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DEVELOPMENTS IN ABSORBENT PRODUCTS AND THEIR IMPACT
ON THE NONWOVENS INDUSTRY

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Introduction

The Absorbent Hygiene Products sector of the personal care industry contains the following products:

Baby Care	Baby diapers
	Training Pants
	Pant diapers
	Baby wipes
Feminine Hygiene	Sanitary napkins
	Pant Shields
	Tampons
	Interlabial devices
	Personal wipes
Adult Incontinence	Adult diapers
	Adult pant diapers
	Two piece insert systems
	Underpads
	Personal / medicated wipes

The Adult Incontinence products are usually designated for the management of Light incontinence, Moderate incontinence and Heavy / double incontinence.

These products collectively constitute a US\$ 32-34 billion end product market worldwide.

Partly because of the sheer size of this business sector and partly due to the accelerating rate of change within the business sector as companies strive to gain market share through constantly changing product formulations, the Absorbent Hygiene Product sector has not only a disproportionately large effect because of its large consumption of roll goods nonwovens, but also through the pressure it exerts in other applicational areas for nonwovens.

To examine this impact on the nonwovens business and to evaluate possible new effects for the future, we need to examine the way in which the absorbent products as we know them today, have developed, where they are now, and then determine what direction future developments might take.

Background

The history of many of the products now included in the Absorbent Hygiene products sector dates back to ancient times.

In the baby care sector it has been argued that the 'swaddling clothes' were used with an absorbent inner layer which meant that in addition to providing cover and protection to the baby, they also provided an early type of containment product.

In the feminine hygiene sector, both internal and external products were known at least 3500 years ago, but ironically had to be 're-developed' in more recent times because the knowledge and technology had become 'lost' in a more puritanical society of the middle ages.

There is little reference to adult incontinence in past history probably due to it being seen as a 'taboo' topic, but the problems almost certainly existed and 'products' would have been selected to deal with them.

The products we associate today with the management of adult incontinence are a much more recent innovation.

Moving forward, the forerunners of today's products date back to 1900 with the first early forms of a sanitary napkin being introduced followed by the introduction of the first modern tampon in 1936.

In the baby care sector, the first disposable baby diaper-like products were introduced in Sweden by 1940, but it was not until about 1975 that it could be claimed that a truly commercially successful baby diaper was available in the USA and Europe.

Similarly in Japan, the first baby diaper appeared in 1960 but it was the entry of Procter & Gamble with 'Pampers' in 1977 that really prompted market growth. Procter & Gamble rapidly achieved 90% share of this market but they were then to lose it again when UniCharm, a Japanese producer entered the market.

Adult incontinence management products as we now know them first appeared in 1972 when Mölnlycke introduced a fluff pad with a plastic liner as part of a 'two piece' adult system. In 1980, Procter & Gamble introduced the first all-in-one product in the USA followed by UniCharm in Japan offering a range of products, including pant diapers, under their 'Liferec' brand.

In more recent product introductions, Kimberly-Clark in the USA introduced their 'Personal' product for ladies followed last year by SCA Hygiene (previously Mölnlycke) with their 'Tena Pant' product which is produced in the Netherlands with technical input from UniCharm Japan under a co-operation agreement

This progressive evolution of products with their attendant changing technologies and product forms to meet changing market requirements has had a significant impact on the growth and direction of technology development within the nonwovens industry.

Evolution and Development of the disposable Baby diaper.

Whilst all product areas have had varying degrees of impact, the changes that have taken place as these products have evolved can be illustrated by reference to the way in which the disposable baby diaper has developed.

The consumption of disposable baby diapers in some areas of the world is illustrated in the following table.

Consumption is based on 4250 diapers per child against the net infant population in the 1 – 4 years old group.

Table 1 Consumption levels for disposable baby diapers.

Location	Consumption	% theoretical
Western Europe	17.14 billion per year	97
USA	18.91 billion per year	95
Japan	5.6 billion per year	93
Brazil	3.5 billion per year	22

It can be seen that the size of the business in world terms drives product innovation especially in the developed markets, whilst the low level of product penetration in countries like Brazil illustrates the still remaining potential.

Early developments of the concept of a disposable diaper relate closely to the development of cellulose wadding. The classification of cotton as a strategic material during the Second World War, meant that the basic raw material to produce the conventional reusable towelling nappy was not available.

This led companies in Sweden to look at the newly developed cellulose wadding as a possible substitute to produce absorbent underpads for use in hospitals. From this simple starting point, there was a logical extension to producing pads of cellulose wadding to be used as a substitute diaper material.

Towelling cloth diapers were normally held in place around the baby by folding the cloth into shape and securing with safety pins. The 'nappy' was then covered with a rubber overpant. When a cellulose wadding pad was introduced, it was also held in place inside a rubber pant. From these rather basic ideas, the concept of a disposable diaper was developed and the major businesses of today emerged.

Initially the products were rather poor quality, and although the concept became more popular in the 1950's they were still made of rectangular disposable pads fitted inside a waterproof pant.

The pants were made of rubber or plastic and had elastic around the waist and legs to try to achieve a tight fit against the body and to hold the pad in place.

(US Patent 2,468,445 April 26 1949 illustrates the concept)

The use of cellulose wadding, whilst better than nothing, did not provide a very satisfactory absorbent material. Developments carried out in Sweden substituted dry defibered wood pulp in place of the cellulose wadding in the core, and when it became available, the then 'new' latex bonded nonwoven was used to replace the knitted mesh cover.

By the mid 1960's, the 'two piece' pad and pant system started to give way to the one piece, wing shaped plastic backed product such as those introduced by Procter & Gamble in the USA under the brand name 'Pampers'

By 1968, Mölnlycke had introduced an 'all-in-one' baby diaper using fluff pulp for the absorbent core and fitted with adhesive tapes. This development was quickly followed in the USA.

In 1969, Mrs Talamani was granted a French Patent (2,063,794) for a shaped elastic leg diaper using multiple elastic threads (the Patent actually issued in June 1971), and in 1972 the first T shaped diaper with a pocket-formed 3-dimensional core was introduced.

During the period 1965-1975, Scott, Johnson & Johnson, Kimberly-Clark, Union Carbide and Weyerhaeuser in the USA, and Colgate, Peaudouce and Begin-Say in Europe all introduced 'all-in-one' type diapers with fluff pulp cores, plastic backsheets and adhesive tapes. Kimberly-Clark 'Huggies' introduced in 1978 were to become a major brand.

From this point forward, the pace of developments started to gain momentum, but it should be noted that it had taken 35+ years to arrive at what could be claimed to be the first real successful disposable diaper.

With the introduction in 1975 by Procter & Gamble of their 'Luvs' shaped elastic leg diaper using a single 1/4inch (6mm) wide rubber strand on each side of the crotch portion of the diaper and a 3/4inch (19mm) plastic flap between the edge of the absorbent fluff core and the outer edge of the elastic strip, the scene was set for the introduction of leg elastics in every shape and size and location. (US Patents 3,860,003 January 14 1975 and 4,081,301 March 28 1978 refer).

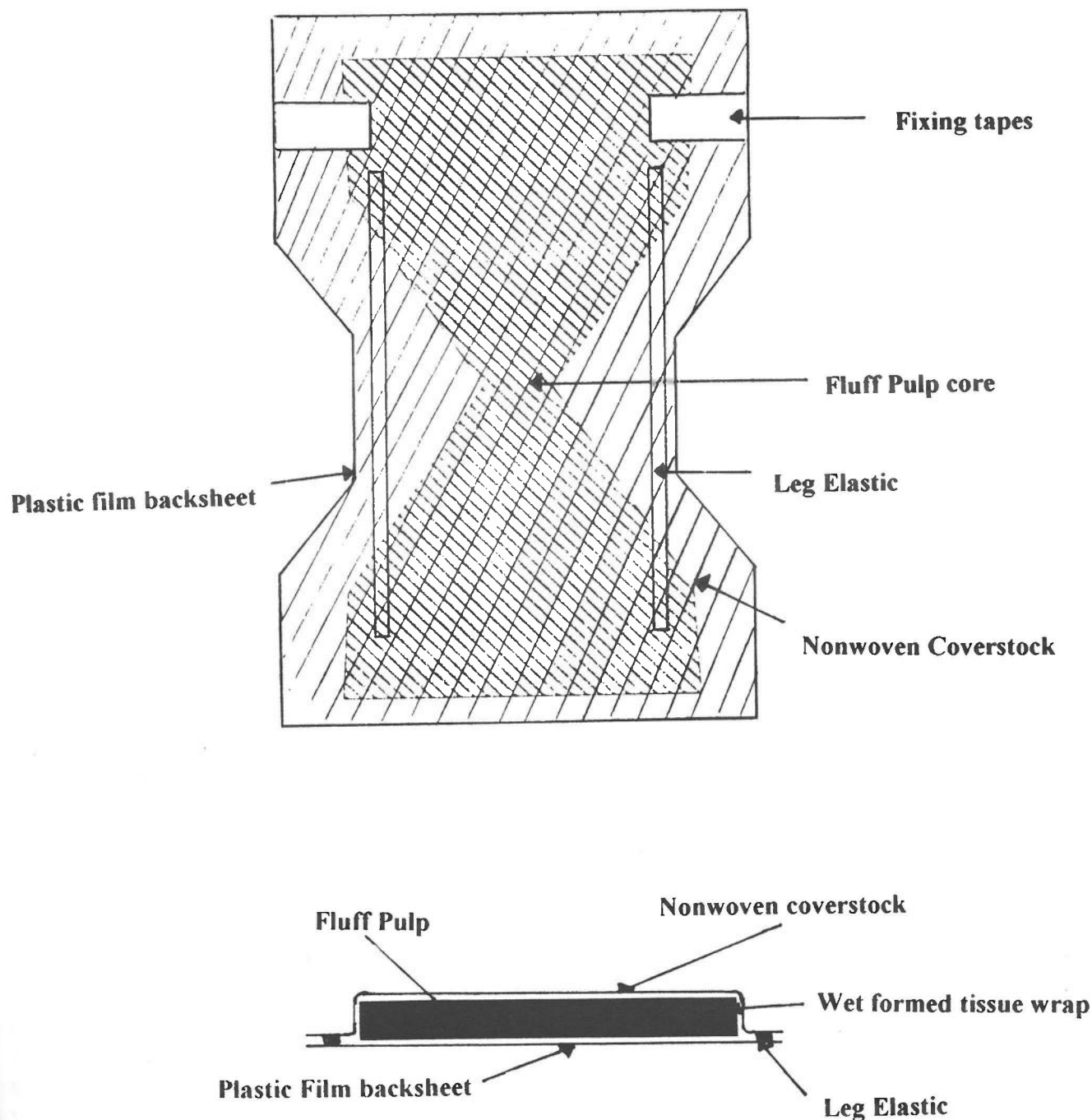
In Japan, in 1980 UniCharm secured the largest share of that market with their 'Moony' and 'Mamipoko' products both of which used a single wide band elastic made of either flat polyurethane or foamed polyurethane.

1980 saw Scott in the USA promote 'Raggedy Ann' and 'Raggedy Andy' as the first examples of gender specific all in one type diapers, a development that was to be followed for a time by most producers.

The other most significant event to occur in 1980 was the introduction of superabsorbent polymers based on polyacrylates used in diapers by UniCharm in Japan and Kaysersberg in France.

The introduction of superabsorbent polymers marked the start of the change from the 'simple' version of the diaper and the first steps towards the multicomponent structure that we have today.

Figure 1. Structure of all-in-one type diaper, circa 1975.



Baby diapers are becoming major business by 1985 and in January of that year Procter & Gamble held the first ever press conference on baby diapers in New York City, USA.

During 1986, in Japan, USA and Europe, all manufacturers offered products with elasticised waistbands and the European manufacturers offered superabsorbent diapers, which were less bulky than the non-superabsorbent types.

Whilst this was probably not realised at the time, this represented the first step in the 'thin is beautiful' development, and very quickly most US producers brought out thinner versions of their products – the 'Ultra' range.

The next important step in the development of these products came in 1989 when Kimberly-Clark introduced 'Huggies for Him' and Huggies for Her' with customised absorbent cores produced on drum formers with superabsorbent positioned in the front for boys and central for girls. At the same time they introduced a multiply 'stay-dry' transport layer / coverstock that was designed to provide a 'spacing' layer between the body contacting surface and the fluid holding absorbent core.

Other significant events at this time were the introduction of 'Huggies Pull-Ups' training pants and UniCharms 'Ultra Moony' product in Japan that was fitted with standing cuff leakage guards.

In 1992 we saw another important step on the evolution pathway. Kimberly-Clark announced a 'second generation' diaper with a high loft type distribution layer. This became the basis of the 'Ultra Trim Huggies' which was claimed to be 50% thinner but with the same absorbency as a diaper twice as thick and used the new carded thermal bonded coverstock transport layer, curved leg elastics and an increased amount of superabsorbent polymer in the core.

Procter & Gamble followed by announcing 'Pampers Ultra Dry' which used the now famous 'curly fibre' (some times referred to as Stiff Twisted Curly Cellulose STCC) as a type of acquisition layer. This product, produced for Procter & Gamble by Weyerhaeuser appears to be covered by US Patents 4,898,642 and 4,935,022 and is used in conjunction with Weyerhaeuser's High Bulk Additive material to prevent collapse of the layer when saturated with liquid and increase absorbency.

The Kimberly-Clark 'Ultra Trim' diapers initially had a problem when K-C removed 50% of the cellulose fluff pulp and doubled the superabsorbent polymer. The pad so produced had adequate total absorbency but could not absorb the urine quickly enough and consequently there was a tendency for side leakage through the permeable barrier cuffs. This led K-C to develop the concept of a high-tech flow spreading layer which would quickly move urine to distant parts of the core to be absorbed before leakage could take place.

The concept of flow spreading was not new. Johnson & Johnson had developed feminine hygiene products with channels by which the menstrual fluid could be quickly moved towards the ends of the pad.

The combination in a diaper of dual superabsorbent placing (in the middle portion where voiding takes place with girls) and in the front portion for boys and the utilisation of flow spreading acquisition and transport layers, meant that 'thin' diapers would perform equally well for boys and girls, and carers need not choose single sex products.

All the major producers start the move back to unisex products!

During 1994, Kimberly-Clark introduced a 'Huggies Supreme' diaper, which had a white cloth-like backsheet and 'hook and loop' fastening system (this later feature was tried out previously by Kaysersburg in France but proved too expensive compared to the tape tab system).

The interesting factor with these 'Supreme' diapers was that they achieved a high level of consumer approval despite a premium price.

Procter & Gamble introduced a 'Luvs Driweave' product with a three-dimensional plastic film topsheet (the same material that mothers had found unacceptable on the original 'Luvs' product in 1975)

Once again the general conclusion was that this material did not perform satisfactorily as a wiping coverstock to allow the removal of faecal material from the babies skin.

Independent tests confirmed that the connulated film material does reduce wet back from the diaper. However, it appears that if the diaper is carefully made and the superabsorbent and fluff pulp well place, the chance of leakage is practically nil and the urine will not be expressed back out of the absorbent core.

It was claimed that the plastic film helps to keep the baby's skin drier and thus reduces nappy rash. However, it is not the volume of fluid that is the problem; it is the surface liquid that is likely to cause skin rash and not the volume of liquid that is locked in the core.

Recent Developments.

By this stage the development of the baby diaper was no longer concerned with producing a product that was basically functional – all diapers work within the basics concept of keeping the baby dry and the baby's environment dry.

From this point, the modifications and additions were concerned with developing greater product differentiation and adding more aesthetic qualities.

The improvements in superabsorbents and their growing use in the core structure of the diaper made it possible to achieve absorbency and retention in much reduced volume cores.

THINNESS had become a major factor. It is perhaps ironic that the concept of thinness had already been developed and exploited in feminine hygiene products but in baby diapers there had been significant initial resistance.

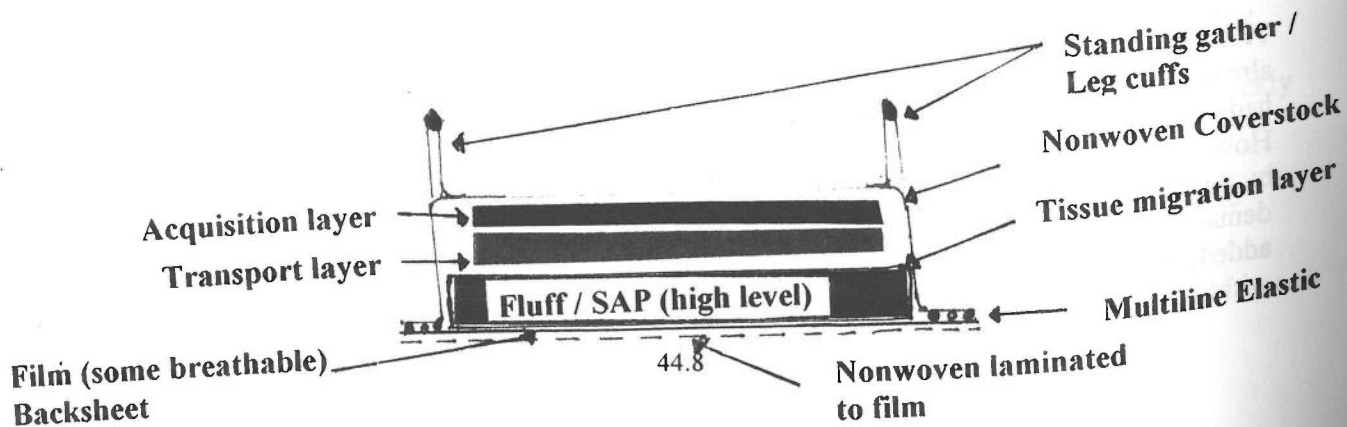
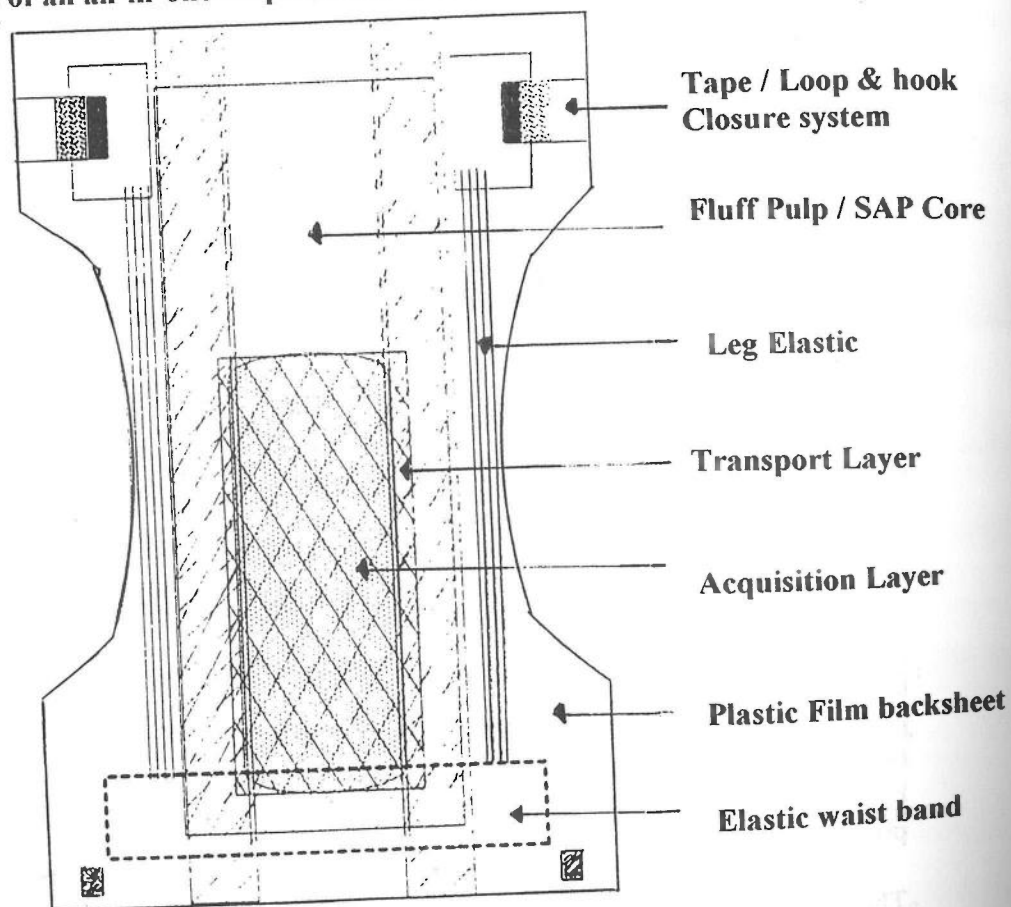
However, once the realisation that a thin product could work as well as a thick one, and aided by the improved appearance of the toddler (they were no longer 'pear shaped'), the customers demanded products that were thinner still. This led to more and more superabsorbents being added, fluff pulp being removed and the whole question of fluid management and stability within the core once again becoming a major issue.

The key to improved fluid management lay in the realisation that expecting the whole product to play an equal part in all of the various function that we now expected a diaper to perform was questionable

This led logically to the idea that there should be separate layers within the overall structure with specific functions allocated. This requires the introduction of purpose designed separate web materials for the acquisition, transport and migration control layers around the central storage layer of high level (50%+) superabsorbent and significantly reduced fluff pulp.

The basic format of the present day diaper was born.

Figure 2 Structure of an all-in-one diaper, circa 1998.



Present-day structures.

There are many different types and formulations of diapers on the market today and it not appropriate here to attempt to evaluate them all.

In order to illustrate the present position we have selected three premium quality products that are freely available in the European market. There are not too many significant differences with products in the US market, but these structures are not representative of products available in Japan.

All products illustrated were purchased in local supermarkets and a number of tests made on the diapers contained within a standard 'maxi' size diaper package.

Figure 3 Cross section of Diaper Type 1.

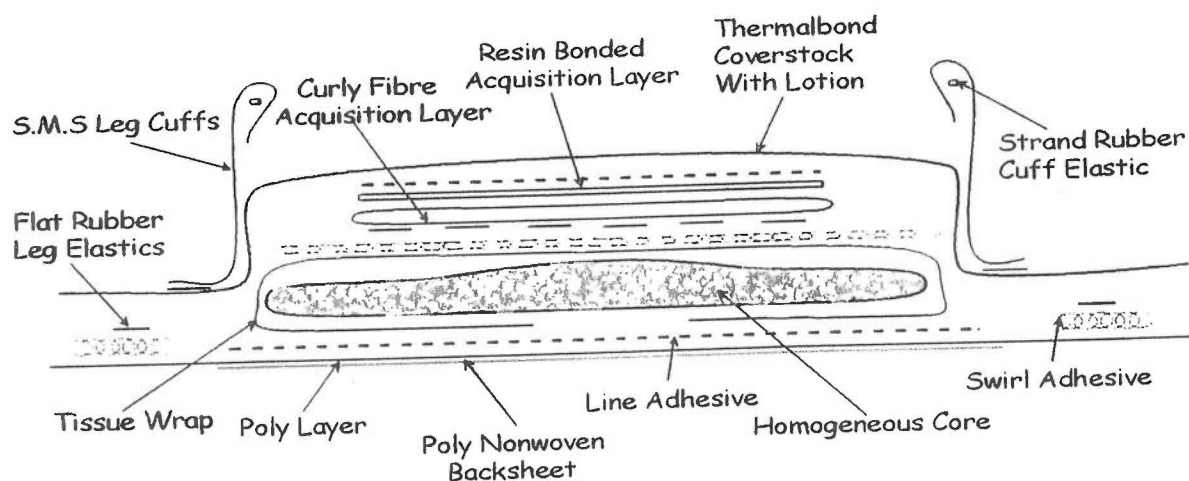


Figure 4 Cross section of Diaper type 2.

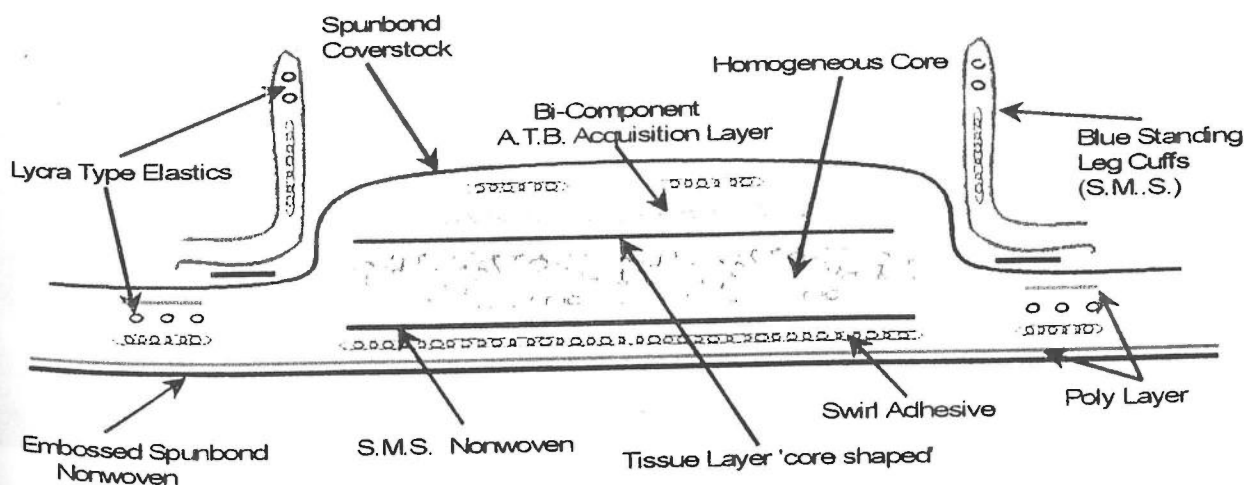


Figure 5 Cross section of Diaper Type 3.

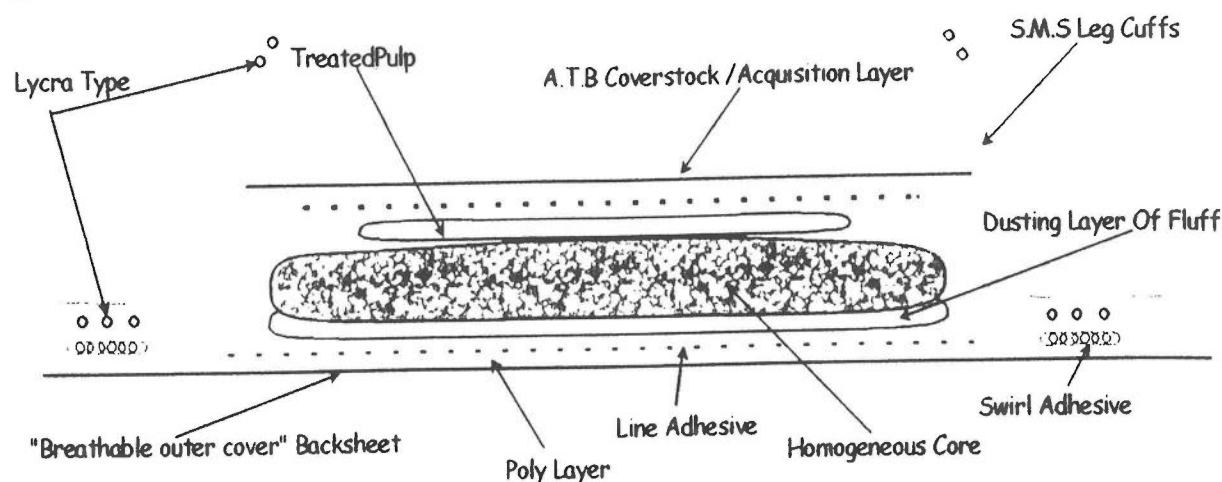


Table 2 Properties of Diapers illustrated.

Sample Reference Number	1	2	3
Total Absorbent core weight g.	26.0	36.0	36.0
Fluff pulp g.	10.0	18.8	20.0
Superabsorbent g.	16.0	17.2	16.9
Superabsorbent %	61.6	47.8	45.7
Rewet - Primary g	0.07	0.20	0.03
Rewet - Secondary g.	0.08	0.10	0.07
Rewet - Tertiary g.	2.49	0.10	0.10
Acquisition rate- Primary g/sec.	2.08	1.79	1.73
Acquisition rate- Secondary g/sec	1.11	1.10	0.75
Acquisition rate- Tertiary g/sec	0.82	0.94	0.58
Core density- Average front	0.21	0.21	0.14
Core density- Insult area	0.22	0.21	0.15
Core density- Average back	0.22	0.21	0.14
Run off- Primary g.	0.32	0.32	0.00
Run off- Secondary g.	0.27	0.15	0.00
Run off - Tertiary g.	3.61	0.22	0.00
Total run off g.	4.19	0.69	0.00
Total absorption g.	835.63	817.0	997.10
Absorption factor g/g.	17.88	16.67	19.27

From these results it can be seen how different producers take different approaches (sometimes dictated by a patent situation) to arrive at basically the same place – a premium quality product which, suitably marketed, will enhance the producers share of what is at best a static or most likely a declining market.

The evolution of the disposable diaper into its present form has been based on feeding raw materials / pre-formed components into a production line assembly system – the diaper machine, to produce individual units (diapers) which emerge from the system finished and packaged at a rate of 300-600 units per minute.

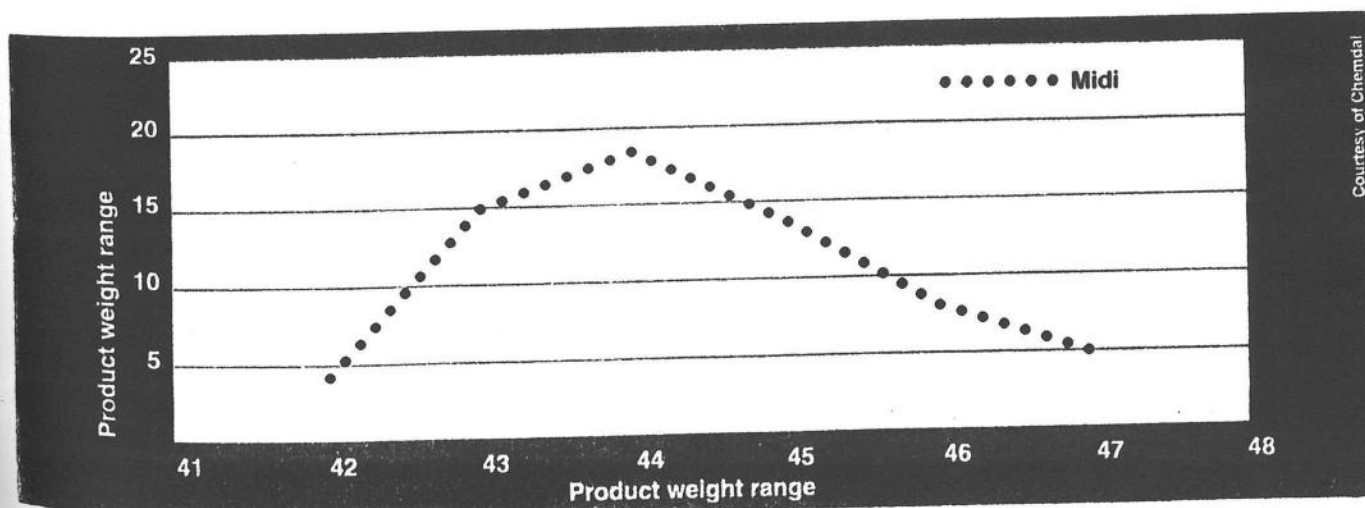
The diaper machine operates without any additional manual input and all of the added features that have appeared on the basic diaper structure to date have to be compatible with a high production rate on a fully automatic production line.

Production of disposable baby diapers as it is currently arranged is therefore based on a typical production line assembly concept and depends on the availability at the right time, in the right place and at the right quality and consistency, of the many component parts.

When the disposable diaper was based simply on a large mass of absorbent fluff pulp, the uniformity of the mass of fluff pulp was not a major issue as there was simply a lot of it. This simple fact meant that any small changes in the pad structure were evened out.

It was therefore reasonable to assume that pads produced from the same pulp, with the same pad compression, were reasonable uniform in pad density. As the product evolved into the multicomponent structure that it is today, it became significantly more difficult to achieve and maintain product uniformity.

This uniformity can be illustrated by taking a standard pack of diapers and plotting the weights of the individual diapers in the pack.



This non-uniformity does not necessarily translate as a detectable non-uniformity in the performance of the diaper as determined by the carer. What it does indicate is that with the present assembly system there is a significant 'waste' of materials through overcompensation by the producer to avoid performance variations that would be detectable by the carer.

It is therefore reasonable to say that whilst the present system produces diapers which basically work, it is not the most cost effective system in terms of value per gram of the construction materials.

Similarly the complexity of the current 'state-of-the-art' diaper machine, whilst a credit to those engineers who design and build such systems, means that any additional features required will press the technology even harder against the unavoidable system constraints.

Future Developments.

Over the past two years, more and more people have asked the question 'surely there has to be a better, more consistent way to produce the current ultra thin diaper'?

Once such a question is posed, it leads in turn to exploring the concept of developing new baby diaper types which have improved product uniformity, performance and cost efficiency.

Current thinking leads us to a diaper design that is very thin, has an increased absorption capacity and the overall product uniformity significantly improved.

The rationale for this approach is based on the idea that such a product would be capable of absorption of a much greater volume of urine per diaper, but with an effective 'dry feel' skin contact layer.

This, coupled with topical surface treatment of the skin contact layer and breathable film backsheet, would lead to prolonged usage times without compromising good skin health.

This concept would reduce the number of diaper changes per day and make it potentially possible to achieve a higher selling price per unit.

It also addresses the disposable product waste question, as there are fewer diapers to dispose of.

To achieve such a level of improvement in product performance requires that two development areas be brought together:

- i) the performance and uniformity of the individual components has to be significantly better than the average achieved today.
- ii) A radical change in manufacturing technology.

New Technology Developments.

It is now widely accepted that in order to produce a baby diaper that can fulfil the many different functions we now require of a satisfactory product, it is necessary that the different functions be assigned to specific areas or layers within the overall product structure

Therefore a future diaper is still likely to require areas or layers to accommodate the following functions:

- A skin contact layer, normally known as cover stock or top sheet.
- An acquisition layer
- A transport or second acquisition layer
- A storage layer or absorbent core
- A containment layer or backsheet (breathable)
- A 'cloth-like' outer layer, normally combined with the backsheet.

With thinner products there will also most probably be a need for some form of inner barrier layer to prevent migration of the high level of superabsorbent polymer from the core.

Considering these individual requirements:

Skin Contact Layer (coverstock, top sheet or facing layer)

Much of the current material used is either conventional 2.0-2.5 denier thermally bonded spunlaid polypropylene, or a thermally bonded carded polypropylene web. The spunlaid web is composed of continuous filaments whereas the carded web is produced from staple polypropylene fibres.

The advantage of the spunlaid web is its lower cost, but the carded web allows the use of crimped fibres which adds to the resultant fabrics softness and flexibility.

Whichever type of web is used, the top sheet has to be very soft and remain 'permanently' hydrophilic to receive repeated insults of urine

Recent developments in the production machinery used in the spunlaid sector has allowed the production of spunlaid webs with much lower denier per filament values and also the production of bicomponent filaments e.g. polypropylene core with polyethylene sheath.

Using the new technology embodied in these new machines allows the production of webs of bicomponent filaments, which have more filaments per unit area for the same web weight, or conversely, the web weight may be reduced but the strength maintained.

The web softness is also improved by the use of a lower level of bonding through the use of bicomponent filaments.

An alternative approach is the utilisation of the now available highly advanced carding systems that have been developed for low denier fibres or bicomponent fibres, with near perfect randomisation, producing webs that can be apertured if required.

In either case, it requires a major investment either in 'in-house' technology or acquiring the latest technology, but there is no doubt that it would be extremely difficult to achieve the new web requirements with existing systems.

The first production units using these new technologies are now coming on stream and we expect to see web weights of the top sheet reduced to 10 g/m² or less with the web strength maintained and with improved softness.

Initial calculations show that the reduction in web weight should accommodate the increased cost of production.

Recent development trends also require that the skin contact layer be a carrier for topical finishes applied to the web in pursuit of an 'active care' concept.

The 'active care' is achieved as a result of the transfer of part of the material, often referred to as a 'lotion', to the skin. Technically, these materials are more correctly described as Caremelts (REF 1). Caremelts are compositions of cosmetic waxes which melt, at least partly, at body temperature and transfer to the skin. They are used at application levels 10-50 times higher than conventional finishes.

They are applied in discontinuous patterns in order to not disturb the liquid acquisition function of the top sheet (a number of Procter & Gamble US Patents refer).

Use of these products can cause problems with some hot melt adhesives because of non-compatibility of the materials.

Acquisition / Transport layers.

Most ultra thin diapers already have at least one acquisition layer as the concept of providing specific layers within the structure to carry out specific tasks becomes more established.

A wide variety of materials are currently used:

- Webs of thru-air bonded bicomponent fibres
- Thermally bonded webs from polyester fibres
- High loft carded web structures
- Modified cellulose fibre structures
- Short fibre airlaid nonwovens

The two major diaper producers have opted for different approaches with Kimberly-Clark favouring their patented bicomponent fibre system whilst Procter & Gamble utilise their patented 'curly' fibre system, it is obvious that there is no 'right' or unique answer. Independent research work seems to favour the synthetic fibre approach, but a number of companies have used their own version of modified cellulose with apparent success.

The acquisition layer has to be predominantly hydrophilic. The fluid that is instantaneously transferred through the top sheet must be absorbed just as quickly by capillary forces in the acquisition layer.

The fibrous structure therefore wicks away the localised insult and distributes it into a larger area and temporarily holds the fluid until it is captured by the absorbent core or the second acquisition or transport layer.

Total pore structure within the acquisition layer has to be sufficiently large to provide the required capacity and mobility of the fluid. Fluid in the small pores of the web will be the last to be drained into the absorbent core.

For a wicking or transport layer, the important characteristics are wettability, pore size and pore distribution. When modified cellulose fibres are used in this type of application, the

modification crosslinking of the cellulose imparts a three dimensional character to the fibre and gives the fibre network more bulk and therefore greater fluid absorption capacity. It also reduces the natural tendency of cellulose to swell when wet.

In the case of synthetic bicomponent fibre structures, the formed web is surfactant treated to ensure complete wettability and the geometry of the pore structure within the web is controlled during the web forming stage.

With the extension of the cellulose conversion technology a wide range of modified cellulose fibres are possible and similarly the extension of the multicomponent fibre technology can produce tricomponent as well as bicomponent fibres in a multitude of different shapes.

At this stage of development, the best performance seems to be offered by high loft nonwoven fabrics with high elastic recovery properties.

These fabrics are produced on modern randomising cards or by use of the short fibre airlay technology with bonding of the webs being achieved by means of latex dispersion binders in combination with bicomponent thermal bonding or the use of high intensity hydrogen bonding.

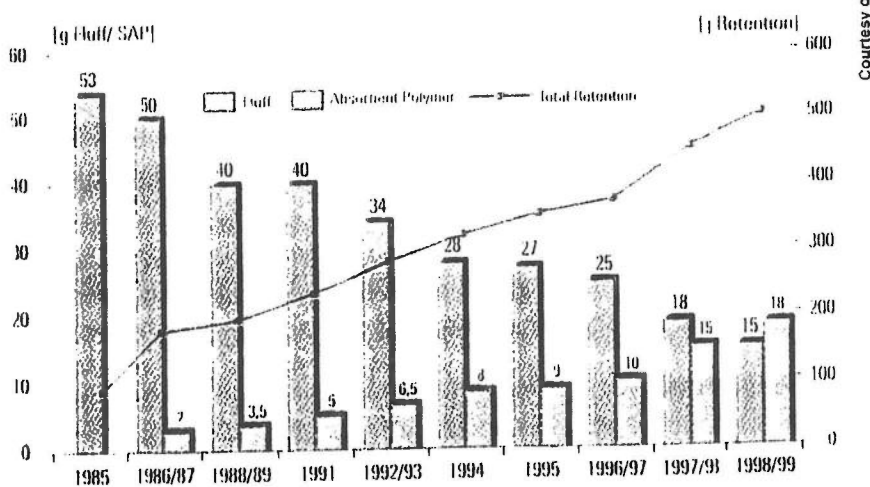
Absorbent Core / Storage layer.

It is in the absorbent core structure that the most radical changes need to be made if the objective of a really thin diaper is to be achieved.

The absorbent core of a new diaper designed to meet the stated consumer and distributor requirements would have to be very thin. It will probably need to use less than half the amount of wood pulp fluff compared to present diaper types and the absorption capacity of the core would then have to be increased and controlled by the use of the fourth generation superabsorbents now available

Diaper Raw Material Composition *

* Premium Class Maxi Diaper (Europe)



Courtesy of Stockhausen

This scenario brings with it significant problems with the existing production systems as it would seem unlikely that there would be sufficient fibres present to ensure the retention of the superabsorbent polymer both in terms of quantity and in its preferred location.

Migration would have to be controlled by some form of a 'wrap' layer around the core, but it is unlikely that the tissue that is used in some products today would be a suitable material. It is essential that the superabsorbent remains well distributed and does not form lumps or the core break up. A SMS web at 10 g/m² might prove suitable.

Whilst there are those who believe that the problems identified with the existing production systems can be solved, there are an increasing number of companies engaged in research and development and test marketing efforts to establish viable alternative systems.

Pre-formed Structures.

The ability to form a multilayer absorbent core structure has been available for some time, but limited operational speeds, relatively low efficiencies and difficult handling problems associated with these webs has tended to restrict developments.

Over the past two years the concept of pre-formed core structures, which are already widely used in feminine hygiene products, has been taken much more seriously at all levels, from raw material suppliers to product manufacturers.

Given all of the developments in basic materials and now the production of these multilayer composite structures that are now available, how could we combine these technologies to achieve our aim of an ultra-thin highly functional baby diaper?

As a first step we need to take one step back and look at the use of a **pre-formed core** in a modified but basically production line system.

Knowlson (REF 2) published a concept of how the pre-formed core material might be used to produce baby diapers using selected parts of an existing production system

Henning Skov Jensen from M&J Fibretech a/s (REF 3) has taken this idea further and shown how using short fibre airlay forming technology, a 5-layer diaper composite could be produced.

According to Skov Jensen's studies, the composite would comprise:

- Acquisition layer
- Spreading layer (transport layer)
- Superabsorbent core layer
- 'Boosting' superabsorbent core layer
- Reinforcement / bonding layer.

All formed on one machine and in one multilayer structure.

Based on these studies and work carried out by other raw material supply companies, and allowing for the projected improvements, there is no doubt that this approach would produce a much more uniform product with significantly enhanced properties.

In related studies, Hanson (REF 4) examined the question of increasing the operational speed of the airlaid system which of course is highly relevant to achieving a commercially viable system.

From a system viewpoint, a change to such a system would eliminate the need for:

- Fluff pulp unwind system and hammermills
- Drum formers
- Tissue unwinds
- Superabsorbent dosing facility

From each line, and this would lead to a reduction in the capital cost of this part of the system of 25-40% depending on the system used.

This coupled with increased efficiency /lower cost of raw materials used because of the reduced wastage and elimination of over engineering of the product, provides the economic basis for the technology change.

Problems initially identified with the handling of the output of large machines as envisaged by Skov Jensen have been partially addressed by companies working on spooling and festooning and the ongoing developments in the web handling and conversion areas mean that we are now in a position to fully exploit these new developments should we choose to do so.

Summation – Present Structures.

The existing production assembly line concept for producing absorbent products consumes large quantities of nonwoven roll goods to produce

- the coverstock layer
- the acquisition layer
- the transport layer
- material for leg cuffs
- cloth-like backsheet

as well as using other nonwoven materials such as stretch bonded elastomeric laminates for training pant applications.

We have illustrated some of the deficiencies of the existing manufacturing systems, which, quite apart from the technological constraints, have an adverse effect on unit costs.

It is possible that some of these constraints could be removed by redevelopment of the manufacturing systems, improved component materials and better overall system controls, but in the end the process remains an 'assembly line' concept.

The big question is 'will this assembly line approach hold good for the future?'

I suspect that the answer is 'NO'.

Possible routes for future development.

If we accept that product thinness remains a highly desirable characteristic, coupled with the primary requirements of a diaper that it should

- 1) keep the baby dry
- 2) keep the baby's environment dry

then any future developments must at least incorporate these basic requirements into the overall product profile.

Taking this further, we now have the added dimensions represented by skin care and breathability as major consumer directed concepts associated with these products.

There seems little doubt that in order to obtain best performances in the many differing functions now required of a baby diaper, we need dedicated layers or areas within the structure assigned to these tasks.

To achieve overall thinness coupled with wearer comfort, we need for these assigned areas or layers to be individually small in volume and at the same time highly efficient in delivering the assigned function.

Given that the existing assembly system has a fairly high degree of variability, then we have to look at alternative methods for achieving the required end performance.

Concept 1.

If the functional layers are individually produced and assembled under strict control into a finished product, it should be possible to design these individual layers to give maximum performance with minimum web variability.

For some layers, such as the top sheet, acquisition layer and transport layer, combining these together from individual feed stocks into a precursor web would represent an important initial step.

For the absorbent core structure, ultra-thinness will require the use of even higher levels of superabsorbent polymer and consequently even less fluff pulp. It could be that the future 'super core' will incorporate a thin layer of superabsorbent fibres combined into a structure made up of 80% + superabsorbent combined with a cellulose (or other fibre) matrix. Such a structure would require a containment and migration control wrap round layer to stabilise the core.

The leakage containment layer would comprise a thin breathable film / nonwoven laminate or possibly a microfibre nonwoven chemically treated to impart the required degree of water repellancy.

In the Concept 1 approach, pre-formed structures could be used in a redesigned diaper machine to produce a finished product which would resemble, but be different to, an existing diaper.

This approach would require that there was a high degree of product uniformity in the specially formulated rolls of nonwoven composite to feed into the redesigned system.

This approach would therefore provide opportunities for nonwoven companies, with the right installed equipment, to become major suppliers to the absorbent products business. This would not necessarily include existing suppliers.

Concept 2.

In this approach, the short fibre air forming technology such as developed by DanWebforming International and M&J Fibertech would play a major role and be used to produce multilayer structures from which finished products would be produced by a product converting system.

The multilayers would be produced as part of a continuous manufacturing system and would incorporate, when appropriate, pre-formed webs to confer specific end use properties.

This would represent a more radical approach but would offer the maximum degree of control at minimum unit cost.

Conclusions.

The evolution of the baby diaper (and the more recent appearance of training pants) has required dramatic changes in the production technology in order to accommodate an ever increasing and widening range of different feed stick materials.

Machinery designs and capabilities have played a major role in enabling the industry to achieve what it has done up to date, but there is now evidence to suggest that in a number of significant areas, real barriers exist to simply being able to continue as before.

New developments in fibres, polymers, additives and in web production and bonding technologies have made it necessary to consider alternative manufacturing strategies if we are to be able to take advantage of them.

The absorbent products business sector is so large and influential that whichever route it decides to take for its future development will have a major impact on the nonwovens business as a whole.

It is to be hoped that this impact will prove to be generally beneficial not only in the absorbent products sector, but in the spin off opportunities that will be generated.

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APPENDIX: TEST METHOD DEFINITIONS - Hygiene Absorbent Products.

Rewet Test:

Method for determining the quantity of liquid a hygienic article will give up under a pressure of 0.72 PSI after multiple insults of 0.9% saline solution. Typical measures for infant products, sizes New Born, Mini and Midi include primary rewet after 80ml insult, secondary rewet after additional 40ml insult and tertiary rewet after final 40ml insult. Typical measures for infant products, sizes Maxi, Maxi Plus, Junior and Extra Large include primary rewet after 100ml insult, secondary rewet after additional 50ml insult and tertiary rewet after final 50ml insult.

Typical measures for adult products include primary rewet after 150ml insult, secondary rewet after additional 150ml insult and tertiary rewet after final 150ml insult.

Rewet Under Load:

Method for determining the quantity of liquid a hygienic article will give up under a pressure of 0.72 PSI after multiple insults of 0.9% saline solution to be acquired under a pressure of 0.72 PSI. Typical measures for infant products, sizes New Born, Mini and Midi include primary rewet after 80ml insult, secondary rewet after additional 40ml insult and tertiary rewet after final 40ml insult. Typical measures for infant products, sizes Maxi, Maxi Plus, Junior and Extra Large include primary rewet after 100ml insult, secondary rewet after additional 50ml insult and tertiary rewet after final 50ml insult.

Typical measures for adult products include primary rewet after 150ml insult, secondary rewet after additional 150ml insult and tertiary rewet after final 150ml insult.

Fluid Acquisition:

Values are generated in conjunction with the rewet under load test, in which the time is measured and expressed as a rate, typically in grams per second (g/sec). This is carried out for primary, secondary and tertiary insults to fully penetrate into the article through a 1" i.d. column.

Fluid Transport:

Method for determining the efficiency of a hygienic article to transport applied fluid within the absorbent product. Typical measures for infant products, sizes New Born, Mini and Midi include primary rewet after 80ml insult, secondary rewet after additional 40ml insult and tertiary rewet after final 40ml insult. Typical measures for infant products, sizes Maxi, Maxi Plus, Junior and Extra Large include primary rewet after 100ml insult, secondary rewet after additional 50ml insult and tertiary rewet after final 50ml insult.

Typical measures for adult products include primary diffusion after 150ml insult, secondary diffusion after additional 150ml insult and tertiary diffusion after final 150ml insult.

Run Off:

Method for evaluating the surface characteristics and capability to acquire liquid of hygienic articles. The procedure consists of placing 10cm of an absorbent article on a 30 degree, dosing three times with 25 ml of 0.9% saline solution at ten minute intervals, and weighing any fluid which "runs off" the article.

SAP Content:

Method for determining the quantity of SAP in a hygienic article by the use of an ion specific determination, typically with a compact sodium ion meter.

SAP Placement & Dispersal:

Method for determining the placement & distribution of SAP in a hygienic article by staining with an aqueous dye solution, typically copper (II) sulphate and visually inspecting the stained article.

Product Dimensions & Weights:

Method for determining the size, shape and weight distribution of a product and its' individual components.

Elastic Tension:

Method for determining the percentage retraction of the leg elastics after being subjected to a load of 530g.