this measurement as well, and lesions learn in that mission will affect the design of this measurement. For mission to the polar cap, any contact instrument will also have to account for the ice core that is being obtained. Sample Acquisition and Processing: All of the hardware infrastructure referred to in this environment must be able to handle relatively large amounts of water. This includes the drills, corers, and precession sample processing and distributions stations. Water can interfere with the drilling process either by making material harder to drill into or by melting and creating a mud like material that can interfere with machinery. Drilling into this material without melting the water or using drilling fluids will need to be developed and demonstrated in both a relevant terrestrial environment and under simulated Martian conditions. Finally, for missions to the polar cap, a different sample acquisition system will need to be developed. This instrument will have to be able to melt and sublimate any CO2 or H2O while collecting impurities in the ice material. 7.4 WaterScience ThemeAssess present (and past?) Martian astrobiology by studying liquid water in the shallow subsurface.Proposed science strategiesDrill, core, or otherwise obtain liquid water sample.Determine concentrations of redox sensitive aqueous compounds, including O2, H2, HCO3-, NO3-, Fe2+, SO42-, H2S, NH4+.Determine presence (if possible, concentrations) of DOC and aqueous organic monomers, including carboxylic acids, amino acids, sugars, hydrocarbons (or should be target functional groups instead?).Determine presence (if possible, sequence or composition) of organic polymers, including proteins, lipids, nucleic acids.Visualize microbial cells (if present) with light microscopy on stained and/or unstained cells.Carry out microculturing on 1-3 samples using tens to hundreds of pre-designed growth media at several different temperatures.8.0Core Mission Components As discussed in sections 6 and 7, there currently are multiple possible variations on the AFL mission theme. Opinions differ as to the specifics of these variations in terms of context and priority, which may lead to revisiting the chosen site if selected. However, the AFL-SSG feels that it is possible to define an invariant core, which is common to most versions, along with a discovery-responsive and competition-responsive cap. The proposed mission requirements to ensure the greatest scientific return for the AFL mission include:“Go-to” mobility (ability to access a specific target). When sites are identified from orbit that possess high astrobiological interest (see Section 6.0) the rover has to be able to access them, even if the nearest safe landing site is 10’s of km away. The rover also has to explore several different regions within a high interest site. An example of this is Holden Crater (see Section 7.1) in which what resembles an ancient river delta is clearly visible in orbital images. Exploring the specific features found there would require not only a landing ellipse directly outside the feature but the ability explore several different locations several km’s apart within the potential delta system.+60 to –60 (seasonal polar cap) for sedimentary/hydrothermal. +45 to +85 for ice mission (See section 7.3).Precision landing (1 km) and the ability to land in terrain that is rougher than we have targeted in the past (hazard tolerance, hazard avoidance).In order to access more of the planet for exploration by AFL, as well as limiting costly “Go-To” traverse, having a suitable landing ellipse smaller then 10km is required. This enables access to regions like Melas Chasma, where suitable landing ellipses greater then ~5 km prove difficult to identify. Subsurface access of 1-3 m, and multiple holes. Probably also have a need to expose / drill into material in outcrops .Organic material on the Martian surface may be extremely scarce, primarily due to an oxidizing layer thought to exist because of UV fluxes at the surface. How far down this oxidant penetrates is not presently known or constrained, therefore shallow (<3 meters) subsurface material may be void of organic material. Accessing and analyzing this material may indicate if extant life is possible in a protected subsurface environment. However, if the surface regolith is largely made-up of unconsolidated material, organic free material may be thoroughly mixed by several billion years of global dust storms. In this scenario all organic material may have destroyed down to >3 meters, making analysis of this material a lower propriety (hence not a requirement). Subsurface access of potential bedrock and out-crops is highly desirable in any scenario where it is present.Organic contamination: be able to collect and deliver Earth-clean samples to on-board laboratoryIt is a requirement to have samples that are not contaminated by terrestrial organics to a level greater then the minimum level of detection of the astrobiology specific instruments. See report of the Organic contamination Science Steering group (Mahaffy et al., 2004).Sample preparation including spatially controlled precision sub-sampling and liquid extractions for selected high-potential samples.The AFL-SSG has determined that identifying the best possible sample for analysis is a primary requirement for a future AFL mission. See section 8.3 for a discussion of these requirements in more detail. 8.1 Payload strategyIt was determined that payload characteristics could be defined as core to any potential AFL mission concept as described in Section 7. These include:Acquiring the right sample.In order to maximize the probability of detecting biosignatures in a location with the high general habitability potential has to be identified. Several of the reconnaissance missions (see section 6), will be used to identify this location. In identifying the location, the understanding of the preservation potential of this location must be better understood. The Earth is inundated with biological material, where most (if not all) sites on the surface (and possibly the subsurface) should have a continual influx of biologic material. On Mars this is not the case. A location on Mars which once supported life, may not have any record of that life, due to chemical interactions, or by meteoritic impacts. Understanding how a site on Mars preserves a record of past life is essential toward acquiring the right sample. In this regard there is the need to be able to access samples with the highest probably of being astrobiologically important. This includes both identification of specific samples as well as the ability to acquire that sample. Understanding the geological, mineralogical, and chemical context of that sampleThe labeled release experiment aboard Viking, released nutrients into a Martian regolith sample to determine if metabolism took place. The results of this experiment on their own can indicate that metabolism was taking place. However when taken with the GC/MS data it was generally understood that a chemical reaction was taking place within that sample due to the oxidants present in the surface material (Mancinelli 1998). A complete understanding of the relationships between geological, mineralogical and chemical characteristics of the sample is needed to determine Astrobiologically implications of analytical measurements.Identifying the best place on the sampleInstead of introducing a core into a bulk rock crusher, in which most of the material will not be analyzed, it was determined that sampling of small features of a sample would be required. Section 8.3 describes this precision sub-sampling in more detail. Performing at least 3 different Astrobiologically related measurements. The detection of biosignatures on Mars would, to put it mildly, fundamentally change our perception of life else where in the universe. In order to avoid potential false positives, three separate measurements would need to be preformed on a sample to confirm any one measurement. Furthermore, repeat measurements will also help to avoid false negatives. Since Martian life may be very different from terrestrial life, different measurement techniques may return a positive, while others measurements may miss more subtle signs that life is present in the samples. If one or two instruments detect interesting signatures, future missions can be designed to further explore the same site for these signatures.8.2 Core Measurements and InstrumentationAs stated in Section 5.2, the proposed overall scientific objective of AFL is, for at least one Martian environment of high habitability potential, to further investigate the potential for habitability, the potential presence of the chemical precursors of life, the potential for preservation of biosignatures, and possible signs of life. This is to be accomplished through measurements supporting the following (un-prioritized) detailed Mission Objectives:Within the region of Martian surface operations, identify and classify environments (past or present) with different habitability potential, and characterize their geologic context.Quantitatively assess habitability potential: Measure isotopic, chemical, mineralogical, and structural characteristics of samples, including the distribution and molecular complexity of carbon compounds.Assess biologically available sources of energy, including chemical and thermal equilibria/disequilibria.Determine the role of water (past or present) in the geological processes at the landing site.Investigate the factors that will affect the preservation of potential signs of life (past or present) on Mars.Investigate the possibility of prebiotic chemistry on Mars (including non-carbon chemistry).Document any anomalous features that can be hypothesized as possible uniquely Martian biosignatures. This will constitute a set of working hypotheses, which will need refinement and further testing on Mars. The following Measurement Requirements for the AFL Core, derived from these objectives, were specified in order to support the instrument development and selection process for AFL:Comprehensive Imaging - Fully image the overall landscape and each investigation scene to assess the variety of local environments (past or present) that can be discerned from expressed surface features such as outcrops. Include both color optical stereo imaging and higher-resolution long-focal-length telescopic imaging of key areas of high interest for further investigation of habitability potential. Target range is 1 m to infinity/horizon. High magnification or high resolution imaging should be able to discern layering at the 10 cm scale from a distance of 1 km. These measurements support the decision to focus more closely on specific sites, targets, and samples. Supports Objectives: 1Definitive Mineralogy and Chemistry - Determine mineralogical and chemical (elemental) composition at all scales of investigation: site/scene surface reconnaissance scale (range: infinity/horizon to meter; resolution: km to cm), hand-sample scale (range: meter to cm; resolution: cm to mm), and acquired subsample scale (bulk measurement of a few-mm subsample with high accuracy), with respectively increasing degrees of definitiveness and sensitivity. Supports Objectives: 1, 2, 3.Redox Potential - Assess the redox potential and oxidation chemistry of the near-surface environment. This measurement details how much energy is available for an organism to use in growth and reproduction and would be required to be measured to a precession of 10 mV. Supports Objectives: 2, 3Fine-Scale Surface Analyses - Investigate the surfaces of exposed or acquired samples at fine scales for morphological, chemical, and molecular signatures suggesting preservation of pre-biotic or biotic organic compounds. This may include directly-detected compositional markers, evidence of minerals formed in or altered by liquid water, or particular sample textures (i.e. concretions). Color optical imaging with resolution below 30 m (although for bacterial analysis in anything other than a macroscopic biofilm structure this would be inadequate) within a larger field of view should provide the context for co-focused spectroscopic tools such as UV-excitation fluorescence, laser Raman, or other fine-scale techniques to perform chemical signature detection. Spectroscopic tools must be able to analyze mm-scale regions on surface or drill core samples (e.g., through a focused excitation source or through high imaging/detector resolution). These surface measurements provide first-order astrobiological analyses and support the intelligent selection of subsamples to be processed in the analytical laboratory. Supports Objectives: 2, 4, 5Subsample Biosignature Analyses - On selected subsamples, perform an array of high-sensitivity, mutually-confirming laboratory investigations related to astrobiology goals. Supports Objectives: 4, 5The identity, abundance, and isomeric distribution of carbon compounds should be thoroughly analyzed to low detection levels (ppb or below by weight within bulk ~102 mg subsamples) and to high molecular weights (hundreds to thousands of Da) at high peak resolutions (~2000 FWHM). Measurements utilizing broadband techniques such as pyrolysis GC-MS should be configured to enable the detection of less volatile species that are particularly relevant to determining preservation of biosignatures.The isotopic ratios of H, C, N, O, and S should be characterized with sufficient precision to enable biogenic, environmental, or meteoritic fractionation trends to be identified based on requirements determined from MSL and other measurements (sub-per-mil to % levels). Compound-specific 13C/12C ratios coupled to the analyses in (1) are highly desired. Additional isotope ratios that further characterize atmospheric loss and other environmental fractionation processes relevant to astrobiology are also desired. Analyses may also be conducted on atmospheric samples to provide a more complete understanding.Highly sensitive tests for the presence and characteristics of specific biosignatures should be conducted on bulk subsamples or isolated downstream extraction products (e.g., phases or concentrates). Biosignatures of particular interest include molecular compounds (or abundance patterns thereof) of distinctly biological origin as known on Earth, indicators of extant metabolic processes such as disequilibrium chemistry (molecular, biogeochemical, agent response, etc.), as well as chemical and morphological traces of such compounds and processes as preserved in the mineralogical microenvironment sampled. While the specific tests to be conducted will depend on the chosen AFL landing site and previous mission results, examples include detection of amino and nucleic acids, lipids, and proteins (with ppt detection limits if possible); chirality of amino acids and sugars (with %-level enantiomeric excess detection sensitivity); detection of concentrations of distinct molecules or isomers of the potential abiotic inventory that may represent the use and or concentration of a fraction of the molecules available through non biological interactions and finally direct detection of microbes, cells, or their fossils. It must be mentioned that the advent of micromachining and the concept of micrototal analysis systems (uTAS) mean that through miniaturization the payload described may be integrated into a very small space whilst retaining accuracy and possible increasing analysis times.The above information is summarized graphically in Figure 5.Within the proposed AFL strategy, techniques to address the above requirements are structured in “tiers” following the expected level of physical sample contact: remote/standoff; contact; and laboratory. In the remote/standoff tier, the target “sample” is a wider area and not acquired by definition. In the laboratory tier, a small sample of interest has been acquired and possibly subjected to a preliminary analysis that supported the decision to subsample and deliver it to the laboratory for further analysis. However, in the contact tier, the sample may be analyzed before or after it is acquired (or both). This is designed to allow multiple levels of “triage” for determining the appropriate course of action with a given sample. An example of a post-acquisition contact measurement is a point-by-point imaging and chemical analysis along the surface of a several-cm long core. Based on this analysis, it may be decided to grind and/or otherwise process some or all of this core for analysis in the laboratory. For a description of the suggested mapping of measurements onto instruments placed in each of these tiers, refer to Section 8.1.4.For completeness, the connection between the AFL measurement strategy and the mission objectives may also be characterized by indicating those objectives addressed while conducting the following activities:Acquire the right samples (primarily 1; also 3)Understand the context (primarily 1, 2; also 3, 4)Identify the best place on the sample (primarily 5; also 2-4)Perform mutually confirming astrobiology measurements (primarily 5; also 2-4)This is summarized in Figure 5.As mentioned above the instrumentation recommended for the Astrobiology Field Laboratory is divided into three categories or tiers: 1) remote sensing instrumentation located on a deployed mast, 2) a contact instrument suite located on a robotic arm, and 3) the laboratory suite located inside the rover and/or platform and fed with a sample acquisition and distribution system. The remote sensing suite is used to provide site characterization and rover navigation targeting. The contact suite performs “triage” analyses, mimicking a field biologist/geologist. The laboratory suite performs the detailed biology, chemistry, and mineralogy experiments required to quantitatively assess samples for past or present biological potential. Sample analysis instruments are supported by sample acquisition and processing infrastructure such as an articulated corer, (cm to 1 m) a rock abrasion/polishing tool, a precision subsampling tool, and possibly a 2.5 m drill.The remote sensing suite includes at a minimum a panoramic multi-filter camera system that is used for site characterization, rover navigation, and first-order target selection. Additional instrumentation that may also be desirable may include reconnaissance-scale chemical and mineralogical experiments, such as hyperspectral imaging, stand-off (multi-meter) laser induced breakdown spectroscopy with fluorescence and Raman detection, and thermal infrared mapping for identifying geothermal sources of heat within the near-horizon of the Martian environment.The contact suite must provide the second order triage for sample selection. The analogy is the selection and preliminary analysis of a surface material or hand sample by a field biologist or geologist. A sample arm equipped with an articulated coring drill and a rotating abrasive tool for clearing and polishing rock surfaces is envisioned for contact arm infrastructure. The contact suite includes at a minimum a course resolution (~20 m) microscope to examine the texture and other features of rocks and fines. Sample triage on AFL will however require additional contact instrumentation that further identifies materials of high interest for subsequent precision subsampling and laboratory measurements. The complement of contact instruments will be determined by the objectives at the type of site chosen for AFL: sedimentary, hydrothermal, ice, or liquid water. Possible arm-mounted spectrometers include: near infrared reflectance, Raman, Mössbauer, APX, deep-ultraviolet fluorescence, and/or various types of laser ablation sampling spectrophotometers and direct-inlet mass spectrometers. These tools are used to probe for and characterize samples of potential biological interest that may be delivered to the laboratory analysis portion of the payload.Figure 5. AFL Measurement RequirementsThe presence and design of the laboratory portion of the AFL payload is predicated upon a high degree of flexibility with respect to sub-sampling of the acquired rock core or soil sample. Therefore, there should be a strong emphasis on an integrated analytical laboratory approach to fully characterize common or related sub-samples: using microscopy as the “eyes”; definitive mineralogical and chemical identification from techniques such as x-ray diffraction, x-ray fluorescence, and laser ablation; and organic chemical and stable isotopic analyses that include at a minimum instrumentation capable of similar measurements to a pyrolysis-gas chromatography-mass spectrometer. Enhanced capabilities for identification of trace pre-biotic or biochemical compounds may be provided by staining followed by fluorescence detection techniques, solvent extraction/derivatization followed by a suitable ion mobility or mass spectrometry system, and other more specific techniques that target the detection of biomarkers such as amino acids, proteins, and/or DNA such as capillary electrophoresis, use of specific probes i.e. polymer or antibody systems and chemical assays. The particular implementation of more-specific biological/chemical analyses will depend both on the results of prior missions, such that their design and interpretation is advised by a solid first-order organic chemical characterization of Martian surface samples, as well as through analog field experiments targeted at terrestrial extremophiles. Additional capabilities such as detection of enantiomeric excess (chirality), rock dating, and fine-scale chemical imaging would be strongly complementary to the laboratory suite and highly desired for AFL. Such experiments might be provided by enhancements of previously mentioned instruments or by additional instruments.The final selection of instrumentation on AFL will be based on a careful cross-matching of measurement requirements to instrument capabilities. It is recommended that the payload resources (mass, power, cost), and thereby the mission scope, for AFL be fundamentally and primarily driven by the sample preparation and instrument needs that are required to fulfill the measurement goals, rather than vise-versa. New instrumentation techniques as well as methods to optimally integrate techniques are desired and encouraged, but these must be maintained within a reasonable cost-risk profile. This necessitates a well-funded, well-advanced instrument development and integration program with strategic oversight form cognizant AFL program members.The core measurements of AFL has been decided upon to answer the specific questions posed in the science rationale. The high number of instruments on this mission definition is a direct response to the findings of both sedimentary and hydrothermal deposits by the Mars Exploration Rovers and the subsequent realization that samples of Astrobiological interest may be much more accessible than originally thought. This allows deep drilling to be traded off against increased number of instruments. 8.3 Sampling and Precision Sub samplingAccording to the various mission scenarios, different types of samples will need to be obtained, i.e. from rock, ice, regolith and sedimentary samples. The design of the SHAP facility and the exact number of samples to be handled and processed will depend on which mission scenario is decided on. This number will help define the sample collection system that will have to be developed. The basic concepts and design of the facility, however, will in principle remain the same for each type of sample and each type of measurement to be performed. Four different facets of the overall process are identified: Obtaining a samplePrecision sampling of that coreLiquid and Heat extraction of organicsContamination concernsIssues were discussed with respect to each of these types of environments and are discussed in more detail in the following.8.3.1 Obtaining a sampleSeveral sample acquisition tools are suggested for integration into SHAP facility. In order to be more precise the following defining terms have been made:Corer: A device that can obtain a core which is ~ 5 cm in length with ~ 1 cm in diameter from an outer region of a rock on the surface of Mars. Drill: A device, which can obtain sample from inside of a rock permafrost or sediment (cm – 1m) or from a distance underneath regolith (1-3 m). Precision sub-sampling mechanism: A device, which can obtain a representative sample form a larger core. This would replace the rock crusher, which crushes the entire core, and produces fines, which might not be representative of the entire core. Scoop: A device which can collect either fragments from a RAT, or unconsolidated regolith or permafrost material from the surface. An aspect to consider is that idly sitting and drilling for significant time spans on Mars, drilling does not seem to be an efficient use of a limit mission lifetime. However, a system that could drill while not shaking the rover or consuming major power would need to be developed. For example, if an instrument such as XRD or deep UV fluorescence can analyze rock fines and fragments during drilling, we can identify samples that might be interesting, either because they are a fundamentally different type of mineralogy, or because of interesting organic components detected in them. This will not only help in sample identification, but also in the operations profile so that overall more samples can be analyzed. Ice:A drill would be required capable of gathering an ice rich sample while avoiding sublimating the ice, melting it, or volatilizing any constituent molecules. The sample must be as chemically similar to the material it is collected from in order to do a proper analysis. This most likely requires nighttime drilling operations in ice rich environments with a drill cooled to a temperature lower than that of the ice to mitigate cutting, melting and drill trapping problems . Permafrost regions: Samples that contain a mixture of ice and other material will have to be specially treated. Terrestrial permafrost can create problems when attempting to obtain a core from it in terms of both hardness and ability to keep the sample pristine. Samples will need to be obtained from a device that can be used multiple times while not heating the sample above freezing. Surface Rock:The depth MSL is coring to, 5 cm, seems to be a good number for the depth inside a surface rock that should be sampled. Terrestrial organisms practicing photosynthesis inside rocks inhabit approximately the outer 2 cm of sample a rock. Sedimentary material can be identified by obtaining several cm in length cores. It would be desirable to analyze the fines from the core if coring is progressing by a pneumatic device for introducing fines into the analytical suite. In this scenario, the XRD can analyze material as it is chilled in order to identify regions of interest, since the XRD can do infinite number of samples. When an interesting sample is identified it can be further processed via the other analytical instrumentation. Regolith: Regolith material would be obtained by a scoop attached to the rover arm and be delivered to sample processing facility. It is worth considering that if the regolith material is unconsolidated, we may assume that it was never in contact with the atmosphere. If it was at some point in the recent past, it could mean that it would be chemically the same as the surface material, and hence not worthy of a drilling effort. Unless the rover is going to head to a site where larger amounts of near surface (to the depth of the drill) water drilling into regolith would be desirable, otherwise it most likely is not. 8.3.2 Sedimentary deposits:If a landing site were selected where drilling into for sedimentary deposits is required, it would be preferable to look at the entire core length. If a complete core could not be obtained because of engineering constraints, having a borehole instruments that can be lowered into the borehole, and examining the entire length of it would be very desirable. Instruments that could be utilized to answer astrobiologically relevant questions (rather then pure geologic questions) would need to be identified. In this scenario it might be worthwhile considering a drill/corer combination, where a drill takes 5 cm cores at a time, delivers to the sample processing facility and be lowered back into the borehole and continue drilling to the desired depth. The ocean drilling industry has begun to develop instrumentation for borehole instrumentation where a geophysics package of instrumentation examines the bore hole. Further development along these lines would be invaluable to any drilling that would take place on Mars. 8.3.3 Precision sampling of a coreOnce a core has been obtained, it would be injected it into a sample triage station. On this station we would like to look down the axis of the core with the contact suite of instruments, especially if the core was delivered intact. This way layering structures can be identified that might be indicative for a sedimentary material or any other area of interest in any type of sample. After the initial analysis, it is not necessarily desirable to process the entire core in an instrument like the rock crusher. If any regions/layers of interest have been identified in the core, these layers would be diluted/mixed with the other less-interesting layers, and thus make the analysis of the core material give results that are not necessarily indicative of a specific region. Furthermore, the rock crushing mechanisms could produce material that is not necessarily representative of the entire core, due to the crushing mechanism. Simply put, a precision sample handling system needs to be developed that is much more advanced then the rock crushers on MSL. This precision sample handling system would most likely replace the rock crushers on MSL as they are currently designed, because there most likely is not enough mass to have both type of instruments aboard. The precision sample handling system would need to produce fines from a core that are on the order of 100 m, although finer material is always preferable. These fines would need to be produced from regions of the core that are less then 1 cm in length. Although an exact amount of samples that would be useful for each analytical instrument cannot be accurately defined without knowing what instruments have been chosen, a good working number is 100 mg.A further developed system for AFL would allow for fines to be obtained from various parts of the core, where astrobiologically interesting signatures were observed. These fines then could be identified by the contact suite or by analysis of the fines that were collected during the coring. A possible method this material can be obtained is via a pneumatic drill, analogous to a dentist drill. This type of sample processing of a core needs to be further addressed, as it may require holding the core so that further processing can occur. If the core would be held in a fixed position, a grinder could grind parts of the core while those fines are collected. Any other material that is produced from this step could be looked at with a microscopic imager, if one is chosen as apart of the science payload, but no further analytical analysis of it would need to be made. 8.3.4 Ice SamplesTerrestrial organisms can maintain a layer of liquid water around them in an environment where the temperature is below the freezing value for that corresponding pressure. Therefore, one of the main science investigations with ice is to determine if there is any liquid water in a sample. In addition, volatile material present in the sample might undergo reaction and hence change its form, which might lead to incomplete analysis of the obtained sample. Because of these reasons, it seems desirable to obtain a sample without allowing the temperature to pass above conditions in which phase transition that any water (and potential brine solution) present would undergo for the ambient pressure and temperatures present. From permafrost, it is expected that a core approximately 5 cm long and 1 cm diameter would be sufficient for further studies, however, a larger core would likely allow more comprehensive analysis to be performed. With permafrost samples, the possibility should be considered to include a sample concentration device in the sample possessing suite. This concentration process would only take place after any measurement on liquid H2O on the pristine sample has been performed. The overall strategy for a “polar” mission largely depends on the choice of landing site, i.e. whether it is permafrost or on the polar cap. If a polar region is decided upon, it is suggested that the obtained ice core is analyzed as a whole, especially if only 5 x 1 cm core are obtained. This based on the assumption that the recent ice deposits will not show much evidence of layering or zoning. However, should new data become available through Phoenix investigations, this approach may have to be restructured and a more capable precision sub-sampling system be integrated into this mission concept.8.3.5 Liquid and Heat extraction of organicsOrganic analysis has been one of the important measurements the Astrobiology Science Steering Group has identified that AFL should be able to perform. In order to identify organic material, they need to be released from the matrix material they are a part of, especially since surface organics on Mars might be very rare. Several ways to extract organics form rock samples were discussed, including using heat and solvent extractions. Each extraction technique has its advantages and disadvantages. However, it is currently not clear whether there would be enough mass to be able to perform both techniques on the same mission. Also, in an extended surface mission (~900 days), which is powered by a nuclear power source, either extraction technique would need to demonstrate that it can perform analysis on a large number of samples (exact number TBD) that such a mission would be able to collect. Different materials require different extraction strategies. For example, some liquid extractions will miss kerogen type material because of its high molecular weight and low solubility, while heat will destroy most of the more fragile biomarkers such as amino acids or hopanes, resulting in the loss of important molecular information. MSL will, most likely, have some form of heat extraction, although what this will look like will be dependent on the instrumentation that is chose for that mission. Generally, more refractory, fossil, nonpolar compounds require organic solvent extraction. The choice of solvent depends largely on the polarity of the target compounds. Solvents commonly used are for example hexane, dichloromethane, toluoene, methanol, ethylacetate, propanol, or mixtures thereof. It is necessary to identify mixtures that have highest extraction efficiencies and at the same time covering the broadest possible polar-nonpolar stretch. Organic solvents would be needed for GC/MS sample preparation (and to some degree HPLC but this varies depending on column design and target compounds; H2O and methanol are commonly used as eluents, but could also be acetonitrile, dioxane, ethanol, isopropanol, etc.), in order to obtain molecular information from refractory compounds.Aqueous solvents (such as super critical water) would be used for amino acid, DNA/protein extraction e.g. for microarray analyses, capillary electrophoresis, culturing experiments, flow cytometry or perhaps even PCR. Numerous proprietary and commercially available extraction kits exist using a variety of different solvent compositions, all being aqueous solutions. It would be required to identify optimized procedures and optimized solvents and/or solvent combinations in future laboratory experiments, e.g. using Mars analogue materials spiked with microbial cells and/or organic target compounds. Other extraction technologies are currently available and need to be examined more in the context of Mars missions these techniques are not limited to but include; microwave, super critical gas (i.e CO2) ultrasonic and sublimation. It is important to point out here that no judgment is made on which extraction technique is preferable. This is simply an attempt to identify which technique (if either) can be made a facility instrument aboard AFL, and hence have several instruments analyze the extract from the surface samples. Currently, different instrument developers focus on developing extraction techniques for their individual instruments. These techniques do not necessarily have much overlap from instruments to instrument. If consensus could be formed that a particular set of extraction mechanism is desirable (i.e. utilizing H2O at 100oC) it could necessitate a facility instrument to perform that extraction and pass the extract to different instrumentation. This would accomplish reduced mass and power requirements, as well as allow for several instruments to analyze the exact same sample. Extraction conditions are currently being investigated utilizing different techniques solvents and temperatures. However, the extraction mechanisms need to demonstrate that they are small and repeatable. Null-results from AFL can have great meaning, but they need to be absolute and definable. The Viking GC/MS results showed no organics, but those results don’t necessarily mean there were no organics in the soil that was analyzed. The GC/MS has limits of detection that can be easily determined for single species. However recent work has demonstrated that the Viking ovens were set to a temperature that would have not released certain organics that could have been present in the soil (Glavin et al., 2001). In addition other types of organics could have been destroyed by the heat, and thus not detected. In order to determine what a possible null-result means, an end-to-end analysis would need to be carried out.Pyrolysis heating:The Viking landers each had ovens as part of the GC/MS system, although the ovens themselves were not able to reach the temperature necessary to detect some of the organics that could exist there. The Rosetta mission has a small oven, Phoenix has the TEGA, which has eight one-time-only use ovens attached to an EGA and a MS. MSL is intended to investigate multiple samples (24 floor, 78 goal) and has baselined a GC/MS as an instrument. If the development of a multi-use oven is not made, then it would require a ground decision as to whether or not to analyze a sample, if only a limited number of samples that can be analyzed. This would necessitate a science decision, which could delay other analysis on the surface, and limit the number of overall sites that can be visited. Another prospect of the pyrolysis method is whether it could be designed in such a way that it is capable of concentrating signatures on a sorption trap. If so, any use of those traps will also have to be shown for the same number of samples that the rover will analyze. Also, as mentioned previously, all limits of detection should be for the entire end-to-end system, for a variety of different mineralogical samples. Liquid extraction: Liquid extraction is a more gentle way to extract organic molecules from rock and soil samples. One analogy to Martian surface investigations is the analysis of organics from meteoritic material. In those investigations, the organic molecules were released by either hot water extraction or by HCl extraction. Current development of novel techniques for the extraction of exophase biomarkers needs to continue, as does the determining the most efficient solvent extraction parameters. Should a sample be analyzed for its indigenous water content, it might require using another, yet to be determined, technique. In addition, different solvents can extract different types of molecules, water, as it approaches the critical point, becomes a good organic solvent. Clearly, more science groundwork has to be carried out to obtain comprehensive information to allow the best possible choice of solvents to be used. Other solvents that are used in the laboratory include HCl and other acids. These acids perform a more complete digestion of the matrix material, and increase efficiency of extraction, but are harder to handle because of their corrosive nature. With any solvent that is chosen for this step it should be noted that it would be able to concentrate the material to ensure a better signal to noise level.It is currently unclear whether the liquid sample handling system needs to be completely reusable or whether one-time only use should be the preferred option. This information will become available as experimentation and technology development continues. The only stipulation that needs to be made is that the extraction technique minimizes mass and power resources. Finally, there are other measurements that can be made during the extraction phase, which would not be possible during pyrolysis heating. These include pH, Redox potential of the material, etc. All of these measurements can help elucidate habitability issues and are an extra measurement that can be made, and if the liquid extraction step is a facility instrument should be made. 8.3.6 Contamination concernsThere are two issues that need to be addressed from for contamination concerns:Contamination issues from organisms brought from EarthCross sample contaminationThe issue of terrestrial contamination being detected and identified, as material present on a Martian sample is, by far, the main concern. Several different mechanisms can help reduce the possibility of this. A sterile sample can be brought from Earth and run through the system for the first analysis to show that the end-to-end system is clean and contamination free. If this step produced positive results, it will show that the sample system was not clean and would have to be cleaned e.g. by flushing with a sterile material blank. After the initial sterile material is analyzed, surface dust could be analyzed next. This material is most likely sterile due to UV irradiation and is most likely homogenous across the planet. After the analysis of such sample through the entire system, this material can be used as a negative check for the entire system. If a sample is later found to have the signatures of life, analyzing another soil sample can perform a negative response check of those results, which will further validate the biosignatures that might have been identified.The other form of contamination is sample to sample. While it should be noted that a general cleaning between samples should be performed, reducing the cross sample contamination should not be a major power and mass drain, which could be better used in other systems.8.4. Time resolved MeasurementsFor some versions of AFL, time-separated repeat measurements (to observe changes) will be valuable, and these were strongly advocated by some members of the SSG. Given current understanding of Mars, we do not know enough to design the time gap that would be needed in such an experiment (minutes?, hours?, days?, months?), or the fidelity to which the subsequent experiment(s) needs to duplicate the conditions of the first in order to provide a meaningful hypothesis test. The AFL SSG takes the position that time-separated repeat measurements are not essential to all versions of AFL.  Thus, this should not be a part of the common overall mission scientific objectives. The AFL SSG recommends that the capability to do at least some time-separated repeat measurements be a general functionality of the surface science system, and that the decision on how and when to use it be deferred to the competitive process. 9.0Engineering analysis of AFL coreBased on input from the AFL SSG, a preliminary engineering design concept was defined so that basic mission parameters (such as mass, cost and power generation systems) could be developed. This was done so that technology developments that will be required to undertake the mission could be identified and pursued. This design concept was based upon the AFL SSG core mission requirement and included possible investigation of sedimentary, hydrothermal and liquid water regions. Other investigation (namely to ice covered and sub-surface ice regions) may require a different architecture and hence have a different mass, cost, and power generation systems. The mission architecture was defined by taking into account the measurement objectives, payload infrastructure rover mobility requirements and lander capabilities (Section 8). Given all these requirements and capabilities, a core AFL mission was developed. The mission studied included 2 instruments for remote sensing placed on the main mast, 2 contact instruments located on an instrument deployment device (IDD), and 6 analytical laboratory instruments capable of analyzing samples obtained from the Martian surface for a total of 10 instruments. The analytical instruments, as well as the sample acquisition and processing infrastructure, will be able to process 25-75 physical samples (rock, regolith, and ice) for detailed analyses by both pyrloysis and wet chemistry instrumentation. Landers, Entry Descent Landing (EDL), cruise launcher, were defined in such a way to meet the mission requirements and so that costing the rover and mission could be done. In order to accomplish this, a list of generic instruments were identified so that parameters such as cost, mass, volume, and power requirements could be included in the engineering design concept. No attempt was made to identify and place individual instruments on the strawman payload (used to assess cost only) and where several instrument from different developers were identified, average mass power and volumes were used. The engineering design concept assumed a launch in either 2013 or 2018 with a Technology Readiness Level (TRL) of 6 for instruments and subsystem technologies that would have to be reached by 2009 and 2014 respectively. Functional redundancy was required on all subsystems except for the science payload, and this included the sample acquisition and processing infrastructure. Landing site availability for the AFL SSG included access to the Martian surface between: +85 to –60 so that access to both ice regions as well as a wide variety of potential Sedimentary and hydrothermal regions can also be investigated. Landing altitudes of 2.5 km or less relative to the MOLA geoid should be reached within a 10x10 km (3-sigma) landing dispersion ellipse assumed for landing. Because AFL will be assumed to be a mission to a specific site of high scientific interest, rover was designed with “Go-to” mobility capabilities of 10-15 km (linear traverse range) so most astrobiology interesting sites could be reached and explored. For data transmission between Earth and Mars, either MTO or the second generation Mars Telecom Orbiter (MTO) was assumed to be available for Mars to Earth telecom greatly increasing the amount of data that could be acquired on the mission. The collected data would be passed to Earth via 0.3 m HGA for 1024 kbps link via MTO. This design allowed for a data intensive 1-3 GBits of daily science data generation. X-Band from rover direct to Earth (DTE) would be used for back-up purposes only. Finally the main power system of the mission was assumed to be a Radioisotopic Thermal Generator (RTG) system, although solar power could also be utilized for missions that are more equatorial, and potentially shorter in duration (depending on final MER mission power results). The power systems was sized to be able to provide sufficient power with reserves for “worst case” extreme drive Sols (large rocks and slopes) and for analytical laboratory days. Based on this analysis a 4 Brick Small RPS system capable of producing 50We, or 1200WeHRS per sol in combination with a 2 x 8 Ahr-Li-Ion battery system was chosen. Because of the inefficiencies in power generation from an RPS system waste heat has to be dissipated. Therefore, A passive thermal loop system driven by the 1000Wt energy from the RTG system, in combination with electrical heaters, thermal switches, and radiators was designed for the rover for keeping the Warm Electronic Box (WEB), external actuators, and instruments at acceptable temperatures ranges. The passive thermal system on the rover would in combination also be used for dissipating energy from the RTG system the during EDL and cruise stages.To generate the required science and analyze 25-75 samples, accommodate the selected science payload strawman and provide sufficient power, data storage, data rate, and telecom to an MTO type orbiter, the rover itself would have a mass of ~550 kg (30% reserve included). Of this ~110 kg (~20% of rover mass) would constitute the science payload (once again, depending on the exact parameters of the instruments selected through AO). Bringing such a rover to the Martian surface would require a launched mass of 2456 kg, which would demand an Atlas V521 or a Delta IV 4040 launcher. Assuming, a MER cruise stage, Viking style EDL system with a live lander, this would give an injected mass at Mars of 2174 kg, and require a 4.57 m aeroshell and two chutes during descent. The rover assumed in this study shares heritage with MER however, final design characteristics for the 2009 MSL mission will influence this decision. The rover includes a mast for the remote sensing instrument, an IDD for the contact instruments and sample acquisition, a detailed sample handling system and an analytical laboratory suite of instruments. The six rover wheels were increased in size to 35 cm (diameter) to negotiate larger rocks and extensive Go-To requirements (as discussed below). Each wheel includes a brushless actuator, which would draw 16-25 W per wheel, and a total of 100-150W for all wheels during traverse depending on surface characteristic of the site (i.e. slop, rock distribution, surface material etc.).The result of the costing exercise resulted in a 2013 mission cost of $ 1.55 Billion (in RY dollars) and 2018 mission cost of $ 1.78 Billion (in RY dollars). This includes ~ 200 million for instruments and infrastructure and ~ 500 million for all the rover subsystems. These numbers should be adjusted as the design for MSL becomes more set. Savings for things like built-to-print hardware and heritage in the EDL and avionics systems may result in mission savings.In order to meet the mobility requirements for AFL, the mass of the rover and the potential investigation site are taken into account. One requirement for AFL is to investigate a site(s) that are most likely to have high astrobiology interest. This requirement can mean traverses of up to 10’s of km depending on landing ellipse constraints such that the rover design for longer traverses in Mars terrains must be taken into consideration. In addition, the AFL payload will be much bigger than MER with a scaled rover and hence the wheel contact area has to grow from the 25 cm wheel diameter on MER to accommodate low surface pressure for minimizing wheel sinkage. There are some basic assumptions we can make based upon Mars geology and the proposed investigation sites, such that the mission requirements (see section 8.0) can be accomplished and \ a reasonable preliminary design can be created from which approximate mission costs can be estimated. It needs to be pointed out here that this preliminary analysis is by no means a complete engineering analysis, but it is designed to show approximate system requirements for planning of total mission costs as well as mobility potential for site selection. Finally, with this analysis a decision on the level of required precision (or pinpoint) landing can be made so that investment in technology development for AFL can be carefully planned.Figure 6. A schematic diagram of how AFL may lookTechnology development to fulfill science and engineering goals is summarized in Table 6.can be seen from Table 6 significant development of critical enabling technology should begin as soon as possible, especially for 2013 launch.As with all other JPL Rovers, AFL’s drive train subsystem was assumed to be a 6-wheel design. Each wheel has two motors: one turning the wheel, the other steering the wheel. All motors are brushless and 2, 4 or 6 wheels can be driven at a time depending on the terrain. Each wheel consumes approximately 8 W in stand-by mode and about 18 W when driving, making the drive train subsystem the largest power consumer (when operating) on AFL. Additionally, a maximum slope tolerance 30o is assumed due to both current design configurations and projected technology advancement. We have assumed that the technology for continuous drive and autonomous hazard avoidance will be developed and eventually will undergo flight qualification so it can be utilized on AFL. The wheel diameter to be chosen will be large enough to avoid typical Martian hazards (i.e. surface rocks) so that linear odometer distance can be maximized while being small enough to minimize mass and power (which is related to wheel size).Table 6. Summary of necessary technology for AFL, in particular highlighting instrument development in critical areas as defined by the AFL team. This is not to exclude established technologies from development but merely highlights other critical technologies that should be further developed. 10.0Planetary ProtectionThe different variants of AFL may end up in any of three Planetary Protection classifications.Category IVb is applied to missions that investigate extant Martian life forms. This may include AFL-Liquid Water and AFL-Ice (depending on the instruments).Category IVc is applied to missions that access Mars “special regions”. This would include AFL-Liquid Water, AFL-Ice, and perhaps other AFL versions, depending on landing site.Category IVa is applied to landed missions other than the above. This could apply to AFL-Sedimentary and AFL-Hydrothermal (depending on landing site).To achieve maximum flexibility, mission engineering should be planned assuming IVb, and de-scoping, if appropriate, can take place from there. The four variants of AFL will have very different implications for Planetary Protection and therefore must be reviewed on a case by case basis.It is noted that many developing technologies are available for contamination monitoring, decontamination and space craft cleanliness issues. These technologies should be vigorously pursued. In particular the following;Low temperature sterilization techniques such as microwave plasma and other plasma ashing techniques,Radiation sterilization technologies for whole space craft as well as ‘hot-spot’ removal.Real time non culture based systems for monitoring amount and types of bioburden.Providing of a suitable mineralogical bio and organic clean sample blank for proofing critical sample handling pathways and It should be noted that several of the analytical techniques mentioned in the AFL instrument section cannot undergo heat sterilization. Protocols that either ensure that instruments are delivered cleaned to the level of the space craft and integrated to the craft after heat sterilization, for the use of cooling loops to keep critical instruments cool during sterilization (obviously the previous point would apply here) or alternatives to heat sterilization must be put in place for these technologies to fly.11.0Relationship between AFL and MSLAFL will depend on the following heritage from MSL.Precision landing using a novel (non airbag) landing systemThe use of RTG technologyThe use of remote, contact and analytical suites of instrumentsCrude sample processing to be used but improved on AFL2.AFL will differ from MSL in the following essential respects:Advanced sample preparation system.Precision sub-sampling is an advanced sample management step that will allow a scientific focus on meso- to micro-scale discoveries of enhanced astrobiological interest. This will allow a much higher capacity to investigate specific anomalous features.Liquid extraction. For advanced studies of carbon chemistry, more efficient sample extraction (and instrument delivery) methods are needed.Better and miniaturized organic molecule and life-detection related instruments.Greater interplay between Precision landing, hazard tolerance/avoidance, go-to mobility. –Will give us the ability to follow-up on specific discoveries, including in “interesting” terrain.12.0The Future of AFLIt is suggested that the SSG reconvene at a later date to Respond to discovery to hone mission concepts for site selectionReview sample handling and instrumentation choices and feed-forward to a possible sample return missionRespond to shifting of the AFL timeline from 2013 to 2018, this would include revisiting the instrument choices based on comments from the SSG as to the use of instruments currently in development but of such a low TRL that it could not feature in the 2013 timeframe example include high vacuum and high voltage instrumentation such as electron microscopy, or photoelectron spectroscopy. In the past, there was competition between in-situ and sample return mission concepts and there was a question as to whether the AFL was to fly before MSR or after. The current schedule envisions an AFL flight as early as 2016 and an MSR some time after 2020. The advantages of flying in-situ missions first are that they are relatively low cost compared to MSR (although the costly infrastructure put in place for an initial MSR would not be needed for follow up missions) and there are no issues of sample degradation, sample amount, sterilization, quarantine or ‘off nominal’ delivery to earth. In addition, the strength of in-situ missions is their ability to assess multiple samples over a spatially diverse area without degradation of the samples. AFL will aid in the identification of sample types for future return missions. This may even include aiding sample caching for a future MSR mission, although that would necessitate a further assessment of precision landing of an MSR mission. A point to remember is that if / once detected life on Mars should be characterized in its entirety for similarity to earth life, evolution and biochemistry (if viable). Therefore both AFL and MSR must be considered necessary tools to be used at the right time to answer science questions within the foreseeable realms of technology..Several aspects of both the sample handling capabilities for AFL and the choice of instrumentation will allow the further development of robotic tools to explore elsewhere in the solar system e.g. Europa. This instrumentation although initially geared for the detection of life would upon the successful accomplishment of this task be needed to be further developed to characterize that life in whatever form. It will not be enough to ask was/is there life there, the next logical step is how did it arise, how is it different from earth life and why? It is only by taking this step will we able to understand truly the processes of abiotic / prebiotic / biotic chemistry in the solar system.Note, the bulk of this work and the draft white paper was completed by September 2004. There have been unavoidable delays to its publication. In the meantime thinking about AFL has progressed. This document reflects the thinking in September 2004. Whilst engineering and programmatic changes have occurred since then, the strength of this document lies in the science definition for the mission.13.0ReferencesAbrajano, T.A. et al (1988). Methane-hydrogen gas seeps, Zimbales Ophiolite, Philippines. Chemical Geology 71: 211-222.Allen C.C. (1979) Volcano-ice interactions on Mars. Journal of Geophysical Research 84: 8048-8059.Allen, C.C. et al., (2001) Importance of a martian hematite site for astrobiology. Astrobiology 1(1): 111-123.Arvidson R. E. (2004). Localization and physical properties experiments conducted by Spirit at Gusev crater. 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Hydrothermal origin for carbonate globules in Martian meteorite ALH84001: A terrestrial analogue from Spitsbergen (Norway). Earth and Planetary Science Letters 204: 323-332.Walter, M.R. and D.J. Des Marais (1993) Preservation of biological information in thermal spring deposits: developing a strategy for the Search for a fossil record on Mars. Icarus, 101: 129-143. 14.0Appendix 1. Discoveries AFL must respond to.Table 7 Summarizes crucial science discoveries that may also directly affect AFL mission, potential follow up questions and measurements15.0Appendix 2 - Instrument descriptions and capabilitiesIn this table, a number of techniques were suggested by AFL SSG members as potentially applicable to one or more identified measurement objectives. This list is not meant to be comprehensive or definitive, but rather to illustrate the kinds of information that would enable instrument development efforts in general to connect to the specific needs of AFL. As such the table does not identify all aspects of each technique, but only those that were discussed in a preliminary analysis of the desired measurements on AFL. The first and second columns identify the technique and the type of measurement(s) with which it is typically associated (Data/Signatures Sought). The third column explicitly lists the most likely AFL measurement requirement that the technique addresses (see Section 7.0). In this way, techniques applicable to a given measurement of interest, or more generally to a mission objective (see Figure 5), can be found by examining those rows containing the category (1-5) desired. This column is meant to serve as an example template, so all potential uses of each technique are not identified. The next three columns indicate the most likely associated tier(s) for the technique, corresponding to the recommended division as discussed above.The following thirteen columns provide data for example implementations of the technique where useful specifications of the sample analyzed and typical instrument parameters could be identified. Given sample data include: 1. the physical form as acquired or as extracted/analyzed – solid (s), liquid (l), or gas (g); 2. the type of material from which it is obtained and/or delivered to the instrument; 3. the type of sample preparation required and/or desired (see key); and 4. the typical size or mass of sample, additionally indicating where a technique looks only at the surface of a solid sample rather than the bulk. The first three columns of the Example Technique Characteristics section provide some of the key distances involved: the standoff, the field-of-view (FOV) or spot size, and the scale of the heterogeneity probed, if appropriate. The heterogeneity is indicated by the structures (e.g., layers or grains) that can be individually analyzed with the method’s FOV or spot size. For example, a Hand Lens instrument might look at individual mineral grains and similar size structures within a mm-cm FOV from a standoff focal length of a cm or so. In this example it is the imaging resolution, not the FOV, that determines the smallest structures observable, and that additional data is found in the resolution column. On the other hand, for a laser mass spectrometer, the spot size does roughly determine the spatial resolution of analysis – a spot size below 100 microns could enable analyses of mineral phases on the mm scale; what is then found in the resolution column is in fact the mass resolution, since that is how the term is used for that method. Further, the Mass Range column gives the typical range of molecular weights that are accessible with a given mass spectrometric method.Finally, the remaining columns provide a correlation of where a technique would be applied in support of various discovery-responsive measurements by AFL that would be called for following the discoveries listed in Appendix 2. This separate correlation, beyond the technique-to-measurement requirement-to-mission objective logical chain, permits a greater flexibility and responsiveness of the AFL concept to specific scenarios that may develop from current Mars missions and over the next several years.ing package gross weight determined in step 2 to obtain the drained weight of that package. Determine the package error (drained weight - labeled drained weight).

Repeat steps 3 through 6 for the remaining packages in the sample, cleaning and drying the sieve and receiving pan between measurements of individual packages.

Transfer the individual package errors to the standard pack report form, page E-4.

To determine lot conformance, return to Chapter 2, Section 2.3., Evaluating Results”.

2.6Drained Weight for Glazed or Frozen Foods

***How is the drained weight of frozen shrimp and crabmeat determined?***

When determining the net weight of frozen shrimp and crabmeat, use the test equipment and procedure provided below. Immerse the product directly in water in a mesh basket or open container to thaw (e.g., it is not placed in a plastic bag). Direct immersion does not result in the product absorbing moisture because the freezing process causes the tissue to lose its ability to hold water. Maintain the water temperature between 23 oC to 29 °C (75 oF to 85 °F). This is accomplished by maintaining a constant flow of warm water into the container holding the product (e.g., place a bucket in a sink to catch the overflow, and feed warm water into the bottom of the bucket through a hose). After thawing, drain the product on a sieve for 2 minutes and then weigh it.

**Equipment**

Partial immersion thermometer or equivalent with 1 °C (2 °F) graduations and a -35 oC to +50 °C (-30 oF to +120 °F) accurate to ±1 °C (2 °F)

Water source and hose with a 4 L to 15 L (1 gal to 4 gal) per minute flow rate

Sink or other receptacle [i.e., 15 L (4 gal) bucket]

A wire mesh basket or other container that is large enough to hold the contents of 1 package [e.g., 2.27 kg or (5 lb) box of shrimp] and has openings small enough to retain all pieces of the product (e.g., an expanded metal test tube basket lined with standard 16 mesh screen)

Number 8 mesh, 20 cm (8 in) or 30 cm (12 in) sieve

Stopwatch

**Test Procedure**

Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A or a Category B sampling plan in the inspection (depending on the location of test); select a random sample; then use the following test procedure to determine lot compliance.

Place the unwrapped frozen shrimp or crabmeat in the wire mesh basket and immerse in a 15 L (4 gal) or larger container of fresh water at a temperature between 23 °C to 29 °C (75 °F to 85 °F). Submerge the basket so that the top of the basket extends above the water level.

Maintain a continuous flow of water into the bottom of the container to keep the temperature within the specified range.

As soon as the product thaws, determined by loss of rigidity, transfer all material to a sieve (20 cm [8 in] for packages less than 453 g [1 lb] or 30 cm [12 in] for packages weighing more than 453 g [1 lb]) and distribute it evenly over the sieve.

Without shifting the product, incline the sieve 30o from the horizontal position to facilitate drainage, and drain for 2 minutes.

At the end of the drain time, immediately transfer the product to a tared pan for weighing to determine the net weight.

***How is the net weight of glazed raw seafood and fish determined?***

For glazed seafood and fish, determine the net weight after removing the glaze using the following procedure. Use this method for any frozen glazed food product.

**Equipment**

Use the equipment listed in Section 2.6.

**Test Procedures**

Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; and use the following test procedure to determine lot compliance.

Fill out a report form and select the random sample. A tare sample is not needed.

Weigh sieve and receiving pan.  Record this weight on a worksheet as “sieve weight.”

Remove each package from low temperature storage; open it immediately and place the contents under a gentle spray of cold water.  Carefully agitate the product to avoid breaking the product.  Continue the spray until all ice glaze that is seen or felt is removed.  In general, the product should remain rigid; however, the ice glaze on certain products, usually smaller sized commodities, sometimes cannot be removed without defrosting the product. Nonetheless, remove the glaze, because it is a substantial part of the package weight.

(Amended 2002)

Transfer the product to the weighed sieve. Without shifting the product, incline the sieve to an angle of 17o to 20o to facilitate drainage and drain (into waste receptacle or sink) for exactly 2 minutes.

Place the product and sieve on the receiving pan and weigh.  Record this weight on a worksheet as the “sieve + product weight.”

The net weight of product is equal to the weight of the pan plus the sieve plus the product (recorded in step 5) minus the “sieve weight” (recorded in step 2).  Record the product net weight on the worksheet.  The package error is equal to the net weight of the product as measured minus the labeled weight.  Record the package error on the worksheet and transfer it to the report form.

Repeat steps 3 through 6 for each package in the sample, cleaning and drying the sieve and the receiving pan between package measurements.

**Evaluation of Results**

Follow the procedures in Chapter 2, Section 2.3., Evaluating Results

Chapter 3.Test Procedures – For Packages Labeled by Volume

3.1Scope

***What types of packaged goods can be tested using these procedures?***

Use this procedure to determine thenet contentsof packaged goods labeled in fluid volume such as milk, water, beer, oil, paint, distilled spirits, soft drinks, juices, liquid cleaning supplies, or liquid chemicals. This chapter also includes procedures for testing the capacities of containers such as paper cups, bowls, glass tumblers, and stemware.

***What types of packages are not covered by these procedures?***

These procedures do not cover berry baskets and rigid-dry measures that are covered by specific code requirements in NIST Handbook 44.

***When can the gravimetric test procedure be used to verify the net quantity of contents of packages labeled by volume?***

The gravimetric procedure may be used to verify the net quantity of contents of packages labeled in volume when the density (density means the weight of a specific volume of liquid determined at a reference temperature) of the product being tested does not vary excessively from one package to another.

***What procedure is followed if the gravimetric test procedure cannot be used?***

Test each package as described in Section 3.3, Volumetric Test Procedure for Liquids.

***What considerations besides density affect measurement accuracy?***

In addition to possible package-to-package variations in product density, the temperature of the liquid will affect the volume of product. The product will expand or contract based on a rise or fall in product temperature.

**Example:** The volume of a liquid cleaning product might be 5 L (1.32 gal) at 20 C (68 F) and 5.12 L (1.35 gal) at 25 C (77 F), which represents a 2.2 % change in volume.

**Note:** This extreme example is for illustrative purposes, a 2.2 % volume change will not occur in normal testing.

***What reference temperature should be used to determine the volume of a liquid?***

Use the reference temperature specified in Table 3-1., Reference Temperatures for Liquidsto determine volume. When checking liquid products labeled by volume using the gravimetric procedure, maintain the packages used to determine product densities at reference temperatures. If testing the packages in a sample volumetrically, each package in the sample must be maintained at or corrected to the reference temperature when its volume is determined.

Note. When checking liquid products using a volumetric or gravimetric procedure, the temperature of the samples must be maintained at the reference temperature 2 ºC (5 ºF).

3.2Gravimetric Test Procedure for Liquids

**Equipment**

A scale that meets the requirements in Chapter 2, Section 2.2, Measurement Standards and Test Equipment.

**Note:**To verify that the scale has adequate resolution for use, it is first necessary to determine the density of the liquid; next verify that the scale division is no larger than MAV/6 for the package size under test. The smallest graduation on the scale must not exceed the weight value for MAV/6.

**Example:** Assume the inspector is using a scale with 1 g (0.002 lb) increments to test packages labeled 1 L (33.8 fl oz) that have an MAV of 29 mL (1 fl oz). Also, assume the inspector finds that the weight of 1 L of the liquid is 943 g (2.078 lb). This will result in an MAV/6 value in weight of 4.715 g (0.010 lb):

29 mL/6 = 4.8 mL(1 fl oz/6 = 0.166 6 fl oz)

943 g/1 000 mL= 0.943 g/mL(2.07 8 lb/33.6 fl oz = 0.061 8 lb/fl oz)

4.8 mL x 0.943 g/mL = 4.5264 g(0.166 6 fl oz x 0.061 8 lb/fl oz = 0.010 lb)

In this example, the 1 g (0.002 lb) scale division is smaller than the MAV/6 value of 4.5264 g (0.10 lb) so the scale is suitable for making a density determination.

A partial immersion thermometer (or equivalent) with a range of –35 oC to +50 C (30 oF to 120 F), at least 1 C (1 F) graduations, and with a tolerance of ±1 C (±2 F)

Volumetric measures

**Example:** When checking packages labeled in SI units, flask sizes of 100 mL, 200 mL, 500 mL, 1 L, 2 L, 4 L, and 5 L and a 50 mL cylindrical graduate with 1 mL divisions may be used. When checking packages labeled in inch-pound units the use of measuring flasks and graduates with capacities of gill, half-pint, pint, quart, half-gallon, gallon, and a 2 fl oz cylindrical graduate, graduated to ½ fluid dram is recommended.

Defoaming agents may be necessary for testing liquids such as beer and soft drinks that effervesce or are carbonated. Two such products are Hexanol or Octanol (Capryl Alcohol).

**Note:** The mention of trade or brand names does not imply that these products are endorsed or recommended by the U.S. Department of Commerce over similar products commercially available from other manufacturers.

Bubble level at least 15.24 cm (6 in) in length

Stopwatch

**Test Procedure**

1.Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection. Select a random sample; then use the following procedure to determine lot compliance.

2.Bring the sample packages and their contents to the reference temperature as specified inTable 3-1., Reference Temperatures for Liquids. To determine if the liquid is at its reference temperature, immerse the thermometer in the liquid before starting the test. Verify the temperature again immediately after the flask and liquid is weighed. If the product requires mixing for uniformity, mix it before opening in accordance with any instructions specified on the package label. Shaking liquids, such as flavored milk, often entraps air that will affect volume measurements, so use caution when testing these products. Often, less air is entrapped if the package is gently rolled to mix the contents.

For milk, select a volumetric measure equal to or one size smaller than the label declaration. For all other products, select a volumetric measure that is one size smaller than the label declaration. For example, if testing a 1 L bottle of juice or a soft drink, select a 500 mL volumetric measure.

(Amended 2004)

**Note:** When determining the density of milk, if the product from the first container does not fill the volumetric measure to the nominal capacity graduation, product may be added from another container as long as product integrity is maintained (i.e., brand, identity, lot code, and temperature).

4.Prepare a clean volumetric measure to use according to the following procedures:

Because flasks are ordinarily calibrated on a “to deliver” basis, they must be “wet down” before using. Immediately before use, fill the volumetric flask(s) or graduate with water. The water should be at the reference temperature of the product being tested. Fill the flask(s) with water to a point slightly below the top graduation on the neck. The flask should be emptied in 30 seconds (± 5 seconds). Tilt the flask gradually so the flask walls are splashed as little as possible as is emptied. When the main flow stops, the flask should be nearly inverted. Hold the flask in this position for 10 seconds more and touch off the drop of water that adheres to the tip. If necessary, dry the outside of the flask. The flask or graduate is then ready to fill with liquid from a package. This is called the “wet down” condition.

**Note:** When using a volumetric measure that is calibrated “to contain,” the measure must be dry before each measurement.

If the liquid effervesces or foams when opened or poured (such as carbonated beverages), add two drops of a defoaming agent to the bottom of the volumetric measure before filling with the liquid. If working with a carbonated beverage, make all density determinations immediately upon placing the product into the standard. This reduces the chance of volume changes occurring from the loss of carbonization.

Before making additional measurements of a liquid, use water to wash or rinse and prepare the volumetric measure. Between each two measurements of liquid from the sample packages, prepare the volumetric measure as described above, dry the outside of the flask, and drain the volumetric measure as described in earlier paragraphs of this section, as appropriate.

If the flask capacity is equal to the labeled volume, pour the liquid into the volumetric measure tilting the package to a nearly vertical position. If the flask capacity is smaller than the package's labeled volume, fill the flask to its nominal capacity graduation. If conducting a volumetric test, drain the container into the volumetric measure for 1 minute after the stream of liquid breaks into drops.

Position the volumetric measure on a level surface at eye level. For clear liquids, place a material of some dark color outside the flask immediately below the level of the meniscus. Read the volume from the lowest point of the meniscus. For opaque liquids, read volume from the center top rim of the liquid surface.

7.Use the gravimetric procedure to determine the volume if the limit specified for the difference in density is not exceeded.

Select a volumetric measure equal to or one size smaller than the labeled volume (depending on the product) and prepare it as described in paragraph 4 of this section. Then determine and record its empty weight.

Determine acceptability of the liquid density variation, using two packages selected for tare according to Chapter 2 as follows:

Determine the gross weight of the first package.

Pour the liquid from the first package into a volumetric measure exactly to the nominal capacity marked on the neck of the measure.

Weigh the filled volumetric measure and subtract its empty weight to obtain the weight of the liquid. Determine density by dividing the weight of the liquid by the capacity of the volumetric measure.

Determine the weight of the liquid from a second package using the same procedure.

If the difference between the densities of the two packages exceeds one division, use the volumetric procedure in Section 3.3., Volumetric Test Procedure for Liquids.

**How is “nominal gross weight” determined?**

Determine the “nominal gross weight” as follows:

Determine the Average Used Dry Tare Weight of the sample according to provisions of Section 2.3.

Calculate the Average Product Density by adding the densities of the liquid from the two packages and dividing the sum by two.

Calculate the “nominal gross weight” using the following formula if the flask capacity is equal to the labeled volume:

Nominal Gross Weight = (Average Product Density [in weight units]) +

(Average Used Dry Tare Weight)

**Note:** If the flask size is smaller than the labeled volume, the following formula is used:

Nominal Gross Weight = (Average Product Density x [Labeled Volume/ Flask Capacity]) + (Average Used Dry Tare Weight)

## How are the errors in the sample determined?

Weigh the remaining packages in the sample.

Subtract the nominal gross weight from the gross weight of each package to obtain package errors in terms of weight. All sample packages are compared to the nominal gross weight.

To convert the average error or package error from weight to volume, use the following formula:

Package Error in Volume = Package Error in Weight/Average Product Density

Per Volume Unit of Measure

**Evaluation of Results**

Follow the procedures in “Evaluating Results” in Chapter 2, Section 2.3, to determine lot conformance.

3.3Volumetric Test Procedure for Liquids

***How is the volume of liquid contained in a package determined volumetrically?***

Follow steps 1 through 6 in Section 3.2., Gravimetric Test Procedure for Liquids for each package in the sample.

***How are the errors in the sample determined?***

Read the package errors directly from the graduations on the measure. The reference temperature must be maintained within 2 C ( 5 F) for the entire sample.

**Evaluation of Results**

Follow the procedures in Chapter 2, Section 2.3, Evaluating Results to determine lot conformance.

3.4Other Volumetric Test Procedures

***What other methods can be used to determine the net contents of packages labeled by volume?***

Depending on how level the surface of the commodity is, use one of two headspace test procedures. Use the first headspace test procedure to determine volume where the liquid has a smooth surface (e.g., oils, syrups, and other viscous liquids). Use the second procedure to determine volume where the commodity does not have a smooth surface (e.g., mayonnaise and salad dressing).

**Test Procedure**

Before conducting any of the following volumetric test procedures, follow Section 2.3, Basic Test Procedure in Chapter 2. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then use the following procedure to determine lot compliance.

**Test Equipment**

Micrometer depth gage (ends of rods fully rounded) 0 mm to 225 mm (0 in to 9 in) or longer

Level (at least 15 cm (6 in) in length)

Laboratory pipets and/or buret

Class A 500 mL buret that conforms to ASTM E 287-94, “Standard Specification for Laboratory Glass Graduated Burets”

Class A Pipets, calibrated “to deliver” that conform to ASTM E 969-95, “Standard Specification for Glass Volumetric (Transfer) Pipets”

Volumetric measures

Water

Rubber bulb syringe

Plastic disks that are 3 mm (1/8 in) thick with diameters equal to the seat diameter or larger than the brim diameter of each container tested. The diameter tolerance for the disks is 50 m (± 0.05 mm [± 0.002 in]). The outer edge should be smooth and beveled at a 30o angle with the horizontal to 800 m (0.8 mm [1/32 in]) thick at the edge. Each disk must have a 20 mm (3/4 in) diameter hole through its center and a series of 1.5 mm (1/16 in) diameter holes 25 mm (1 in) from the outer edge.

Stopwatch

***How is the volume of oils, syrups, and other viscous liquids that have smooth surfaces determined?***

Make all measurements on a level surface

Bring the temperature of both the liquid and the water to be used to measure the volume of the liquid to the reference temperature specified inTable 3-1., Reference Temperatures for Liquids.

Measure the headspace of the package at the point of contact with the liquid using a depth gauge with a fully rounded, rather than a pointed, rod end. If necessary, support the package to prevent the bottom of the container from distorting.

Empty, clean, and dry the package.

Refill the container with water measured from a volumetric standard to the original liquid headspace level measured in paragraph (3) of this section until the water touches the depth gauge.

Determine the amount of water used in paragraph (5) of this section to obtain the volume of the liquid and calculate the “package error” based on that volume.

**Evaluation of Results**

Follow the procedures in “Evaluating Results” in Chapter 2, Section 2.3, to determine lot conformance.

3.5Mayonnaise and Salad Dressing

**Volumetric Headspace Test Procedure**

Use the volumetric headspace procedure described in this section to determine volume when the commodity does not have a smooth surface (e.g., mayonnaise, salad dressing, and other water immiscible products without a level liquid surface). The procedure guides the inspector to determine the amount of headspace above the product in the package and the volume of the container. Determine the product volume by subtracting the headspace volume from the container volume. Open every package in the sample.

1.Make all measurements on a level surface.

2.Bring the temperature of both the commodity and the water used to measure the volume to the appropriate temperature designated in Table 3-1., Reference Temperatures for Liquids.

Open the first package and place a disk larger than the package container opening over the opening.

4.Measurement Procedure

Deliver water from a flask (or flasks), graduate, or buret, through the central hole in the disk onto the top of the product until the container is filled. If it appears that the contents of the flask may overfill the container, do not empty the flask. Add water until all of the air in the container has been displaced and the water begins to rise in the center hole of the disk. Stop the filling procedure when the water fills the center disk hole and domes up slightly due to the surface tension. Do not add additional water after the level of the water dome has dropped.

If the water dome breaks on the surface of the disk, the container has been overfilled and the test is void; dry the container and start over.

To obtain the headspace capacity, record the volume of water used to fill the container and subtract 1 mL (0.03 fl oz), which is the amount of water held in the hole in the disk specified.

Empty, clean, and dry the package container.

7.Repeat steps 4 and 5 of this section. Refill the package container with water measured from a volumetric measure to the maximum capacity of the package, subtract 1 mL (0.03 fl oz), and record the amount of water used as the container volume; and

8.From the container volume determined in paragraph 7 of this section, subtract the headspace capacity in paragraph (5) of this section to obtain the measured volume of the product and calculate the “package error” for that volume where “package error” equals labeled volume minus the measured volume of the product.

**Evaluation of Results**

Follow the procedures in Chapter 2, Section 2.3., Evaluating Results to determine lot conformance.

**3.6Goods Labeled by Capacity - Volumetric Test Procedure**

### **What type of measurement equipment is needed to perform the headspace test procedures?**

Use the test equipment in Section 3.4. (except for the micrometer depth gage) to perform these test procedures.

***How is it determined if goods labeled by capacity meet the average and individual requirements?***

Before conducting any of the following volumetric test procedures, refer to Chapter 2, Section 2.3., Basic Test Procedure. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then use the following test procedure to determine lot compliance.

Make all measurements on a level surface.

When testing goods labeled by capacity, use water at a reference temperature of 20 °C 2 C (68°F 5 F).

Select a sample container and place a disk larger than the container opening over the opening.

4.Measurement Procedure

Add water to the container using flask (or flasks), graduate, or buret corresponding to labeled capacity of the container. If it appears that the contents of the flask may overfill the container, do not empty the flask. Add water until all of the air in the container has been displaced and the water begins to rise in the center hole of the disk. Stop filling the container when the water fills the center disk hole and domes up slightly due to the surface tension.

If the water dome breaks on the surface of the disk, the container has been overfilled and the test is void; dry the container and start over.

Record the amount of water used to fill the container and subtract 1 mL (0.03 fl oz) (this is the amount of water held in the hole in the disk specified) to obtain the total container volume.

5.Test the other containers in the sample according to the procedures in paragraph (4) of this section.

6.To determine package errors, subtract the total container volume obtained in paragraphs (4) and (5) from the labeled capacity of the container.

**Evaluation of Results**

Follow the procedures in Chapter 2, Section 2.3., Evaluating Results to determine lot compliance.

**3.7Pressed and Blown Glass Tumblers and Stemware**

### **What requirements apply to pressed and blown glass tumblers and stemware?**

This handbook provides a tolerance to the labeled capacity of glass tumblers and stemware. The average requirement does not apply to the capacity of these products. See Table 3-2., Allowable Differences for Pressed and Blown Glass Tumblers and Stemware.

### **How is it determined if tumblers and stemware meet the individual package requirement?**

Follow the Basic Test Procedure in Section 2.3. Define the inspection lot and determine which sampling plan to use in the inspection, select a random sample, and then use the following volumetric test procedure to determine container capacity and volume errors.

### **What type of measuring equipment is needed to perform the test procedures?**

Use the equipment specified in Section 3.4., (except for the micrometer depth gage) to perform these test procedures.

### **What are the steps of the test procedure?**

Follow steps 1 through 6 in 3.6, Goods Labeled by Capacity - Volumetric Test Procedure.

### **How is it determined if the samples conform to the allowable difference?**

Compare the individual container error with the allowable difference that applies in Table 3-2., Allowable Differences for Pressed and Blown Glass Tumblers and Stemware. If a package contains more than one container, all of the containers in the package must meet the allowable difference requirements in order for the package to pass.

**Evaluation of Results**

Count the packages in the sample with volume errors greater than the allowable difference and compare the resulting number with the number given in Column 3 of Table 2-11., in Appendix A.

If the number of containers in the sample with errors exceeding the allowable difference exceeds the number allowed in Column 3, the lot fails.

If the number of packages with errors exceeding the allowable difference is less than or equal to the number in Column 3, the lot passes.

**Note:** The average capacity error is not calculated because the lot passes or fails based on the individual volume errors. Act on the individual units containing errors exceeding the allowable difference individually even though the lot passes the requirement.

3.8Volumetric Test Procedure for Paint, Varnish, and Lacquers – Non-aerosol

### **How is the volume of paint, varnish, and lacquers contained in a package determined?**

Use one of three different test methods depending upon the required degree of accuracy and the location of the inspection. The procedures include both retail and in-plant audits and a “possible violation” method, which is designed, for laboratory or in plant use because of cleanup and product collection requirements. The procedures are suitable to use with products labeled by volume and packaged in cylindrical containers with separate lids that can be resealed.

**Equipment**

A scale that meets the requirements in Chapter 2, Section 2.2., Measurement Standards and Test Equipment

Volumetric measures

Micrometer depth gage (ends of rods fully rounded), 0 mm to 225 mm (0 in to 9 in)

Diameter (Pi) tape measure, 5 cm to 30 cm (2 in to 12 in)

Spanning bar, 2.5 cm by 2.5 cm by 30 cm or (1 in by 1 in by 12 in)

Rule, 30 cm (12 in)

Paint solvent or other solvent suitable for the product being tested

Cloth, 30 cm (12 in) square

Wood, 5 cm (2 in) thick, by 15 cm (6 in) wide, by 30 cm (12 in) long

Rubber mallet

Metal disk, 6.4 mm (1/4 in) thick and slightly smaller than the diameter of package container bottom.

Rubber spatula

Level at least 15 cm (6 in) in length

Micrometer (optional)

Stopwatch

### **What test procedure is used to conduct a retail audit test?**

Conduct a retail audit using the following test procedure that is suitable for checking cylindrical containers up to 4 L (1 gal) in capacity.  Use step 2 in the retail audit test procedure with any size container, but step 3 must be used for containers with capacities of 4 L (1 gal). The method determines the volume of a single can in the sample selected as most likely to contain the smallest volume of product. Do not empty any containers because only their critical dimensions are being measured.

***How accurate is the dimensional test procedure?***

The configuration of the bottom of the can, paint clinging to the lid, and slight variations in the wall and label thicknesses of the paint container may produce an uncertainty estimated to be at least 0.6 % in this auditing procedure. Therefore, this method is recommended solely to eliminate from more rigorous testing those packages that appear to be full measure.  Use the violation procedures when the volume determined in step 10 is less than the labeled volume or in any case where short measure is suspected.

### **What worksheets make data recording easier?**

Use the following format to develop worksheets to perform audits and determine the volume when checking paint. Follow the procedure and it will indicate the column in which the various measurements made can be recorded.

**Note:** When the following instructions require recording a measurement, refer to the numbered columns in the “Audit Worksheet for Checking Paint” shown above.

### **How is a retail audit test performed?**

Select a random sample.  A tare sample is not needed.

For containers less than 4 L or (1 gal): measure the outside diameter of each container near its middle to the closest 0.02 mm (0.001 in). Use a diameter tape measure to record the measurements in Column 3. Place the containers on a level surface and using the micrometer depth gage, record their heights in Column 1 on the worksheet.  If the range of outside diameters exceeds 0.125 mm (0.005 in) or the range in heights exceeds 1.58 mm (0.062 5 in), do not use this procedure.  If the ranges are within the specified limits, weigh all cans in the sample, select the container with the lightest gross weight, and remove its lid.  Continue with step 4 below.

For 4 L (1 gal) containers: gross weigh each package in the sample. Select the package with the lightest gross weight and remove its lid.

Use a direct reading diameter tape measure to measure the outside diameter of the selected container near its top, middle (already measured if step 2 was followed), and bottom to the closest 0.02 mm (0.001 in). Record these measurements in Columns 2, 3, and 4. Add the three diameter values and divide by three to obtain the average diameter and record this value in Column 5.

If a micrometer is available, measure the wall and the paper label thickness of the container; otherwise, assume the wall and label thicknesses given in Table 3-3. Thickness of Paint Can Walls and Labels below:

Subtract twice the thickness of the wall of the can and paper label from the average can diameter (step 4) to obtain the average liquid diameter. Record the liquid diameter in Column 6.

On a level surface, place the container on the circular metal disk that is slightly smaller in diameter than the lower rim of the can so the bottom of the container nests on the disk to eliminate any “sag” in the bottom of the container.

Place the spanning bar and depth gage across the top of the paint can and mark the location of the spanning bar on the rim of the paint container. Measure the distance to the liquid level, to the nearest 20 m (0.02 mm) (0.001 in), at three points in a straight line. Take measurements at points approximately 1 cm (3/8 in) from the inner rim for cans 12.5 cm (5 in) in diameter or less (and at 1.5 cm [1/2 in] from the rim for cans exceeding 12.5 cm [5 in]) in diameter and at the center of the can. Add the three readings and divide by three to obtain the average distance to the liquid level in the container.  Record the average distance to the liquid level in Column 7.

Measure the distance to the bottom of the container at three points in a straight line in the same manner as outlined in step 7.  Add the three readings and divide by three to obtain the average height of the container and record it in Column 8.

Subtract the average distance to the liquid level (Column 7) from the average height of the container (Column 8) to obtain the average height of the liquid column and record it in Column 9.

Determine the volume of paint in the container by using the following formula:

Volume = 0.7854 D2H

Where D = average liquid diameter (Column 6) and H = average liquid height (Column 9)

Record this value in Column 10. If the calculated volume is less than labeled volume, go to the Violation Procedure.

### **How is an in-plant audit conducted?**

Use the following procedures to conduct an in-plant audit inspection. This method applies to a container that probably contains the smallest volume of product.  Duplicate the level of fill with water in a can of the same dimensions as the one under test. Use this method to check any size of package if the liquid level is within the measuring range of the depth gage. If any paint is clinging to the sidewall or lid, carefully scrape the paint into the container using a rubber spatula.

Follow steps 1 through 6 of the retail audit test.

Place the spanning bar and depth gage across the top of the paint can. Measure the liquid level at the center of the surface and record the level in Column 7.

Select an empty can with the same bottom configuration as the container under test and with a diameter and height equal to that of the container under test within plus or minus the following tolerances:

a. For 500 mL or (1 pt) cans - within 25 m (0.025 mm) (0.001 in)

b. For 1 L or (1 qt) cans - within 50 m (0.05 mm) (0.002 in)

c. For 2 L or (1/2 gal) cans - within 75m (0.075 mm) (0.003 in)

d. For 4 L or (1 gal) cans - within 100 m (0.1 mm) (0.004 in)

Set the empty can on a level work surface with a circular metal disk that is slightly smaller in diameter than the bottom can rim underneath the can to eliminate sag.  Set up the spanning bar and depth gage as in step 2 above.  Fill the container with water from a volumetric measure of the same volume as the labeled volume.  Measure the distance to the liquid level at the center of the container and record this level in Column 7 below the reading recorded in step 2. If this distance is equal to or greater than the distance determined in step 2, assume that the package is satisfactory. If the distance is less than the distance determined in step 2, the product may be short measure. Use the possible violation procedure given in the next section when the audit test indicates that short measure is possible.

**Violation Procedure**

### **How is it determined if the containers meet the package requirements?**

Use the following method if the liquid level is within the measuring range of the micrometer. The first step is to follow the Basic Test Procedure in Section 2.3. Define the inspection lot to determine which Category A sampling plan to use; select a random sample; and then use the following procedure. The steps noted with an (\*) are required if there is paint adhering to the lid and it cannot removed by scraping into the can.

Do not shake or invert the containers selected as the sample.  Determine the gross weight of these packages and record in Column 2 of the “Example Worksheet for Possible Violation in Checking Paint” below.

Record the labeled volume of the first tare sample package in Column 1 of the worksheet.  Use a circular metal disk to eliminate can “sag” and remove the lid.  If paint clings to the lid of the container, scrape it off with a spatula.

If paint that adheres to the lid cannot be completely removed by scraping the paint into the can, determine the weight of the lid plus any adhering paint. Clean the paint lid with solvent and weigh again. Subtract the clean lid weight from the lid weight with paint to determine the weight of the paint adhering to the lid. Record this weight in Column 3.

Place the spanning bar and depth gage across the top of the paint can. Mark the location of the spanning bar on the rim of the paint container. Measure the distance to the liquid level at the center of the container to the nearest 20 m (0.02 mm) (0.001 in).  Record the distance in Column 4.

Empty and clean the sample container and lid with solvent; dry and weigh the container and lid. Record the tare weight in Column 5.

Set up the container in the same manner as in step 1.

Place the spanning bar at the same location on the rim of the paint container as marked in step 3.  With the depth gage set as described in step 3, deliver water into the container in known amounts until the water reaches the same level occupied by the paint as indicated by the depth gage.  Record this volume of water (in mL or fl oz) in Column 6 of the worksheet.  This is the volume occupied by the paint in the container.  Follow steps, 7a, 8a, and 9a if scraping does not remove the paint from the lid.  In order to determine if gravimetric testing can be used to test the other packages in the sample, follow only steps 7, 8, and 9 when no paint adheres to the lid.

Subtract the weight of the container (Column 5) from the gross weight (Column 2) to arrive at the net weight of paint in the selected container. Record the net weight in Column 7 of the worksheet.

7a\* Subtract the weight of the container (Column 5) and the weight of product on the lid (Column 3) from the gross weight (Column 2) to arrive at the net weight of paint in the container.  Record in Column 7 (excluding the weight of the paint on the lid).

Calculate the weight of the labeled volume of paint (for the first package opened for tare = on the lid).

net weight (Column 7) x labeled volume (Column 1) ÷ volume of paint in can (Column 6)

Record this value in Column 8.

8a\* Calculate the package volume =

volume in can (Column 6) + [lid paint weight (Column 3) x

volume in can (Column 6) / net weight (Column 7)]

Record it in Column 9 of the worksheet.

Calculate the package error. Use the following formula if paint does not adhere to the lid:

Package error = (Column 6 value) - (labeled volume)

9a\* Use the following formula if paint does adhere to the lid and will not come off by scraping.

Package error = (Column 9 value) - (labeled volume)

Repeat steps 1 through 9 for the second package chosen for tare.

***When can a gravametric procedure be used?***

A gravimetric procedure is used if the weights of the labeled volume for the first two packages do not differ from each other by more than one division on the scale (if they meet this criterion, check the rest of the sample gravimetrically and record in Column 8).

***How is “nominal gross weight” determined?***

Determine the “nominal gross weight” for use with Chapter 2, Section 2.3. as follows:

The nominal gross weight equals the sum of the average weight of the labeled volume (average of values recorded in Column 8) plus the average tare (average of values recorded in Column 3) for the packages selected for tare.  Note that the weight of a given volume of paint often varies considerably from container to container; therefore, volumetric measurements may prove necessary for the entire sample.

**Evaluation of Results**

Follow the procedures in “Evaluating Results” in Chapter 2, Section 2.3. to determine lot conformance.

3.9Testing Viscous Materials - Such As Caulking Compounds and Pastes

### **How are viscous materials such as caulking compounds and paste tested?**

Use the following procedure for any package of viscous material labeled by volume. It is suitable for very viscous materials such as cartridge packed caulking compounds, glues, pastes, and other similar products. It is best to conduct this procedure in a laboratory using a hood to ventilate solvent fumes. If used in the field, use in a well ventilated area. Except for the special measurement procedures to determine the weight of the labeled volume, this procedure follows the basic test procedure.  For each weight of a known volume determination, pack a portion of the packaged product into a pre-weighed cup of known volume (called a “density cup” or “pycnometer”) and weigh.  From the weight of the known volume, determine the weight of the labeled volume. Compare the nominal gross weight with the gross weight to determine the package error.

### **What type of measurement equipment is needed to test packages of caulk, pastes, and glues?**

A scale that meets the requirements in Chapter 2, Section 2.2. Measurement Standards and Test Equipment.

Pycnometer, a vessel of known volume used for weighing semifluids.  The pycnometer can be bought or made. If it is made, refer to it as a “density cup.” To make a 150 mL or 5 fl oz density cup, cut off the lip of a 150 mL beaker with an abrasive saw and grind the lip flat on a lap wheel.  The slicker plate is available commercially. Calibrate the density cup gravimetrically with respect to the contained volume using the procedure in ASTM E 542–94, “Standard Practice for Calibration of Laboratory Volumetric Apparatus.”

Appropriate solvents (water, Stoddard solvent, kerosene, alcohol, etc.)

Caulking gun (for cartridge packed products)

### **How is a pycnometer prepared for use?**

Before using, weigh and calibrate the pycnometer (or the density cup and slicker plate) with respect to volume (mL or fl oz).  If applicable, comply with any special instructions furnished by the manufacturer to calibrate a pycnometer that has not been calibrated.  It is not necessary to reweigh or recalibrate for each test; however, mark the pieces of each unit to prevent interchange of cups and slicker plates.

### **How is it determined if the containers meet the package requirements?**

First, follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then, use the following procedure to determine lot compliance.

Weigh a calibrated pycnometer and slicker plate and record as “pycnometer weight” and record this weight and the volume of the pycnometer.

Determine the gross weight of the first package and record the weight value. Open the package and transfer the product to the pycnometer by filling it to excess.  Use a caulking gun to transfer product from the caulking cartridges. If using a pycnometer, cover it with a lid and screw the cap down tightly. Excess material will be forced out through the hole in the lid, so the lid must be clean.  If using a density cup, place the slicker plate over 3/4 of the cup mouth, press down and slowly move the plate across the remainder of the opening. With the slicker plate in place, clean all the exterior surfaces with solvent and dry.

Completely remove the product from the package container; clean the package container with solvent; dry and weigh it to determine the tare weight.

Weigh the filled pycnometer or filled density cup with slicker plate and record this weight. Subtract the weight of the empty pycnometer from the filled weight to determine the net weight of the product contained in the pycnometer and record this weight.

Clean the pycnometer and repeat steps 3, 4, and 5 for the second package in the tare sample.

Determine acceptability of the density variation on the two packages selected for tare. If the difference between the densities of both packages exceeds one division of the scale, do not use the gravimetric procedure to determine the net quantity of contents. Instead, use the procedure in steps 9 and 10.

**Note:** If the gravimetric procedure can be used perform steps 8 and 10.

Calculate the weight of product corresponding to the labeled volume of product according to the following formula:

Weight of Product in Pycnometer Pycnometer Volume = Product Density

Test each package individually by determining the product density in each package using the pycnometer and record the gross, tare, and net weight of each package. Subtract the weight of the labeled volume (determined for each package) from the net weight of product to arrive at each individual package error in units of weight.

Convert the package errors to units of volume using the following formula:

Package Error (volume) = (Package Error [weight] x Pycnometer Volume)

(Weight of Product in Pycnometer)

Record the package errors on the report form using an appropriate unit of measure.

**Evaluation of Results**

Follow the procedures in “Evaluation Results” in Chapter 2, Section 2.3 to determine lot conformance.

**3.10Peat Moss**

### **How are packages of peat and peat moss labeled by compressed volume tested?**

Measure the dimensions of the compressed material to determine if it contains the labeled quantity.

### **How are packages of peat and peat moss labeled by uncompressed volume tested?**

Use the following method to test peat moss sold using an uncompressed volume as the declaration of content.  The procedure is based on ASTM D 2978-90, “Standard Method of Test for Volume of Processed Peat Materials.”

### **Equipment**

12.7 mm (or ½ in) sieve.

Use one of the following measures as appropriate for the package size. (See Table 3-4., “Specifications for Test Measures for Mulch and Soils” for additional information on test measure construction.)

28.3 L (1 ft3) measure with inside dimensions of 30.4 cm (12 in) by 30.4 cm (12 in) by 30.4 cm (12 in). Mark the inside of the measure with horizontal lines every 1.2 cm (1/2 in) so that package errors can be directly determined.

100 L (3.5 ft3) measure with inside dimensions of 50 cm (19.68 in) by 50 cm (19.68 in) by 40 cm (15.74 in). The inside of the measure should be marked with horizontal lines every 1.2 cm (1/2 in) so that package errors can be directly determined.

Straight edge, 50.8 cm (20 in) in length.

Sheet for catching overflow of material.

Level (at least 15.24 cm (6 in) in length).

### **How is it determined if the packages meet the requirements in this handbook?**

Follow Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then, use the following procedure to determine lot compliance.

Open each package in turn, remove the contents, and pass them through the sieve directly into the measuring container (overfilling it). Use this method for particulate solids (such as soils or other garden materials) labeled in cubic dimensions or dry volume.  Some materials may not pass through the sieve for peat moss; in these instances, separate the materials by hand (to compensate for packing and settling of the product after packaging) before filling the measure.

**Note:** Separated material (product not passing through the sieve) must be included in the product volume.

Shake the measuring container with a rotary motion at one rotation per second for 5 seconds. Do not lift the measuring container when rotating it.  If the package contents are greater than the measuring container capacity, level the measuring container with a straight edge using a zigzag motion across the top of the container.  Empty the container. Repeat the filling operations as many times as necessary, noting the partial fill of the container for the last quantity delivered using the interior horizontal markings as a guide.  Record the total volume.

To compute each package error, subtract the labeled quantity from the total volume and record it.

**Evaluation of Results**

Follow the procedures in “Evaluating Results” in Chapter 2, Section 2.3 to determine lot conformance.

3.11Mulch and Soils Labeled by Volume

### **What products are defined as mulch and soil?**

Mulch is defined as “any product or material except peat or peat moss that is advertised, offered for sale, or sold for primary use as a horticultural, above-ground dressing, for decoration, moisture control, weed control, erosion control, temperature control, or other similar purposes.”

Soil is defined as “any product or material, except peat or peat moss that is advertised or offered for sale, or sold for primary use as a horticultural growing media, soil amendment, and/or soil replacement.”

***What type of measurement equipment is needed to test packages of mulch and soil?***

A test measure appropriate for the package size that meets the specifications for test measures in Table 3-4.

Drop cloth/polyethylene sheeting for catching overflow of material.

Level (at least 15 cm (6 in) in length).

***How is it determined if the packages meet the package requirements?***

Use the following procedure:

Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection, select a random sample, then, use the following procedure to determine lot conformance.

Open each package in turn.  Empty the contents of the package into a test measure and level the contents by hand.  Do not rock, shake, drop, rotate, or tamp the test measure. Read the horizontal marks to determine package net volume.

**Note:** Some types of mulch are susceptible to clumping and compacting. Take steps to ensure that the material is loose and free flowing when placed into the test measure. Gently roll the bag before opening to reduce the clumping and compaction of material.

Exercise care in leveling the surface of the mulch/soil and determine the volume reading from a position that minimizes errors caused by parallax.

### **How are package errors determined?**

Determine package errors by subtracting the labeled volume from the package net volume in the measure. Record each package error.

Package Error = Package Net Volume Labeled Volume

**Evaluation of Results**

Follow the procedures in Chapter 2, Section 2.3., Evaluating Results to determine lot conformance.

**Note:** In accordance with Table 2-10., in Appendix A, apply an MAV of 5 % of the declared quantity to mulch and soil sold by volume. When testing mulch and soil with a net quantity in terms of volume, one package out of every 12 in the sample may exceed the 5 % MAV (e.g., one in a sample of 12 packages; two in a sample of 24 packages; four in a sample of 48 packages.) However, the sample must meet the average requirement of the Category A Sampling Plan.

**Ice Cream Novelties**

Note: The following procedure can be used to test packaged products that are solid or semisolid and that will not dissolve in, mix with, absorb, or be absorbed by the fluid into which the product will be immersed. For example, ice cream labeled by volume can be tested using ice water or kerosene as the immersion fluid.

*How are ice cream novelties inspected to see if the labeled volume meets the package requirements?*

Use the following volume displacement procedure that uses a displacement vessel specifically designed for ice cream novelties such as ice cream bars, ice cream sandwiches, or cones. The procedure determines the volume of the novelty by measuring the amount of water displaced when the novelty is submerged in the vessel. Two displacements per sample are required to subtract the volume of sticks or cups.

The procedure first determines if the densities of the novelties are the same from package to package (in the same lot) so that a gravimetric test can be used to verify the labeled volume. If a gravimetric procedure is used, compute an average weight for the declared volume from the first two packages and weigh the remainder of the sample. If the gravimetric procedure cannot be used, use the volume displacement procedure for all of the packages in the sample.

### **Equipment**

A scale that meets the requirements in Chapter 2, Section 2.2. Measurement Standards and Test Equipment.

Volumetric measures

Displacement vessel with dimensions that are appropriate for the size of novelties being tested. Figure 3-1., shows an example of a displacement vessel. It includes an interior baffle that reduces wave action when the novelty is inserted and the downward angle of the overflow spout reduces dripping. Other designs may be used.

Figure 3-1. Example of a Displacement Vessel

**Note:** This displacement vessel can be constructed or similar devices may be obtained from any Laboratory Equipment or Science Education suppliers. The U.S. Department of Commerce does not endorse or recommend any particular device over similar commercially available products from other manufacturers.

Thin wire, clamp, or tongs

Freezer or ice chest and dry ice

Single-edged razor or sharp knife (for sandwiches only)

Ice water/kerosene maintained at 1 °C (33 °F) or below

Indelible marker (for ice pops only)

Level, at least 15.24 cm (6 in) in length

A partial immersion thermometer (or equivalent) with a range of -1 oC to +50 C (30 oF to 120 F), at least 1 C (1 F) graduations, and with a tolerance of ±1 C (±2 F)

A table-top, laboratory-type jack of sufficient size to hold the displacement vessel

Stopwatch

**Test Procedure**

Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then use the following procedure to determine lot compliance.

1.Maintain the samples at the reference temperature for frozen products that is specified in Table 3-1. Reference Temperatures for Liquids in this chapter [i.e., -18 oC (0 oF)]. Place the samples in the freezer or ice chest until they are ready to be tested, and then remove packages from the freezer one at a time.

2.According to the type of novelty, prepare the sample products as follows:

Ice-pop. Mark on the stick(s) with the indelible marker the point to which the pop will be submerged in the ice water. (After the ice-pop contents have been submerged, remove the novelty to determine the volume of the stick.)

Cone. Make a small hole in the cone below the ice cream portion to allow air to escape.

Sandwich. Determine whether the declared volume is (a) the total volume of the novelty (that is, including the cookie portion) or (b) the volume of the ice-cream-like portion only. If the declared volume is the volume of only the ice-cream-like portion, shave off the cookie with a razor or knife, leaving some remnants of cookie to ensure that no ice cream is accidentally shaved off. Work quickly, and return the novelty to the freezer before the sandwich softens.

Cup. Remove the cap from the cup. (After the cup and novelty contents have been submerged, remove the novelty from the cup to determine the volume of the cup.)

### **How is it determined if the ice cream novelty packages meet the requirements in this handbook?**

Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then use the following procedure to determine lot compliance.

Fill the displacement vessel with ice water until it overflows the spout. Allow it to sit until dripping stops. Raise the displacement vessel as necessary and place the graduate beneath the spout.

Remove a package from the freezer, determine its gross weight and record it.

Submerge the novelty as suggested until it is below the surface level of the water.

Ice-pop. Use a clamp, tongs, or your fingers to hold the stick(s) and submerge the pop to the level marked in Step 2 of the Test Procedures.

Cone. Shape the wire into a loop, and use it to push the cone, headfirst (ice cream portion first) into the ice water. Do not completely submerge the cone immediately: let water fill the cone through the hole made in Step 2 of the Test Procedures before completely submerging the novelty.

Sandwich or cup. Skewer the novelty with the thin wire or form a loop on the end of the wire to push the sandwich or ice-cream-portion or cup completely below the liquid level.

Record the total water volume in the graduate. For a cone or sandwich, record the water volume as the net volume and go to step (7). For ice-pops or cups, record the water volume in the graduate as the gross volume and go to step (6).

Refill the displacement vessel with water to overflowing and reposition the empty graduate under the spout.

Ice-pop. Melt the ice pop off the stick or sticks. Submerge the stick or sticks to the line marked in step (4). Record the volume of tare material (i.e., stick) by measuring the water displaced into the graduate. The net volume for the ice-pop is the gross volume recorded in step (5) minus the volume of the tare materials in this step. Record this volume as the “volume of novelty.” To determine the error in the package, subtract the labeled quantity from the volume of novelty.

Cup. Remove the novelty from the cup. Rinse the cup, and then submerge it in the displacement vessel. Small pinholes in the base of the cup can be made to make submersion easier. Record the volume of water displaced into the graduate by the cup as the volume of tare material. The net volume for the novelty is the gross volume determined in step (5) minus the volume of the tare materials determined in this step. Record this as the net volume of the novelty. To determine the error in the package, subtract the labeled quantity from the volume of novelty.

Clean and air-dry the tare materials (sticks, wrappers, cup, lid, etc.). Weigh and record the weight of these materials for the package.

Subtract the tare weight from the gross weight to obtain the net weight and record this value.

Compute the weight of the labeled volume for the package using the following formula and then record the weight:

Product Density = (weight in item 3) ÷ (the total water volume in item 5)

Weight of labeled volume = (labeled volume) x (Product Density)

Repeat steps (3) through (9) for a second package.

If the weight of the labeled volume in steps (9) and (10) differ from each other by more than one division on the scale, the gravimetric test procedure cannot be used to test the sample for compliance. If this is the case, steps (2) through (6) for each of the remaining packages in the sample must be used to determine their net volumes and package errors. Then go to evaluation of results.

### **How is “nominal gross weight” determined?**

Determine the Average Used Dry Tare Weight of the sample according to provisions in Chapter 2, Section 2.3.

Using the weights determined in step (11) calculate the Average Product Weight by adding the densities of the liquid from the two packages and dividing the sum by two.

Calculate the “nominal gross weight” using the formula:

Nominal Gross Weight = Average Product Weight + Average Used Dry Tare Weight

### **How are the errors in the sample determined?**

Weigh the remaining packages in the sample.

Subtract the nominal gross weight from the gross weight of each package to obtain package errors in terms of weight.

**Note:** Compare the sample packages to the nominal gross weight.

Follow the Basic Test Procedure in Section 2.3.

To convert the average error or package error from weight to volume, use the following formula:

Package Error in Volume = (Package Error in Weight) ÷ (Product Density)

## Evaluation of Results

Follow the procedures in Chapter 2, Section 2.3., Evaluating Results to determine lot conformance.

3.13 Fresh Oysters Labeled by Volume

### **What requirements apply to packages of fresh oysters labeled by volume?**

Packaged fresh oysters removed from the shell must be labeled by volume. The maximum amount of permitted free liquid is limited to 15 % by weight. Testing the quantity of contents of fresh oysters requires the inspector to determine total volume, total weight of solids and liquid, and the weight of the free liquid.

**Equipment**

A scale that meets the requirements in Chapter 2, Section 2.2 Measurement Standards and Test Equipment

Volumetric measures

Micrometer depth gage (ends of rods fully rounded), 0 mm to 228 mm (0 in to 9 in)

Strainer for determining the amount of drained liquid from shucked oysters. Use as a strainer a flat bottom metal pan or tray constructed to the following specifications:

Sides: 5.08 cm (2 in)

Area: 1,935 cm2 (300 in2) or more for each 3.78 L (1 gal) of oysters

Perforations:

Diameter: 6.35 mm (1/4 in)

Location: 3.17 cm (1 1/4 in) apart in a square pattern, or perforations of equivalent area and distribution.

Spanning bar, 2.54 cm by 2.54 cm by 30.48 cm (1 in by 1in by 12 in)

Rubber spatula

Level, at least 15.24 cm (6 in) in length

Stopwatch

### **How is it determined if the containers meet the package requirements?**

Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then, use the following test procedure to determine lot compliance.

Determine and record the gross weight of a sample package.

Set the container on a level surface and open it. Use a depth gage to determine the level of fill. Lock the depth gauge. Mark the location of the gauge on the package.

Weigh a dry 20.32 cm or 30.48 cm (8 in or 12 in) receiving pan and record the weight. Set strainer over the receiving pan.

Pour the contents from the container onto the strainer without shaking it. Tip the strainer slightly and let it drain for 2 minutes. Remove strainer with oysters. It is normal for oysters to include mucous (which is part of the product) that will not pass through the strainer, so do not force it.

Weigh the receiving pan and liquid and record the weight. Subtract the weight of the dry receiving pan from the weight of pan and liquid to obtain the weight of free liquid and record the value.

Clean, dry, and weigh the container and record the tare weight. Subtract the tare weight from the gross weight to obtain the total weight of the oysters and liquid and record this value.

Determine and record the percent of free liquid by weight as follows:

Percent of free liquid by weight = [(weight of free liquid) ÷ (weight of oysters + liquid)] x 100.

Set up the depth gauge on the dry package container as in step 2. Pour water from the flasks and graduate as needed to re-establish the level of fill obtained in step 2. Add the volumes delivered as the actual net volume for the container and record the value.

**Note:** Some containers will hold the declared volume only when filled to the brim; they may have been designed for other products, rather than for oysters. If the net volume is short-measure (per step 8), determine if the container will reach the declared volume only if filled to the brim. Under such circumstance, the package net volumes will all be short measure because the container cannot be filled to the brim with a solid and liquid mixture. A small headspace is required in order to get the lid into the container without losing any liquid.

**Evaluation of Results**

Follow the procedures in “Evaluating Results” in Chapter 2, Section 2.3, to determine lot conformance.

3.14Determining the Net Contents of Compressed Gas in Cylinders

### **What type of compressed gases may be tested with these procedures?**

These procedures are for industrial compressed gas. Compressed gas may be labeled by weight (for example, Liquefied Petroleum [LP] gas, or carbon dioxide) or by volume. Acetylene, liquid; oxygen, nitrogen, nitrous oxide, and argon are all filled by weight. Acetylene is sold by liters or by cubic feet. Helium, gaseous oxygen, nitrogen, air, and argon are filled according to pressure and temperature tables.

### **What type of test procedures must be used?**

Checking the net contents of compressed gas cylinders depends on the method of labeling; those labeled by weight are generally checked by weight. Cylinders filled by using pressure and temperature charts must be tested using a pressure gauge that is connected to the cylinder. Determine the volume using the pressure and temperature of the cylinder.

### **Should any specific safety procedures be followed?**

Yes, be aware of the hazards of the high pressure found in cylinders of compressed gas. An inspector should handle compressed gas only if the inspector has been trained and is knowledgeable regarding the product, cylinder, fittings, and proper procedures (see *Compressed Gas Association [CGA] pamphlet P-1, "Safe Handling of Compressed Gases in Containers*,” for additional information). Additional precautions that are necessary for personal safety are described in the CGA Handbook of Compressed Gases. All personnel testing compressed gases should have this manual for reference and be familiar with its contents. It is essential that the inspector be certain of the contents before connecting to the cylinder. Discharging a gas or cryogenic liquid through a system for which the material is not intended could result in a fire and/or explosion or property damage due to the incompatibility of the system and the product. Before connecting a cylinder to anything, be certain of the following:

Always wear safety glasses.

The cylinder is clearly marked or labeled with the correct name of the contents and that no conflicting marks or labels are present. Do not rely on the color of the cylinder to identify the contents of a cylinder. Be extremely careful with all gases because some react violently when mixed or when coming in contact with other substances. For example, oxygen reacts violently when it comes in contact with hydrocarbons.

The cylinder is provided with the correct Compressed Gas Association (CGA) connection(s) for the product. A proper connection will go together smoothly; so excessive force should not be used. Do not use an adapter to connect oxygen to non-oxygen cleaned equipment. When a cylinder valve is opened to measure the internal pressure, position the body away from the pressure gauge blowout plug or in front of the gauge if the gauge has a solid cast front case. If the bourdon tube should rupture, do not be in a position to suffer serious injuries from gas pressure or fragments of metal.

Thoroughly know the procedure and place emphasis on safety precautions before attempting any tests. Do not use charts referred to in the procedure until the necessary training has been completed. When moving a cylinder, always place the protective cap on the cylinder. Do not leave spaces between cylinders when moving them. This can lead to a “domino" effect if one cylinder is pushed over.

Open all valves slowly. A failure of the gauge or other ancillary equipment can result in injuries to nearby persons. Remember that high gas pressure can propel objects with great force. Gas ejected under pressure can also cause serious bodily injuries if someone is too close during release of pressure.

One of the gauges will be reserved for testing oxygen only and will be prominently labeled “For Oxygen Use Only.” This gauge must be cleaned for oxygen service and maintained in that “clean” condition. The other gauge(s) may be used for testing a variety of gases if they are compatible with one another.

Observe special precautions with flammable gas in cylinders in addition to the several precautions necessary for the safe handling of any compressed gas in cylinders. Do not “crack” cylinder valves of flammable gas before connecting them to a regulator or test gauge. This is extremely important for hydrogen or acetylene.

### **What type of measurement equipment is needed to test cylinders of compressed gas?**

Use a scale that meets the requirements in Chapter 2, Section 2.2 Measurement Standards and Test Equipment. Use a wooden or non-sparking metal ramp to roll the cylinders on the scale to reduce shock loading.

Two calibrated precision bourdon tube gauges or any other approved laboratory-type pressure-measuring device that can be accurately read within plus or minus 40 kPa (5 psi). A gauge having scale increments of 200 kPa (25 psi) or smaller shall be considered as satisfactory for reading within plus or minus 40 kPa (5 psi). The range of both gauges shall be a minimum of 0 kPa to 23 MPa (0 psi to 5 000 psi) when testing cylinders using standard industrial cylinder valve connections. These standardized connections are listed in “CGA Standard V-1, Standard for Compressed Gas Cylinder Valve Outlet and Inlet for use with Gas Pressures up to 21 MPa (3 000 psi).” For testing cylinders with cylinder valve connections rated for over 21 MPa (3 000 psi), the test gauge and its inlet connection must be rated at 14 MPa (2 000 psi) over the maximum pressure that the connection is rated for in CGA V-1. Note: there are standard high-pressure industrial connections on the market that are being used up to their maximum pressure of 52 MPa (7 500 psi).

**Note**: Any gauge or connectors used with oxygen cylinders must be cleaned for oxygen service, transported in a manner which will keep them clean, and never used for any other gas including air or oxygen mixtures. Oxygen will react with hydrocarbons and many foreign materials that may cause a fire or explosion.

An approved and calibrated electronic temperature measuring device or three calibrated mercury-in-glass thermometers having either a digital readout or scale division of no more than 1 oF (0.5 °C). The electronic device equipped with a surface temperature sensor is preferred over a mercury-in-glass thermometer because of its shorter response time.

Two box-end wrenches of 29 mm (1 1/8 in) for oxygen, nitrogen, carbon dioxide, argon, helium, and hydrogen and 22 mm (7/8 in) for some sizes of propane. All industrial CGA connections are limited to these two hex sizes. Avoid using an adjustable wrench because of the tendency to round the edges of the fittings, which can lead to connections not being tightened properly.

Use a separate gauge and fitting for each gas to be tested. If adapters must be used, do not use on oxygen systems.

### **Test Procedure for Cylinders Labeled by Weight**

### **How is it determined if the containers meet the package requirements using the gravimetric test procedure?**

1.Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then use the following test procedure to determine lot compliance.

2.The cylinder should be marked or stenciled with a tare weight. The marked value may or may not be used by the filling plant when determining the net weight of those cylinders sold or filled by weight. If there is a tare weight marked on the net contents tag or directly on the cylinder, then an actual tare weight was determined at the time of fill. If there is no tare weight marked on a tag or on the cylinder, then the stamped or stenciled tare weight is presumed to have been used to determine the net contents.

**Note:**  Check the accuracy of the stamped tare weights on empty cylinders whenever possible. The actual tare weight must be within (a) 1/2 % of the stamped tare weight for 9.07 kg (20 lb) tare weights or less or (b) 1/4 % of the stamped tare weight for greater than 9.07 kg (20 lb) tare weights. (See NIST Handbook 130, Section 2.16, “Method of Sale Regulation.”)

3.Place cylinder on scale and remove protective cap. The cap is not included in the tare weight.

Weigh the cylinder and determine net weight, using either the stamped or stenciled tare weight, or the tare weight marked on the tag. Compare actual net weight with labeled net weight, or use the actual net weight to look up the correct volume declaration (For Acetylene Gas), and compare that with the labeled volume.

**Note:** The acetone in acetylene cylinders is included in the tare weight of the cylinder. Therefore, as acetylene is withdrawn from the cylinder, some acetone will also be withdrawn, changing the tare weight.

Most producers will replace acetone in the cylinder before the cylinder is refilled, filling the cylinder with acetone to the stamped tare weight. Other producers, although not following recommended procedures, do not replace the acetone until it drops to a predetermined weight. In the latter situation, the refilling plant must note the actual tare weight of the cylinder and show it on the tag containing the net content statement or on the cylinder itself. Refer to tables for acetylene if necessary (if the acetylene is labeled by volume).

**Test Procedure for Cylinders Labeled by Volume**

### **How is it determined if the containers meet the package requirements using the volumetric test procedure?**

Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then use the following test procedure to determine lot compliance.

Determine the temperature of the cylinders in the sample. Place the thermometer approximately halfway up a cylinder in contact with the outside surface. Take the temperature of three cylinders selected at random and use the average temperature of the three values.

Using the appropriate pressure gauge, measure the pressure of each cylinder in the sample.

Determine the cylinder nominal capacity from cylinder data tables or from the manufacturer. (These tables must be obtained in advance of testing.)

Using NIST Technical Note 1079 “Tables of Industrial Gas Container Contents and Density for Oxygen, Argon, Nitrogen, Helium, and Hydrogen” determine the value (SCF/CF) from the content tables at the temperature and pressure of the cylinder under test.

Multiply the cylinder nominal capacity by the value (SCF/CF) obtained from the content tables. This is the actual net quantity of gas.

Subtract the labeled net quantity from the actual net quantity to determine the error.

**Evaluation of Results**

Follow the procedures in “Evaluating Results” in Chapter 2, Section 2.3 to determine lot conformance.

**3.15Volumetric Test Procedure for Packaged Firewood with a Labeled Volume of 113 L** **(4 Ft3) or Less**

### **How are packages of firewood tested?**

Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample, then use the test procedure provided in Section 3.17 to determine lot compliance.

**Equipment**

Linear Measure. Take all measurements in increments of 0.5 cm (3/16 in) or less and round up.

Binding Straps. Binding Straps are used to hold wood bundles together if the bundles need to be removed from the package/wrapping material.

### **How is it determined if the containers meet the package requirements?**

Unless otherwise indicated, take all measurements without rearranging the wood or removing it from the package. If the layers of wood are crosshatched or not ranked in discrete sections in the package, remove the wood from the package re-stack and measure accordingly.

**3.16Boxed Firewood**

### **How is the volume of firewood contained in a box determined?**

### Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then use the following test procedure to determine lot conformance.

Open the box to determine the average height of wood within the box; measure the internal height of the box. Take three measurements (record as “d1, d2...etc.”) along each end of the stack. Measure from the bottom of a straight edge placed across the top of the box to the highest point on the two outermost top pieces of wood and the center-most top piece of wood. Round measurements down to the nearest 0.5 cm (1/8 in). If pieces are obviously missing from the top layer of wood, take additional height measurements at the highest point of the uppermost pieces of wood located at the midpoints between the three measurements on each end of the stack. Calculate the average height of the stack by averaging these measurements and subtracting from the internal height of the box according to the following formula.

Average Height of Stack = (Internal Height of Box) – (sum of measurements) ÷

(number of measurements)

Determine the average width of the stack of wood in the box by taking measurements at three places along the top of the stack. Measure the inside distance from one side of the box to the other on both ends and in the middle of the box. Calculate the average width.

Average Width = (W 1 + W 2 + W 3) ÷ (3)

To determine the average length of the pieces of wood, remove the wood from the box and select the five pieces with the greatest girth. Measure the length of each of the five pieces from center-to-center. Calculate the average length of the five pieces.

Average Length = (L1 + L2 + L3 + L4 + L5) ÷ (5)

Calculate the volume of the wood within the box. Use dimensions for height, width, and length.

Volume in liters = (height in cm x width in cm x length in cm) **÷** (1 000)

Volume in cubic feet = (height in inches x width in inches x length in inches) **÷** (1 728)

For boxes of wood that are packed with the wood ranked in two discrete sections perpendicular to each other, calculate the volume of wood in the box as follows: (1) determine the average height, width, and length as in 1, 2 and 3 above for each discrete section, compute total volume, and (2) total the calculated volumes of the two sections. Take the width measurement for Volume 2 (V2) from the inside edge of the box adjacent to V2 to the plane separating V1 and V2. Compute total volume by adding Volume 1 (V1) and V2 according to the following formula.

Total Volume = V1 + V2

Follow the procedures in Chapter 2, Section 2.3., Evaluating Results to determine lot conformance.

**3.17Crosshatched Firewood**

### **How must the volume of stacked or crosshatched firewood be measured?**

Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; and use the following test procedure to determine lot compliance.

Stack the firewood in a ranked and well-stowed geometrical shape that facilitates volume calculations (i.e., rectangular). The number of measurements for each dimension given below is the minimum that should be taken.

Determine the average measurements of the stack:

Height: Start at one end of the stack; measure the height of the stack on both sides at four equal intervals. Calculate and record the average height.

Length: Start at the base of the stack; Measure the length of the stack in four equal intervals. Calculate and record the average length.

Width: Select the five pieces with the greatest girth. Measure the length of the pieces, calculate and record the average piece length. (3)

Calculate Volume:

Volume in liters = (Avg. Height [cm] x Avg. Width [cm] x Avg. Length in [cm]) **÷** 1 000

Volume in cubic feet = (Avg. Height [in] x Avg. Width [in] x Avg. Length [in]) **÷** 1 728

Follow the procedures in Chapter 2, Section 2.3., Evaluating Results to determine lot conformance.

**3.18Bundles and Bags of Firewood**

### **How is the volume of bundles and bags of firewood measured?**

Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then use the following test procedure to determine lot compliance.

Average area of ends: secure a strap around each end of the bundle or bag of wood to prevent movement during testing and to provide a definite perimeter. Use two or more straps to secure the wood.

Set one end of the bundle or bag on tracing paper large enough to cover the end completely. Draw a line around the perimeter of the bundle or bag on the tracing paper.

Transfer the tracing paper to a template graduated in square centimeters or square inches. Count the number of square centimeters or square inches that are enclosed within the perimeter line. Estimate portions of square centimeters or square inches not completely within the perimeter line to the nearest one-quarter square inch.

Repeat this process on the opposite end of the bundle or bag.

Calculate the Average Area.

Average Area = (Area 1 + Area 2) ÷ 2

Average length of the pieces of wood: select the five pieces with the greatest girth and measure the length of the pieces. Calculate the average length of the pieces of wood:

Average Length = (L1 + L2 + L3 + L4 + L5) ÷ 5

Calculate Volume:

Volume in liters = (Average Area [cm2] x Average Length [cm]) ÷ 1 000

Volume in cubic feet = (Average Area [in2] x Average Length [in]) ÷ 1 728

**Evaluation of Results**

Follow the procedures in Chapter 2, Section 2.3., Evaluating Results to determine lot conformance.

**Note:**  Specified in Table 2-10., Appendix A, maximum allowable variations for individual packages are not applied to packages of firewood.

Chapter 4.Test Procedures – Packages Labeled by Count, Linear Measure, Area, Thickness, and Combinations of Quantities

4.1Scope

### **What types of packaged goods can be tested using these procedures?**

Use these procedures to determine the net contents of products sold by count, area, thickness, and linear measure. If a package includes more than one declaration of quantity, each declaration must meet the package requirements.

### **Can the gravimetric test procedure be used to verify the net quantity of contents of packages labeled by count and linear measure?**

Use the gravimetric procedure to test products sold by measure or count if the density of the product does not vary excessively from one package to another.

### **What procedures may be used if the gravimetric test procedure cannot be used?**

Open each package in the sample and measure or count the items.

4.2Packages Labeled by Count

### **How are packages tested labeled by count?**

If the labeled count, is 50 items or less, use Section 4.3. If the labeled count is, more than 50 items see Section 4.4.

### **Can a gravimetric test procedure be used to verify the labeled count of a package?**

Yes, if the scale being used is sensitive enough to determine the weight of individual items. Use the following procedures to determine if the sample packages can be tested gravimetrically.

For packages labeled with a count of 84 or higher, calculate the weight equivalent for the MAV/6 for the labeled count of the package. MAV/6 must be at least equal to one-half scale division on a mechanical scale or one division on a digital scale.

For packages with a labeled count of 83 or fewer, when each unit weighs at least 2 scale divisions, consider the scale acceptable.

**Example:** According to Table 2-7., in Appendix A, the MAV is 7 for a package labeled with a count of 250 items. The scale should be capable of measuring differences corresponding to MAV/6 or, in this example, the weight of one item.

If the scale meets the appropriate requirement, gravimetric testing can be used to determine package count or,

If the scale does not meet the criteria, count the content in each package in the sample.

4.3Packages Labeled with 50 Items or Less

**Test Procedure**

1.Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then use the following test procedure to determine lot compliance.

2.Open the packages and count the number of items in each. Record the number of packages that contain less than the labeled count.

**Evaluation of Results**

For the sample size indicated in Column 1 of Table 2-11., Accuracy Requirements for Packages Labeled by Low Count of (50 or less), refer to Column 2 to determine the number of packages that are allowed to contain less than the labeled count.

If the number of packages in the sample that contain less than the labeled count exceeds the number permitted in Column 2, the sample and the lot fail to meet the package requirement.

**Note:** For statistical reasons, the average requirement does not apply to packages labeled by count of 50 or fewer items, and the MAV does not apply to the lot. It only applies to the packages in the sample.

Maximum Allowable Variations: The MAVs listed in Table 2-7., MAVs for Packages Labeled by Count define the limits of reasonable variation for an individual package even though the MAV is not directly used in the sampling plan. Individual packages that are undercount by more than the MAV are considered defective. Even if the sample passes, these should be repacked, relabeled, or otherwise handled.

**Example:** If testing a lot of 160 packages of pencils labeled “50 pencils,” choose a random sample of 12 packages from the lot. If the scale cannot discriminate between differences in count, open every package and count the pencils.  For example, assume the 12 package counts are: 50, 52, 50, 50, 51, 53, 52, 50, 50, 50, 47, and 50.

Because only one package contains fewer than 50 pencils, the sample passes the test (Refer to Table 2-11.). However, the package containing 47 pencils should not be introduced into commerce even though the lot complies with the package requirements because it is undercount by more than the MAV (1 item) permitted in Table 2-7.

4.4Packages Labeled by Count of More than 50 Items

**Test Procedures**

There are two procedures to determine count without opening all packages in the sample.  Both use the weight of a counted number of items in the package.  If the weight of discrete items or numbers of items in a package varies, the packaged items must be counted rather than weighed.

**Equipment**

Use a scale that meets the requirements in Chapter 2, Section 2.2, Measurement Standards and Test Equipment.

**Audit Procedure**

Use this procedure to audit lots of packages labeled by count of more than 50 items, but the precision of this procedure is only ± 1 %. Determine the lot compliance based on actual count or the violation procedure.

Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then use the following test procedure to determine lot compliance.

Select an initial tare sample according to Chapter 2, Section 2.3.

Gross weigh the first package in the tare sample and record this weight.

Select the number of items from the first tare package that weighs the greater:

10 % of the labeled count; or

a quantity equal to at least 50 minimum divisions on the scale.

**Example:** Using a scale with 1 g divisions, the selected count must weigh at least 50 grams. If a scale with 0.001 lb divisions is used, the selected count must weigh at least 0.05 lb. Record the count and weight.

Calculate the weight of the labeled count using the following formula:

Weight of the Labeled Count = (labeled count x weight of items in step [4]) ÷

(count of items in step [4])

Record the result as “labeled count weight.”

Gross weigh the remaining packages of the tare sample and keep contents of opened packages separated in case all of the items must be counted.

Determine the Average Used Dry Tare Weight of the sample according to Chapter 2, Section 2.3.

The weight of the labeled count plus the average tare weight represents the “nominal gross weight.”

Subtract the nominal gross weight from the gross weight of the individual packages and record the errors.

(Package error [weight]) = (actual package gross weight) (nominal gross weight)

Convert the package errors in units of weight to count:

Package error (count) = (Package error [weight] x labeled count) ÷ (labeled count weight)

Round any fractional counts up to whole items in favor of the packager. Record the package error in units of count. Compute the average error.

If the average error is minus, go to the “procedure to use if the inspector suspects the lot violates the package requirements” below

If the average error is zero or positive, the sample is presumed to conform to the package requirements.

## Procedures to use if the inspector suspects the lot violates the package requirements

If possible, use the gravimetric procedure to determine compliance. To minimize the number of packages to be opened, combine the measurement of the weight of the number of units in the package with the determination of tare. Therefore, it will not be necessary to open more packages than the tare sample. If the audit procedure in this section has been used, the possible violation procedure below can be followed with the same sample if package contents have been kept separate and can still be counted. Use the following steps to determine if the sample passes or fails.

Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then use the following test procedure to determine lot compliance. Use a scale that meets the criteria specified in 4.2.

Select an initial tare sample according to Chapter 2, Section 2.3.

Gross weigh the packages selected for the tare sample and record these weights. Open these packages and determine the tare and net weights of the contents, and count the exact number of items in the packages. Record this information.

Calculate and record the weights of the labeled counts for the first two packages using the formula:

Weight of labeled count = (labeled count) x (contents weight ÷ contents count)

To avoid round off errors, carry at least two extra decimal places in the calculation until the weight of the labeled count is obtained. To use the gravimetric procedure, the difference in weights of the labeled counts of the two packages must not exceed one scale division.

If the difference in weights exceeds this criterion, determine the actual count per package for every package in the sample recording plus and minus errors. Then, follow the procedures in “Evaluating Results” in Chapter 2, Section 2.3, to determine lot conformance.

If the difference is within the criterion, average the weights of the labeled count and go on to step (5).

Determine the Average Used Dry Tare Weight of the sample according to provisions in Chapter 2, Section 2.3.

Determine and record the nominal gross weight by adding the average weight of the labeled count of items in the package step (4) to the average tare weight step (5).

Weigh the remaining packages in the sample, subtract the nominal gross weight from the gross weight of the individual packages, and record the errors.

Package Error (weight) = (Actual Package Gross Weight) (Nominal Gross Weight)

Look up the MAV for the package size from Table 2-7. and convert it to weight using the formula:

MAV (weight) = (MAV (count) x Avg. Wt. of Labeled Count step [4]) ÷ (Labeled Count)

Convert the MAV to dimensionless units by dividing the MAV (weight) by the unit of measure and record.

## Evaluation of Results

Follow the procedures in Chapter 2, Section 2.3., Evaluation Results to determine lot conformance.

Convert back to count when completing the report form using the following formula:

Avg. Pkg. Error (count) = (Avg. Pkg. Error [dimensionless units]) x (Unit of Measure) x

(Labeled Count) ÷ (Avg. Weight of Labeled Count.)

4.5Paper Plates and Sanitary Paper Products

### **How are the labeled dimensions of paper plates and sanitary paper products verified?**

### Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then use the following procedure to determine lot compliance.

The following procedures are used to verify the size of paper plates and other products. The following procedure may be used to verify the size declarations of other disposable dinnerware.

**Note:** Do not distort the item’s shape during measurement.

The count of sanitary paper products cannot be adequately determined by weighing.  Variability in sheet weight and core weight requires that official tests be conducted by actual count.  However, weighing can be a useful audit method. These products often declare total area as well as unit count and sheet size.  If the actual sheet size measurements and the actual count comply with the average requirements, the total area declaration is assumed correct.

**Equipment**

Steel tapes and rules. Determine measurements of length to the nearest division of the appropriate tape or rule.

Metric Units:

For labeled dimensions 40 cm or less, Linear Measure: 30 cm in length, 1 mm divisions; or a 1 m rule with 0.1 mm divisions, overall length tolerance of 0.4 mm.

For labeled dimensions greater than 40 cm, 30 m tape with 1 mm divisions.

Inch pound Units:

For labeled dimensions 25 in or less, use a 36 in rule with 1/64 in or 1/100 in divisions and an overall length tolerance of 1/64 in.

For dimensions greater than 25 in, use a 100 ft tape with 1/16 in divisions and an overall length tolerance of 0.1 in.

Measuring Base

**Note:** A measuring base may be made of any flat, sturdy material approximately 38 cm (15 in) square.  Two vertical side pieces approximately 3 cm (1 in) high and the same length as the sides of the measuring base are attached along two adjoining edges of the measuring base to form a 90° corner. Trim all white borders from two or more sheets of graph paper (10 divisions per centimeter or 20 divisions per inch). Place one sheet on the measuring base and position it so that one corner of graph paper is snug in the corner of the measuring base and vertical sides.  Tape the sheet to the measuring base.  Overlap other sheets on the first sheet so that the lines of top and bottom sheet coincide, expanding the graph area to a size bigger than plates to be measured; tape these sheets to the measuring base.  Number each line from the top and left side of base plates: 1, 2, 3, etc.

### **How are paper products inspected?**

Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then use the following test procedure to determine lot compliance.

Select an initial tare sample according to Chapter 2, Section 2.3.

Open each package and select one item from each.

**Note:**  Some packages of plates contain a combination of different-sized plates. In this instance, take a plate of each declared size from the package to represent all the plates of that size in the package. For example, if three sizes are declared, select three different plates from each package.

### **How are paper products measured?**

### **Note:** Occasionally, packages of plates declared to be one size contain plates that can be seen by inspection to be of different sizes in the same package. In this instance, select the smallest plate and use the methods below to determine the package error. If the smallest plate is not short measure by more than the MAV, measure each size of plate in the package and calculate the average dimensions.

**Example:** If 5 plates measure 21.41 cm (8.43 in) and 15 measure 21.74 cm (8.56 in), the average dimension for this package of 20 plates is 21.66 cm (8.53 in).

For paper plates: place each item on the measuring base plate (or use the linear measure) with the eating surface down so two sides of the plate touch the sides of the measuring base. For other products, use either the measuring base or a linear measure to determine actual labeled dimensions (e.g., packages of napkins, rolls of paper towels). If testing folded products, be sure that the folds are pressed flat so that the measurement is accurate.

If the measurements reveal that the dimensions of the individual items vary, select at least 10 items from each package.  Measure and average these dimensions. Use the average dimensions to determine package error in step 5 below.

The package error equals the actual dimensions minus the labeled dimensions.

**Evaluation of Results**

Follow the procedures in Chapter 2, Section 2.3., Evaluating Results to determine lot conformance.

4.6Special Test Requirements for Packages Labeled by Linear or Square Measure (Area)

### **Are there special measurement requirements for packages labeled by dimensions?**

Yes, products labeled by length (such as yarn) or area often requires the application of tension to the ends of the product in order to straighten the product before measuring. When testing yarn and thread apply tension and use the specialized equipment specified in ASTM D 1907-97, “Standard Test Method for Linear Density of Yarn (Yarn Number) by the Skein Method,” in conjunction with the sampling plans and package requirements described in this handbook.

## Evaluation of Results

Follow the procedures in Chapter 2, Section 2.3., Evaluating Results to determine lot conformance.

4.7Polyethylene Sheeting

### **Which procedures are used to verify the declarations on polyethylene sheeting and bags?**

### Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then use the following test procedure to determine lot compliance.

### 

**Note:** Most polyethylene products are sold by length, width, thickness, area, and net weight.

**Equipment**

A scale that meets the requirements in Chapter 2, Section 2.2., Measurement Standards and Test Equipment.

Steel measuring tapes and rules as specified in 4.5.

Deadweight dial micrometer (or equal) equipped with a flat anvil, 6.35 mm or (1/4 in) diameter or larger, and a 4.75 mm (3/16 in) diameter flat surface on the head of the spindle. The anvil and spindle head surfaces should be ground and lapped, parallel to within 0.002 mm (0.0001 in), and should move on an axis perpendicular to their surfaces.  The dial spindle should be vertical, and the dial should be at least 50.8 mm (2 in) in diameter. The dial indicator should be continuously graduated to read directly to 0.002 mm (0.0001 in) and should be capable of making more than one revolution. It must be equipped with a separate indicator to indicate the number of complete revolutions.  The dial indicator mechanism should be fully jeweled.  The frame should be of sufficient rigidity that a load of 1.36 kg (3 lb) applied to the dial housing, exclusive of the weight or spindle presser foot, will not cause a change in indication on the dial of more than 0.02 mm (0.001 in). The indicator reading must be repeatable to 0.001 2 mm (0.000 05 in) at zero. The mass of the probe head (total of anvil, weight 102 g or [3.6 oz], spindle, etc.) must be 113.4 g (4 oz).  The micrometer should be operated in an atmosphere free from drafts and fluctuating temperature and should be stabilized at ambient room temperature before use.

Gage blocks covering the range of thicknesses to be tested should be used to check the accuracy of the micrometer

T-square

### **Test Procedure**

Follow the Basic Test Procedure in Section 2.3. Define the inspection lot. Use a Category A sampling plan in the inspection; select a random sample; then use the following test procedure to determine lot compliance.

Be sure the product is not mislabeled. Check the label declaration to confirm that all of the declared dimensions are consistent with the required standards. The declaration on sheeting, film, and bags shall be equal to or greater than the weight calculated by using the formulas below. Calculate the final value to four digits and declare to three digits dropping the final digit (e.g., if the calculated value is 2.078 lb, then the declared net weight is truncated to 2.07 lb).

**Example Label:**

3.Use the following formulas to compute a target net weight. The labeled weight should equal or exceed the target net weight or the package is not in compliance.

For metric dimensions:

Target Mass in Kilograms = (T x A x D) ÷ 1,000

Where: T = nominal thickness in centimeters

A = nominal length in centimeters x nominal width (the nominal width for bags is twice the labeled width) in centimeters

D = density in grams per cubic centimeter\*

For inch-pound dimensions:

Target Weight in Pounds = T x A x D x 0.036 13

Where: T = nominal thickness in inches;

A = nominal area; that is the nominal length in inches x nominal width (the nominal width for bags is twice the labeled width) in inches;

D = density in grams per cubic centimeter; 0.036 13 is a factor for converting g/cm3 to lb/in3.

\*Determined by ASTM Standard D 1505-98, “Standard Method of Test for Density of Plastics by the Density Gradient Technique.” For the purpose of this handbook, the minimum density shall be 0.92 g/cm3 when the actual density is not known.

**Evaluation**

### Perform the calculations as shown in the following samples. If the product complies with the label declaration, go to step (2).

Sample Calculations

For metric units:

(0.010 16 cm x [(1.82 m x 100 cm/m) x (30.48 m x 100 cm/m)] x 0.92 g/cm3) ÷ 1,000 g/kg

= a target net mass of 5.18 kg

at one end and along the length on one side of the In this example, the labeled net mass of 5.03 kg does not meet the target net mass, so the product is not in compliance.

For inch-pound units:

(0.004 in) x [(6 ft x 12 in/ft) x (100 ft x 12 in/ft)] x 0.92g/cm3 x 0.03613 = a target net weight of 11.48 lb

In this example, the labeled net weight of 11.1 lb does not meet the target net weight, so the product is not in compliance.

Select packages for tare samples. Determine and record the gross weights of the initial tare sample.

Extend the product in the sample packages to their full dimensions and remove by hand all creases and folds.

Measure the length and width of the product to the closest 3 mm (1/8 in).  Make all measurements at intervals uniformly distributed along the length and width of the sample and record the results. Compute the average length and width, and record.

With rolls of product, measure the length of the roll at three points along the width of each roll and measure the width at a minimum of 10 points along the length of each roll.

For folded products, such as drop cloths or tarpaulins, make three length measurements along the width of the sample and three width measurements along the length of the sample.

Determine and record the average tare weight according to Chapter 2, Section 2.3, Tare Procedures.

## Evaluation of Results – Length, Width, and Net Weight

Follow the procedures in Chapter 2, Section 2.3., Evaluating Results to determine the lot conformance requirements for length, width, and weight.

If the sample fails to meet the package requirements for any of these declarations, no further measurements are necessary. The lot fails to conform.

If the sample meets the package requirements for the declarations of length, widths, and weight, go to step 6 to verify the thickness declaration.

Measure the thickness of the plastic sheet with a micrometer using the following guide. Place the micrometer on a solid level surface. If the dial does not read zero with nothing between the anvil and the spindle head, set it at zero.  Raise and lower the spindle head or probe several times; it should indicate zero each time.  If it does not, find and correct the cause before proceeding.

Take measurements at five uniformly distributed locations across the width at each end and five locations along each side of each roll in the sample. If this is not possible, take measurements at five uniformly distributed locations across the width product for each package in the sample.

When measuring the thickness, place the sample between the micrometer surfaces and lower the spindle head or probe near, but outside, the area where the measurement will be made.  Raise the spindle head or probe a distance of 0.008 mm to 0.01 mm (0.000 3 in to 0.000 4 in) and move the sheet to the measurement position.  Drop the spindle head onto the test area of the sheet.

Read the dial thickness two seconds or more after the drop, or when the dial hand or digital readout becomes stationary. This procedure minimizes small errors that may occur when the spindle head or probe is lowered slowly onto the test area.

For succeeding measurements, raise the spindle head 0.008 mm to 0.01 mm (0.000 3 in to 0.000 4 in) above the rest position on the test surface, move to the next measurement location, and drop the spindle head onto the test area.  Do not raise the spindle head more than 0.01 mm (0.000 4 in) above its rest position on the test area.  Take measurements at least 6 mm (1/4 in) or more from the edge of the sheet.

Repeat Step 6 above on the remaining packages in the sample and record all thickness measurements. Compute and record the average thickness for the individual package and apply the following MAV requirements.

**Evaluation of Results – Individual Thickness**

No measured thickness of polyethylene labeled 25 µm (1 mil) or greater should be less than 80 % of the labeled thickness.

No measured thickness of polyethylene labeled less than 25 µm (1 mil) should be less than 65 % of the labeled thickness.

Count the number of values that are smaller than specified MAVs (0.8 x labeled thickness if 25 µm [1 mil] or greater or 0.65 x labeled thickness, if less than 25 µm [1 mil]).  If the number of values that fail to meet the thickness requirement exceeds the number of MAVs permitted for the sample size, the lot fails to conform to requirements. No further testing of the lot is necessary. If the number of MAVs for thickness measurements is less than or equal to the number permitted for the sample size, go on to Evaluation of Res