HOT MELTS IN THE GRAPHIC INDUSTRY - CURRENT TRENDS AND FUTURE IDEAS

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ABSTRACT

Although the new electronic media is increasingly common in daily life, there is still a recognizable trend towards an increase of printed, graphic products. This can be seen among others by the constant increase of world-wide paper production, the majority of which is used for graphic products.

During the last decades hot melts penetrated this market segment. Today a large number of graphic products is manufactured with the help of hot melts that are used in different applications. Classical EVA-based hot melts are used as well as PSA hot melts based on block copolymers. Reactive polyurethane hot melts are used for high-quality graphic products.

Increases in production speed, more demanding materials and new application techniques made a further development of hot melts necessary, e. g., EVA hot melts with very short setting speed and very flexible film properties, hot melts with lower application temperature, hot melts for the two shot process, accelerated reactive polyurethane hot melts, as well as hot melts with special rheological properties for nozzle application.

INTRODUCTION

The number of books, catalogues, brochures and other graphic articles produced increases annually. For example in 1999 German publishing houses set a new record with 80,000 titles, 60,000 of them being first editions. Every 10th new book was published as a paperback. The production of these products and especially of mass-produced articles like mail-order catalogues is economically not possible without bonding.

But not only is the number of books and other graphic articles rising, their design and construction become more and more sophisticated. In order to guarantee a safe and economically reasonable production it is essential to constantly improve and modify the production processes. As for the converting of printed goods, bonding is the most important process technology. Adhesives and their related application technology are always a substantial part of the perfect binding of brochures, the gluing-off of thread-stitched book blocks, or the casing-in of book blocks into the cover.

The desire for economic production is shown by the steadily increasing production speeds that can be achieved in book, brochures or catalogue production today. Speeds of up to 12,000 items per hour when using reactive polyurethane hot melts, and of up to 18,000 items when using EVA hot melts, are increasingly common [Fig. 1].

As the production runs of many graphic products are getting smaller today, not only is machine speed of importance, so is the set-up time between runs. Therefore it is not surprising that the machine industry during the last years has made special efforts to optimize the changeover times of perfect binding machines and their peripheral units.

ADHESIVE FOR THE GRAPHIC INDUSTRY

All adhesive types suitable for the binding of paper can be found in the Graphic Industry. Three adhesive types [Fig. 2] have dominated the field in perfect binding, gluing-off of thread-stitched book blocks, and for many other applications:

- Dispersion adhesives
- Hot melts
- Reactive polyurethane hot melts

Although the adhesive technology in this industry reached a high standard years ago, improvements are constantly being worked on.

Which of the three systems is used for a specific application depends in part on the machines and adhesive application system, and especially on the performance demands placed on the finished publication.

Bindery conditions have changed considerably because of higher machine capacities and different paper qualities, such as coated papers, LC papers, and papers with a high content of secondary fibers. Adhesives and application methods have been developed which can bond these difficult substrates even at today's faster production runs.

Both adhesives themselves and their application technology change constantly. If we look at adhesive application technology, we see a trend towards nozzles in many applications. Nozzle technology from a closed system allows a high degree of automation and also provides protection from moisture when using reactive adhesives [1].

HOT MELTS

Hot melts are sold for the production of graphic products because of their ability to achieve high production speeds (up to 18,000 per hour). Mass-produced articles like mail-order catalogues and magazines are manufactured almost exclusively with hot melts today. Hot melts permit the binder to manufacture graphic products completely in line so that no additional delay time and expense occurs.

Hot melts are used for perfect binding as well as for gluing-off of thread-stitched book blocks. Furthermore they are used as side glues in brochure production and for the manufacturing of "Swiss brochures".

While for perfect binding EVA or reactive polyurethane hot melts are used almost exclusively, for gluing-off thread-stitched book blocks EVA, Polyolefin or reactive polyurethane hot melts are used. Among side glues we distinguish between fast, hard products based on EVA and soft products, some with pressure sensitive properties, based on EVA or block copolymers.

The fast setting speed of hot melts does limit their ability to penetrate paper. When the processing of the spine is insufficient or when there is paper dust on the spine, adhesion values are not as good with hot melt as they are for dispersion adhesives.

In spite of this limitation hot melts have been used in the graphic industry increasingly in recent years. Hot melts with an improved adhesion spectrum have made it possible to produce safely and economically even products that are difficult to bond. Besides a general improvement of the product quality in the areas of adhesion, viscosity stability, color, and odor, there have been some very interesting developments in recent years in the graphic industry field. Among these are special developments in the field of spine glues, for example low-temperature hot melts, hot melts for two-shot process, and especially new reactive polyurethane hot melts.

LOW-TEMPERATURE HOT MELTS

A trend that can be noticed these days is the desire to be able to process hot melts at lower processing temperatures. Operating temperatures of 160°C-180°C were traditional in the graphic industry, but now "low-temperature hot melts" which can be processed between 120°C and 130°C are offered by almost every supplier. Due to the low temperatures the hot melt is exposed to, it is considerably less stressed thermally. This leads to better viscosity stability over a longer time and also its color will remain stable for days. As a result of the low application temperature, the application equipment is less stressed, which leads to a longer working life with less maintenance.

These low process temperatures also lead to a noticeable faster cooling of the adhesives to room temperature and so the strength of the film increases faster. This property is an advantage for 3-side trim on shorter cooling lines and high processing speed, as no box pleats occur and knives do not gum up.

The high temperatures with which hot melts are applied to paper can result in a local drying out of the paper. So wrinkling can be minimized when using low temperature hot melts with cross-grain papers, as the water leaking out of the paper is reduced.

On the other hand, when using low temperature hot melts adhesion may be affected by the fast speed of set. The smaller difference between application temperature and setting temperature means that the adhesive molecules have not much time to adjust themselves to the surface of the paper. This effect could impact adhesion. Especially for more difficult-to-bond papers, a pre-production test is absolutely essential to verify that adhesion is sufficient. Heat resistance of the bonded product should be tested at this time, too.

TWO-SHOT SYSTEMS

When compounding adhesives, two contrary wishes have to be fulfilled. On the one hand, one would like to develop very good adhesion power to the surfaces, which is achieved by having a structure of the system as low-molecular-weight as possible. But on the other hand the cohesion of the film should be as high as possible, which is guaranteed by having a high-molecular-weight adhesive structure. As both wishes cannot be fulfilled simultaneously, a solution is to use the so-called "two-shot process", in which one adhesive is optimized for adhesion (primer) while the second one is responsible for cohesion [2].

Hot melt - Hot melt

To reach higher pull and flex values, binders have used hot melts in a two-shot process for some years. The first application is made with a low-viscosity hot melt as primer. This product can form very good adhesion, as the viscosity is correspondingly low and the setting time is not too fast. The second adhesive, a fast setting hot melt, is used for attaching the cover and is responsible for the speed of the system.

Dispersion - Hot melt

A possibility to achieve performance in a hot melt bonded book equal to books bonded by dispersion, and at the same time increase production speed, is to use a hot melt top coat optimized for lay flat in the two-shot process.

In this process dispersion adhesives are applied very thin (about 0.1-0.2 mm) and immediately dried in line, often by infrared (IR) drying. Subsequently, another very thin layer is applied with a layflat hot melt that is responsible for attaching the cover. Books, catalogues, and magazines that are produced with these flexible adhesive systems can be opened very well and exhibit what we call good layflat behavior.

Dispersion - Reactive polyurethane hot melt

Another possibility to improve the pull and flex values in a two-shot process involves applying the primer as aqueous dispersion, usually with rollers, then applying a reactive polyurethane hot melt via nozzle to the cover.

In this technique, the difficult bonding of the spine is made not with polyurethane but with the dispersion primer. A direct bonding with polyurethane alone would also give better pull and flex values, but with the two-shot dispersion/reactive polyurethane hot melt process the pull and flex values can be exceptional, and this two-shot technique can be advantageous for certain graphic products. A key feature of this two-shot system is that the polyurethane can be applied to the cover with nozzle. The advantage to this is that the applied layer thicknesses can be adjusted optimally and not much reactive polyurethane hot melt is needed. With reactive polyurethane hot melts as second shot the production speed can be increased considerably compared to a pure dispersion two-shot system. In comparison to a dispersion/EVA hot melt two-shot system, reactive polyurethane hot melts offer in the finished product the advantage of covering low as well as high temperatures and hence the bonded products can be used in a much wider temperature spectrum.

REACTIVE POLYURETHANE HOT MELTS

For papers difficult to bond, for products that are exposed to extreme temperatures (e. g., road atlases on the back shelf of a car), and when high pull and flex values are required because of the stress to be expected, reactive polyurethane hot melts are used.

Due to their extraordinary good properties polyurethane hot melts are the fastest growing product group in the graphic industry, averaging 20% growth annually in recent years. This triumphant advance of polyurethane

adhesives started at the end of the 1980s, when the first reactive polyurethane hot melts for bonding were introduced into the market. The products that were on the market at that time did give outstanding bonding, but processing was difficult because viscosity stability was not very good and because application devices had not been adjusted to the special requirements of reactive polyurethane hot melts. At the beginning of the 90s special application devices for reactive polyurethane hot melts were developed in the graphic industry. These applicators made it possible to process reactive polyurethane hot melts a lot more carefully, so that premature reactions were avoided in the application devices. Also the quality of the adhesives improved. The 3rd generation reactive polyurethane hot melts introduced into the market at the end of the 90s are adhesives that combine the excellent properties of bonding with easy processing [Fig. 3]. Adhesives offered today are characterized by low viscosity, good processability and also by a small viscosity increase during processing. In addition the cure time of the chemical reaction has been accelerated considerably [Fig. 4]. While in the past often days passed until the adhesive films reached their final strength, today articles produced with accelerated polyurethane adhesives can be safely trimmed and distributed within a few hours (6 - 16 hours).

These newly-developed adhesives have very good initial tack, low processing viscosity, and a very good viscosity stability during processing. The very good viscosity stability is especially necessary when the adhesive is melted with tanks, as is done when processing with nozzles.

Processing with reactive polyurethane adhesives is the standard for many bookbinding companies today. They are increasingly used in the production of certain catalogues, because they allow machine speeds of up to 8,000 items per hour today with roller application and up to 12,000 with nozzle application.

ADHESIVE APPLICATION

In the past, adhesives for perfect binding and gluing-off of thread-stitched book blocks have been processed for different applications with rollers without problems [Fig. 5]. However it has to be taken into account that the adhesive is exposed to the atmospheric environment at processing temperatures in the open tank (e. g., oxygen and humidity). If the process takes longer, as when the machine has to be stopped, this can cause an effort of cleaning at the end of the production or when starting the machine again. Especially the processing of reactive adhesives in the open tank can lead to premature curing reactions. Because of that, nozzle systems have been developed [Fig. 6]. In closed nozzle systems the cleaning effort is avoided almost completely. While for roller application the adhesive application is determined automatically by the length and width of the book blocks, with nozzle application the length of the book block is detected by the steering device. The application width can be adjusted fast and continuously to match the width of the book block. Tolerances in the block are balanced by side guides. These side guides prevent a mushroom spine of the book blocks and contribute to reducing the encapsulation of adhesive between the layers compared to roller application.

Under the precondition of an exact spine roughing process, application layers of 0.2–0.3 mm or less can be reproduced accurately, which makes a saving of adhesive at high pull values possible and at the same time provides better layflat. To guarantee an exact and clean application from the nozzle at fast speeds, adhesives with special rheological properties have been developed.

Although the nozzle application process is basically a very mild process for the adhesive, since the adhesive is no longer kept at a high temperature in an open pot, certain stability requirements must be fulfilled by the reactive polyurethane hot melts used in nozzle application. When adhesives are melted with tank units, viscosity-stable products are absolutely necessary, and these are available in a wide range of products today.

In addition, nozzle application systems allow the use of two-shot systems also in one-shot binder (binder with only one application tank). The first adhesive is applied as usual with roller and the second one is applied with nozzle e. g., on the cover.

RECYCLING OF GRAPHIC PRODUCTS

Recycling of graphic products has been done successfully for years [Fig. 7]. However, the more sophisticated design of modern graphic articles has complicated the regaining of cellulose fibers during the last years, as the proportion of cellulose fibers in a modern coated and printed graphic article has decreased considerably.

If we look at the recycling process of used graphic articles, we can see that basically the papers are broken down mechanically in a large amount of water to regain the cellulose fibers [Fig. 8]. All non-paper components should survive this mechanical repulping process as large particles if possible, so that they can be sorted out. Adhesives that get into the waste paper recycling process as set films survive this procedure without damage if they have a sufficient inherent strength under the conditions of the paper recycling (pH value, temperature). Since today the water loops in the paper mills are closed more and more, all non-cellulose fiber components have to be eliminated by sorting. The earlier in the recycling process they can be screened out, the better: the pulper is the best place to do this. Hot melt adhesives fulfill this requirement easily. The inherent strength of an adhesive film depends not only on the chemical composition of the adhesive, but also on the geometry of the film, i. e. it is also determined by the application technique [3].

The influence of adhesives on paper recycling has been discussed intensively for years. The most important application field regarding the amount of hot melts used in the graphic industry is perfect binding of magazines and catalogues. EVA hot melts and for high-quality products reactive polyurethane hot melts are used. Concerning the chemical composition, hydrophilic films that are stable in the pH values of the paper recycling are preferred.

For paper recycling the layer thickness is also very decisive [Fig. 9]. While thick layers can be separated easily, thin layers and adhesives that are sprayed or applied as points cannot be separated so easily. Layer thicknesses are for reactive polyurethane hot melts between 0.2-0.5 mm, and for EVA hot melt between 0.4-1.0 mm and therefore thick enough to overcome the stress in the recycling plant.

If we look at what was mentioned above, it can be easily seen that perfect binding of graphic products should not cause many problems in paper recycling, and indeed it does not. Hot melt films are hydrophobic and normally are so thick that they can be sorted out easily. Polyurethane films are so stable that even their thinner layers can be sorted out reliably [4].

Another important although smaller application in the production of magazines and catalogues is side gluing. For this different hot melts (EVA or rubber-based) are used. These are often soft, tacky products and the films that form during side gluing are relatively thin (0.2-0.3 mm). Due to these facts the films can be torn into such tiny particles under harsh recycling conditions that a complete separation is sometimes not possible. The reason for that is that many side glues are relatively soft, low-viscosity products, and are permanently tacky. Such products with thin layer thicknesses can be so soft at the higher temperatures usual in paper recycling (more than 50 °C), that they are no longer stable enough to survive the paper recycling process without damage. However for this problem there are product solutions, adhesives that are mechanically stable enough to survive paper recycling in the usual application geometry.

Another point that has a strong influence on the conduct of adhesive films in the recycling process is the fixation of the adhesive films on the substrates. Different preparations of the spine can lead to different sortabilities, even when using the same adhesive.

To test the influence of different hot melt formulations and processing, identical mail-order catalogues were produced from different bookbinding companies with different hot melt systems and were afterwards defibered in a pulper. The mail-order catalogues were produced with different side gluing adhesives. In figure 10 and 11 the percentage share of stickies that are smaller than 2,000 µm (circle diameter equal in area) is given. These tests were made once with the whole mail-order catalogues (i. e. with cover and side gluing) [Fig. 10] and once after removal of the cover with the film of the side glue [Fig. 11]. It is obvious that the perfect binding adhesives have only a small potential to form stickies. No more than 3% of the stickies found were smaller than 2,000 µm. From this we can conclude that with a sorting of 150 µm nearly 100% of the perfect binding adhesives can be separated. If we look at the result of the tests of the whole catalogues (with side glue), on the one hand the values are substantially higher

(up to 20% stickies < 2,000 µm). But on the other hand we can see that different side gluing adhesives behave very differently. Depending upon the formulation of the side glue, films of these adhesives may contribute very few (2-3%) or quite a few (20%±) stickies smaller than 2,000 µm. By a clever choice of the side glue possible problems by stickies from adhesives can be reduced considerably [5].

TRENDS FOR THE FUTURE

In the future we expect that hot melts based on EVA and rubber will be adjusted to accommodate special applications in the graphic industry. Raw materials that make better adhesion possible will lead to qualitatively higher products. However, as has been the case in recent years, we can also expect that reactive systems will become even more important in the market.

One future trend that can be foreseen today is dual-cure systems. These could be reactive polyurethane adhesives that additionally contain groups that make UV cross-linkage possible. If such systems are used for perfect binding, the book blocks would pass over a UV lamp [Fig. 12] directly after the application of the adhesive to the spine, and a cross-linkage of the UV-reactive groups would take place within seconds. Such a high immediate strength of the adhesive film would be achieved that inline rounding of the book blocks becomes possible [Fig. 13]. Thus the bonded books could be cased-in immediately after the rounder. Final strength is achieved by the moisture reaction, which is usually finished after 6-16 hours.

UV systems will also become more important in other applications. Today there are a large number of pressure sensitive adhesives based on UV systems. With these systems it is possible to control the properties of the adhesives very accurately by their exposure to UV energy. Recently there can be found UV-curable PSA systems in the graphic industry that consist of 100% solids and can be processed as low melts at relatively low temperatures. Some of those systems are so low in viscosity that they can be used in the printing process in the graphic industry [Fig. 14]. With such systems, adhesives can be applied like printing inks, then cured with UV energy to produce the special permanent tacky properties that are typical for pressure sensitive adhesives.

In the future, more and more customers will expect good recyclability of graphic products, as well as the traditional requirements. Newly-developed products, e. g., for side gluing, will make it possible to produce graphic products which are recyclable and thus do not cause problems in the paper mills.

SUMMARY

Without hot melt adhesives a cost-saving and high-quality production of graphic articles could not be imagined today.

More sophisticated designs, produced by new application techniques with innovative adhesives, will insure that books remain an integral part of our daily life in spite of the advance of the electronic media in the future.

In the future, adhesives will make even higher production speeds possible and will fulfil the wish for "Binding on Demand".

Economic and ecological requirements will both be important in the future. As many surveys have shown, the adhesives that are normally used for production of catalogues and brochures cause no problems in paper recycling. Thus the ever-stronger call for sustainability of our economic actions can be fulfilled by the use of modern adhesives.

ACKNOWLEDGEMENTS

The author would like to thank Mr. Bill Leach from Henkel Adhesives for his valuable assistance.

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Fig. 1 Perfect binder

Demand	Dispersion	Hot melt EVA basis	Hot melt PUR basis
Adhesion	+++	++	++++(+)
Cold resistance	++	(+)	++++(+)
Heat resistance	+++	+	++++(+)
Resistance against oil	+++	(+)	++++
Aging	++++	++	++++
Setting speed	+	++++	+++(+)
Cutting ability	+	+++	++
Rounding ability	+++	+++	+++(+)
Processability	+++	+++	+++

Fig. 2 Adhesive systems for perfect binding

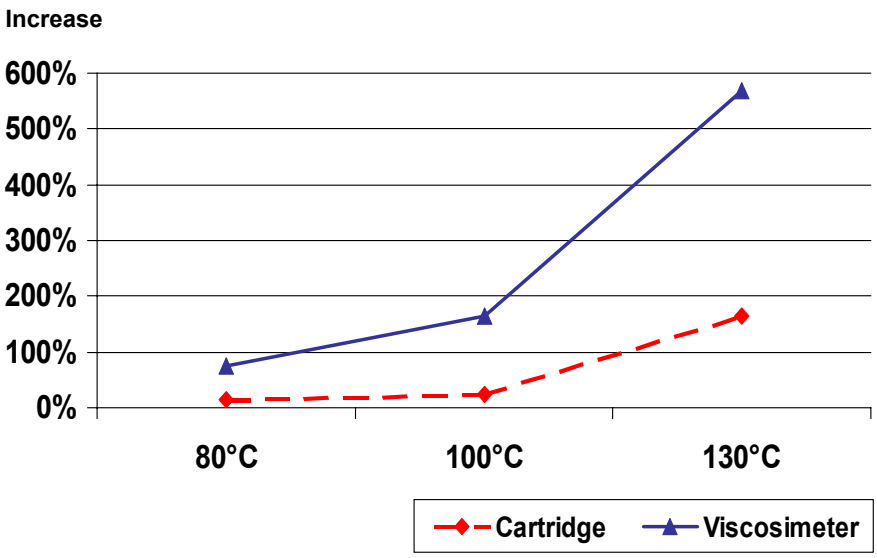

Fig. 3 Viscosity increase over 24 hours

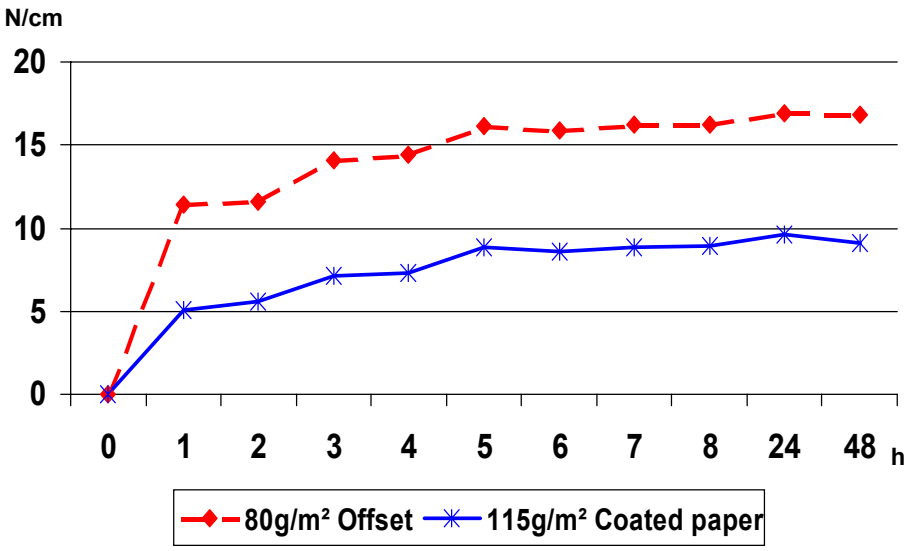

Fig. 4 Pull value depending on curing time

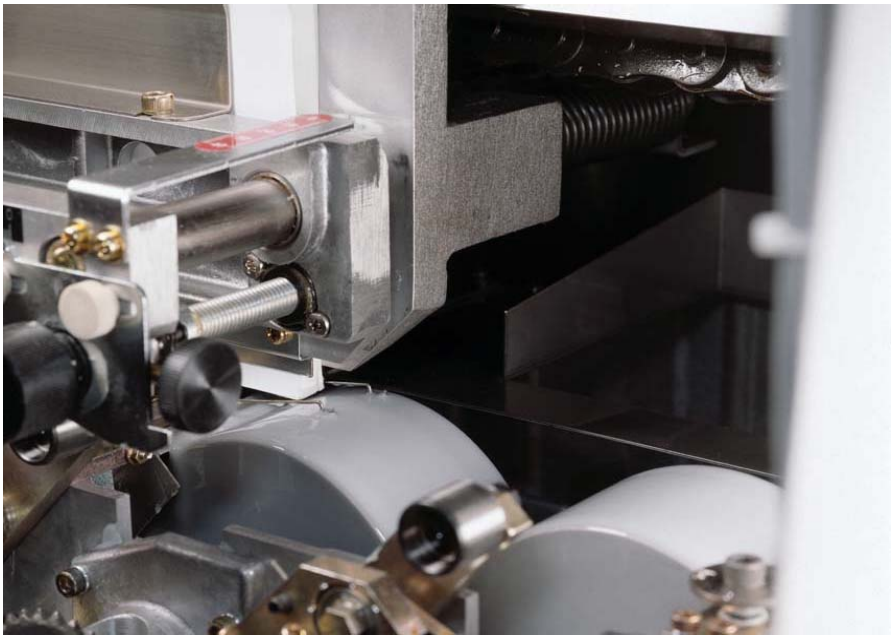

Fig. 5 Roller application for perfect binding

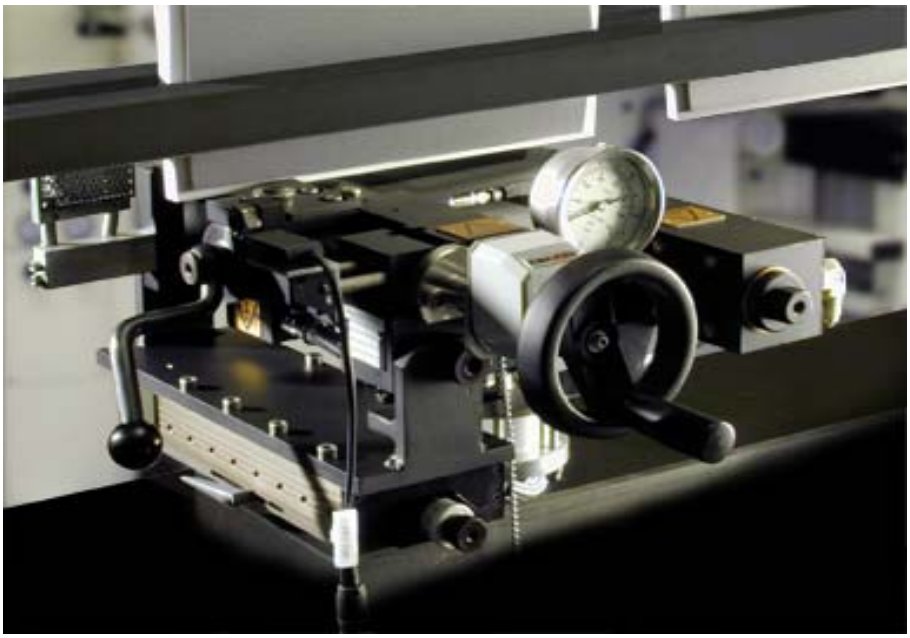

Fig. 6 Nozzle application for perfect binding

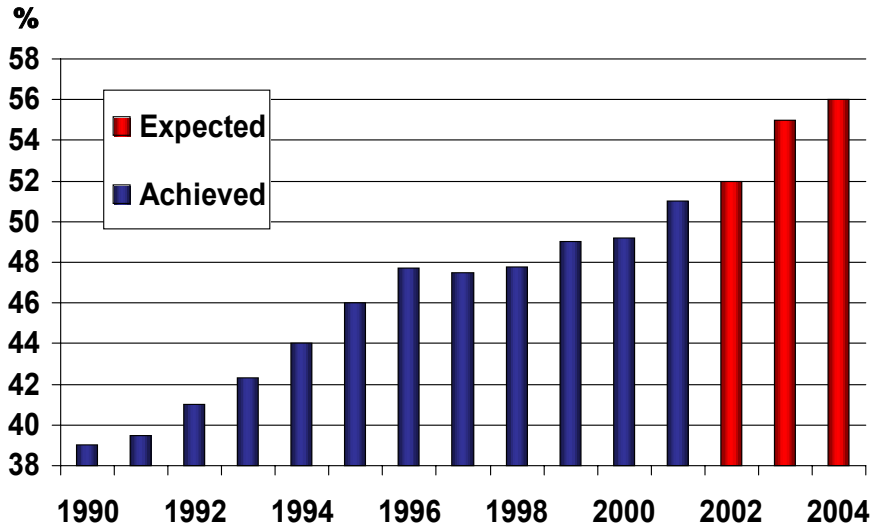

Fig. 7 Paper recycling in Europe

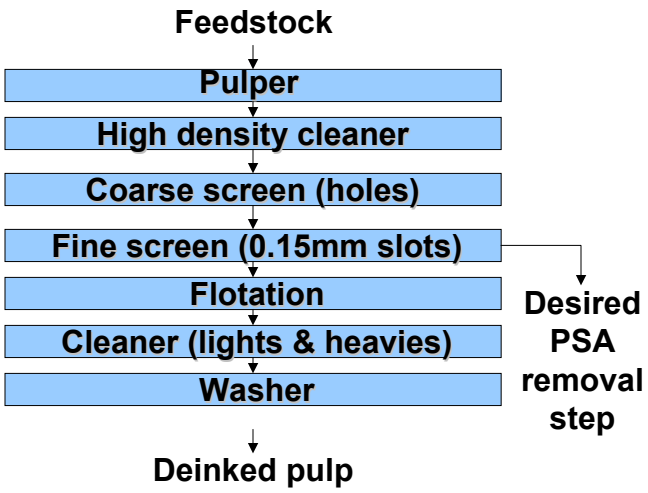

Fig. 8 Paper recycling process

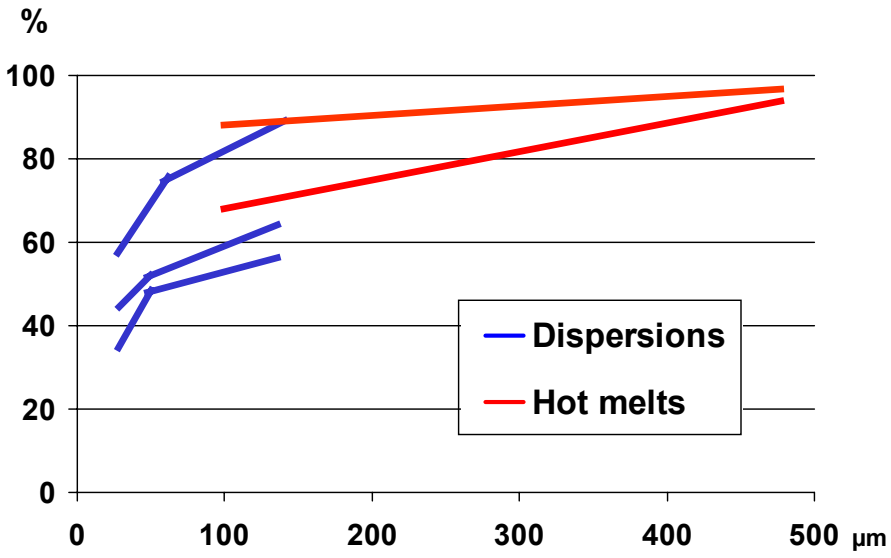

Fig. 9 Influence of adhesive film thickness

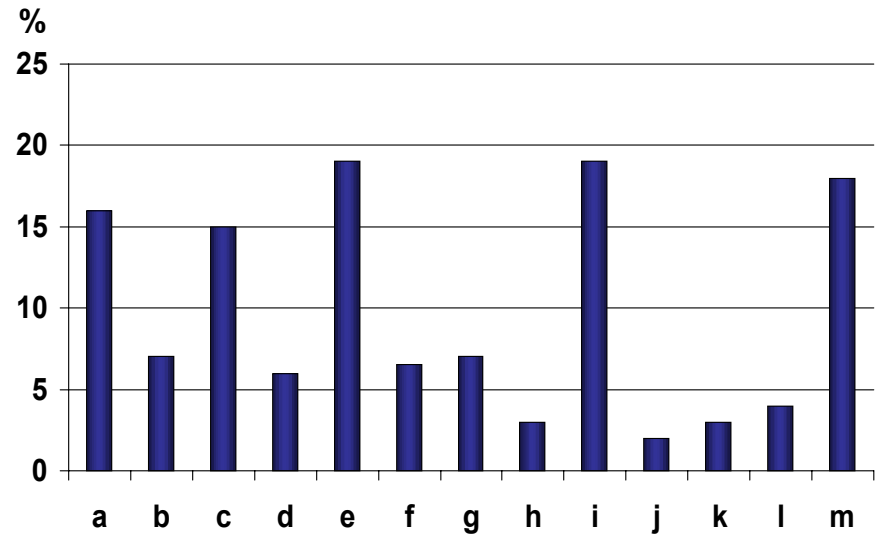

Fig. 10 Amount of stickies, complete catalog application

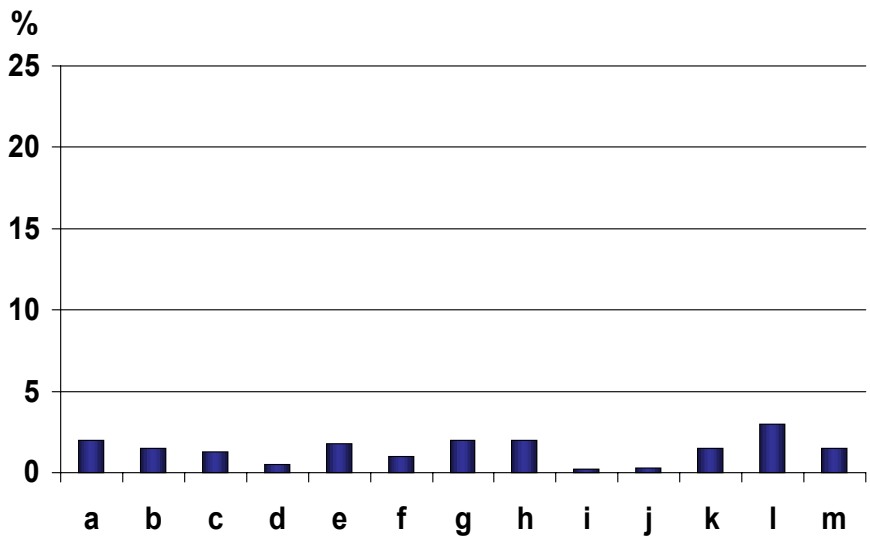

Fig. 11 Amount of stickies, only spine application

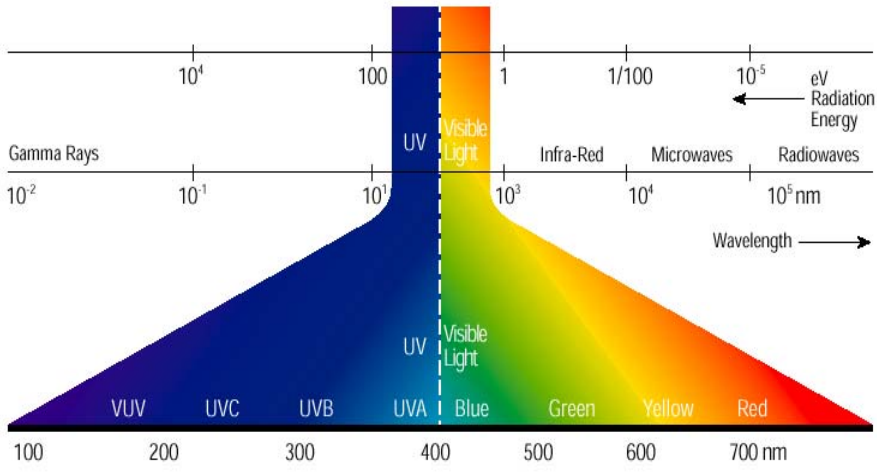

Fig. 12 Electromagnetic spectrum

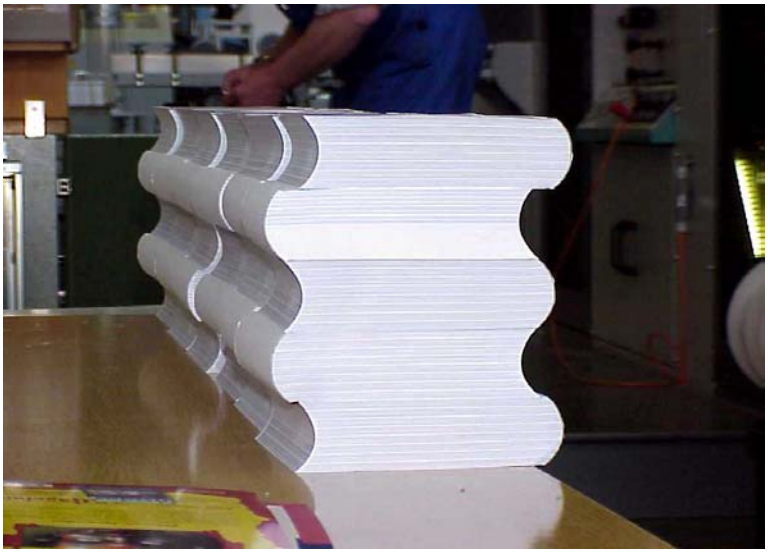

Fig. 13 Inline rounded book blocks

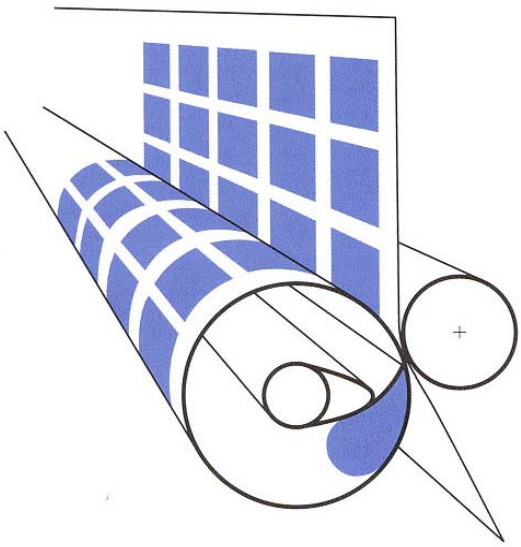

Fig. 14 Printable adhesive systems

Courtesy of Adhesives.org

Fig. 1 Perfect binder

Demand	Dispersion	Hot melt EVA basis	Hot melt PUR basis
Adhesion	+++	++	++++(+)
Cold resistance	++	(+)	++++(+)
Heat resistance	+++	+	++++(+)
Resistance against oil	+++	(+)	++++
Aging	++++	++	++++
Setting speed	+	++++	+++(+)
Cutting ability	+	+++	++
Rounding ability	+++	+++	+++(+)
Processability	+++	+++	+++

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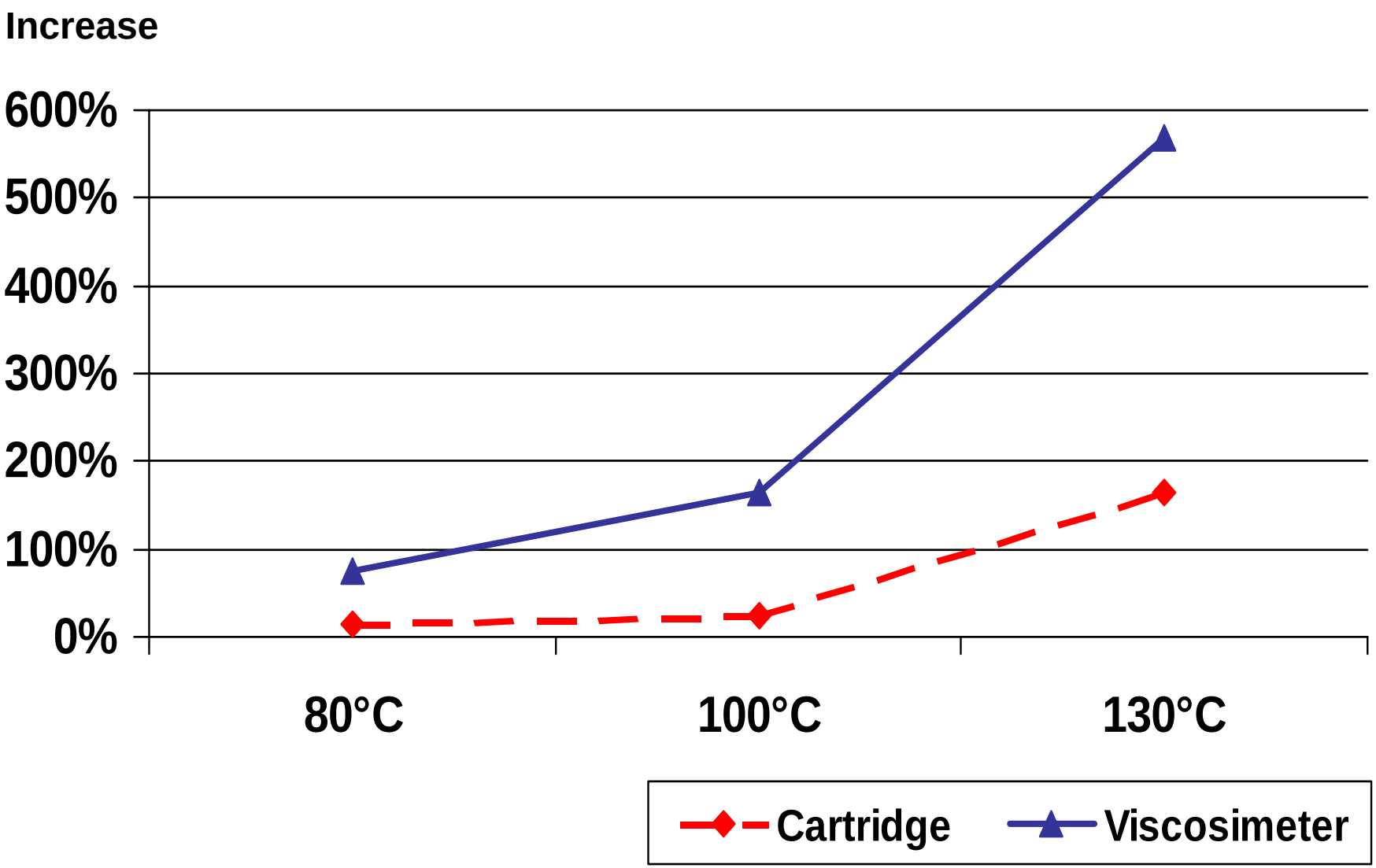

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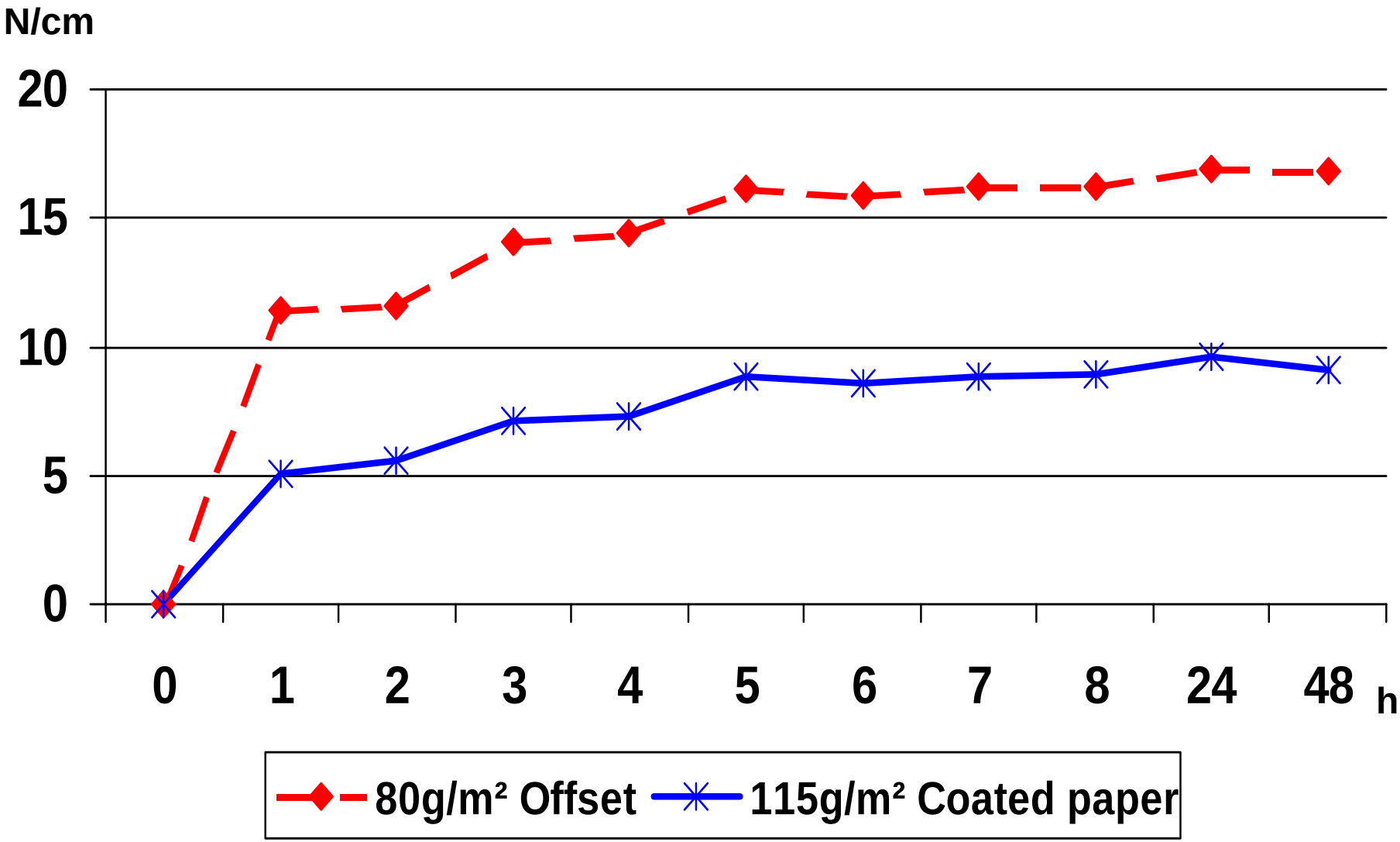

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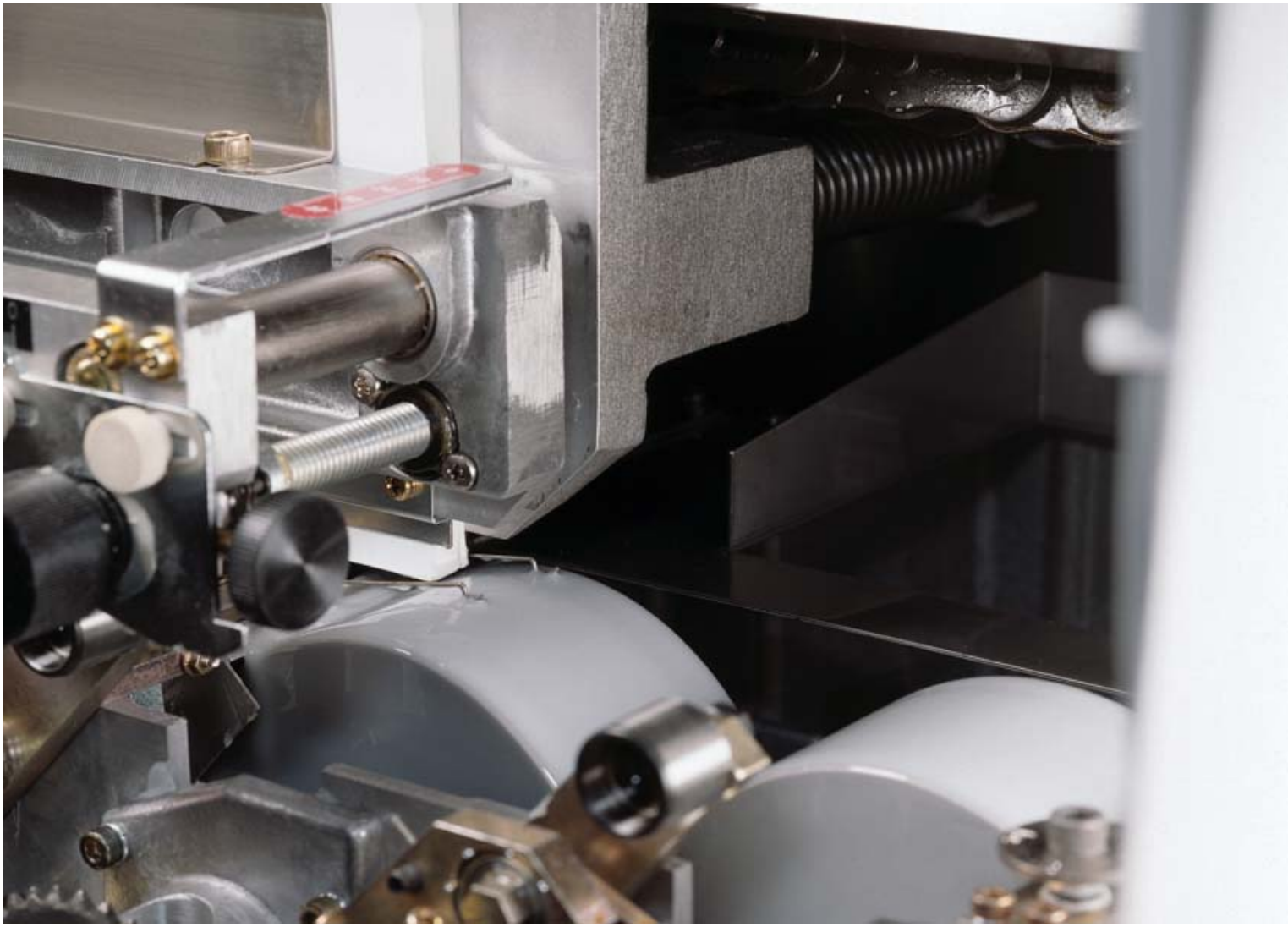

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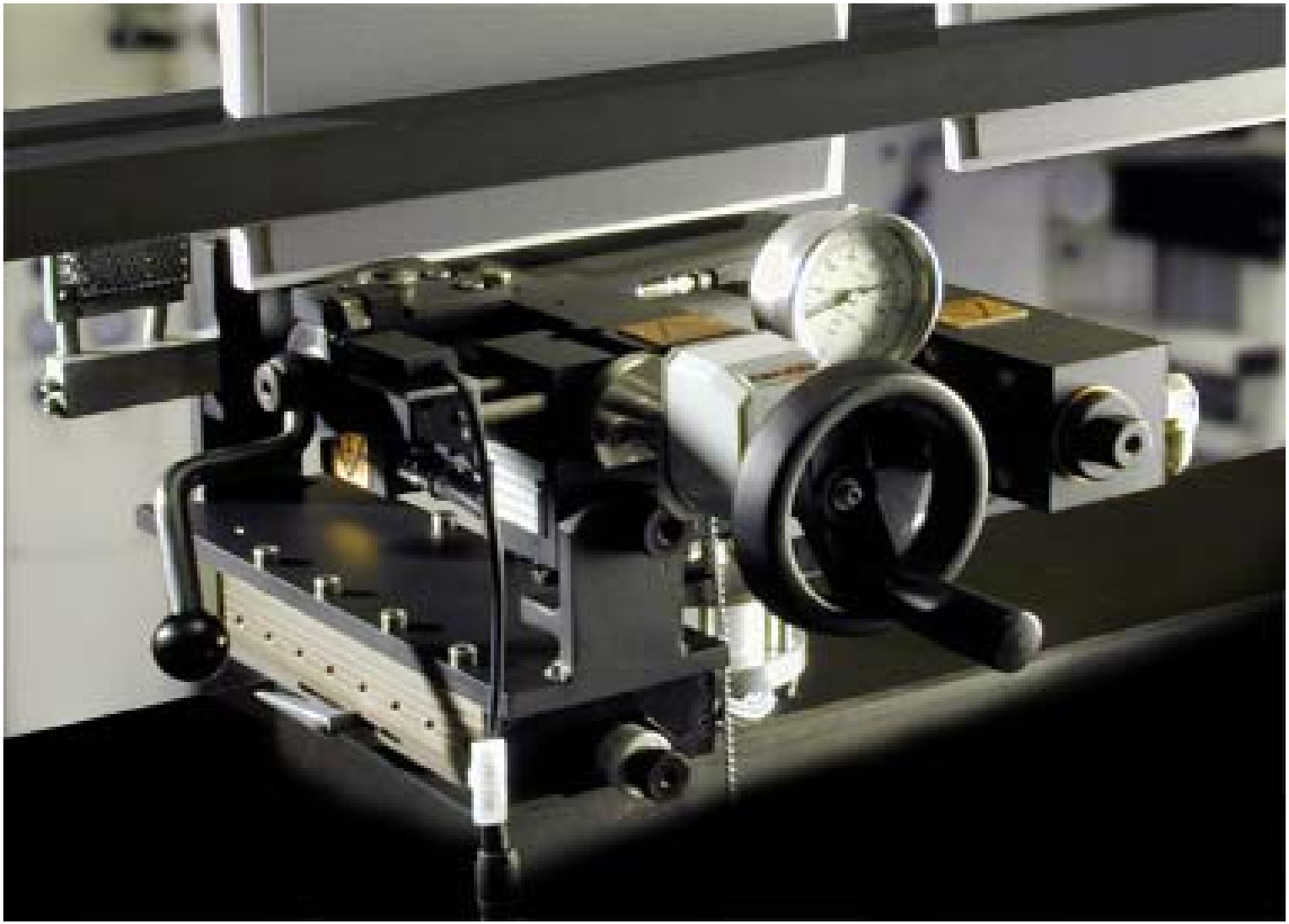
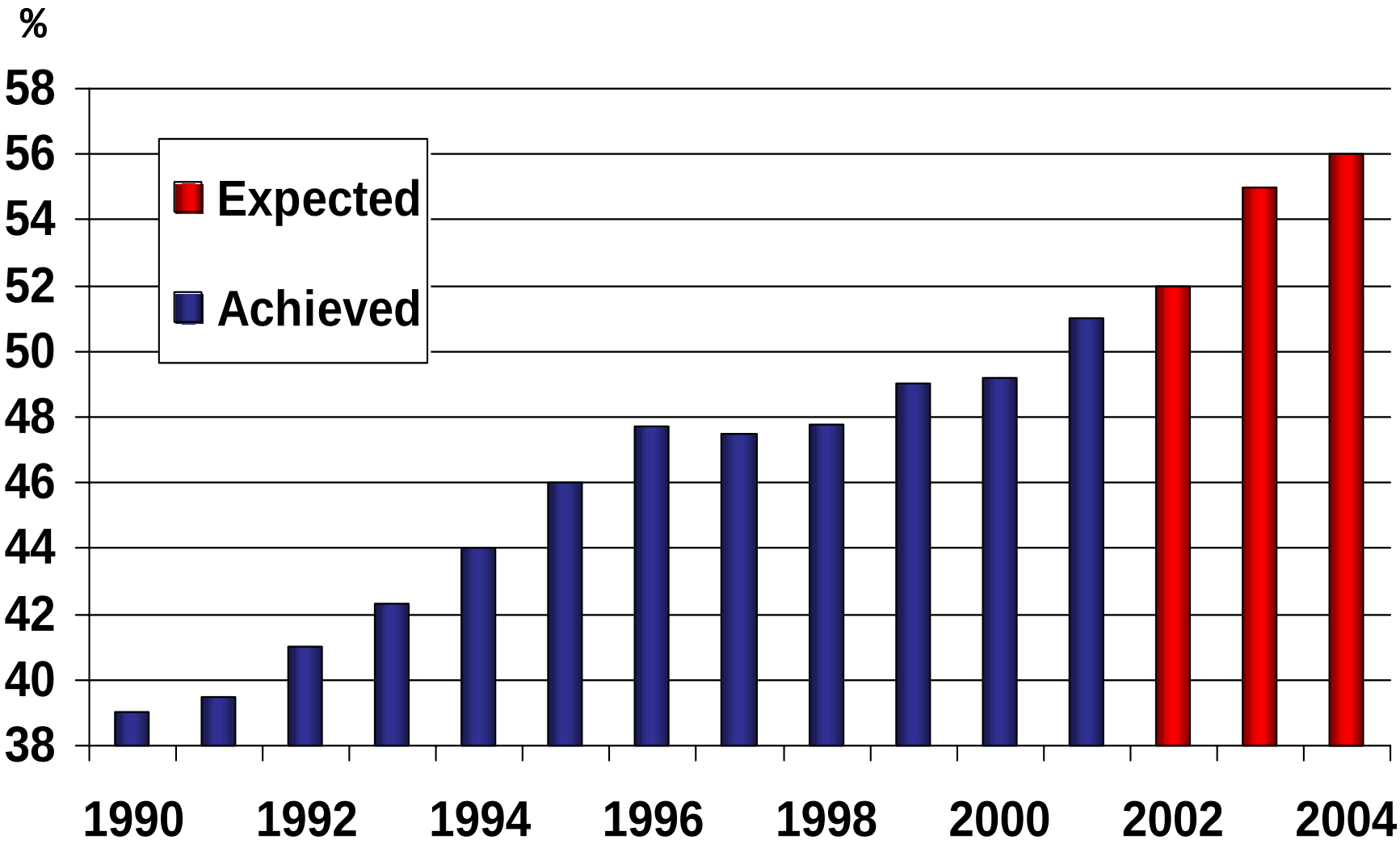


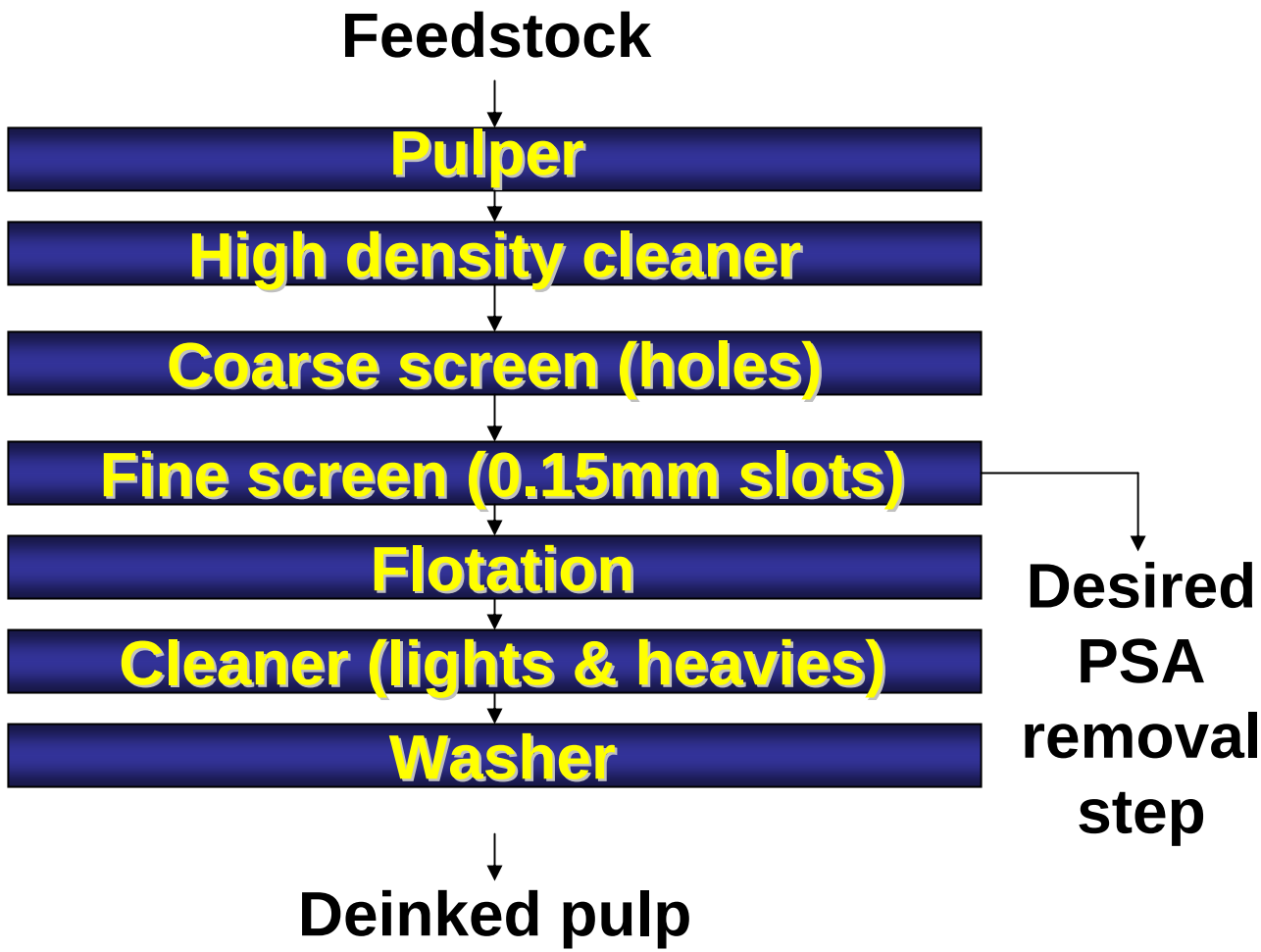
Courtesy of Adhesives.org

Fig. 6 Nozzle application for perfect binding



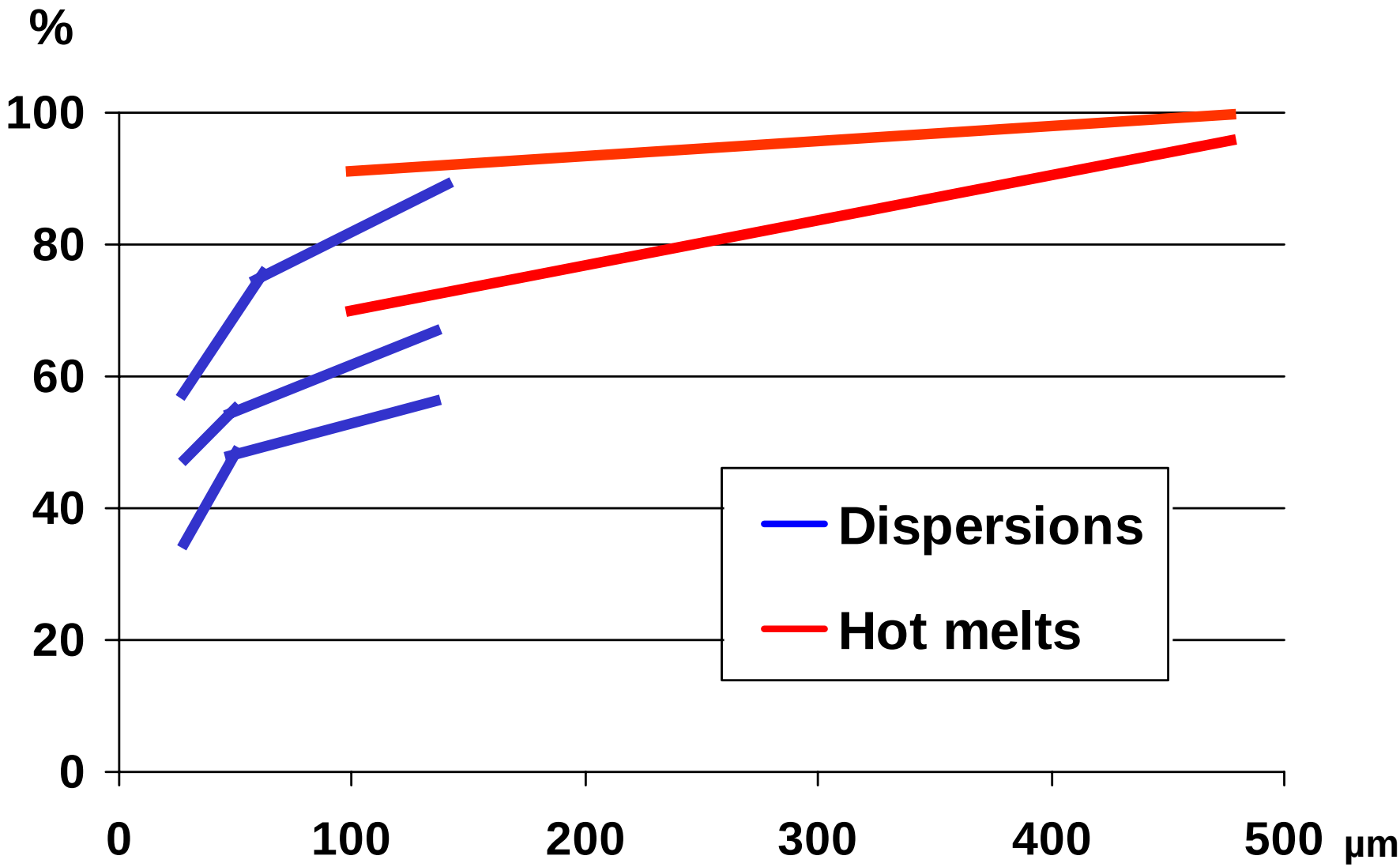
Courtesy of Adhesives.org

Fig. 7 Paper recycling in Europe



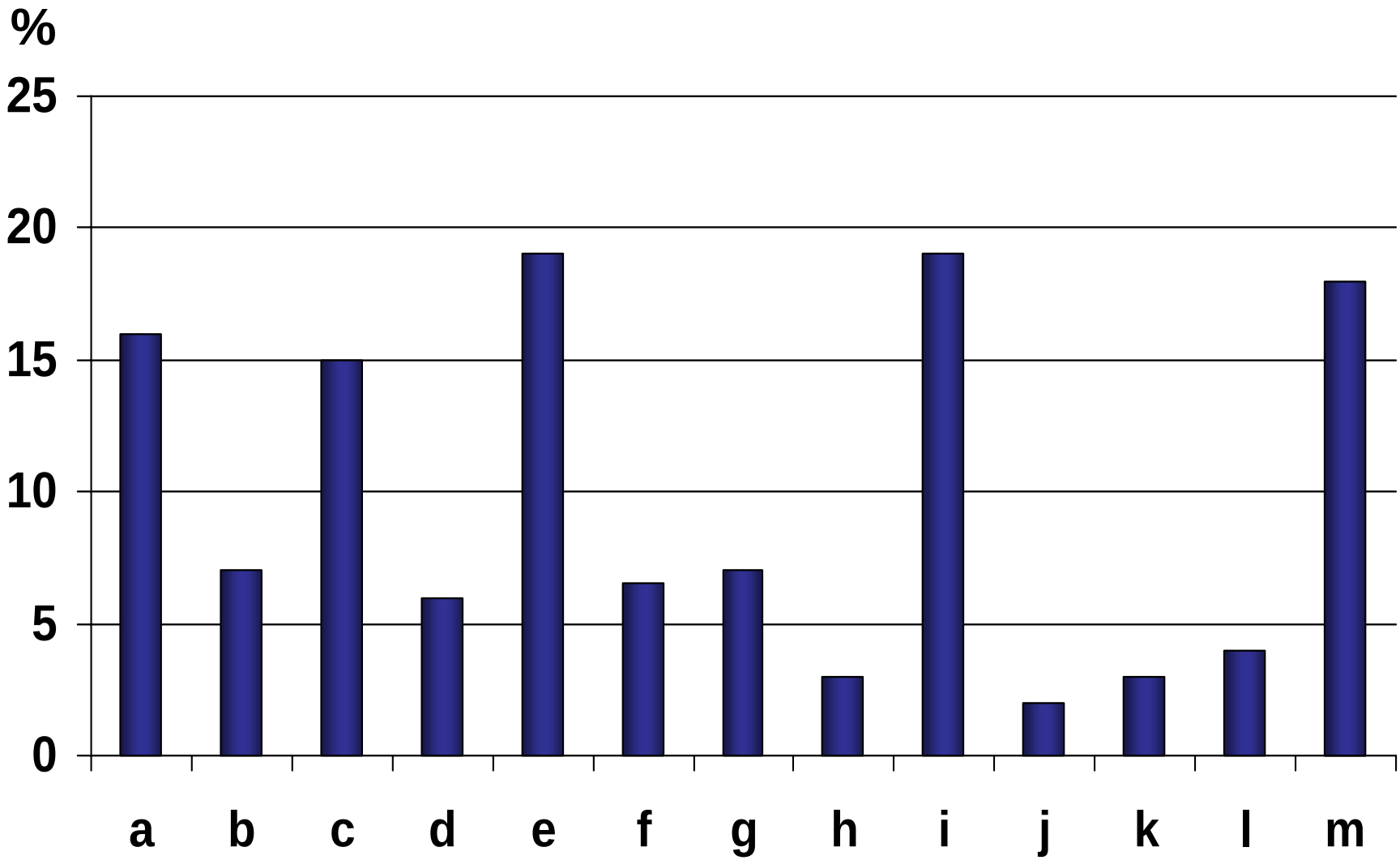
Courtesy of Adhesives.org

Fig. 8 Paper recycling process



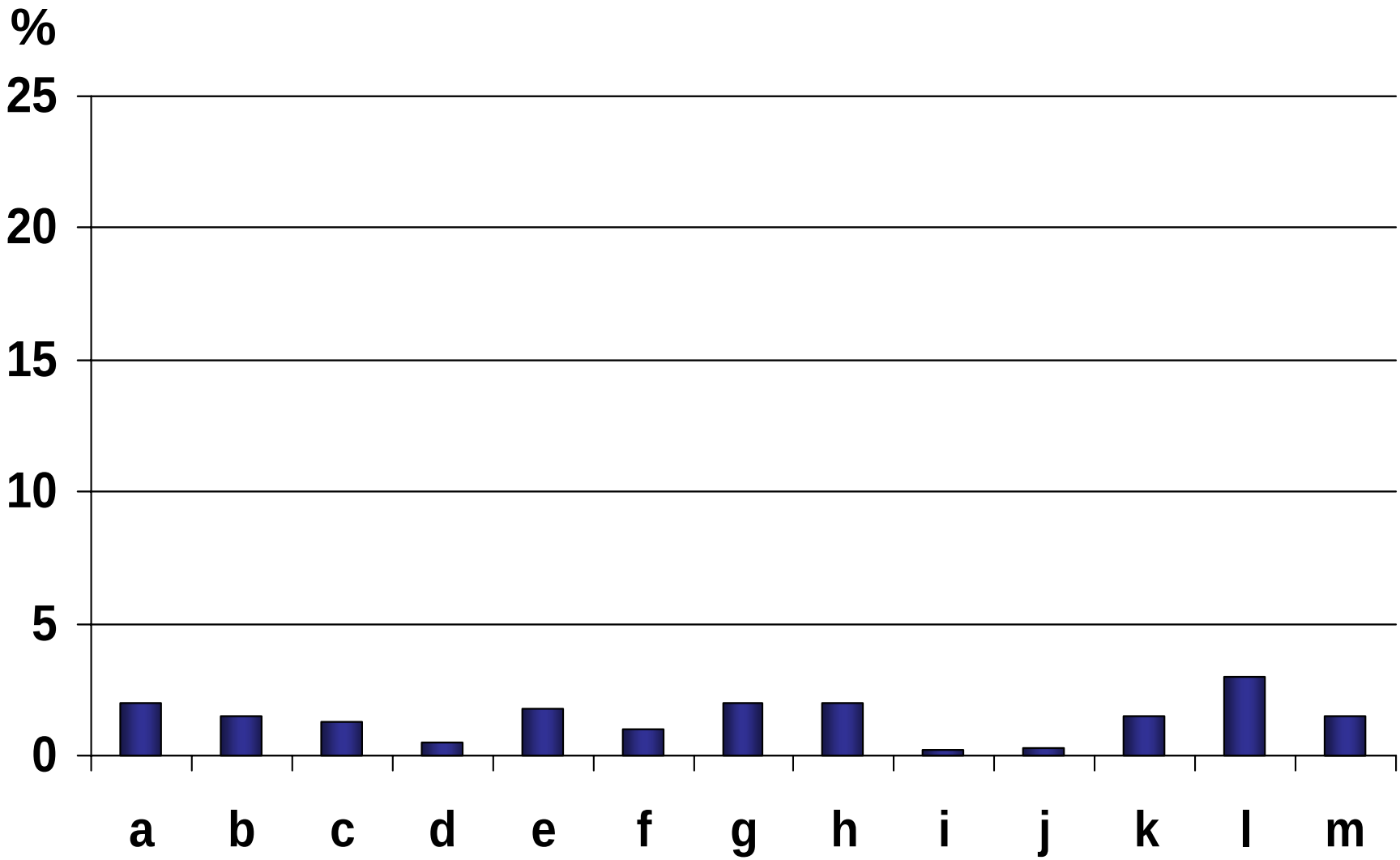
Courtesy of Adhesives.org

Fig. 9 Influence of adhesive film thickness



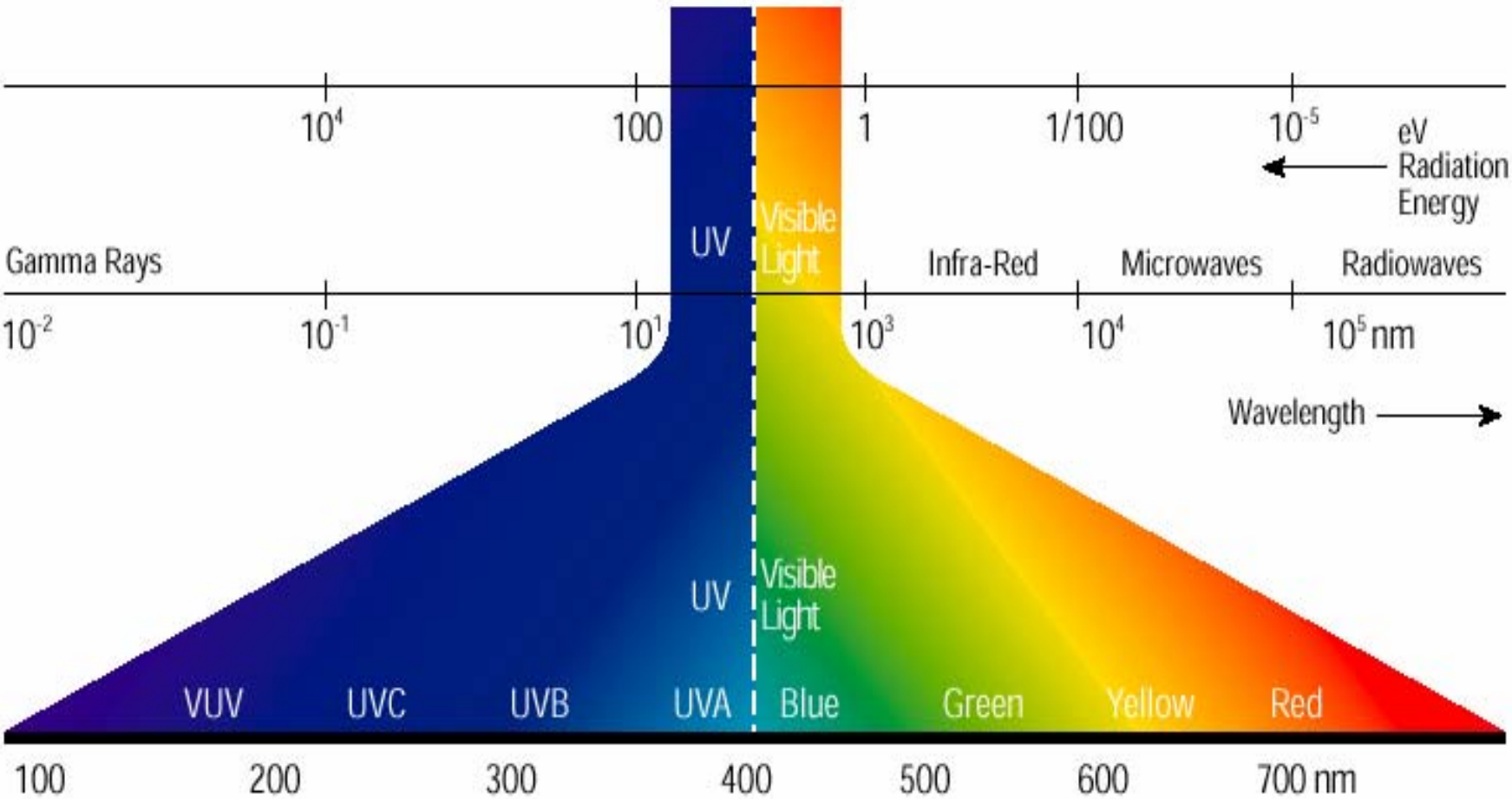
Courtesy of Adhesives.org

Fig. 10 Amount of stickies, complete catalog application



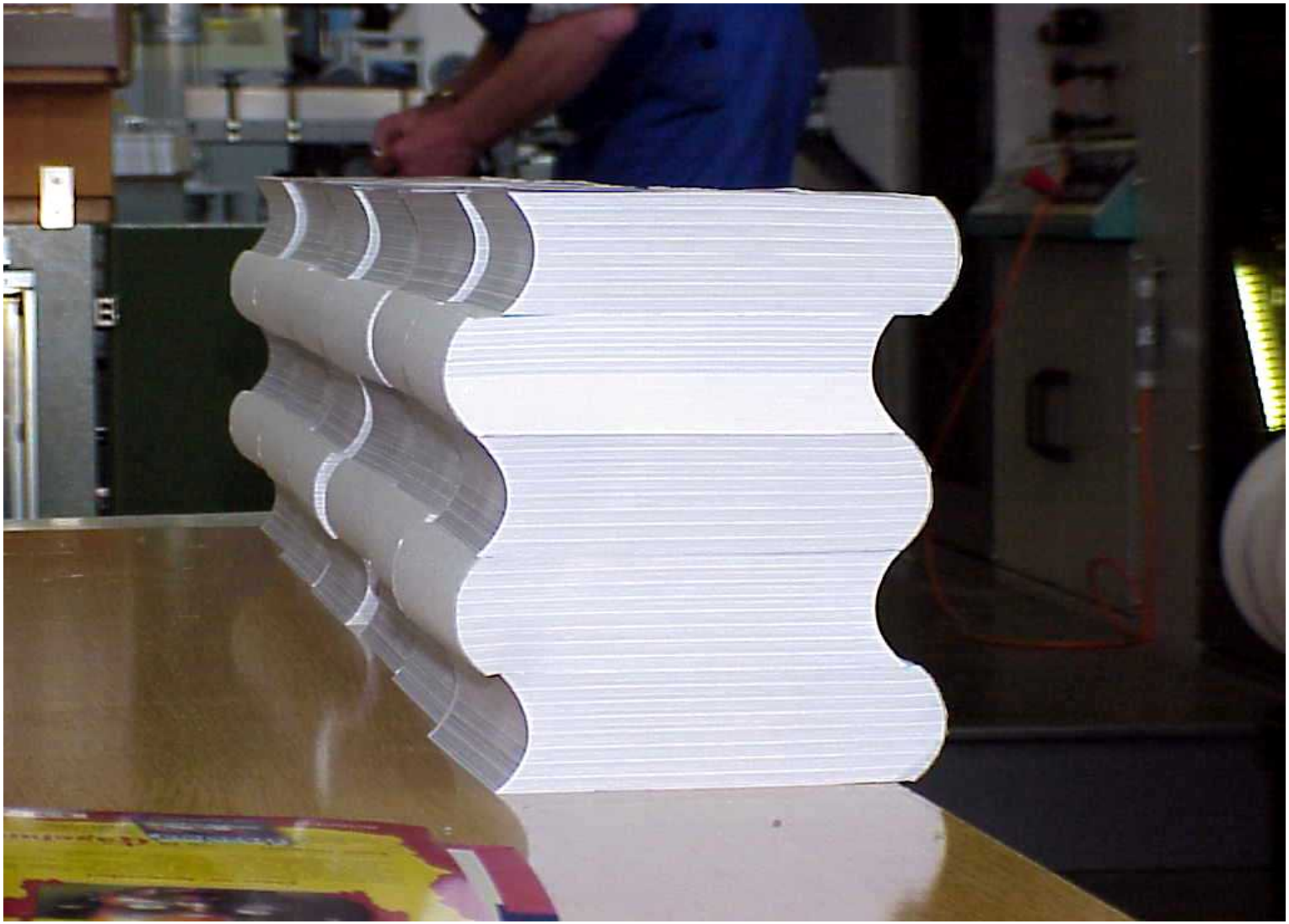
Courtesy of Adhesives.org

Fig. 11 Amount of stickies, only spine application



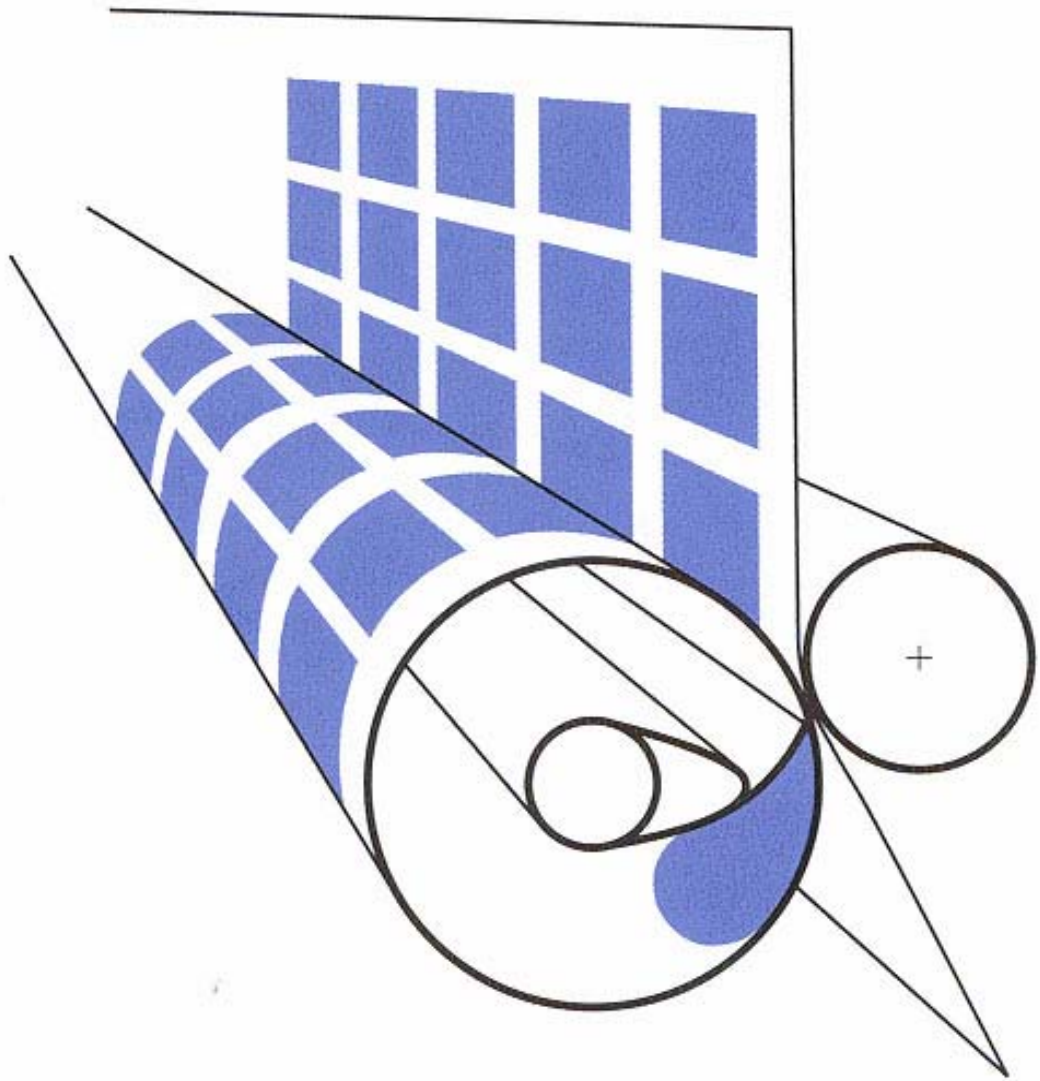
Courtesy of Adhesives.org

Fig. 12 Electromagnetic spectrum



Courtesy of Adhesives.org

Fig. 13 Inline rounded book blocks



Courtesy of Adhesives.org

Fig. 14 Printable adhesive systems