Cookstove Durability Protocol

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INTRODUCTION

Durability affects numerous aspects of the cookstove sector, including usability, performance, safety, and user perception. However, despite the importance of durability, and frequent discussion about this topic, little concrete information is available with regard to cookstove durability. Numerous references can be found that discuss the importance of durability and the need to quantify durability, but little information is available to help quantify what it means for a cookstove to be "durable."

The protocol developed here is intended to give the cookstove sector some tests for evaluating cookstove durability. Although the term durability is used here, quality may be a more appropriate term. The tests we propose seek to identify not only aspects of cookstove designs that may affect usable life, but also the larger concept of cookstove quality. Four primary aspects of cookstove quality were considered when developing the tests.

COMPONENTS OF QUALITY

a) Performance – will performance and safety change as the cookstove ages?
b) Reliability – will the cookstove continue to perform as anticipated?
c) Durability – will the cookstove last?
d) Perceived Quality – will the customer feel, regardless of true performance that the product they have purchased is worth the price?

PROTOCOL PRINCIPLES

Cookstove durability encompasses a wide range of topics. And, different organizations may have different goals when evaluating durability. However, four overarching principles dictate the level of detail, equipment, and analysis that was included in this protocol.

1. Tests were designed to be as technologically agnostic as possible. Not all of the tests outlined in this protocol are needed for every type of cookstove. And, there are some targeted tests which are outside the scope of this protocol. But, the majority of the durability issues investigated can be found in numerous types of cookstoves. Guidelines for determining which tests are required have been provided in the Appendix.
2. Tests were designed to allow for assignment of quantitative scores. It was felt that, in order to compare different types and designs of cookstoves, a method of scoring was required. The use of numeric scores allows multiple different tests to be combined, which is not possible using letter scores.
3. Durability or quality tests should be accessible to and feasible in a broad range of organizations. Although it meant not testing some aspects of cookstove quality, tests were designed such that they could be conducted by many different groups, with fairly minor financial investment in equipment and only basic training.
4. Tests were also designed without any assumption that the tester had prior knowledge about the cookstove. The test does not need to know the construction or configuration of the cookstove prior to testing.

SCORING APPROACH

As mentioned previously, the test incorporates a numeric scoring method. Cookstoves are scored based on risk level. The higher the risk of durability issues, the higher the overall score. This approach was used instead of the more common 0-100 scoring method for a number of reasons. First, it allows additional tests to be added in the future without reworking the scoring criteria. As the sector gains additional knowledge regarding common failure modes and causes, additional tests can be added and their scores added to those presented here. The other major rationale for the scoring approach used is that it presents a more conservative message. A score of zero does not imply that a particular cookstove has no durability concerns, only that no durability concerns have yet been identified.

ORDER OF TESTS

The larger test protocol is comprised of a series of targeted durability tests. The tests should be completed in the order outlined in Figure 1. The order was established because certain tests require the cookstove to be fully assembled while others target specific components. Tests are conducted in two parallel paths. Therefore, a minimum of two copies of each cookstove are needed for testing. After completing internal impact testing, one of the two cookstoves needs to be broken down into its primary components, if at all possible. This may require the use of basic hand tools.

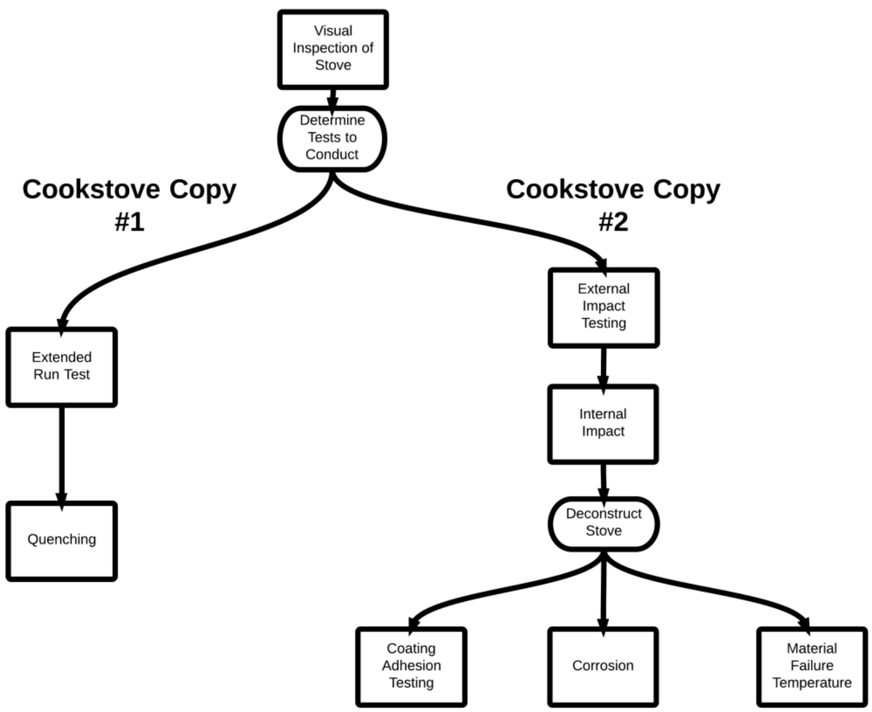


FIGURE 1: ORDER OF TESTING

Targeted Quality Assessment Tests

SELECTION OF COOKSTOVES

Cookstoves for testing should be selected randomly to prevent bias. Numerous methods of ensuring that samples are being collected randomly are available. The most appropriate method will vary with location. This protocol only calls for two cookstoves to be tested. However, for situations with potentially high variability in production quality, multiple sets of cookstoves should be tested.

KNOWN LIMITATIONS ASSOCIATED WITH THE TEST PROTOCOL

Although every effort has been made to develop a robust and versatile protocol, known limitations do exist. Understanding these limitations is important for interpreting the results of each test.

1) Cookstove Age: The tests outlined here do not inherently account for the age or current condition of any cookstove. The tests can only evaluate potential durability risks based on the state of the cookstove being tested. Because the results of many of the tests outlined in this protocol will be affected by the current condition of a cookstove, it is critical to document the appearance and condition of test stoves prior to beginning testing. Understanding this limitation is important when using the protocol to compare different cookstove designs or samples. Unbiased comparisons require that the stoves being tested are of an approximately equal age. This test protocol can be conducted on new as well as aged cookstoves to evaluate how durability changes with age.

2) Fuel Variability: The protocol does not specify specific fuels to be used during testing. This was a conscious decision in order to make the protocol appropriate for testing in different locations. Fuels, however, can be highly variable in composition and energy content. These variations can have a direct impact on some of the tests outlined in this protocol. Two examples include the resulting surface temperatures and corrosion of cookstoves. Surface temperature will be influenced by the energy content of the fuel being used. Fuel variability will also impact the amount of corrosion or discoloration seen in stoves, due to variations in fuel composition. Whenever possible, the fuels used for testing should be the ones specified by the manufacturer and/or similar to the fuels used in practice, to ensure that testing represents actual conditions.
3) Evaluation Ambiguity: This protocol seeks to assign numeric risk factor scores for each test. Assignment of numeric scores is challenging for some tests because of the degree of ambiguity that is inherent to the tests. Wherever possible, concrete evaluation criteria have been included. But, this system is not perfect. Tests conducted by different individuals may result in slightly different predicted risk scores. However, these differences are anticipated to be fairly minor for any given test.
4) Cookstove Type: This protocol has sought to include tests appropriate for a wide range of cookstove designs and configurations. However, it is not possible to include tests for every possible cookstove design or type. When interpreting the results, it is important to remember that the scoring system is meant to identify known risks. The results do not imply that all possible durability risks have been tested. Some cookstove designs will require additional, targeted durability tests for specific potential failure modes.

1. Extended Run Test

Significance:

This test determines the temperature that cookstove components reach during use. It is understood that the rate of temperature change (both heating and cooling) can have a major impact on material durability. However, this test only focuses on steady state temperatures. Information about the rate of temperature change of components can provide useful information for evaluating both component failure and risk, but this is considered outside the scope of this protocol.

Steady state temperature information collected in this step is used repeatedly in subsequent tests. Temperatures recorded during the extended burn test are used to evaluate risk of component failure, realistic ranges for thermal shock testing, and bounds for thermal cycling.

Approximate Total Time Required to Complete Test:

32-36 hours

Required Supplies & Materials:

- High temperature safety gloves and protective sleeves
- Safety glasses
- Representative fuel – enough for 12 hours of operation
- Infrared thermometer with adjustable emissivity
- Ruler
- Cooking Pot

External Standards & Methods Used in the Development of this Test:

ASTM C1171, ASTM D1183, and ASTM D3045

Testing Protocol:

1. Place the cookstove in a location where it may be operated for at least three days. The location should have adequate ventilation to prevent exposing the tester to pollutants.

NOTE: When testing a cookstove that depends on sunlight (i.e. solar cookers), the cookstove should be placed in a location that receives full sunlight for at least 4 hours. Testing of solar cookers should only be conducted on days with minimum cloud cover.

2. Prior to testing, each cookstove should be inspected in detail, including with photographs. Observations should be noted on a data sheet. Whenever possible, a ruler should be included in photos, as a point of reference.
3. An infrared thermometer is sensitive to material emissivity. Emissivity of different construction materials can be determined using the guidelines in the Appendix. Although emissivity can vary with temperature, unless a primary temperature standard is available, it is necessary to assume constant emissivity with respect to temperature.
4. A simple two dimensional schematic of the cookstove should be drawn and included on the data sheet. On this schematic, cracks, wear marks, chipped/damaged/discolored coatings, etc., should be noted. Also on this form, the tester should document the locations of temperature measurements. Important measurement locations to include, when applicable, are as follows:
   - Combustion chamber (multiple locations)
   - Fuel entrance/stove mouth
   - Stove exit/pot support
   - Chimney
   - Exterior body (bottom, back, and sides of entrance)
   - Reflectors (in the case of solar cookers)
   - Burner (in the case of liquid and gasifier cookstoves)
5. The cookstove is to be run for 4 hours. If cookstove power can be controlled, the cookstove should be run at the highest-possible firepower. Tests should be conducted with a water-filled pot.

NOTE: It is understood that some cookstove manufactures specify the firepower to be used for optimum cookstove performance. However, for this test, the cookstove should be operated at its maximum firepower, to re-create a worst-case scenario.

6. Temperature should be measured after the cookstove has been running for 4 hours. While the cookstove is still running, begin by taking measurements of the stove exterior. After completing exterior measurements, the fire should be extinguished and internal temperatures should be measured immediately, using the infrared thermometer.

NOTE: Care should be taken to ensure that the infrared thermometer is not exposed to infrared radiation from flames, as this will interfere with the accuracy of measurements. Details on calibration and use of an infrared thermometer can be found in the Appendix.

NOTE: Temperature should be measured as quickly as possible. All temperature measurements much be completed within 5 minutes of the fire being extinguished.

NOTE: No strict meaning of “maximum” firepower can be defined. The test should be run in such a manner as to maximize cookstove temperature.

SAFETY: Safety gloves, shirt with long sleeves, and safety glasses should be worn when measuring temperatures.

7. Temperatures should be recorded on a data sheet.
8. The cookstove should be allowed to cool for a minimum of 6 hours.
9. Steps 4-7 should be repeated two additional times, for a total of three tests, with averaging of temperature measurements for each location.
10. Post-testing observations and photographs should be recorded and documented on the data sheet.

Evaluation of Results and Quality Scoring:

Level	Examples	Risk Factor
No Change	N/A	**+0**
Minor	Discoloration, minor abrasion, etc.	**+1**
Major	Cracks < 2 cm in length, twisted metal, etc.	**+3**
Critical	Broken components, cracks > 2 cm in length, cloudy/hazy reflectors or glass, etc.	**+5**

NOTE: Although extensive data will be collected on the surface temperature of different cookstove components, this information does not play any part in the risk factor determined from this test. The surface temperature data is only used to inform subsequent tests.

2. External Impact Test

Significance:

Cookstoves are often exposed to rough handling and treatment. This can occur for a number of reasons, including, but not limited to, transportation, dropping of the cookstove, dropping of other items on the cookstove, and tipping over of the cookstove. This test is used to determine the ability of the cookstove to withstand short duration impacts.

Approximate Total Time Required to Complete Test:

1-2 hours

Required Supplies & Materials:

- Tube with inner diameter of 2.5 cm, and 1 m in length
- 2 cm diameter steel rod segments with the following masses:
    - 25 g (approximately 1 cm in length)
    - 50 g (approximately 2 cm in length)
    - 100 g (approximately 4 cm in length)
    - 150 g (approximately 6 cm in length)
    - 200 g (approximately 8 cm in length)
    - 250 g (approximately 10 cm in length)
- Steel sphere with a diameter between 1.8-2.2 cm

External Standards & Methods Used in the Development of this Test:

ASTM D2794 and ASTM D968

Testing Protocol

1. Place the cookstove on a granite or other level working surface.
2. Secure the tube in a vertical orientation, such that the bottom of the tube is just touching the outside surface of the cookstove.
3. Place a steel sphere inside the tube. The steel sphere helps to ensure a repeatable impact.
4. Starting with the heaviest weight, drop the weight down the inside of the tube.
5. Move the tube away from the cookstove and observe for any substantial damage.

NOTE: In the context of this test, substantial damage constitutes any of the following:

- Chipped paint/coatings
- Cracks > 2 cm in length
- Dents > 5 mm in depth

6. If substantial damage is visualized, move the tube over a new region of the stove and repeat the test with a lighter weight.
7. Repeat steps 1-6 until substantial damage is not visualized.
8. Repeat steps 1-7 for all external components of the cookstove.

Evaluation of Results and Quality Scoring:

The overall score for this test is derived from the material with the largest risk factor:

Lowest Weight at Which Damage is Seen	Risk Factor
No Damage Seen at Any of the Weights Tested	+0
250 g	+1
200 g	+2
150 g	+3
100 g	+4
50 g	+5
25 g	+6

3. Internal Impact

Significance:

Similar to external components, internal cookstove components are often exposed to rough handling and treatment. This can occur for a number of reasons, including, but not limited to, fuel being added to the combustion chamber and removal of ash or charcoal. One major difference between external and internal components of a cookstove is that internal components are often subjected to repeated impacts. This test is used to determine a cookstove's ability to withstand repeated, short-duration impacts.

Approximate Total Time Required to Complete Test:

1-2 hours

Required Supplies & Materials:

- Tube with inner diameter of 2.5 cm, and 1m in length
- 2 cm diameter steel rod segments with the following masses:
  - 2 5g (approximately 1 cm in length)
  - 50g (approximately 2 cm in length)
  - 100 g (approximately 4 cm in length)
  - 150 g (approximately 6 cm in length)
  - 200 g (approximately 8 cm in length)
  - 250 g (approximately 10 cm in length)
- Steel sphere with a diameter between 1.8-2.2 cm

External Standards & Methods Used in the Development of this Test:

ASTM D2794 and ASTM D968

Testing Protocol

1. Place the cookstove on a granite or other level working surface.
2. Secure the tube in a vertical orientation, such that the bottom of the tube is just touching the internal surface of the cookstove.
3. Place a steel sphere inside tube. The steel sphere helps ensure a repeatable impact.
4. Starting with the heaviest weight, drop the weight down the inside of the tube ten times.
5. Move the tube away from the cookstove and observe for any substantial damage.

NOTE: In the context of this test, substantial damage constitutes any of the following:

  - Chipped paint/coatings
  - Cracks > 2 cm in length
  - Dents > 5 mm in depth

6. If substantial damage is seen, move the tube over a new region of the stove and repeat the test with a lighter weight.
7. Repeat steps 1-6 until substantial damage is not visualized.
8. Repeat steps 1-7 for all internal components of the cookstove. Some components may need to be removed from the cookstove for testing.

Evaluation of Results and Quality Scoring:

The overall score for this test is derived from the material with the largest risk factor:

Weight	Risk Factor
No Damage Seen	+0
250 g	+1
200 g	+2
150 g	+3
100 g	+4
50 g	+5
25 g	+6

4. Corrosion Testing

Significance:

Many materials have the potential to corrode or rust. There are many factors that promote corrosion, including temperature, humidity, a high rate of thermal cycling, and salts. Due to the number of factors that affect corrosion, accurately judging the risk of corrosion can be extremely challenging. One method of addressing these challenges is to conduct comparative tests, where unknown and standard reference materials are tested in parallel. When samples are only coated on one side, all evaluations should be conducted on both the coated and uncoated sides of the material.

Approximate Total Time Required to Complete Test:

120-130 hours (per sample)

Required Supplies & Materials:

- Electric kiln (example: GS-Bead Cube or Paragon QuikFire 6)
- Sodium chloride solution (example: Instant Ocean)
- Spray water bottle
- High temperature safety gloves and protective sleeves
- Safety glasses
- Metal tongs
- Air tight chamber containing a small humidifier
- Reference materials (4 cm x 4 cm):
    - Mild steel
    - Hot-Dipped Galvanized steel
    - ASTM Stainless steel 304
    - ASTM Stainless steel 409 or 410

External Standards & Methods Used in the Development of this Test:

ASTM C1171, ASTM D1183, ASTM D6944, ASTM G1, ISO 4530, ISO 4536, ISO 11845, and ISO 14993

Testing Protocol

1. Collect samples of metal components from a disassembled cookstove.
2. Take photographs and record observations of samples prior to testing. Record these observations on a data sheet.
3. Use temperatures from the Extended Run Test to determine the cycling temperature for each component, based on the origin of each component from the cookstove. If multiple temperatures were recorded, the maximum temperature should be used.
4. Prepare a 20 g/L salt solution in a spray bottle.
5. Set the humidifier to achieve a relative humidity of at least 95%.
6. Place one of the test samples into the kiln with a sample of each of the reference materials.
7. Kiln temperature should be increased by approximately 10°C/minute, until the target temperature is achieved.
8. Kiln temperature should be maintained for 30 minutes.
9. After 30 minutes, the kiln temperature should be lowered as fast as appropriate for the kiln.
10. Once the kiln temperature is below 150°C, remove the samples from the kiln.
11. Samples should be sprayed liberally with the salt solution and then placed into the humidified chamber.

NOTE: The goal is to keep droplets of salt solution on the metals samples as they are transported into the humidity chamber.

12. Store samples in the humidity chamber for at least 12 hours.
13. Repeat steps 6-12 nine more times, for a total of 10 cycles.
14. Repeat steps 6-13 for the remaining samples.

NOTE: A different set of reference materials are needed for each sample material being testing.

NOTE: Multiple sets of samples can be placed in the humidity chamber at the same time if care is taken to keep track of the different materials.

Evaluation of Results and Quality Scoring:

Risk for corrosion is being evaluated in comparison to other known materials. The materials should be ranked in order of visible corrosion and material build-up. Material discoloration, with no change in the material surface finish, should not be considered when ranking materials. The overall risk score is based on the highest value found with any of the tested components.

Material Rank	Risk Factor
Least Corrosion Seen	**+0**
Second Place	**+0**
Third Place	**+1**
Fourth Place	**+3**
Most Corrosion Seen	**+5**

5. Coating Adhesion Testing

Significance:

Many cookstoves incorporate some sort of coating (i.e. paint, powder coating, enamel, etc.) into their design. This is done for many reasons, including aesthetics and corrosion prevention. These coatings can be damaged, which affects both user perception and, in some cases, product durability. The adhesion testing presented here only investigates how well a coating adheres to the cookstove. Maximum coating temperatures are investigated in the extended run tests.

The adhesion of many coatings can be affected by temperature. These changes can be both positive and negative. Although adhesion is often reduced after a coating has been thermally cycled, in some cases the coatings “cure”, which improves their strength. Both conditions are tested here.

Approximate Total Time Required to Complete Test:

3-4 hours (per sample)

Required Supplies & Materials:

- Electric kiln (example: GS-Bead Cube or Paragon QuikFire 6)
- High temperature safety gloves and protective sleeves
- Safety glasses
- Cutting tool, such as a razor blade, scalpel, or box cutter
- Flexible ruler (or printed ruler included on the data sheet)
- Scotch Brand #845 Tape (a specific tape is used for consistency)

External Standards & Methods Used in the Development of this Test:

ASTM D3359, ASTM D3451, ASTM D6944, and ISO 4530

Testing Protocol

1. Looking at the cookstove, identify all components that appear to be covered by some sort of coating. Record these items on the data sheet.
2. Collect samples of coated components (at least 5 cm x 5 cm) from a disassembled cookstove.

NOTE: Smaller samples can be used. However, sample size should be recorded on the data sheet.

3. Use the temperatures identified from the Extended Run Test to determine the target temperature for each component, based on the origin of each component from the cookstove. If multiple temperatures were recorded, the maximum temperature should be used.
4. Place one of the two samples from each component into the kiln.
5. Kiln temperature should be increased by approximately 10°C/minute, until the target temperature is achieved.
6. Kiln temperature should be maintained for 30 minutes.
7. After 30 minutes, the kiln temperature should be lowered as fast as appropriate for the kiln.
8. Steps 5-7 should be repeated four more times, for a total of five cycles.
9. Using both aged and un-aged samples, attempt to cut cross hatches through the samples, down to the substrate. The cross hatches should be spaced approximately 1 mm apart and be approximately 20 mm in length. Each cut should be made using a ruler and with one steady motion. If the cut does not penetrate the coating, it can be scored again using the straight edge to ensure that repeated cuts are being placed in the same location. Repeat the process until there are six vertical and six horizontal cuts.
10. After cutting has been completed, gently brush the samples to remove any loose material.

11. Pieces of tape should be pressed firmly onto the cut samples.
12. After leaving the tape in place for 2 minutes, remove the tape in one quick motion from each sample.
13. Using Figure 2, estimate the amount of material removed by the tape.

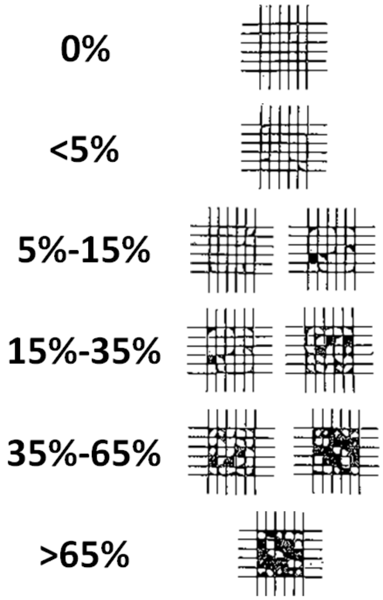


FIGURE 2: MATERIAL LOSS FROM ADHESION TESTING (ADAPTED FROM ASTM 3359)

14. Repeat steps 3-14 for the remaining cookstove components.

EVALUATION OF RESULTS AND QUALITY SCORING:

The quality score is based upon the higher value of any of the components for either test (i.e. un-aged vs aged).

Material Loss	Risk Factor
0%	+0
<5%	+1
5%-15%	+2
15%-35%	+3
35%-65%	+4
>65%	+5

6. QUENCHING TEST

SIGNIFICANCE:

Due to the existence of hot combustion temperatures and relatively cool cooking temperatures of many cooking practices, there is a risk for sudden temperature changes. This thermal shock may crack or break many components of the cookstove. Many international thermal shock testing procedures evaluate performance based upon material strength of small sample pieces. This approach is not appropriate for cookstoves, since cookstove components are typically highly constrained. Because of this, tests are conducted on the complete cookstove.

Approximate Total Time Required to Complete Test:

85-90 hours

Required Supplies & Materials:

- Representative fuel – enough for 5 hours of operation
- High temperature safety gloves and protective sleeves
- Safety glasses
- Cook pot with a diameter between 22-30 cm
- Ruler
- Water container or pitcher appropriate for pouring

External Standards & Methods Used in the Development of this Test:

ASTM C1171, ASTM C1525, ISO 718, and ISO 28703

Testing Protocol

1. Prior to testing, a detailed visual inspection of the cookstove should be conducted, including documentation with photographs. Observations should be recorded on a data sheet. Whenever possible, a ruler should be included in photographs, as a point of reference.
2. Fill a cook pot to within 1 cm of the brim.
3. The cookstove should be run for 1 hour. If cookstove power can be controlled, the cookstove should be run at the maximum possible firepower.

NOTE: It is understood that some cookstove manufactures specify the firepower for optimum performance. However, for this test the cookstove should be operated at its maximum firepower, to model a worst-case scenario.

4. The tester should wear safety glasses, high temperature safety gloves, and protective sleeves.
5. The user should quickly pour an additional 1 L of water into the cook pot, causing overflow of water into the stove.

SAFETY: There is a risk of water overflowing the container and/or hot cookstove components. Extreme cautions should be taken while conducting these tests.

6. Allow at least 16 hours for the cookstove to dry completely.
7. Repeat steps 2-6 four times, for a total of five tests.
8. Post-testing observations and photographs should be taken and noted on the data sheet.

Evaluation of Results and Quality Scoring:

Level	Examples	Risk Factor
No Change	N/A	**+0**
Minor	Discoloration or cracks < 2 cm in length.	**+1**
Major	Warped components or cracks > 2 cm in length.	**+3**
Critical	Broken or missing components, cloudy or hazy reflectors or glass, etc.	**+5**

7. Material Failure Temperature

Significance:

Cookstoves can reach extremely high temperatures, temperatures at which materials can begin to breakdown and fail. Although many materials have reported failure temperatures, without knowing the specifics of each material in the cookstove, using these databases of information is challenging.

Approximate Total Time Required to Complete Test:

9-11 hours (per sample)

Required Supplies & Materials:

- Electric kiln (example: GS-Bead Cube or Paragon QuikFire 6)
- High temperature safety gloves and protective sleeves
- Digital camera

External Standards & Methods Used in the Development of this Test:

ASTM D2485, ASTM D6944, ISO 4530, and ISO 21608

Testing Protocol

1. Collect samples of each of the major components used in the cookstove.
2. Use the temperatures derived from the Extended Run Test to determine the operating temperature for each component, based on the origin of each component from the cookstove. If multiple temperatures were recorded, the maximum temperature should be used.
3. Testing should begin at 100°C below the operating temperature determined in Extended Run Test. For example, a stove component that reached 350°C during the Extended Run Test would begin testing at 250°C.

NOTE: For convenience, starting temperatures can be set at the closest 50°C increment below the ideal temperature. For example, a component that was supposed to start testing at 265°C could begin testing at 250°C.

4. Place the sample in the kiln.

NOTE: Multiple samples can be heated in the kiln at once, assuming they have the same temperature target.

5. Kiln temperature should be increased by approximately 10°C/minute, until the target temperature is reached.
6. Kiln temperature should be maintained for 30 minutes at the target temperature.

NOTE: Some materials may off-gas or smoke. Care should be taken to maintain adequate airflow around the kiln.

7. After 30 minutes, kiln temperature should be lowered as fast as appropriate for the kiln.
8. Samples should be removed and photographed against a white background.
9. Repeat steps 4-8 using the same sample, increasing the kiln maximum temperature by 50°C each time until component “fails”. The final kiln setting prior to the component failing is considered the maximum operating temperature.

NOTE: In the context of this test, failure constitutes any of the following:

- Significant corrosion
- Exposure of the majority of base material through coating

- Melted components
- Significant twisting or warping of components
- In the context of organic materials, such as wood, failure is indicated by burned, scorched, or charred components

10. Repeat steps 3-10 for the remaining components, as required.

Evaluation of Results and Quality Scoring:

Risk factor scoring is based on how close the operating temperature is to the maximum operating temperature for that component.

$$R = \frac{Operating\ Temperature\ (K)}{Maximum\ Operating\ Temperature\ (K)}$$

R	Risk Factor
R<0.6	**+0**
0.6<R<0.7	**+1**
0.7<R<0.8	**+2**
0.8<R<0.9	**+3**
0.9<R<1	**+4**
R>1	**+5**

Appendix I

Guidelines for Determining Which Tests to Perform

Test	Test Applicability
Visual Inspection of Stove	Should be conducted for all cookstoves
Extended Run Test	Should be conducted for all cookstoves
Quenching Test	Should be conducted for all cookstoves
External Impact Test	Should be conducted for all cookstoves
Coating Adhesion Test	Should be conducted if any component has coating. If unsure testing should be conducted
Corrsion Test	Should be conducted if there are any metal components
Internal Imapct Test	Should be conducted for all cookstoves
Material Failure Test	Should be conducted for all cookstoves

Appendix II

Infrared Thermometer Calibration

When used correctly, infrared thermometers can be used to measure cookstove surface temperatures. However, there are several factors which must be considered to obtain accurate measurements.

Material Emissivity:

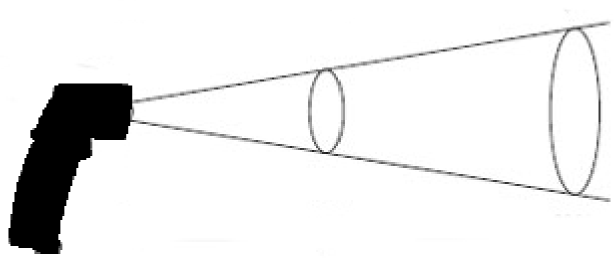
All materials have an emissivity. Emissivity is a measure of the amount of energy radiated by a material at a given temperature. Emissivity will change with material and surface finish, and varies between 0 and 1. An infrared thermometer determines temperature by measuring the infrared radiation emitted by an object, which is influenced by emissivity. Obtaining an accurate temperature measurement requires knowing a material's emissivity. Emissivity of a material can be determined through a calibration process.

Calibration:

A convenient method of calibrating infrared thermometers is to use materials which are at known temperatures. By heating a sample of material to a known temperature, the emissivity setting of the infrared thermometer can be adjusted until it displays an accurate temperature. As emissivity is temperature dependent, it is important to calibrate the emissivity of the infrared thermometer using materials which are at a temperature representative of the objects to be measured.

Field of View/Measurement Area:

Other important factors to consider when using an infrared thermometer are field of view and measurement area. Field of view is defined by what the infrared detector is seeing. A reading from the infrared thermometer will be incorrect if it is angled or held in a place in which it is picking up infrared radiation from other sources. A similar error can occur if the infrared thermometer is held too far away from the object being measured. The measurement area of infrared thermometers increases with the distance from the object being tested. To ensure accurate readings, infrared thermometers should be held as close to the object being measured as is safe for both the tester and the instrument.



Data Sheet 1

Extended Burn Test

Cookstove Being Tested:____________________________ Test Dates_____________________________________

Visual Inspection of Cookstove

Cookstove Schematic with Measurement Locations

Measurement Location	Material Emissivity	Test 1	Test 2	Test 3

Risk Score

Date:_____________________________

DATA SHEET 2

EXTERNAL IMPACT TEST

Cookstove Being Tested:___________________________ Test Dates___________________________________

Measurement Location	Largest Mass at Which No Damage Is Seen

Observations and Notes

Risk Score

DATA SHEET 3

INTERNAL IMPACT TEST

Cookstove Being Tested:___________________________ Test Dates___________________________________

Measurement Location	Largest Mass at Which No Damage Is Seen

Observations and Notes

Risk Score

Data Sheet 4

Corrosion Test

Cookstove Being Tested:_____________________________ Test Dates______________________________________

Sample Material	Temperature Target from Extended Burn Test	Observations

Risk Score

Data Sheet 5

Coating Adhesion Test

Cookstove Being Tested:___________________________ Test Dates___________________________________

Sample Material	Temperature Target from Extended Burn Test	Observations	Material Loss Estimation

Risk Score

Fold along dotted line

DATA SHEET 6

QUENCHING TEST

Cookstove Being Tested:___________________________ Test Dates___________________________________

Sample Material	Observations

Risk Score

Data Sheet 7

Material Failure Temperature Test

Cookstove Being Tested:___________________________ Test Dates___________________________________

Sample Material	Temperature Target from Extended Burn Test	Observations	Failure Temperature

Risk Score

Date:____________________________