Abrasion and Ink-Rub Testing
Correlation studies with the CAT, the Sutherland and the Taber

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Abstract: An extensive overview is given of the basic principles applied in the use of three abrasion test instruments: the Comprehensive Abrasion Tester (CAT), the Sutherland ink-rub tester and the Taber Abraser.
Several correlation tables are presented to allow easy interpretation of results obtained with either one of the instruments.
There is also a general survey of the different types of scuffing, rub-off and flaking encountered during handling and shipping of printed materials.

Introduction

How appropriate that at the occasion of the 40th annual meeting of the Technical Association of the Graphic Arts I have been given the honor and the priviledge to bring you up to date on the State of the Art of a testing method generally referred to as the "Ink Rub Test". It is indeed also 40 years ago that the "thumb of the Press foreman" was replaced by an instrument patented in the U.S. under the name of the "Sutherland Rub Tester". This instrument has become very familiar not only to all the printers, large or small, but also to the ink makers and paper makers.

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Printers, Ink Makers and Paper Makers

The printer constantly faces the challenge to be able to predict as early as possible during the printing process just how much rub resistance the printed product will have. (Terry Scarlett - "Aye, there's the Rub" - G.A.M. (Scarlett,1986) But as Marie Kelly Loftus of Printing Impressions (Loftus, 1988)) stated in her article entitled "Testing inks so they don't rub you the wrong way", "the printers don't really want to think about things like viscosity, dynamic cohesive energy of inks" and similar complex technological aspects of the inks they use: "they just want to see a quality finished product without any production problems".

So the challenge shifted towards the ink makers when asked to come out with inks which would not only have higher gloss, shorter drying times but also good or better rub resistance.

However, one of these ink makers, William Tasker of Acme Printing Ink Co., was able to demonstrate in his recent paper presented to the TAGA meeting of 1986 (Tasker, 1986) that his "experiments showed that the effect of paper selection on abrasion was the most significant of the three variables studied. The shipping conditions were also found to be significant, but ink was not a factor". A study of nine papers showed that the filler in the paper coating could be responsible for abrasion.

Magazines, books and catalogs, folding cartons and all packaging materials

When William Tasker in his paper to TAGA stated that "There appeared to be an industry-wide problem with abrasion that could not be traced to any particular ink, paper or process" he was mostly referring to problems of publishers and printers of magazines. "Usually the damage was blotches or white specks called pick-offs" says Tasker. And he went on: "The existing equipment used to test abrasion did not simulate actual damage conditions and the researchers were having trouble finding a solution. They decided to find a new piece of equipment that would make research more exacting and easier."

Another but somewhat similar situation took place in the book industry: with the constantly advancing technology of products used in the book manufacturing industry (plastic over coatings, laminates, U.V cured products, etc.) the use of the Sutherland became impractical and the Taber Abraser was introduced. Printed and/or over coated materials which would require one or even several thousands of rubs with the Sutherland could be evaluated with the Taber, yielding an answer within some 30 or 40 cycles. Even today it is quite common to read in the specifications of the brewing and soft drink industry that the printed cartons "must pass a 2,000 or even a 5,000 rub test"!

The Packaging Professional

We have mentioned the challenge the printers, the ink makers and also the paper makers are facing. But it doesn't stop there: every professional package designer constantly faces new challenges which are directly or indirectly related to scuffing, or abrasion. A recent study at Dartmouth College (Deighton, 1984) has mentioned that "Managers are finding that funds invested in creative graphic design and package research will often yield a greater return than the same funds applied to media advertising, while accomplishing precisely the same goals of product awareness, image formation, and incentive to purchase. The study concluded that: "Package aesthetics are the single most important consideration influencing package design decisions.The image projected by packages and their labels is crucial."
As a result, any blemish of any type on a package immediately creates a blemish on its image. Scratches, scuff marks, blemishes or any type of abrasion mark, do not only suggest the possibility of tampering but could also create errors and frustration when printed bar codes are involved.

Therefore it is up to the package designer to also choose the right raw materials and supplies such as paper stock, carton or corrugated, the inks and varnishes to mention only a few.

Terminology

Before we examine into details the three abrasion testers under consideration we should clarify some of the terms used.

● Tribology:

Tribology is defined as the science and technology of interfacing surfaces in relative motion. Tribo comes from the Greek word tribos which means rubbing.

● Abrasion resistance:

Also referred to as - scuff-resistance, rub-resistance, the ability to withstand any kind of damage resulting from rubbing two surfaces against each other.
The abrasion resistance of surface A is inversely proportional to the abrasivity of the surface B with which it is in contact during the rubbing action.

● Abrasivity:

The degree to which the surface A under investigation is capable of damaging (abrading, scratching, scuffing) another surface B with which it is in contact during a rubbing action.

● Abrasion marks:

It is interesting to note that in most technical books (The Lithographers Manual from GATF for instance or Complaint Handbook System from PCI the terms which are defined in the sections on "Problems" such as Hickeys, Dry Trapping, Wet Trapping, Picking, Piling, Ghosting, Blocking, etc., all refer to problems at the press. Very few books (if any) refer to the problems in the field, that is the type of abrasion marks found on printed materials after handling or transportation.
Some of the terms used by printers and ink makers are:

- scuffing
- blotching
- pick-off
- rub-off
- scratches

Types of Abrasion:

The different types of abrasion are related to one or several causes. That relationship is not always well established: this is due, in part, to the fact that the Taber and the Sutherland do not reproduce exactly the wear- or abrasion- marks found in the field. Here follows an illustration of the 5 types of abrasion which are quite common in the field and which are also reproduced or simulated by the CAT.

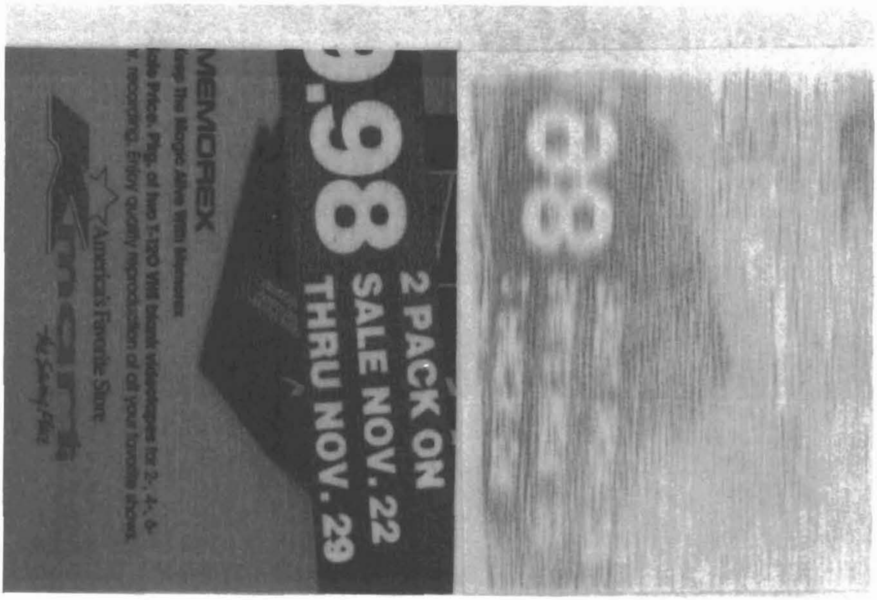


Illustration A: C.I.T. (Complete Image Transfer)
Paper, Ink and Press related.
This is a 20 sec. Rub-off on a Standard Receptor C-1 with the CAT - Standard settings.

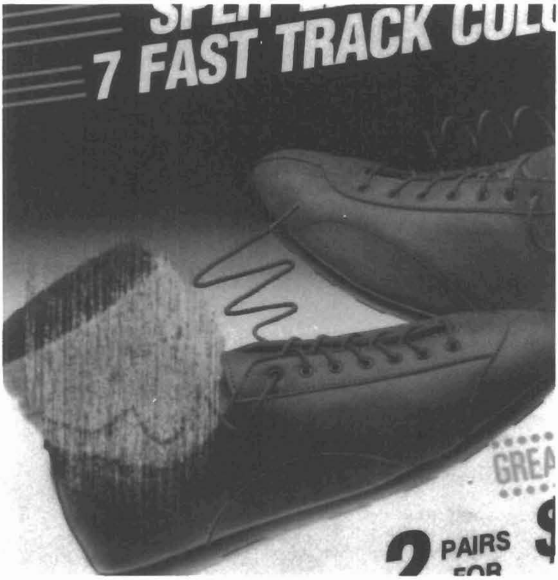


Illustration B: P.I.T. (Partial Image Transfer)
Ink related.
This is a 120 sec. Rub-off on a Standard Receptor C-1 with the CAT - Standard settings.

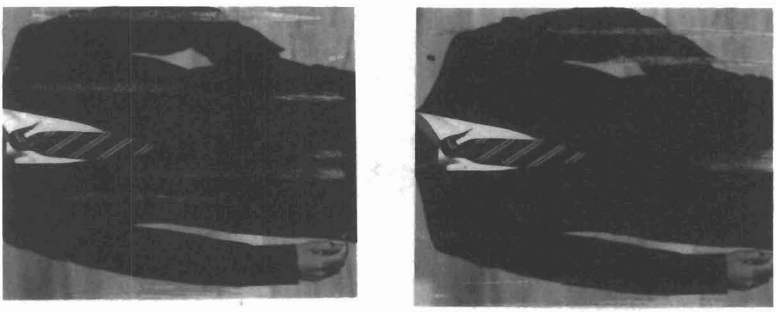


Illustration C: R.I.T. (Random Image Transfer)
Paper and Press realted.
This is a 120 sec. Rub-off on a Standard Receptor C-1 with the CAT - Standard settings.

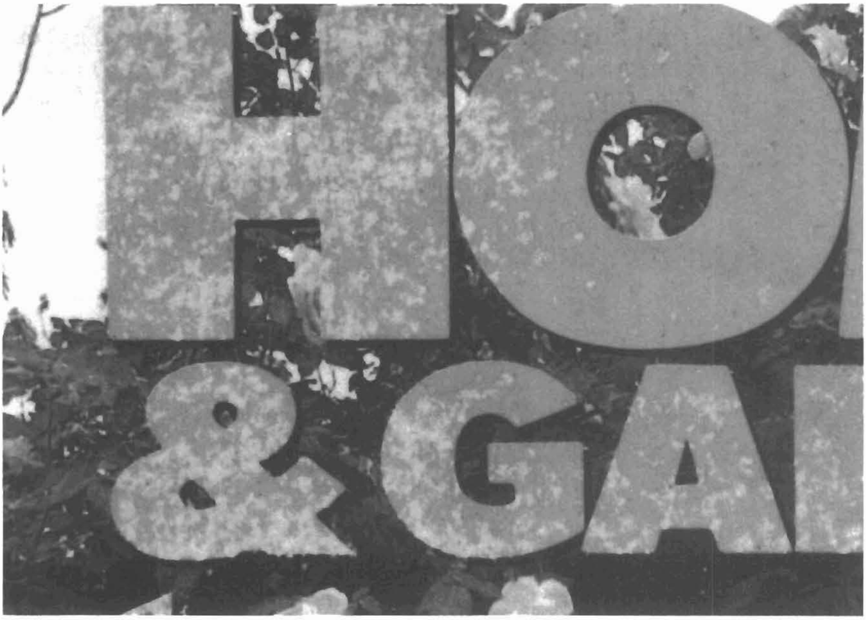


Illustration D: P.O. (Pick-off)
Ink and Paper related.
This is a field specimen demonstrating the pick-off with a particular color.

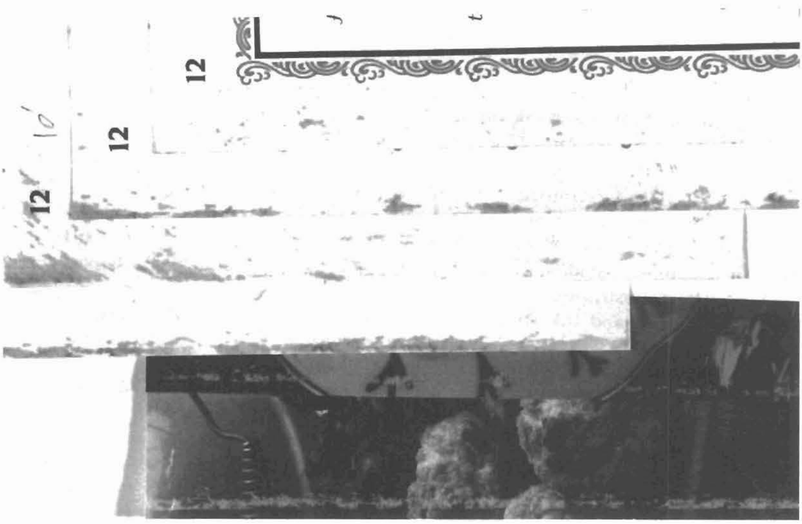
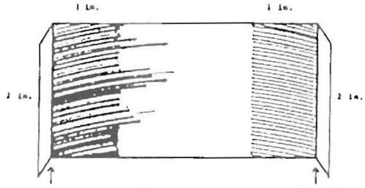


Illustration E: Blotching
Press related and Binding related.
These are field specimens demonstrating blotching inside the book; principal cause: spiral binding.

For most of the correlation studies only type A (Complete Image Transfer) samples were used: these were totally repeatable and reproducible, very fast (20 sec. runs) and sensitive to any changes.

Correlation CAT and Sutherland



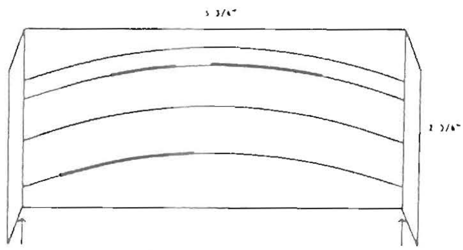


Figure represents schematically the type of abrasion marks obtained with the Sutherland ink rub tester.

- The *"receptor"* (2 in. × 6 in.) is cut from the printed meterial to be tested (rub of product to product) or form plain paperstock. This piece is clamped or taped onto a 2 lb. or 4 lb. weight after being scored and folded as indicated.
- The *"test material"* (2¾ in. × 7 in.) is cut from the printed material to be tested and is attached over a rubber pad onto the base plate of the instrument.

The Sutherland Ink Rub Tester has a motorized arm on which a removeable weight (2 lbs. or 4 lbs.) can be placed; a plain or printed piece of material can then be wrapped around the weight.

The weight then rests on a flat piece of printed material. As soon as the machine is switched on, it rubs back and forth for a predetermined number of rubs (cycles). The distance over which the weight moves back and forth is approximately 2 inches. At the end of the test, both pieces of material are examined to determine the ink-to-paper or ink-to-ink characteristics. It is obvious that this kind of operation bears little resemblance to what happens to a product during normal use or transportation: first of all in reality, the relative motion between the two surfaces in contact is very much smaller and secondly the pressures applied to these surfaces are not constant but are constantly changing. The results obtained by this method lack generally linearity and reproducibility

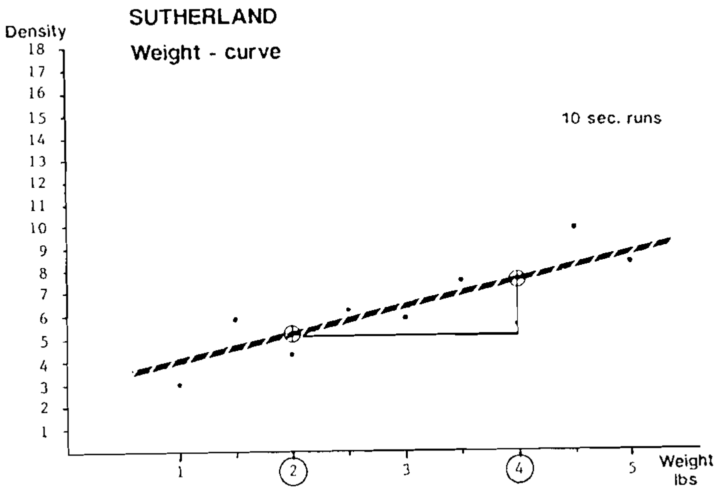
SUTHERLAND RUB TESTER

"Stroke" comprises one complete to and fro motion of the test weight

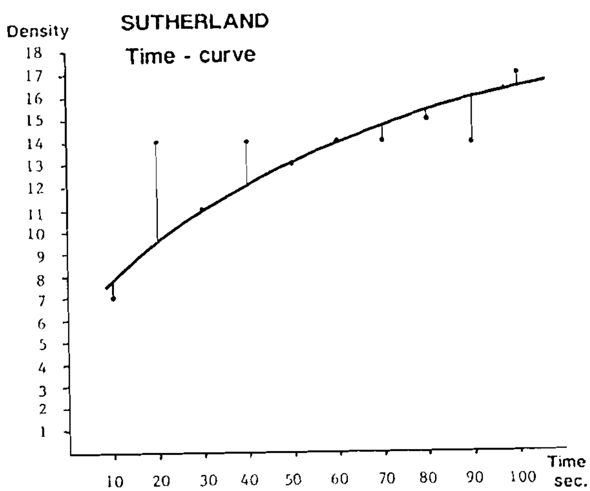
Strokes	Time Sec.	Time Min/Sec.
1	1.4	
10	13.8	
20	27.6	
30	41.4	
40	55.2	
50	69.0	1 min 9 sec
60	82.8	1 min 23 sec
70	96.6	1 min 37 sec
80	110.4	1 min 50 sec
90	124.2	2 min 4 sec
10	138.0	2 min 18 sec
200	276.0	4 min 36 sec
300	414.0	6 min 54 sec
400	552.0	9 min 12 sec
500	690.0	11 min 30 sec
1,000	1,380.0	23 min
2,000	2,760.0	46 min
5,000	6,900.0	1 hr 55 min
10,000	13,800.0	3 hr 50 min

In order to facilitate the correlation between the Sutherland and the CAT the following features were analyzed:

Relationship of removable weight (2 lb or 4 lb) with amount of rub-off.
NOTE: amount of rub-off (in this case as well as in all following examples) was determined by measuring the reflective density of the darkest area (5 readings averaged) of the receptor.



Effect of hardening of the replaceable rubber pads.
A series of tests were accomplished with a whole series of pads with durometers ranging from 10A to 85A.
Conclusion was that as the pads get harder by aging, the scuff marks will get darker and less uniform over the entire surface.



This Time-curve shows the non linearity of the Sutherland.

In view of the non linearity of the Sutherland test method, it is recommended that a series of tests be repeated (for instance 10 times) and averaged. This will improve the reproducibility on a statistical basis.
There are some limitations which have to be taken into account:

Preparing the sample: the scoring and bending of the sample will greatly influence the end result of the test.

Attaching or clamping the sample: every one has his/her own technique to try to hold the sample in place; this becomes worse as material gets thicker like for folding cartons or corrugated or impossible in the case of sheet metal.

The sample has to be cut to a specific dimension which is not always available.

The durometer or hardness of the rubber pads to which the sample is attached is constantly changing with time.

Some of the more demanding packaging materials — beverage mastercartons or book covers for instance — need a testing time of 45 minutes (2,000 strokes) or even close to 2 hours (5,000 strokes) per test.

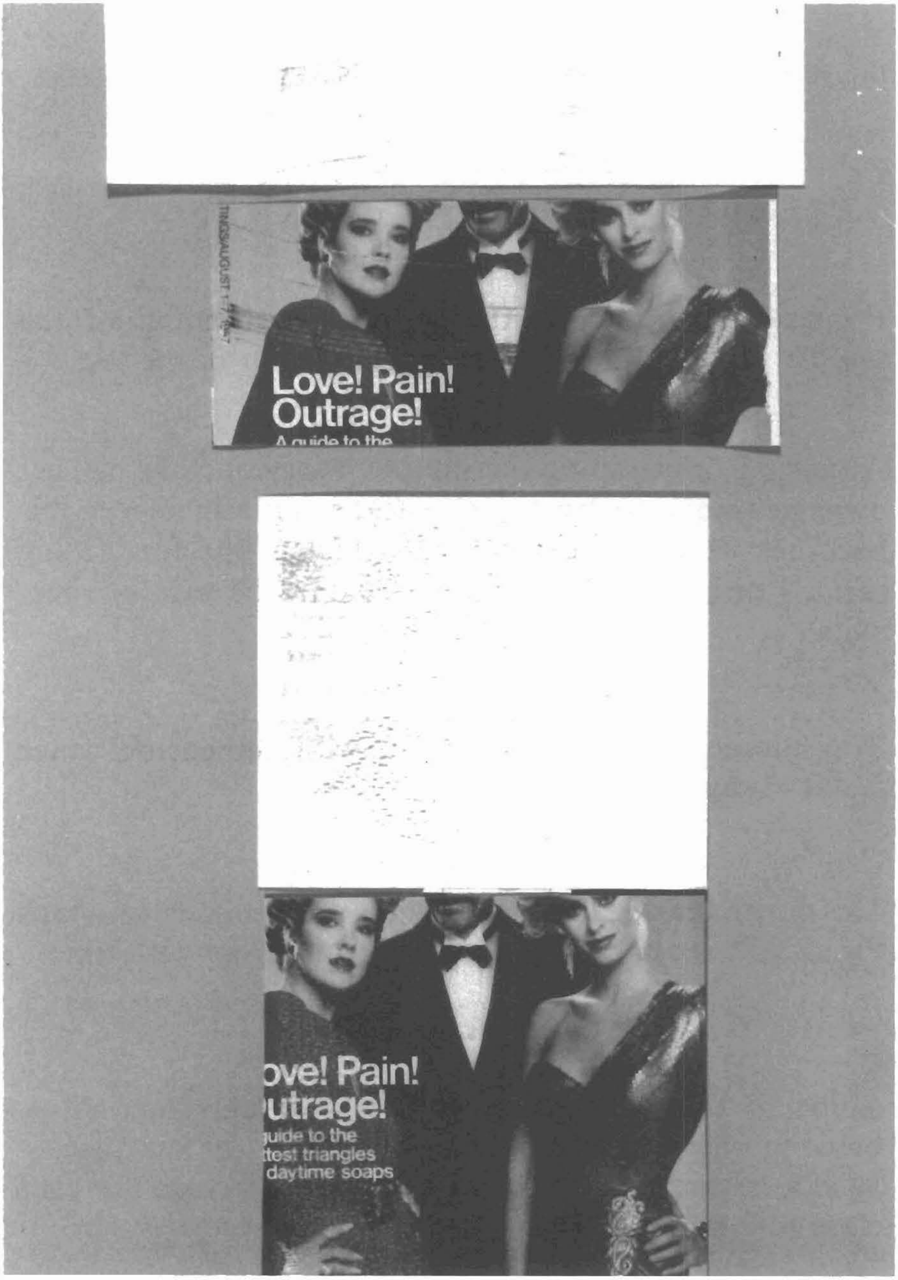


Illustration F:
This is a clear illustration of a pick-off problem in the field. The Sutherland showed only some long scratches across the different colors, while the CAT simulated exactly the pick-off problem of one single color (lady on the left).

Correlation CAT and Taber

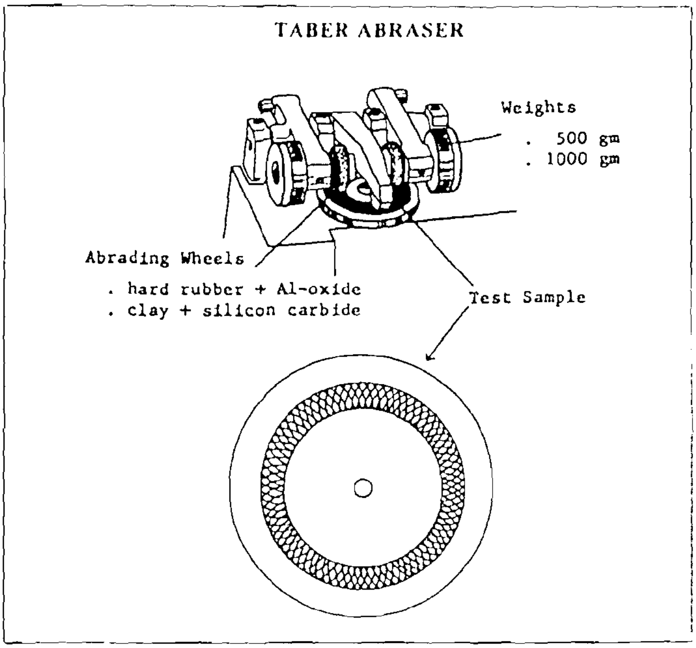


Figure represents schematically the instrument and the type of abrasion marks obtained with the Taber Abraser.

Some of the limitations of the Taber can be summarized as follows:

Preparing the sample: a disc has to be cut out of which only a very small band will be tested.
The abrasion tool becomes clogged with grinding material arising from the abrasive process.
The diameter of the grinding tool is constantly changing from one test to another.
The simulation of rubbing product against product is impossible with this instrument.

Illustration G:
Shows one of the most serious problems encountered in the correlation study of the Taber.
This picture represents a printed material over-coated on the left, not over-coated on the right. The CAT (at the bottom) indicated a considerable difference between the two where the over-coat was considerably better, as was the case in actual field shipments. The Taber (at the top) showed the opposite.

The runs on the Taber were 30 cycles for both and the CAT runs were 2 sec. each with the Standard Receptor A-6 and standard settings on the CAT.

The CAT - Comprehensive Abrasion Tester

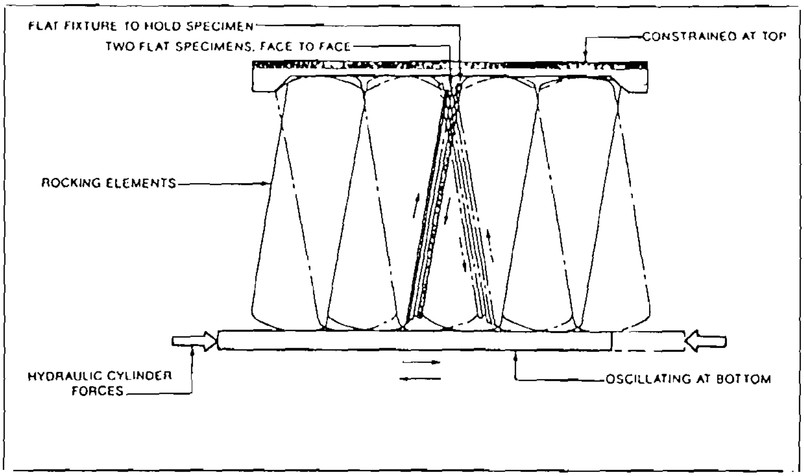


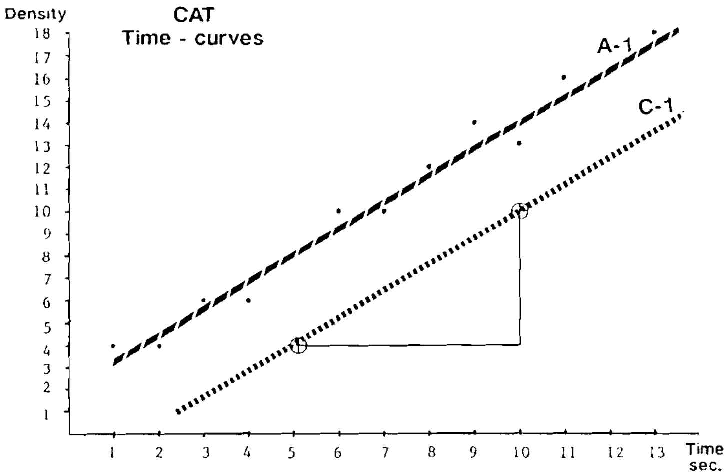
Figure represents a diagram of the GA-C.A.T rub action.

The materials to be tested on the GA-C.A.T may be cut to any size: anywhere from a small strip to a very large square (4.5 in. × 4.5 in.). These test samples are then placed in contact with each other and sandwiched between two synthetic plastic blocks. The surfaces of the two blocks are covered with a spongy layer which causes the test samples to remain in place during the rubbing action: no clamping, scoring or folding is necessary.

As a result, a wide range of products may be tested ranging from very thin tissue paper, labels, magazine covers or inserts, cardboard, folding cartons, book covers, corrugated, plastic film or sheet, to metal foil or even steel or aluminum sheet.

Pressure can be applied at the top and sides. These pressures will be constantly changing during the test as a result of the motion of the carriage on which the blocks are resting. Both the frequency of vibration and the distance or span of the side-to-side movement can be set very accurately. The instrument can then be turned on for a given period of time, at the conclusion of which the two surfaces can be examined for wear or rub-off. The results obtained are extremely reproducible and linear, and can differentiate very fine degrees of rub.

Illustration H:
This picture illustrates very clearly to what degree the abrasion resistance can change by using three different paper stocks.



This represents two Time curves on the CAT; one with a receptor A-1 and another one with a receptor C-1.

The following table can be used as a general guideline for a correlation between the CAT and the Sutherland. Some good judgement has to be used when evaluating materials of very different nature; for instance metal foil, corrugated, etc.
Our various studies have demonstrated that reproducibility and repeatability begin to suffer in all instances where a run lasts longer than a couple of minutes. This holds true for both instruments Sutherland and Taber. We have reason to believe that this is related to local heat developed at the interface of the rubbing surfaces.
It is by far better to adapt the abrasiveness of the receptor to the quality level of the material to be tested and to work in a time frame of 1 to 120 sec. As can be seen from the correlation table, the whole range of products rated on the Sutherland from 10 to 10,000 strokes can very efficiently and easily be covered by the use of the three Standard Receptors C-1, A-1 and A-6 and with a tremendous savings in time. Unfortunately any reasonable correlation with the Taber is practically impossible.

Overall Correlation Table

st = strokes c = cycles sec = seconds

Sutherland (st) 4 lb wt	Taber (c) 500 gm	CAT C-1 (sec)	A-1 (sec)	A-6 (sec)
10		10		
20		20		
40		(60)	1	
100	120	120	5	
200			20	
500	30 - 40		(60)	1
1,000	30 - 40		120	5
2,000	30 - 40		360	20
5,000				(60)
10,000	80 - 120			120

Literature Cited

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