EGR 3380
Engineering Design I

REQUEST FOR PROPOSAL
FOR THE DESIGN OF AN

AUTOMATED STATIC COF TESTER FOR PRINTING PAPER

Baylor University
Department of Electrical and Computer Engineering
Department of Mechanical Engineering

Fall 2008

1 STATEMENT OF WORK

Qualified engineering design teams are invited to submit technical proposals for the design of an *Automated Static COF Tester for Printing Paper*, hereinafter referred to as the *COF Tester*. Proposals are to be submitted to the instructors of EGR 3380, hereinafter referred to as the *client*. Upon client approval of a conceptual design, each engineering design team, hereinafter referred to as the *team*, shall build, test, and evaluate a prototype device, and shall provide the client with engineering documentation of the prototype design.

Additional instructions and schedules not included in this RFP for completing design, presentation, construction, testing, and documentation milestones will be found in the course calendar, milestone assignment documents, and other specific documents to be distributed by the client at appropriate times during the project. The design, construction, testing, and reporting of the COF Tester is a requirement for completion of Engineering 3380 - Engineering Design I at Baylor University for the fall semester 2008.

2 DESIGN SPECIFICATION

2.1 General Description

Printers and photocopiers are ubiquitous devices in both the office and home. They come in many different types and sizes, but one thing all such devices have in common is the need to remove paper one sheet at a time from a paper stack and feed it through the processing mechanism. Paper feeding mechanisms are sensitive to the frictional forces between sheets of paper as they slide over one another. If the coefficient of friction between paper sheets is too high, double-feeding can occur; that is, additional sheets can be dragged along with the top sheet resulting in paper jams in the mechanism. Consequently, printer/copier paper is carefully manufactured and controlled to have coefficients of friction within an acceptable range. This creates the need for a method of testing paper for coefficient of friction.

Appended to this RFP is a copy of ASTM Standard D4918—Standard Test Method for Coefficient of Static Friction of Uncoated Writing and Printing Paper by Use of the Inclined Plane Method. ASTM International (formerly, American Society for Testing and Materials) is a highly influential standards organization whose standards and specifications are widely adopted by engineering organizations, corporations, and government regulatory agencies worldwide. The D4918 standard addresses the procedure and apparatus for measuring the coefficient of static friction of printing paper sliding on itself. The standard provides both specific criteria and general guidelines for a properly conducted test. However, the standard leaves much room for customization of the testing apparatus and procedure. For instance, the standard can be followed using a fairly crude manually operated apparatus. Or, it can be followed using a very sophisticated automated device.

This RFP calls for the design and development of a COF Tester for printing paper. The design should follow the ASTM standard. Additionally, the design should meet the client-required specifications outlined below. Chief among these is a desired level of automation.

2.2 Design Requirements

The design team shall design the device to meet or exceed all of the criteria listed below.

2.2.1 *ASTM Standard D4918:*

The design shall follow the ASTM standard. Justification shall be provided for any deviations from the standard, with approval obtained from the client.

The standard discusses testing of paper either from a "finished ream" or from a "lift sample". The latter is a stack of paper cut from a continuous roll. This RFP will only be concerned with testing paper from a finished ream. Therefore, Section 7.3.2 of the standard can be disregarded.

2.2.2 *Paper Specimens:*

Performance of the device will be measured with respect to two types of paper.

- 20lb weight Boise Aspen™ 30 printer paper
- 34lb weight glossy laser HP presentation paper

Each paper type will be tested in both the *machine direction* and the *across machine direction* per the standard. These designations refer to the direction paper travels through the machine when it is manufactured. Paper can have different properties in the directions parallel and perpendicular to the machine direction. These are also known as the grain and cross-grain directions. Two simple methods for determining paper grain direction are the droop test and curl test. Information on performing these tests can be found at: http://www.hewit.com/sd10-pape.htm.

2.2.3 *Automation:*

The operation of the COF Tester shall be partially automated as follows. Set-up and leveling of the apparatus, along with the loading and unloading of specimens, may be manually accomplished. Once a specimen is loaded and ready for testing, the device shall be activated with an electrical switching action, after which no further operator input is allowed until such time as the test is complete. Thus, the device shall automatically incline the plane. At the angle at which the sled begins to move, the device shall pause and record and digitally display the angle according to the ASTM standard. The device shall return the plane to horizontal with a reset command in preparation for the next test.

2.2.4 *Power:*

The COF Tester shall be powered by a voltage source of less than or equal to 24 VDC. This voltage may be achieved either through the use of dry cell batteries or via a transformer that converts 120 VAC.

2.2.5 *Size & weight:*

There are no specific limitations on size and weight. However, an important design objective is for the COF Tester to be a desktop device that is as light and compact as practical, including being easily portable by hand.

2.2.6 *Ease of Use:*

An important design objective is for the device to be operator-friendly. This means that the set-up and operation should be as clear and intuitive as possible, including the interpretation of results. Also, specimen preparation and loading should be easily accomplished by an operator without extensive experience or manual skills.

3 SAFETY REQUIREMENTS

The team shall conduct all construction and testing with safety as the paramount consideration. Failure to observe workplace safety rules will lead to penalties in performance evaluation. Egregious or repeated safety violations, or disregard for Safety Officers, can result in dismissal from the course.

Cleanliness in the workplace is expected at all times and in all work areas. Failure to observe workplace rules will lead to penalties in performance evaluation. The design team shall clean all work areas with each use.

4 REPORTING & DOCUMENTATION REQUIREMENTS

The team shall document the design by use of manuscripts, calculations, schematics, flowcharts, computer code, and design models/drawings. Specifications for required documentation and due dates not otherwise contained herein will be contained in the course calendar and/or will be distributed by the client at appropriate points during the project.

4.1 Conceptual Design Review

4.1.1 *Date*

September 25, 2008

4.1.2 *Objective*

The CDR is a *top-down* presentation to the client of the design concept. The client should understand how your proposed design will meet the specifications in this RFP. The client should gain a clear picture of the major components/systems and their overall arrangement/function. Furthermore, the client should understand your team's implementation plan for completing the project.

4.1.3 *Format*

- <10 minute duration
- Given by two team members, with approximately equivalent contributions.
- Professional quality visual aids (PowerPoint as primary platform); other visual aids as appropriate
- Business casual dress.

4.2 Preliminary Design Review 1 (PDR 1)

4.2.1 *Date*

October 2, 2008

4.2.2 *Objective*

PDR 1 is for the purpose of communicating the detailed design of a major *subsystem* through a presentation and drawings.

4.2.3 *Presentation Format*

- < 8 minute duration
- Given by one team member
- Professional quality visual aids (PowerPoint as primary platform); other visual aids as appropriate
- Business casual dress

4.2.4 *Drawing Format*

- Subsystem Drawings
    - Assembly drawing(s) of subsystem including *bill(s) of materials*.
    - Circuit schematic(s) for subsystem.
    - Detailed drawings of subsystem parts that must be manufactured

4.3 Subsystem Test

4.3.1 *Date*

October 9, 2008

4.3.2 *Objective*

The subsystem test is a hardware demonstration of the performance of the subsystem described in the PDR 1.

4.4 PDR 2

4.4.1 *Date*

October 16, 2008

4.4.2 *Objective*

PDR 2 is for the purpose of communicating the detailed design and integration of two major *subsystems* through a presentation and drawings.

4.4.3 *Presentation Format*

- < 8 minute duration
- Given by one team member
- Professional quality visual aids (PowerPoint as primary platform); other visual aids as appropriate
- Business casual dress

4.4.4 *Drawing Format*

- Subsystem Drawings
    - Assembly drawing(s) of both subsystems including *bill(s) of materials*.
    - Circuit schematic(s) for subsystems.
    - Detailed drawings of subsystem parts that must be manufactured

4.5 System Integration Test

4.5.1 *Date*

October 23, 2008

4.5.2 *Objective*

The system integration test is a hardware demonstration of the integrated performance of the two subsystem described in the PDR 2.

4.6 PDR 3

4.6.1 *Date*

October 30, 2008

4.6.2 *Objective*

PDR 3 is for the purpose of communicating the detailed design of the entire device through a presentation and drawings.

4.6.3 *Presentation Format*

- < 8 minute duration
- Given by one team member
- Professional quality visual aids (PowerPoint as primary platform); other visual aids as appropriate
- Business casual dress

4.6.4 *Drawing Format*

- Subsystem Drawings
    - Assembly drawing(s) of entire system and all subsystems including *bill(s) of materials*.
    - Circuit schematic(s) for entire system.
    - Detailed drawings of parts that must be manufactured

4.7 Preliminary System Test

4.7.1 *Date*

November 6, 2008

4.7.2 *Objective*

The preliminary system test is a preliminary hardware demonstration of the performance of the entire system as described in the PDR 3.

4.8 Compliance Test

4.8.1 *Date*

November 13, 2008

4.8.2 *Objective*

The compliance test is the final and critical hardware evaluation. System performance will be evaluated against all specifications. Data will be collected and analyzed.

4.9 Final Design Review (FDR)

4.9.1 *Date*

November 20, 2008

4.9.2 *Objective*

The FDR is a public presentation of the design to a general audience including the client, other design teams, invited faculty, students, and guests.

4.9.3 *Presentation Format*

- < 4 minute duration
- Given by one team member
- Professional quality visual aids (PowerPoint as primary platform); other visual aids as appropriate
- Professional dress

4.10 Final Report and Drawings

4.10.1 *Date*

November 25, 2008

4.10.2 *Objective*

The Final Report and Drawings are archival documents that provide a complete and permanent record of the design.

4.10.3 *Report Format*

The format for the final report will be communicated to the design teams by the client by November 10, 2008

4.10.4 *Drawing Format*

- Subsystem Drawings
    - Assembly drawing(s) of entire system and all subsystems including *bill(s) of materials*.
    - Circuit schematic(s) for entire system.
    - Detailed drawings of parts that must be manufactured

Designation: D 4918 – 97 (Reapproved 2002)

An American National Standard

Standard Test Method for Coefficient of Static Friction of Uncoated Writing and Printing Paper by Use of the Inclined Plane Method[1]

This standard is issued under the fixed designation D 4918; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method describes a procedure for the determination of the coefficient of static friction of paper measured when sliding against itself. The inclined plane procedure is used.

1.2 Although this test method is basic in concept, the precision statement has been developed on uncoated writing and printing papers. While the use of this test method is recommended for those grades only, it may be used with other types of paper giving specific attention to special paper characteristics and with the understanding that the precision may not be the same.

1.3 Static coefficient of friction (COF) relates to the force required to initiate movement between two surfaces while kinetic COF relates to the force required to cause continuation of the movement at uniform speed. Kinetic COF cannot be measured by this test method. Both static and kinetic COF can be measured by Test Method D 4917.

1.4 A horizontal plane method is described in Test Method D 4917, which gives similar results. The choice of approach depends upon the equipment available and the means of measurement.

1.5 The determination of this characteristic for corrugated and solid fiberboard is described in Test Methods D 4521 and D 3247. The test methods differ in that, in Test Methods D 4521 and D 3247, the two specimens are allowed to slip upon one another three times before the angle of inclination is determined, while in this test method, the angle is determined on the first slip.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 528 Test Method for Machine Direction of Paper and Paperboard[2]

D 585 Practice for Sampling and Accepting a Single Lot of Paper, Paperboard, Fiberboard or Related Product[2]

D 685 Practice for Conditioning Paper and Paper Products for Testing[2]

D 1968 Terminology Relating to Paper and Paper Products[2]

D 3247 Method of Test for Coefficient of Static Friction of Corrugated and Solid Fiberboard (Horizontal Plane Method)[3]

D 3460 Specification for White Watermarked and Unwatermarked Bond, Mimeo, Spirit Duplicator, Reprographic and Laser Printer Cut-Sized Office Papers[2]

D 4521 Test Method for Coefficient of Static Friction of Corrugated and Solid Fiberboard[2]

D 4917 Test Method for Coefficient of Static and Kinetic Friction of Uncoated Writing and Printing Paper by Use of the Horizontal Plane Method[2]

3. Terminology

3.1 *Definitions*—Definitions shall be in accordance with Terminology D 1968 and the *Dictionary of Paper.*[4]

4. Summary of Test Method

4.1 One specimen of the paper sample is clamped to an inclined plane, the other to a rubber-faced sled. The sled is placed on the inclined plane and the plane raised until the sled begins sliding. The coefficient of static friction is equal to the tangent of the angle at which sliding begins.

5. Significance and Use

5.1 The coefficient of friction of printing and writing papers indicates the ease with which the top or bottom sheet of a stack of paper will slide across the succeeding sheet, such as occurs on the infeed of a sheet-fed printing press or the sheet transport into a copier machine. A minimum coefficient of friction is required to prevent the double-feeding of any sheets.

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[1] This test method is under the jurisdiction of ASTM Committee D06 on Paper and Paper Products and is the direct responsibility of Subcommittee D06.92 on Test Methods.

Current edition approved Dec. 10, 1997. Published November 1998. Originally approved in 1989. Last previous edition approved in 1995 as D 4918 – 95.

[2] *Annual Book of ASTM Standards*, Vol 15.09.

[3] Withdrawn 1988, replaced by Test Method D 4521.

[4] Available from the Technical Association of the Pulp and Paper Industry, P.O. Box 105113, Atlanta, GA 30348

5.2 Since each sheet is removed from the stack only once, a single slide of each pair of specimens is performed and the value recorded.

6. Apparatus (Fig. 1)

6.1 *Inclined Plane*—A plane surface, hinged so that it can be tilted, with a smooth, incompressible top surface which may be made of metal, wood, plate glass, or plastic having a width at least 25 mm (1 in.) wider than the sled and a length sufficient to permit the sled to move at least 15 mm (⅝ in.). The plane is provided with a clamp at the upper end to fix the test specimen to the plane.

6.2 *Sled*—A 63.5 by 63.5-mm (2.5 by 2.5-in.) metal block with a rubber-faced lower surface weighing a total of 200 g. The size and weight of the metal block are not critical but the sled specified has been found satisfactory. A means for clamping the specimen to the sled is desirable, but is not necessary if the lower surface is faced with soft rubber 3 mm (⅛in.) thick.

6.3 Means to smoothly increase the inclination of the plane from horizontal through an arc of at least 45° at a rate of 1.5 ± 0.5°/s.

6.4 Means to indicate the angular displacement of the plane to within 0.5°.

6.5 Means to determine if the plane is level in all directions at the start of the test and adjustable legs to allow leveling adjustment.

6.6 *Paper Cutter*, to cut test specimens.

7. Sampling and Test Specimen Preparation

7.1 The sample, selected in accordance with Practice D 585, should be in the form of a finished ream or a "lift" sample from a roll. A lift is a stack of sheets about 1.3 cm (½ in.) cut from a roll.

7.1.1 Transfer of small quantities of oil or grease to the sample or test specimen during sampling, test specimen preparation, or testing can lower the measured values determined using this test method. Handle samples and test specimens by the edges wherever possible, and wear clean, dry cloth gloves for all sample handling applications in Sections 7 and 8.

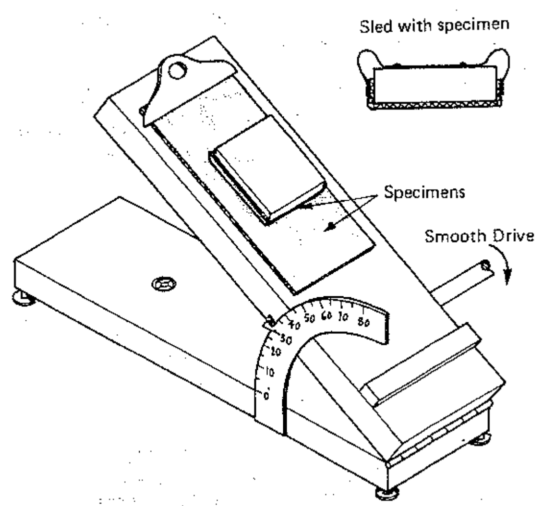

FIG. 1 Schematic of Inclined Plane Apparatus

7.2 Precondition, condition, and test in the atmospheres described in Practice D 685.

7.3 Cut the sample into test specimen pairs as follows:

7.3.1 *Finished Ream Sample*:

7.3.1.1 *With Machine Direction COF*—Lift off a stack of six consecutive sheets, identify the machine direction and the felt (or top) side of the top sheet, and cut two specimens from each sheet: one 100 by 215 mm (4 by 8.5 in.) and the other 75 by 130 mm (3 by 5 in.). Cut the specimens so that the machine direction is parallel to the long dimension. Stack the two sets of specimens in separate piles, maintaining the same order of sheets as in the ream. Take the top sheet off the pile of larger specimens and discard. Use the second large specimen with the first small specimen, the third large specimen with the second small specimen, and so on, performing the test with five pairs of specimens from consecutive sheets. There will be one left-over small specimen (sixth) which can be discarded.

7.3.1.2 *Across Machine Direction COF*—Follow directions given in 7.3.1.1, except: Cut the specimens so that the machine direction is parallel to the shorter dimension.

7.3.2 *Lift Sample*:

7.3.2.1 *With-Machine Direction COF*—Lift off a stack of seven consecutive sheets, identify the machine direction and the felt (or top) side of the top sheet, and cut two specimens from each sheet: one 100 by 215 mm (4 by 8.5 in.) and the other 75 by 130 mm (3 by 5 in.). Cut the specimens so that the machine direction is parallel to the longer dimension. Discard the top sheet from each stack and test five pairs of specimens. Each pair is from the same sheet. Discard the bottom sheets.

7.3.2.2 *Across-Machine Direction COF*—Follow directions given in 7.3.2.1 except: Cut the specimens so that the machine direction is parallel to the shorter dimension. Discard the top sheet from each stack and test five pairs of specimens. Each pair is from the same sheet. Discard the bottom sheets.

8. Procedure

8.1 Check and adjust the instrument so that it is level in both directions, either through the use of a spirit level or a leveling device incorporated in the instrument.

8.2 *With-Machine Direction COF*—Select the set of specimens cut with the grain direction parallel to the long dimension, 7.3.1.1 or 7.3.2.1.

8.2.1 Place the larger specimen (100 by 215 mm (4 by 8.5 in.)) on the plane, with the top (felt) side upward, sliding the 100-mm (4-in.) edge under the clamp. Handle the paper specimens by the edges only.

8.2.2 Place the smaller specimen (75 by 130 mm (3 by 5 in.)) on top of the larger, with the wire side facing down, and grain directions parallel. Butt a 75-mm (3-in.) edge up to the clamp, and place the front 130-mm (5-in.) edge 0.6 cm from the edge of the plane. Place the sled on the top of the smaller specimen.

8.2.2.1 When placing the sled as described in 8.2.2, it is important that the sled be positioned without any lateral movement, particularly upward toward the end where the larger specimen is clamped. Particularly, any sliding motion of the sled or smaller specimen in an upward direction (the direction toward the clamped end of the larger specimen and opposite that which the sled will begin to travel during the test) can change measured results.

8.2.3 Incline the plane at the specified rate. When the sled starts to move, immediately stop movement of the plane. Read the angular displacement of the plane to the nearest 0.5° and record.

NOTE 1—Some instruments are provided with an electrical/mechanical device which stops the inclination of the plane upon the first movement of the sled. Check to see that there is no delay time between the sled motion and the plane elevating mechanism.

8.2.4 Test the remaining specimen pairs in identical fashion.

8.3 *Across-Machine Direction COF*—Select the set of specimens cut with the grain direction parallel to the short dimension, 7.3.1.2 or 7.3.2.2.

8.3.1 Repeat the procedure described in 8.2.1-8.2.4.

9. Calculation

9.1 Determine the tangent of the angle at which sliding began. Calculate the average of the five determinations. This is the coefficient of static friction. Also calculate the standard deviation.

10. Report

10.1 Report the coefficient of static friction, and the standard deviation for both with- and across-machine directions.

10.2 Report whether the sample was taken from a finished ream or a lift.

11. Precision and Bias

11.1 *Within-Laboratory Variability (Repeatability Conditions):*[5]

11.1.1 *Repeatability Standard Deviation*—A standard deviation of 0.036 for individual test determinations and 0.016 for the average of the five determinations was obtained using this procedure on writing papers of the type described in Specification D 3460 having a coefficient of static friction varying from 0.40 to 0.70.

11.1.2 *Repeatability Limit*—Approximately 95 % of the time, two test results, each of the average of five tests, will differ by less than 2.77 times the repeatability standard deviation. For these papers the 95 % repeatability limit therefore was as follows:

$$2.77 \times 0.016 = 0.045$$

11.2 *Between-Laboratory Variability (Reproducibility Conditions)*—This information will be gathered once this test method is published.

[5] A report concerning the within-laboratory precision statement is contained in ASTM files. Request RR: D1000.

APPENDIX

(Nonmandatory Information)

X1. SIGNIFICANCE AND INTERPRETATION OF TEST METHOD

X1.1 In 7.1 the procedure for selecting the sample in two manners depending upon the form of the paper to be tested is described. In 7.3 the procedure for preparing test specimens depending upon the form of the paper to be tested is described. Sampling of a cut size ream of the type commonly used in sheet-fed printing presses and copy machines is described in 7.3.1. Sampling paper from a roll is described in 7.3.2.

X1.2 *Ream Sample*—In the manufacturing process of converting paper from rolls to sheets, it is common practice to combine the webs of two or more rolls in the processing equipment. As a result, successive sheets in the stack of cut paper represents the combination of the several rolls that are processed together. By using the sampling procedure described in 7.3.1, the resulting COF values represent the relationships between successive sheets. This is comparable to the manner in which the sheets are fed into the press or copier.

X1.2.1 If there is a need to determine the COF of an individual sheet in such a way as to not be influenced by the adjacent sheet from another roll, the operator may select a single sheet, prepare a test specimen pair, and test in accordance with the instructions given.

X1.3 *Roll Sample*—If the paper to be tested is in the form of a roll, the samples are to be selected as described in 7.3.2. The test results will not be influenced by other sheets.