EXTRUSION COATING TECHNOLOGY
FOR THE IMAGING INDUSTRY

Company Background

Great Lakes Technologies, LLC was formed by the author in July, 1998 by the author to provide high quality specialty coated films, papers, and non-woven materials to for the imaging, industrial, release, automotive, and medical market segments. Equipped with a brand new, custom designed 72” (1.8m) Black Clawson co-extrusion coating line, in a very clean manufacturing environment, we are able to manufacture those products with the most stringent quality requirements. The company is an OEM of jumbo rolls of poly-coated film and paper for the graphic arts and digital imaging markets. Located in Central New York with convenient access to rail, sea, and trucking lines, Great Lakes is poised to become the new industry leader in specialty coated films and papers.

Evolution of Extrusion Coating Technology

Extrusion coating as we know it today was co-developed in 1949 in a co-operative effort by Frank W. Egan Machinery company, E.I. DuPont de Nemours & Company and the St. Regis Paper Company in Oswego, New York. The use and availability of polyethylene (LDPE) became widespread after the end of World War II, during which time LDPE was used almost exclusively for military applications such as wire coatings. The first application for LDPE coated paper was “locker” or butcher paper, which is still in use today. Shortly thereafter, milk packaging was converted from wax and vinyl coated cartons to LDPE coated paperboard. The 1950’s saw nearly two dozen extrusion coating lines installed solely for the purpose of manufacturing paper-based milk cartons. A schematic of the extrusion coating process is shown in Figure 1.

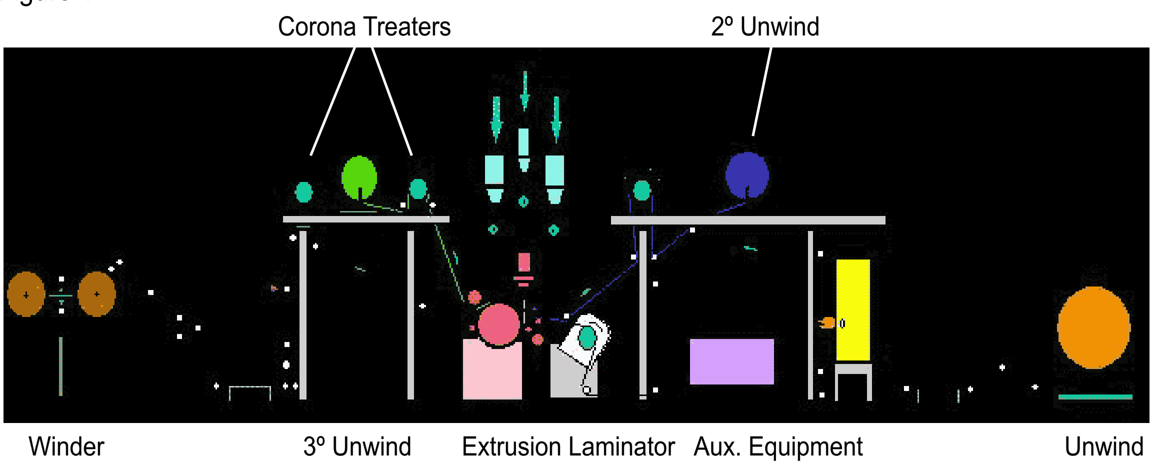


Figure 1. *Schematic Diagram of Extrusion Coating Process [1]*

As time went on, more and more applications for “poly coated” paper were conceived, such as sack or bag kraft, sachet packages and pouches, and various industrial and building applications. Time also saw the development of new polymeric materials, such as polypropylene, polyester, and many copolymers of polyethylene. This required equipment modifications, but also allowed new product development, and products such as release liners, “ovenable” board, advanced packaging and the like. In the early ‘70’s, Eastman Kodak developed a resin-coated base paper for use in photographic paper, thus shifting away from Baryta coatings. The “heart” of the process is shown in Figure 2.

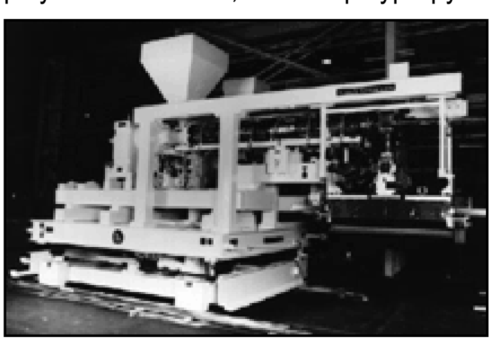


Figure 2. Extrusion Coating Carriage, *showing extruder and die [2]*

The ‘70’s saw the international oil crisis and the introduction of co-extrusion technology into the marketplace. Coextrusion is the simultaneous extrusion of more than one layer of plastic through a single die. Fueled by this crisis, many resin producers pushed the idea of co-extrusion as a method of reducing raw material costs for converters. The added side effect of coextrusion was the benefit of customer designing products with properties to meet end user requirements while minimizing cost. This technology produced many of the commonplace items in use today, such as packaging, labels, and the like.

The '70's also saw the introduction of beta gauges and automatic gauge control, whereby coating weight could be automatically controlled via computer feedback. Prior to this time, all adjustments were made manually, which quite often required long time periods for process stabilization, thereby increasing waste or reducing product quality. Figure 3 shows a state-of-the-art die design in use at Great Lakes Technologies. It is a Black Clawson designed short-die-land, internally-deckled die, which routinely produces a cross-direction coating weight profile variation of less than 5%. Another added advantage of this die design, which are now the industry standard, is reduced streaking. This is critical in high-quality, "optical" products such as photographic paper, digital imaging papers, thermal laminating film, and fabric transfer film. A schematic of this genre of die is shown in Figure 4.

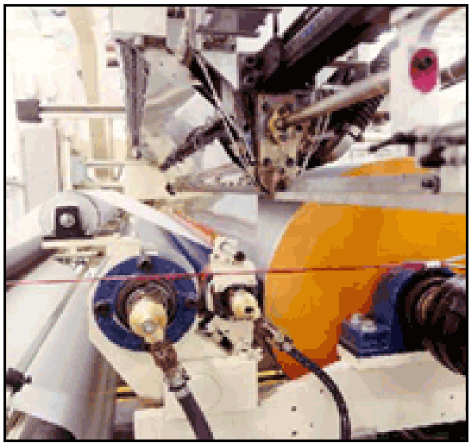
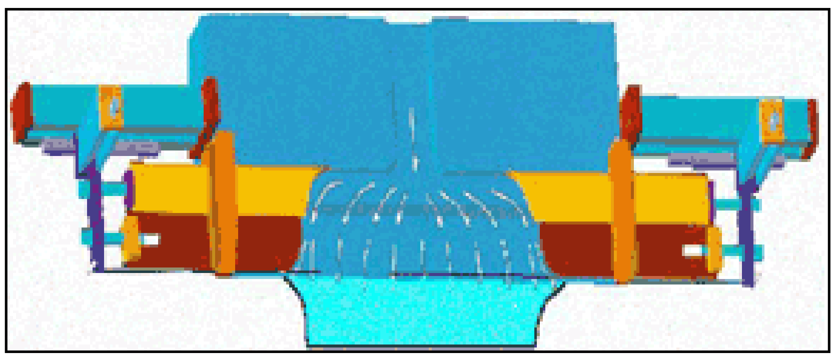


Figure 3 left is the extrusion lamination section of the extrusion coating line at Great Lakes Technologies. Here we can see the spreader roll leading into the nip section, the backup cooling roll, the nip (or pressure roll), the ozone applicator, the chill roll, and the extrusion die with molten polymer exiting the die. The combination of these variables, and the ability to manipulate these variables, is the core knowledge required to manufacture high quality resin coated base for the imaging industry. Here we can see a matte finish chill roll, which is typically used on the back side of resin coated ink jet base paper. That finish can be tailored to meet any specification required for an application.

Figure 4 below. *Schematic Diagram of an Internally Deckled Extrusion Coating Die [3]*



While the '80's and '90's saw refinements in coextrusion, die, and computer technologies, the hallmark of these two decades was resin development. Resin companies were now able to design polymers with the exact properties required or desired for a particular application. This spawned products and market segments, especially within the food packaging market.

Concurrently, the computer revolution permanently altered the way images were put to paper. While the early to mid-'90's saw a total photographic paper market size to be in excess of ten billion square feet growing about 2-3% annually, that market size today is roughly the same size, with growth coming from the digital imaging market. The digital imaging (frequently called "ink jet") product designs were segmented based on image quality and price. The higher quality product was a resin-coated paper similar in design to photographic paper, with the exception that a waterproof base was not required. [As an aside, the explosion of plain, high-quality ink-jet (non-resin coated) paper was not realized until the wet-strength additive was removed from the paper furnish.]

Modern extrusion coating lines have the capability of coating a wide variety of substrates with a wide variety and number of polymers having a variety of surface finishes. An array of adhesion promotion techniques are available, including corona treatment, flame treatment, chemical priming, and ozone priming, which allow the converter to supply the end user with the desired combination of substrate and coating required for the application. Computer feedback of gauge information from the beta gauge to the automatic die allows for very quick stabilization of cross machine direction coating weight control. Web tension settings are likewise monitored and controlled by computer to assure consistent roll quality. Stationary knife winders assure good roll starts and minimal waste due to foldover at the core. A coating station after the extrusion coating operation may be used if a top coating is required, but is often not necessary if proper resin selection and converting procedures are used.

While there are more than 225 extrusion coating lines in operation in the United States, only a half dozen or so lines can be said to be in a "clean" environment, and only one or two of these are actually situated in a "clean room type" environment. The benefits of such an arrangement are obvious, especially when taken in the context of imaging products. The photograph below shows an overview of the line at Great Lakes Technologies from the winder end. The room is positively pressurized with make-up air, and that make-up air is hospital-quality HEPA filtered air. In addition to the clean environment, numerous proprietary web-cleaning strategies are employed on the line to provide a completely dust-free surface. In fact, the techniques used on this line are identical to those used in the manufacture of X-Ray film, where defects on the surface are not tolerated. For example, there is perfect electrical continuity between the chill roll and the extrusion die, which minimizes any static charge, which can attract dust to the web. This represents the state-of-the-art technology in extrusion coating.

Market Size & Structure

There are many studies and reports on the size of the extrusion coating market in general, and the digital imaging market in particular. By far, the bulk of the ink jet market usage is on plain paper. While internal marketing surveys are proprietary, some generalizations can be made to put the "resin-coated ink-jet" market into perspective.

Ink Jet Ink
Receptive coating (sometimes with opacifier)
Face Side LDPE (typically with Pigment)
Raw Base Paper
Back Side HDPE
Gel-subbing

Figure 6. Typical Resin-Coated Ink-Jet Structure

Each extrusion coating line is capable of producing about 10,000 metric tons of product per year. This can vary widely depending on the speed, width, and basis weight run through each machine, but this figure is an accurate representation of the "average" output of each of the 225 extrusion coating lines in the United States. This equates to a total annual industry capacity of approximately 2,250,000 metric tons, or about five billion pounds of product, for an approximate value of six billion dollars. A similar capacity exists abroad.

Various marketing reports put the size of the annual, worldwide, resin-coated ink-jet market at 500-600 million square feet, which equates to approximately 8,000 metric tons of product. This represents less than one-third the output of a single, "optimally-designed" extrusion coating line. Our internal marketing data generally corroborates these numbers.

These products get to market via the following general scenario. An extrusion coater supplies the resin-coated base paper to a coater, who applies the receptive coating to the face side of the base paper. The coater can supply this semi-finished product to a distributor, who can either rewind in into wide format rolls for the professional market, or sheet it for the consumer cut-sheet market. Those coaters who perform this function are known as coater/distributors, who take the base directly from an extrusion coater and sell it directly to the end market. There are a limited number of each of these players in the United States, and really only two capable of producing high quality, industry standard resin-coated base sheets. Figure 6 shows a typical resin-coated ink-jet paper.

The structure shown in Figure 6 resembles a typical photo base paper. This is of course due to the fact that ink jet paper was born out of the traditional photographic paper market. Once the gel subbing used on the face side of photographic paper was replaced with a suitable ink-jet receptive layer, the resin-coated ink jet product commercially was born. While the quality requirements of an ink jet paper are not nearly as stringent as that of a photographic paper, they exceed the capability of all but the most skilled and equipped extrusion coaters in the world.

The purpose of the extrusion coating process is to transform the rough surface of the paper substrate (Figure 7A) into a smooth surface (Figure 7B), upon which a receptive layer can be coated. The smoothness levels achievable via extrusion coating are less than 10 Sheffield, or less than 1.0 rms.

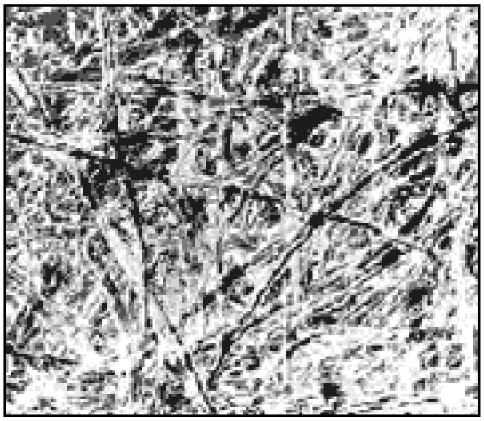


Figure 7A. Rough Paper Fiber Structure [4]

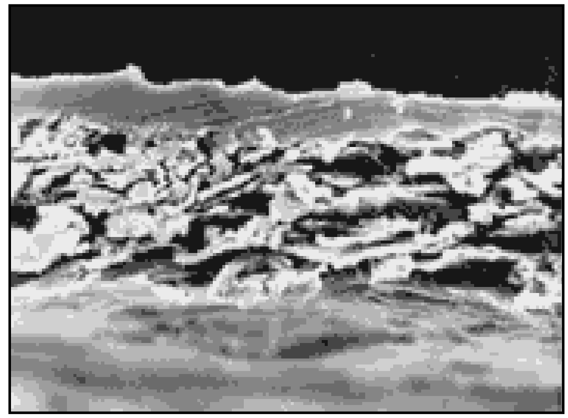


Figure 7B. Coated Surface of Extrusion coated paper[4]

Laminating & Adhesion Requirements

It is well known that a majority of the professional ink jet images (Figure 6) are over-laminated with thermal laminating film (Figure 8). This film is typically an oriented polyester (PET) film (Mylar™ is the most recognized tradename) coated with various amount of Ethylene Vinyl Acetate (EVA) resin. This is done for protection of the print, durability, stiffness, and to achieve desired gloss levels. The PET film is heat resistant and typically glossy while the EVA provides a clear, heat-activated lamination. As such, the laminating film must adhere to the high-value ink jet print so that a defect-free finish product is achieved.

Oriented Polyester film
Ethyiene Vinyl Acetate Adhesive

Figure 8. Typical Thermal Laminating Film Structure

There is a general misconception that laminating films, as well as receptive coatings, only adhere to gel-subbed surfaces. Gel subbing is a means by which to alter the surface chemistry to promote adhesion (see Figures 9A & 9B [4]). However, it is only one means by which to do so. The three traditional methods used in industry to alter the surface chemistry to improve adhesion are: 1) chemical priming; 2) corona treatment; and 3) flame treatment.

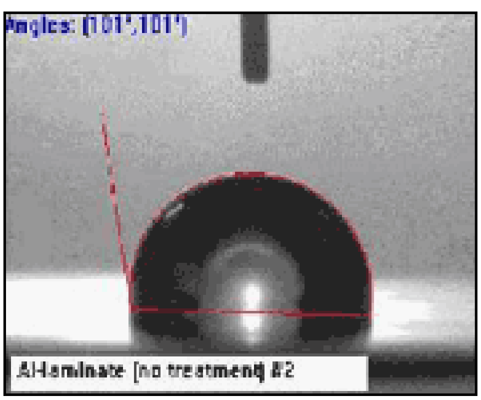


Figure 9A. Contact angle of a water droplet on an untreated surface. [5]

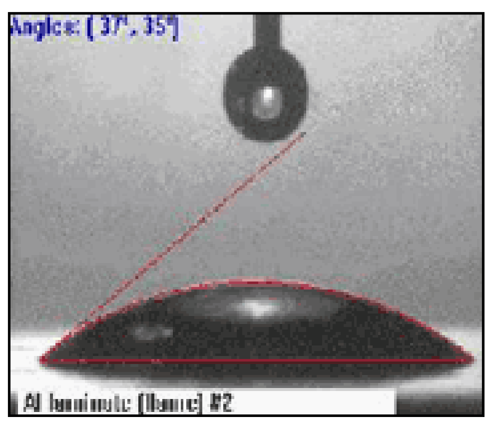


Figure 9B. contact angle of a water droplet on a treated surface. [5]

The principal purpose for any priming technique is to elevate the surface tension of the substrate to promote adhesion of a coating, such as an ink jet receptive layer, to the substrate, as shown in Figure 9. The method by which this is done is less relevant than the results achieved.

Equipment availability, the products being made, the local environmental laws, etc., determine which the suitability of the treatment method. Typically however, as long as the surface tension is raised to the level that allows the coating or adhesive to “wet-out”, satisfactory treatment has been achieved. The preferred method used industry wide today is corona treatment. This is true in the printing, coating, and extrusion coating industries. Figure 10 shows a close-up view of plasma arc generated during corona treating. The purple haze is the plasma created by the corona arc, which polarizes the surface of the substrate with many different chemical species, and actually alters the chemical make-up of the surface. These species, both polar and non-polar in nature, promote adhesion between the substrate and the liquid subsequently coated onto it.

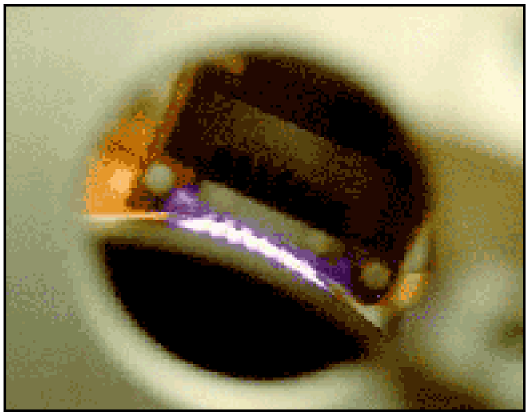


Figure 10. Close-Up of the Corona Arc Within a Corona Treating Unit (Courtesy PLC Technologies).

New Applications/Product Designs

Given the need to reduce cost and the desire to maintain product quality, new developments have opened heretofore unavailable options for the coater to explore. These options make use of new technology previously unused and untapped in the digital imaging market. These are:

- Coextrusion technology
- New resin technology
- Adhesion promotion technology
- Clean room technology

These technologies allow for 1) improved ink jet bases; 2) improved laminating film; and 3) improved fabric transfer films.

For example, adhesion of laminating films to plain paper is not problematic, as these materials have good chemical and physical adhesion properties to the EVA resin used in common laminating films. The traditional methods for ensuring adhesion of laminating films to resin coated papers are to:

1) Use no over-laminating film;
2) Laminate only the face side of the ink jet print; or
3) Treat the surface of the back-side of the resin coated ink jet substrate, via gel subbing

Modern techniques are available which offer the coater / printer more options than in the past. Among these new techniques, we offer:

1) Use of corona treatment as a primer;
2) Proper selection of layer or layers to achieve adhesion to the laminating film;
3) Proper selection of the laminating film to adhere to the back side of the ink jet print; or
4) Use a combination of all of the above to achieve a system approach.

The use of a system approach in the digital imaging market whereby the ink jet substrate, the receptive layer, the ink jet ink, and the laminating film work together in harmony offers the base paper supplier, coater, distributor, coater/distributor, OEM, and end user unique opportunities for future development and performance. It is possible to design a base paper with improved adhesion to a laminating film, and a laminating film with improved adhesion to a particular ink system or even a particular color of ink. Figure 11 shows a possible new resin coated base paper for evaluation, and Figure 12 shows a possible new laminating film for evaluation.

	Ink Jet Ink
	Rreceptive coating (sometimes with opacifier)
Coex Structure	Face Side LDPE, Layer 2 (w/or w/o Pigment)
	Face Side LDPE, Layer 1 (w/ or w/o Pigment)
	Raw Base Paper
Coex Structure	Back Side, Layer 1 HDPE or other
	Back Side, Layer 2 HDPE or other
	Corona treated Back Side

Figure 11. Possible New Resin-Coated Ink Jet Structure

	Oriented Polyester Film
Coex Structure	Ethylene Vinyl Acetate Adhesive, layer 1
	Receptive Layer modified EBA Adhesive, Layer 2

OR

	Oriented Polyester Film
Coex Structure	Ethylene Vinyl Acetate Adhesive, layer 1
	HDPE modified EVA Adhesive, Layer 2

Figure 12. Possible New Laminating Film Structures

The new base paper in Figure 11 can be optimized for adhesion to laminating film, curl, etc via selection of the appropriate material in the coextruded layers in the structure. Likewise, it is possible to tailor the composition of the laminating film to promote adhesion, for example, to difficult-to-adhere-to ink jet colors. This is proprietary patent-pending technology available from only one source.

Another growth market in the digital imaging market is the fabric transfer film market, aimed at high-end custom T-shirt design. This is a relatively established market, but the renewed vigor with which coaters are looking to supply this market is encouraging from both a business and technological perspective. These products are typically custom design blends of polymers with unique melting point properties. Some of these materials are pigmented, which poses another challenge to the extrusion coating converter. Many of products involve the use of a silicone release liner, which in and of itself is challenging for a high speed converters to handle.

Future Outlook

The new pricing structures of resin-coated papers have limited the profitability of these products to the point where it may not be viable for the extrusion coater to produce high quality products for the market, which will pose an interesting scenario. For example, the cost of new product development can easily exceed $500,000 (US). If quality levels are to be maintained, either only one or two suppliers will survive, or choose to survive, in this market segment. Another possible scenario is that a large coater distributor will emerge and choose to install their own dedicated extrusion coating line to supply their own needs.

The interesting fact is that this market, while apparently large at the surface, is not too large, and is actually small enough to be called a “specialty market”. Over the last five to seven years, there has been a lack of suppliers able to produce quality ink jet base papers upon which an ink jet receptive layer could then subsequently coated. As with many markets, this limited source of supply elevated the price of the resin-coated base paper. As competition at the coater/distributor level increased, finished prices decreased, and the desire for lower cost substrates or alternative products grew.

There being no alternative to the industry leader, coaters improved their processes and chemistry, and new, low-quality suppliers emerged. In some cases, product quality eroded and waste increased, but the desired result of reduced resin-coated base price was achieved. These actions also spawned the development of new, high-quality, non-resin-coated base papers. These new developments not only took advantage of the capital equipment installed at various producers, but also new technological developments which now competed directly with resin-coated papers. These new products, including micro-porous coated plain papers, when taken in combination with over-lamination, produce high quality finished prints which, from a moderate distance, appear to be “as good as” ink jet prints made from resin-coated base papers.

The outlook for digital imaging products in general remains strong, as the evolution of computer technology widens and gains acceptance. The question remains as to whether the growth of resin-coated ink jet-base market segment will grow as fast as the remainder of the market. The cost of the high-quality resin-coated base itself exceeds that of the finished price of the plain papers. The market itself will decide over the next few years if the image quality achieved with resin coated ink jet papers supports the price thereof. Again, as with any market, the likely outcome is that the resin coated market segment will achieve only a portion of the total ink jet market, and it is anyone’s guess what that might be.

The cost of entry of new extrusion coaters is prohibitive, so it is unlikely that many new suppliers will appear. The core competency exists in only two of the current suppliers to make the level of quality required for the digital imaging market. These things taken together imply that there will be two offerings in the resin-coated ink jet market: quality-based and price based. The coater/ distribution must decide if one or the other or both are incorporated into its market strategy.

Biography

Mr. Thomas Bezigian obtained a Bachelor of Science in Plastics Engineering from the University of Lowell and a Master of Business Administration from Bryant College. He has worked in various engineering and management capacities for Cryovac Division W.R. Grace, Mobil Chemical Plastics Division, Fortifiber Corporation, James River Corporation, and Schoeller Technical Papers. He served as an independent consultant to the extrusion coating, converting, and packaging industry for about ten years before starting his own specialty extrusion coating company. He is a frequent lecturer on the topic of extrusion coating and converting, and has written and presented many technical papers at TAPPI around the world. He was a contributing author of Polymer Processing column for the CONVERTING Magazine from 1991 to 1999. He is an adjunct professor of Plastics Engineering at the University of Massachusetts - Lowell. He is also the author of “The Extrusion Coating Manual”, the official publication of the Technical Association of the Pulp and Paper Industry on this subject. He is now the President and General Manager of Great Lakes Technologies, LLC in Liverpool, New York, a manufacturer of high quality specialty films and papers for use in industrial, printing, medical, and automotive markets.

Bibliography

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2) Ibid., p17
3) Ibid., p 57
4) Ibid., p 76-77
5) Ibid., p 95