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Measurement of Adhesion by a Blister Method*

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INTRODUCTION

This paper deals with a new method of measuring the adhesion of organic coatings to metals and, potentially, to other substrates.

As an introduction it may be appropriate to review briefly our concept and theories of adhesion in general as well as existing methods for measurement of adhesion.

Theories of Adhesion

There exists a tremendous amount of literature on the subject of adhesion, containing many different and often controversial viewpoints. Good reviews are available.[4,6,10]

Seen from the physical angle, adhesion is related to surface free energy. If the joining of two surfaces decreases the sum of their surface energies, they will adhere to each other. To calculate the work of adhesion, the physicist is likely to assume that the surfaces are perfectly clean and ideally smooth, thus providing maximum proximity between adherand and adhesive. Plausible values for adhesive energies have been calculated[20] on the basis of ionic forces emanating from the metal adherand and dipole forces from the organic adhesive, with the additional assumption that size and shape of the organic molecule permit only a limited number of contact points.

From the chemical angle, we have to consider, in addition to the different molecular structures and polar characters of the compounds in question, the presence, at the interface, of contaminants such as air, water, oxides, or organic monolayers which would interfere with obtaining maximum proximity of the mating surfaces. Measurements of contact angles are frequently used to ascertain that the surfaces are reasonably clean, and proximity is obtained by wetting.[21]

When the physicist speaks of work of adhesion, he refers to the energy obtained when the surfaces join; the chemist, however, is likely to mean the energy needed to break the bond. The two values are not identical; the reason lies in the fact that separation frequently takes place in a plane different from that where the joint was formed. To be specific, breakage of the bond may occur (*1*) at the original interface (this would be true adhesive failure); (*2*) between the metal substrate and an oxide layer; (*3*) in or on an organic boundary layer (this possibility has been emphasized by Bikerman[4,5] and also is in good agreement with our findings in the study of "cratering" of surface coatings where the existence of an adsorbed multilayer next to the metal was demonstrated); (*4*) in the adhesive proper (this is called cohesive failure); or (*5*) at flaws such as air pockets. In practical cases, we frequently have a combination of several modes of failure.[2]

METHODS OF MEASURING THE ADHESION OF ORGANIC COATINGS

Regardless of the theory of adhesion and the mechanism of adhesive failure, it must be possible to determine the strength of an adhesive bond and correlate it with other properties of adherand and adhesive. A discussion of some of the test methods used in the organic coatings field follows.

Qualitative and Semiquantitative Methods

An old and simple method, quite dependable in the hand of an expert, is the use of a pointed knife to detach a chip of the coating and estimate the force needed to do so. Other widely used tests that give some information on adhesion are the mandrel bending test and the reversed-panel impact test.[11] A somewhat more advanced method is the microknife test[3,14] in which the film is detached by a series of close-spaced, parallel cuts. In all these tests, the adhesion is more or less

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obscured by other properties such as shear strength, modulus and maximum elongation.

Quantitative Methods

An instrument that has found considerable attention and appears to be rather widely used is the adherometer by Green and Lamattina,[12] frequently called the Interchemical adherometer. In the original version of this instrument, an ivory knife cuts a swath of the coating material off the specimen panel and the force required to do this is measured. While this method is quite suitable and precise for the determination of the adhesion of coatings of related materials and constant thickness, a number of difficulties have been reported with film thickness, and a trend toward jerky detachment. Several authors have suggested improvements of design,[7] procedure,[16] and evaluation.[17] L. R. Brantley[8] has suggested that the adhesion at the film thickness of one mil be determined by interpolation, and that this value be called "milhesion." A shortcoming of this adherometer can be seen in the fact that unless the adhesion is very low, failure occurs in shear and the values found might be related to the shear strength of the coating material.

More recently, a very ingenious supercentrifuge has been developed for adhesion measurements of surface coatings by Soller and co-workers.[1,14] A paint spot applied to a small rotor revolves at speeds up to 2,600,000 rpm until the centrifugal force throws the paint off. This machine is capable of excellent precision and results are obtained in physical units. Conditions are such that failure will be either purely adhesive or cohesive near the interface. Shortcomings of the method are seen in its limitation to high-strength steel as a substrate and in the fact that it measures the adhesion of the weakest point.

While our work was in progress, a very interesting development in adhesion measurement was reported from the laboratories of the Imperial Chemical Industries, Ltd.[15] Here, an air gun is used to shoot a small specimen carrying a paint spot against a target. The target has a hole arranged in such a way that the substrate will be stopped, but the paint will fly on. Failure will be in cohesion or adhesion, whichever is weaker. A great advantage is the possibility of preparing specimens from any coated panel; a possible drawback is seen in the high speed of load application, which is very dissimilar to common conditions of adhesive failure.

BLISTER ADHEROMETER

The instrument to be described next was designed in an attempt to establish a method capable of (*1*) measuring adhesion in preference to cohesion, (*2*) being applied to a wide variety of specimens, and (*3*) giving precise results expressed in physical units. The development of this instrument has passed through several stages and has arrived at a point where the objectives have been achieved to a considerable extent. A detailed description follows.

Principle, Design, and Operation

The principle is to inject a liquid between substrate and coating in such a way that the coating is detached in form of a blister. Pressure and volume of the injected liquid are measured and used to compute the work needed to detach the film. A similar arrangement was tried many years ago[18] and again quite recently,[15] but in both cases the authors considered their results unsatisfactory.

Shape of Blister. Our preliminary experiments indicated that in order to obtain reproducible results it is necessary to form blisters of well-defined size and shape. Also, oblong blisters were found to offer advantages over round ones because the formation of an oblong blister takes place along a prescribed path whereas a round blister grows randomly along various radii. The oblong shape is obtained by having in contact with the specimen a steel plate with a milled-in groove to accept and shape the blister. The dimensions of the groove are shown in Figure 1. The $^1/_{32}$-in. diameter bore shown is a bleed hole to release trapped air.

Access Holes. In order to inject the liquid between substrate and coating, an access hole in the panel is needed. Two methods of access hole preparation have been developed. The simpler one consists in drilling a small hole through the specimen panel before application of the coating,

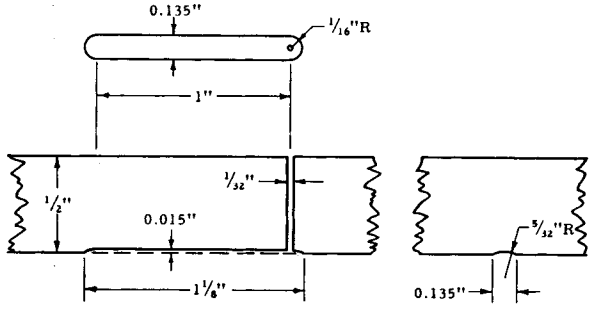

Fig. 1. Blister-shaping groove

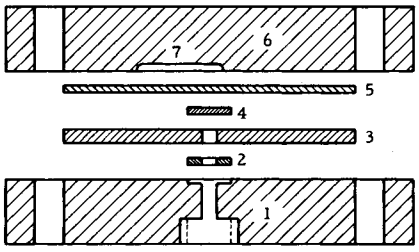

Fig. 2. Specimen holder: (1) lower clamping plate, (2) gasket, (3) substrate for specimen, (4) aluminum patch, (5) specimen (coating deposited on substrate), (6) upper clamping plate, (7) blister-shaping groove.

covering this hole with a small patch of aluminum foil glued down with weak rubber cement, and applying the coating over the patch. The force needed to detach the patch during the subsequent test is negligible. Five such access holes and patches are usually applied to each panel to allow replicate measurements.

The other method of forming access holes, employed primarily in cases where specimens cannot be specially prepared for the test, consists in a process of electrolytic etching. With the test panel used as anode, hypodermic needles as cathodes, a 15% aqueous sodium chloride solution as an electrolyte, and a potential of 8 v., five holes per panel can be cut in approximately 1 hr. without damage to the coating.

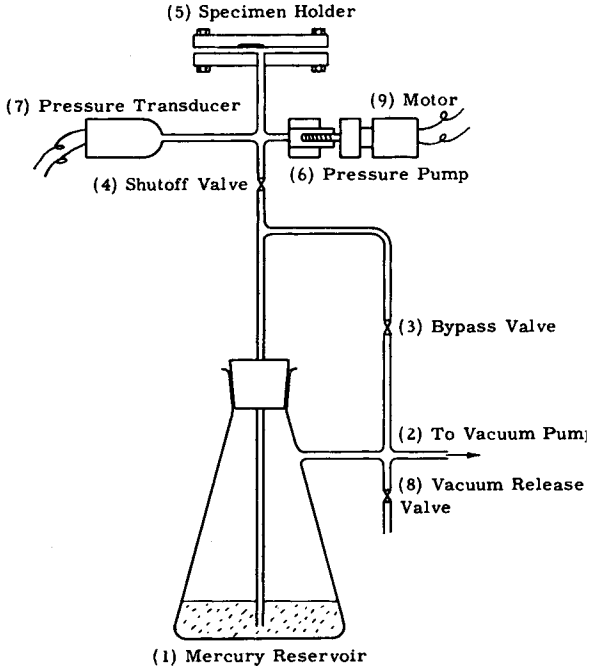

Fig. 3. Schematic diagram of blister adherometer.

Application of Pressure. To apply liquid pressure to the access hole, the specimen is clamped tightly between two steel plates. Figure 2 shows the general arrangement in exploded view. Going from the bottom up, we have the lower clamping plate (1) through which the compression liquid is introduced, next a gasket (2) for leakproof connection to the underside of the specimen, then the specimen consisting of substrate (3), aluminum patch (4) and coating (5) and finally the upper clamping plate (6) containing the blister-shaping groove (7).

The compression liquid used is mercury, in most cases. However, in cases to which mercury is not applicable because of rapid amalgamation of the metal (e.g., tin), other liquids have been used. Silicone oil was found to have an excessively high compressibility, but glycerol was suitable.

The device used to compress the liquid and pump it at a slow but defined rate through the access hole is shown schematically in Figure 3. It also serves to evacuate the system before pressurization, since any remaining air would disturb the pressure–volume relationship to be measured. The figure shows a mercury reservoir (1) connected to a vacuum line (2) and, via bypass valve (3) and shutoff valve (4), also connected to the specimen holder (5), the compression pump (6), and a pressure transducer (7). When a vacuum of 25 μ has been attained, the bypass (3) is closed and the vacuum released through valve (8). This forces the

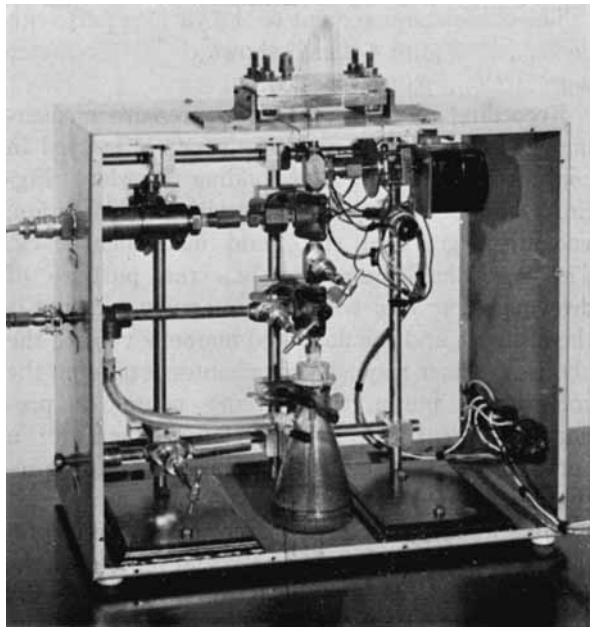

Fig. 4. Blister adherometer, front panel removed.

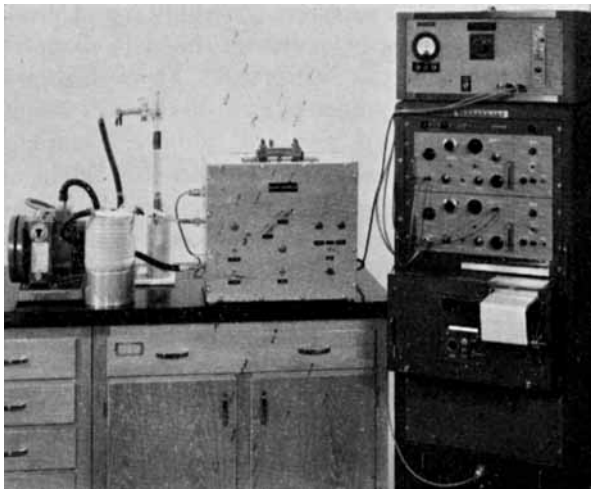

Fig. 5. Blister adherometer with accessories.

mercury through the dip tube (9) into the access hole and effects air-free filling of (6) and (7). Now the shut-off valve (4) is closed, confining the liquid volume above it for pressurization.

The compression pump consists of a standard needle valve with Teflon packing coupled to a small 1-rpm synchronous motor to open or close it. The spindle of this valve, when rotated in the closing direction, acts as a displacement plunger and forces mercury into the line. The delivery of this arrangement is 21.3 mm.^{3} per revolution with a maximum of approximately 150 mm.^{3}. Limit switches prevent the valve from going to the fully closed or fully open positions.

The actual arrangement of the various parts can be seen in Figure 4 which shows the adherometer with the front panel removed.

Recording of Pressure. The pressure measuring device is a pressure transducer; it is used in conjunction with a fast-responding recorder. Figure 5 shows the set-up complete with vacuum pump, vacuum gage, cold trap, and instrument rack. The recording equipment has the purpose of drawing a curve in which the mercury pressure is the ordinate and the delivered mercury volume the abscissa. Since a synchronous motor is used on the compression pump, the mercury volume is proportional to the pumping time; therefore, a curve of pressure versus time is recorded to represent the relation of pressure to volume.

Integration. The area under this curve is proportional to the integral of $p\,dV$ and represents the work supplied to raise the blister. In the initial work, the integration was carried out by means of a planimeter; later on an electronic integrator was installed. The integral values produced by this instrument are recorded on the same chart as the pressure values, in order to facilitate the choice of the desired integration limits. Altogether, the instrumentation consists of a stabilized d.c. power supply, a stabilized d.c. amplifier, a recorder for the pressure curve, an integrator, an amplifier for the integral signal, and a recorder for the integral. The arrangement permits selection of several ranges, as well as instantaneous range extension.

Blank Correction. The integral of $p\,dV$, as measured and recorded by the described equipment, is not yet the desired value of "work of detachment," because during the application of pressure, some work is done for purposes other than detaching the coating. Energy is used (*1*) to compress the mercury or other fluid, (*2*) to actuate the pressure transducer, (*3*) to expand the connecting tubing, and (*4*) to stretch the film to make it fit the groove. The sum of these factors is of the order of magnitude of the work of detachment, and is by no means negligible. To determine it, a blank test is performed with the use of a procedure and specimen similar to the normal run, but instead of the regular coating a *detached* film, placed loosely on the panel and clamped down tightly in the specimen holder, is employed. In the major part of this work, the detached film was obtained by pulling a strip of coating off the substrate after completion of a series of measurements. Since this was sometimes difficult to do, an alternative method was designed in which the film is bared by electrolytically etching the metal away.

The difference between the integral values obtained in measurements on attached and free films is the desired work of detachment. It is divided by the projected area of the groove and expressed in centimeter-grams per square centimeter of detached area. If manual integration is employed, the curves of pressure versus time obtained in the main run and the blank run are superimposed and the area between the curves is measured. This is indicated by the shaded areas in Figures 6 and 7. The result, again, is converted to cm.-g./cm.^{2}.

Prevention of Puncture. In the early work, a rather frequent occurrence during the formation of a blister was a breakthrough of the mercury through the film, called puncture. Apparently, there were three causes for this: (*1*) pinholes in the coating, (*2*) weak spots in the coating, (*3*) lower tensile strength of the film at the prevailing thickness than

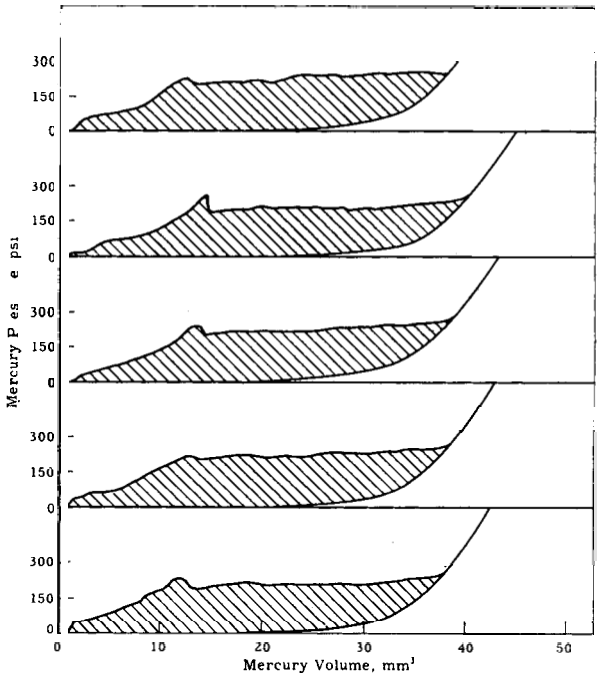

Fig. 6. Consecutive detachment curves for XA-200 varnish on stainless steel.

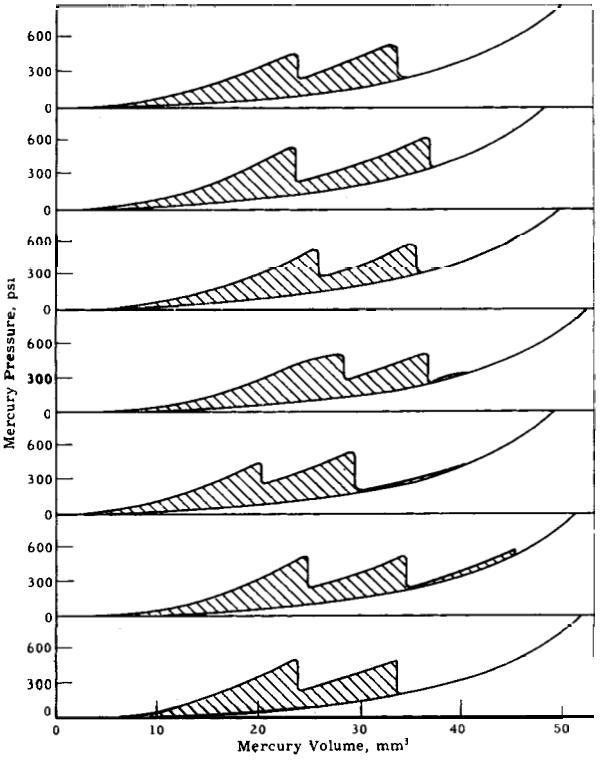

Fig. 7. Consecutive detachment curves for L-8 ester on tantalum.

adhesive strength. The obvious remedy for the first two causes is the use of multilayer films. The remedy for cause (*3*) is the use of thicker films. However, since the number and thickness of coatings are frequently dictated by other considerations, auxiliary means were developed to prevent puncture. One way is to cover the panel with strong (glass-cloth reinforced) adhesive tape, such as Scotch Electrical Tape No. 27; another is the application of a topcoat of a solventless varnish that cures at room temperature to form a strong film. The first method is generally applicable, the second is preferred for thin coatings and wherever the coating is not attacked by the varnish. Of course, the same covering is used in the blank test, to cancel out the extra work needed for its deformation.

Performance and Scope of Application

Reproducibility. The most important property of an instrument of this kind is, of course, its ability to reproduce values precisely and consistently. Available test results indicate that a coefficient of variation of 5% or below is obtained in many cases. However, in other cases, the irregular character of the adhesive bond seems to be the determining (i.e., limiting) factor for the available accuracy. Inadequate surface preparation, in particular, is likely to cause low as well as erratic adhesion.

Two examples of good reproducibility are presented in Table I. One test was carried out with an amine-cured epoxy resin varnish, hereafter referred to as XA-200 varnish, the other with a linseed ester of an epoxy resin, referred to as L-8 varnish. Each example represents consecutive tests on one panel. The coefficients of variation for the work of detachment are 1.8 and 5.25%, respectively. The detachment curves obtained in these tests are presented in Figures 6 and 7; they show a surprisingly high similarity within each group, but great dissimilarity between the two coatings. The jagged appearance of the curves in Figure 7 will be discussed in the next section.

Specimens of poor reproducibility may have coefficients of variation as high as 30%.

Uneven Detachment. A very puzzling phenomenon is the occurrence of uneven detachment. By this term we mean a detachment proceeding in steps; the pressure is built up slowly and then drops sharply, and this may recur several times.

Curves of pressure versus volume showing a normal (i.e., smooth) detachment have been presented in Figure 6, whereas Figure 7 shows a

TABLE I
Reproducibility of Adhesion Values

	XA-200 coatings[a]	L-8 Ester coatings[b]
Work of detachment, cm.-g./cm.^{2}	542, 524, 524, 524, 513	465, 520, 446, 508, 458, 484, 496
Average	525	482
Standard deviation	9.35	25.3
Coefficient of variation	1.8	5.25

[a] Substrate: MEK-cleaned stainless steel; 3 coats, total thickness 6.1 mils. Consecutive measurements.

[b] Substrate: acid-cleaned tantalum. Consecutive measurements.

typical stepwise or jerky detachment. It is particularly notable that of the three coating materials tested, XA-200 always showed smooth detachment whereas L-8 ester and Vinylite always exhibited uneven detachment.

This phenomenon has been studied photographically and cinematographically with the aid of a transparent upper clamping plate and a prism arrangement that made it possible to view and photograph the growing blister simultaneously from the top and from the side. The results indicated that in the case of smooth detachment the angle of advance of the blister is small (approximately 7°). This is shown in Figure 8 together with an explanation of how to read these photographs. In the case of uneven detachment, however, the angle increases slowly from a low value of approximately 16° to a high value of approximately 38° (see Fig. 9) and, when detachment begins, abruptly returns to the low value.

The phenomenon of stepwise detachment has not been explained with certainty; however, it appears plausible that a viscoelastic deformation of the bulging coating is involved.

Stepwise detachment should not influence the accuracy of the measurements since the recording and integrating devices respond very rapidly; the final value for work of detachment should be nearly independent of the course of the detachment.

It should also be noted that irregular detachment has bothered the users of the Interchemical adherometer[14,16] and, finally, that there is a literature reference[19] to a similar phenomenon explaining it as a changeover from adhesive to cohesive failure. However, no evidence for this statement was presented.

Limitations of the Method. We have found coatings of highly adhesive materials, especially

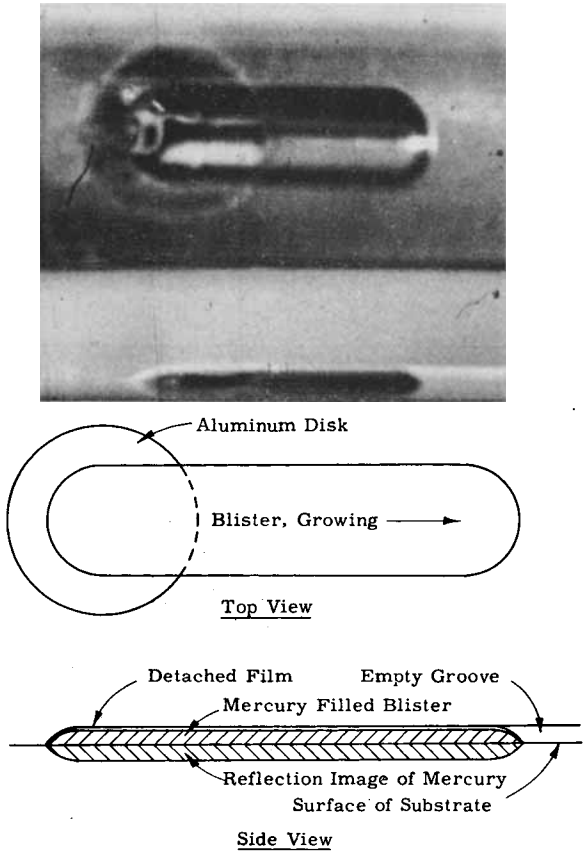

Fig. 8. Photograph (4×) and explanatory diagram of top view and side view of a blister during smooth detachment.

when laid down on etched or freshly sand-blasted surfaces, which could not be detached at all, in spite of the described protective measures. Also, brittle coatings have been resistant to detachment. Another limitation concerns the substrate. Panels of steel, aluminum, and tantalum have been used

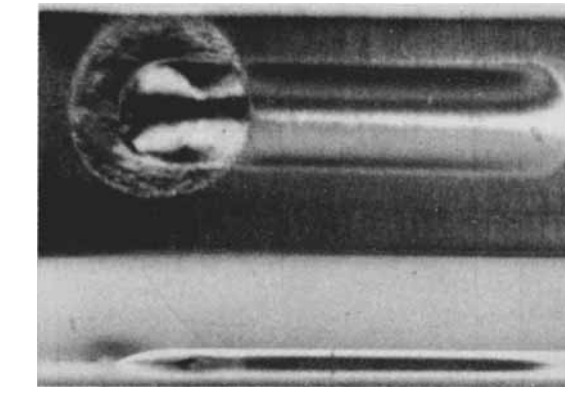

Fig. 9. Top view and side view of a blister preceding a detachment step. The advancing angle is 32°. 4×

as substrates in conjunction with mercury; however, metals that are readily amalgamated (e.g., tin) must be measured with other liquids such as glycerin. When glass panels were used, breakage frequently occurred upon application of the clamping pressure.

Methods of Coating. Coatings have been applied by dipping, spraying, or spreading with a doctor blade.

Intercoat Adhesion. A special feature of the method described is the possibility of measuring, with only minor modifications, the adhesion between coats, the so-called intercoat adhesion. To do this, aluminum patches are applied between coats rather than on the substrate. Thus, a starting area between any two coats can be established.

STUDY OF VARIABLES INFLUENCING ADHESION OF SURFACE COATINGS

A limited number of variables were given a preliminary study while the development of the equipment was in progress. Some of the variables studied and the results obtained follow.

Preparation of the Substrate

It is well known that the preparation of the substrate has a decisive influence on the adhesion of coatings. Cleaning methods such as sand-blasting, solvent cleaning, alkaline treatment, and acid pickling are widely used. A series of successive cleaning steps which had been used successfully in the preparation of metals for adhesive bonding was applied to stainless steel. One panel was withdrawn after each step and immediately coated with XA-200 varnish. A freshly sand-blasted panel was included. The results (Table III) clearly show the beneficial effect of radical methods, i.e., methods that remove the old metal surface, as compared to cleaning methods that leave the old surface intact.

Different solvent cleaning methods were compared in an attempt to find a superior method. Methyl ethyl ketone was used as a solvent and the treatment was carried out (*1*) by scrubbing, (*2*) by extraction in a Soxhlet apparatus for 18 hr., and (*3*) by ultrasonic vibration. The differences between the three solvent cleaning methods appeared to be minor.

The difference between solvent treatment and pickling or sand-blasting treatment is probably due to the fact that all organic contaminants except for an adsorbed multilayer are removed in the former case, whereas all organic matter as well as an oxide layer are removed in the latter case; roughening of the surface is believed to be of secondary importance. This was demonstrated by an experiment with tantalum, a metal that can be cleaned with strong acids without being attacked: An XA-200 coating on a drastically cleaned tantalum panel gave the very high adhesion value.

TABLE II
Effect of the Preparation of Stainless Steel Panels on the Adhesion of XA-200 Coatings

Method of preparation	Work of detachment, cm.-g./cm.^{2}
Vapor degreasing	113
Alkaline wash[a]	99
H_2SO_4 etch[a]	436
HF brightener[a]	221
Sandblasting	659

[a] This treatment was given in addition to the treatments listed on the lines above.

Influence of Film Thickness

There is considerable literature demonstrating that adhesion is a function of film thickness. Some authors report an increase,[12,13] others a decrease (Reference 9, p. 31) or maximum (Reference 10, p. 414) with increasing film thickness.

Adhesion measurements for multilayer coatings of XA-200 varnish on stainless steel and tantalum substrates were carried out and the following results were obtained:

(*1*) When the thickness of the first coat is varied but the thickness of the composite coat is kept

TABLE III
Relation Between Adhesion and Thickness of First Coat When Total Thickness Is Constant
(XA-200 varnish coated onto stainless steel by dipping)

Concentration of solution,[a] %	Film thickness		Work of detachment, cm.-g./cm.^{2}
	First coat, mils	Total, mils	
27.5[b]	0.05	2.72	97
30[b]	0.13	2.82	103
42[c]	0.27	2.42	123
50[d]	0.65	2.70	131

[a] Dipping solution for first coat.

[b] Three subsequent coats were dipped in 50% solution.

[c] Two subsequent coatings in 50% solution, the fourth coating in 40% solution.

[d] Two subsequent coatings in 50% solution. Fourth coating omitted.

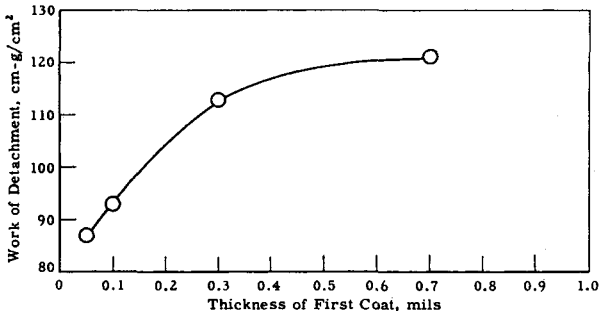

Fig. 10. Relation between adhesion and thickness of first coat of XA-200 varnish on stainless steel.

constant, the adhesion increases strongly with the thickness of the first coat. This is shown in Table III and in Figure 10. The magnitude of the increase is approximately 60% for a thickness increase of 1 mil.

(*2*) When the thickness of the first coat is kept constant but the total film thickness increased, the apparent adhesion increases also, but not nearly as much as in the first case. Examples are presented in Table IV and Figure 11. The increase, in this case, is approximately 5% for a thickness increase of 1 mil and appears to be similar for stainless steel and tantalum substrates.

Neither effect can be explained with certainty at the present time. The former effect is probably closely related to the nature of the adhesive bond, in particular, to an increase of the bonding forces emanating from the adhesive with increasing thickness, whereas the latter is assumed to be an experimental factor that may be related to the compressibility of the film under hydrostactic pressure.

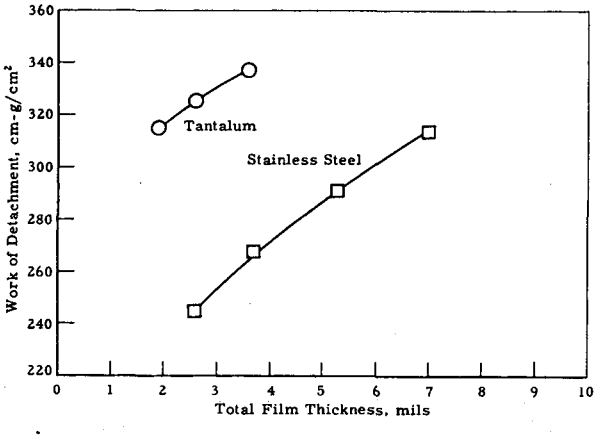

Fig. 11. Relation between adhesion and total film thickness of XA-200 varnish coatings. The thickness of the first coat was the same in all cases.

TABLE IV

Relation Between Adhesion and Film Thickness When Thickness of First Coat Is Constant

Number of coats	Total thickness, mils	Work of adhesion, cm.-g./cm.²	Coeff. of variation, %
XA-200 varnish, dipped, on tantalum			
3	1.9	315	5.15
4	2.6	326	2.07
5	3.6	331	8.0
XA-200 varnish, dipped, on stainless steel			
3	2.6	245	8.8
3	3.7	268	10.0
3	5.3	291	6.1
3	7.0	314	3.9

Influence of Viscosity

Alter and Soller[1] observed a decrease of adhesion when they increased the viscosity of coating solutions by varying the degree of polymerization, but an increase of adhesion when they increased the viscosity by raising the concentration. In the present work the influence of viscosity was studied in a series of experiments in which composition and concentration of the film-forming solution were kept constant while the time elapsed between addition of the curing agent and laying down of the coating was varied. The effect of film thickness was eliminated by making first coats as well as composite coats equally thick for all specimens. The results appear in Table V; an increase of adhesion with viscosity is evident.

TABLE V

Influence of Solution Viscosity on Adhesion[a]

Coating solution		Film thickness		
Age, hr.	Viscosity, poises	First coat, mils	Total, mils	Work of detachment, cm.-g./cm.²
0	0.58	1.0	3.3	173, 185
0.5	0.75	1.1	3.3	177, 153
1	0.93	1.1	3.2	182, 184
2	1.13	1.6	3.5	207, 187
4	1.40	1.1	3.5	244, 233
7	2.25	1.0	3.3	213, 222
24	50	1.4	3.8	278, 291

[a] Three coats of XA-200 varnish were applied with doctor blade on stainless steel.

Influence of Pigmentation

Coatings of L-8 ester and XA-200 varnish containing 88 and 100 parts, respectively, of titanium

oxide per hundred parts of resin were tested on solvent-cleaned stainless steel. Values of 513 cm.-g./cm.^{2} for pigmented L-8 and 525 cm.-g./cm.^{2} for pigmented XA-200 were obtained; the corresponding values for unpigmented films were approximately 700 and 900 cm.-g./cm.^{2}, respectively.

Effect of Surface-Active Materials

It is well known that contamination with surface-active materials can reduce adhesion greatly. To demonstrate this effect numerically, a small amount of a material of high interfacial activity (copolymer of octadecene and vinyl alcohol) was added to XA-200 varnish and the adhesion on stainless steel was determined. The adhesion without additive was 245 cm.-g./cm.^{2} ± 10.8% S.D., and that with additive was 175 cm.-g./cm.^{2} ± 13% S.D. Thus the loss of adhesion amounted to approximately 30%.

CONCLUSION

The instrument and method presented should be useful for accurate measurement of adhesion of many types of surface coatings to metal and, possibly, to other substrates, as well as for studies of the various factors that influence adhesion.

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Synopsis

An instrument for the measurement of the adhesion of organic coatings has been developed. It is based on the formation of a blister by injecting a liquid (generally mercury) under pressure between the coating and the substrate. The work of detachment, i.e., the energy needed to detach 1 cm.^{2} of coating, is determined by recording the liquid pressure as a function of the injected volume and computing the area under this curve. Extraneous factors such as deformation of the film and compressibility of the liquid are eliminated through a blank run. The design and operation of the instrument are described, an evaluation of its performance and limitations is given, and examples of its application are presented. The method should be useful for accurate measurement of adhesion of many types of surface coatings to metal and, possibly, to other substrates, as well as for studies of the various factors that influence adhesion.

Résumé

On a étudié un instrument pour la mesure de l'adhésion de recouvrements organiques. Le procédé est basé sur la formation d'ampoule en injectant un liquide (généralement du mercure) sous pression entre le recouvrement et le substrat. On détermine le travail de détachement, c'est-à-dire l'énergie nécessaire pour détacher un centimètre carré de recouvrement, en exprimant la pression du liquide en fonction du volume injecté et en calculant la surface à partir de cette courbe. On élémine les facteurs étrangers telles la déformation du film at la compressibilité du liquide par un essai à blanc.

On donne la description de l'instrument, le mode opératoire, ainsi que ses performances et ses limitations; on donne

en outre divers exemples de ses applications. Cette méthode serait très intéressante pour la mesure très précise de l'adhésion de divers types de recouvrement à des surfaces métalliques et à divers substrats aussi que pour l'étude de divers facteurs influençant l'adhésion.

Zusammenfassung

Ein Instrument zur Messung der Adhäsion organischer Überzüge wurde entwickelt. Es beruht auf der Bildung einer Blase durch Einspritzen einer Flüssigkeit (im allgemeinen Quecksilber) unter Druck zwischen Überzug und Unterlage. Die Ablösungsarbeit, d.h. die Energie, die zur Ablösung eines Quadratzentimeters Überzug notwendig ist, wird durch Aufzeichnung des Flüssigkeitsdruckes als Funktion des eingespritzten Volumens und Bestimmmung der Fläche unter dieser Kurve ermittelt. Fremdeinflüsse, wie Deformation des Films und Kompressibilität der Flüssigkeit, werden durch einen Leerversuch ausgeschaltet. Der Bau und Betrieb des Instruments werden beschrieben, sein Anwendungsberiech ermittelt und Anwendungsbeispiele mitgeteilt. Die Methode sollte sich sowohl für genaue Messung der Adhäsion vieler Typen von Oberflächenüberzügen auf Metall und möglicherweise auf anderen Stoffen, als auch für die Untersuchung der verschiedenen Faktoren, welche die Adhäsion beeinflussen, als nützlich erweisen.

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