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**HORIZONTAL APPLICATION  
OF TAPE SYSTEM (HATS)**

**A thesis submitted in partial  
fulfilment of the requirements for  
the degree of**

**Master of Technology  
In  
Engineering and Automation**

**Massey University  
Palmerston North, New Zealand**

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**2001 – 2002**

## **ABSTRACT**

The aim of this course of study was to design and construct a prototype for the automatic horizontal application of adhesive tape, in order to close cardboard cartons containing export meat product. This method of carton closure has been acknowledged as superior, by MAF and the NZ meat industry, to existing methods and it is anticipated that it will significantly reduce the incidence of meat shipments being returned to New Zealand due to evidence of tamper. Project work has been completed at Graphpak Services Limited – a small engineering business servicing the printing and packaging industries.

Key project objectives are identified as follows:

- Resurrection and observation of a historical prototype.
- Design, construction and testing of a hand held model head for testing and poof of function.
- Design, construction and testing of a rotary carton transport assembly.
- Design, construction and testing of a head mounting assembly.
- Design, construction and testing of a carton lidding assembly.
- Individual control systems design for each of the above.
- Integration of the above systems.

- Design of an overall modern multivariable control design model for the integrated system
- Prototype build.
- Commissioning and testing of prototype.

The project was undertaken in a modular fashion. The historical prototype was reconstructed and a new three step tape application process was identified as superior. A new hand held application head was designed, constructed and tested and the principle of operation has a patent pending.

A production model has been scoped and partially designed based on the hand held prototype and is yet to be built. This is to be integrated with a selected Rotary carton handling system that is partially designed.

Appropriate control systems have been identified for each part of the overall prototype and control models are yet to be developed as stand alone models for each module of the prototype. As testing proceeds, an overall modern multivariable control model will be developed and a production machine will be produced.

Other work has included:

- Funding applications for the project.
- Company infrastructure development for the project.
- Marketing of the Horizontal Application of Tape system (HATS).

While the overall project remains incomplete, this dissertation presents the development of the tape application head and the overall machine architecture that have been completed successfully.



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- Ministry of Agriculture and Forestry New Zealand (MAF).
- AFFCO New Zealand Limited.
- Charter Packaging Limited.
- Sellotape New Zealand Limited.
- MeatNZ limited.

## **1 Introduction**

Graphpak Services Limited (GSL) was established in 1981 to invent, engineer and deliver technology solutions and services to the printing and packaging industries throughout New Zealand. Servicing of any type of printing or packaging machinery occurs either on site, or at our workshop, by experienced and qualified staff.

Innovative systems and solutions are developed for problems and with consultation, knowledge and experience in the industry, we are able to source and supply the right machinery for the job. We also have the expertise to install and commission new machinery and integrate it with other or existing machinery. If suitable machinery doesn't exist, then (GSL) has the capacity to design and build this equipment using modern computer design techniques and a well-appointed workshop.

GSL has more than 20 years experience in packaging machinery including sales and service of strapping, taping, stapling and gluing machinery. So, 1992 GSL focused on a feasibility study for a horizontal taping machine with the intention of replacing the use of polypropylene strapping. Interest has been shown by both the primary produce processing sector and MAF, in the horizontally applied taping system (HATS) project over the course of study and market research. During this process GSL gave a full time commitment towards producing a prototype. It became evident that the company could not put all their resources into such an activity and there was a need for a party that could assist in providing the right technology and knowledge to make this project a success.

In 2001 technology in industry fellowship funding (TIFF) was applied for and a masterate student was employed to re-address the project in order to develop a production model.

## 1.1 Facts

Graphpak Services Limited is located in New Zealand's lower North Island at:

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Email: [graphpak\\_dsl@clear.net.nz](mailto:graphpak_dsl@clear.net.nz)

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Directors:

- John Bradley (Managing Director)
- Bob McIlhatton (Partner)

Staff:

- 2 Service & Production Engineers.
- Automation and Control Engineer.



## **1.2 Tamper Evidence**

The New Zealand meat export industry has recently been a victim of unscrupulous foreign operators removing meat product from cartons and repacking the cartons with counterfeit product. These cartons then proceed to the original destination where they may or may not be discovered to be counterfeit.

Due to lack of security no clear indication of this form of tampering has been provided causing recipients to reject shipments of New Zealand product based on, often unreasonable, suspicion of cartons being tampered with. Sometimes a container load of cartons is rejected on the basis of only a few cartons suffering some general handling damage. (See Appendix A.9 Pgs 80)

These shipments of meat are returned, at New Zealand's expense, and then redistributed on the domestic market!

Commonly, the various cuts of meat are loaded into cardboard cartons and a lid is strapped into place using polypropylene strapping material. Official Ministry of Agriculture and Forestry (MAF) adhesive labels are placed onto the carton, bridging the seam created between the lid and the base of the carton while also covering the strap that passes this juncture. This is the sole current means of providing evidence of tamper using this closure system.

There are pitfalls associated with this method of tamper evidence. These include

- MAF labels (seals) are vulnerable to rough handling often being damaged or partially removed by as much as only rubbing one box against another (often entire container loads of products are rejected based on this alone).

- Strapping the carton does not make for a rigid and uniform package causing the cartons to be difficult to handle and stack and increasing the risk of MAF seal damage.
- The strapping does not secure the lid to the base of the carton at the corners, which allows access to the contents of the carton at these points without disturbing the MAF seals.

### 1.3 Environmental

The Meat, Fish, Butter, Cheese and Fruit export industries are subject to environmental regulations to limit the use of non-recyclable or non-reusable packaging imported into Europe. By mid 1995 all European Community countries had some restriction on the use of non-recyclable materials present in packaging sent to the European Community. These materials include

- Polypropylene.
- Nylon and P.E.T. Straps.
- Hot melt adhesive.
- Plastic Liners.
- Metal Staples.

All the above incur punitive recycling fees **Recycling System** (RESY) because they require expensive processes to render them recyclable. (See Appendix A.3 Pgs 71).

These fees become a tariff barrier to our exports and there is major concern within the primary export industries that these barriers are a way in which the markets can get around the General Agreement on Tariffs and Trade (GATT) free trade accord, which allows free access for our New Zealand products but does not apply to the packaging. (See Appendix A.2 Pgs 69).



Currently most fish and meat cases exported from New Zealand are cardboard cases held together with polypropylene straps or hot melt adhesive. The company responsible for importing these cases into the European Community is expected to recover all the used cases and closures, separate out the polypropylene straps, liners or adhesives and recycle the materials separately. Therefore it is the closure method that attracts the highest Tariff (RESY).

There are other environmental issues involved with this method of closure including

1. The strapping system does not seal the closure and a plastic liner is introduced to seal the contents of the box to inhibit freezer burn and protect the board used for the carton from the inherently damp contents.
2. Strapping, hot melt glues, metal staples, board, and the plastic liner are incompatible in terms of recycling and require separation to be recycled effectively.
3. Strapping, when carelessly discarded, has a reputation as being an environmental hazard to wildlife. A scenario of a fishing boat sliding the loops of strap off a bait carton and tossing it over the side typically represents this. Marine animals often become entangled in these loops of strap that can ultimately cause the unnecessary death of these animals. Nor does the strap discriminate between an endangered or non-endangered species of animal.
4. The hot melt adhesive system of closure consumes larger amounts of energy and is relatively expensive.

Within the interests of our primary exports and extensive research on the subject - Graphpak have developed an alternative closure method that attracts the least amount of Tariff being applied.

#### 1.4 Principles

The tape is applied horizontally around the carton seam with the width of the tape applied evenly to the bottom side of the lid, the bottom edge of the lid and the adjacent side of the bottom of the carton as illustrated. (See Fig 1).

(Carton with applied tape)

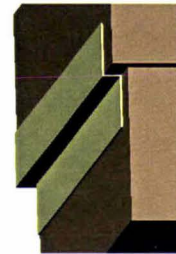


Figure 1

The proposed method of closure employing taping will produce a sealed package eliminating the need for polypropylene strapping and plastic liners, providing the board used to make the carton has an aqueous coating. The system will also improve recyclability as the two remaining substrates are cardboard and cellulose based tape. In terms of recycling, these are compatible with each other.

The structural integrity of a HATS closed carton is superior due to the inclusion/lamination of the lid as an integral part of the box.

If as is the case with strapping or gluing, the sides of the base of the box are unsupported then the sides are prone to buckling and bending when the full box is being handled. Under these circumstances, the neutral axis of bending is effectively within the base plane of the box and there will be minimal resistance to bending.

If the sides of the lid are HATS taped to the sides of the base, then the sides are less prone to buckling and the neutral axis of bending is effectively shifted halfway up the sides of the closed box. This gives the box a greatly improved second moment of area and an improved structural integrity.

Fish, venison, sheep meat, goat meat, fruit and vegetable packaging could also benefit from the new method – particularly with the improved structural

integrity of the package giving better protection to contents that could be easily bruised or damaged.

Palletizing, freezing, storage and shipping are greatly improved, as the package becomes brick.

Presently in New Zealand, there are approximately 700 polypropylene strapping machines being used by our various export sectors. It is anticipated at least one third of these machines will be ultimately replaced by an alternative method of case closure. Benefits of this method of closure as previously described are:

- The case becomes tamper evident.
- Improved structural integrity.
- Can be sealed to eliminate freezer burn without a plastic liner substrate.
- Conforms the shape of the carton to a uniform standard.
- Conforms to current requirements for recycling.

The principal of this type of closure is unique in as far as research at this time has shown throughout the world. While the relevant industries have an interest, this taping principal requires an appliance which, by the nature of the industries targeted, needs to be a versatile to cope with varying case sizes and types. Research has been carried out to quantify the design of an appliance incorporating variations for industry types. Because of the nature of the industries these machines will be utilised in, the design is simple and reliable, automatic and adaptable and be able to be serviced by in-house engineers.

It is foreseen that should New Zealand be successful in having product exported into key markets with this type of closure, the export potential of this system to countries such as Chile, Argentina, USA, Australia and other primary producing countries would be the next step after commercialisation.

## **1.5 Thesis Content**

The content of this thesis will focus on the following areas:

1. Analysis of the infrastructure of GSL and the difficulties in tackling a project of this nature and size and the identification and development of a sustainable solution.
2. Market research, literature research and development of the functional requirements to produce a machine that will effectively fill the need for a system of taping cases to meet the needs outlined.
3. The development and selection of a suitable overall conceptual mechanical model.
4. Development of the project plan.
5. Overall machine architecture, synopsis of operation and identification of suitable control system models.
6. Technical development of the tape application head and analysis of adhesive tape properties.
7. Identification of funding sources for the research and development (R&D) and the work undertaken to secure suitable funding.
8. Revision of the project progress at the conclusion of this TIFF period.

## **1.6 Planning**

Graphpak Services Limited (GSL) is a small engineering business servicing the printing and packaging industries. At the beginning of the masterate period, GSL staff consisted of two trade service engineers and the owner operator. The business operated out of workshop on Bennet Street in Palmerston North. The main workshop plant machinery consists of:

- Two lathes.
- Milling machine.



- Welding bay (Gas MIG and TIG).
- Sundry grinding and cutting machines.
- Sundry Hand tools and power tools.

The machinery listed enables GSL to manufacture most replacement parts required for maintenance and repair of printing and packaging machinery (often it is less expensive for Graphpak to manufacture a part than to source an original part). Repairs to machinery are undertaken both on-site and in-house.

One off design and build of machinery items are undertaken by Graphpak. Since the masterate has begun, these have included:

- One automated paper pick and place machine with pile lifter.
- One automated stapling machine for carton assembly.
- One die cutting machine for perforating hardboard containers for humblebee packaging.

These machines have been completed and are currently working well in their respective environments. The typical procedure for tackling these projects is ordered as follows:

1. Approach by customer for a solution.
2. Discussion between owner operator and customer to develop a concept solution.
3. Development of concept drawings, lead time and quote by owner operator for customer.
4. Go ahead from customer.

5. Discussion about and amendment of conceptual drawings to suit, with engineering staff at GSL.
6. Project is completed from concept, based on trial and error and the past collective engineering experience of the staff.

This procedure is effective in terms of a result for the customer but in all of the above mentioned cases, cost and lead time overruns have been evident. The cost overruns have been directly proportional to the lead time overruns exposing the initial engineering time estimates to be underestimated. The procedure however is still suitable for smaller projects and is useful and fast where engineering experience can be substituted for significant amount of research and planning. It leads to an individual or small business being able to forgo costly planning procedures (Draughting, project management, consultants, industrial design and etc.) and manufacture relatively simple, and sometimes quite complex, solutions to a problem.

Larger projects do require more formalised planning and a conclusion drawn here is that the above procedure should be rearranged to include item five: "Discussion about and amendment of conceptual drawings to suit, with engineering staff at GSL" before item three: "the development of concept drawings, lead time and quote by owner operator for customer" occurs. It would also be useful to develop a time line with, overrun buffers worked in, and to set goals and milestones for the project. The extent of the planning required is dependent on the complexity of the project.

### 1.7 The HATS project

The scale of the HATS project is acknowledged as large and there is little existing previously engineered technology available to bypass larger component assemblies of the machine development. Thus it is important that the infrastructure of GSL is adjusted to take advantage of up to date planning, design and management tools and to import a specialist skill base to complete the project. Work here has included:

- Identification of specialist skills required.
- Purchase of up to date computers.
- Networking of the computers.
- Introduction of:
  - Cad software.
  - Project management software.
  - Database spreadsheet and word processing software.
  - Internet enable software.
- Institution of systems for information management.

Consultation with potential customers.

To develop a machine, it must suit the environment that it will operate within. To assess the operating environment, visits to and consultation with various potential customers have served to help produce the list of functional requirements for the machine development. These potential customers are seen as part of New Zealand's meat exporting industry. The main players in this market are identified as Richmond's and Alliance, New Zealand's two largest meat exporters. However, the operation is mirrored in smaller

exporting companies such as Taylor Preston and Manawatu Beef Packers. The processes in these smaller companies are considered representative in terms of:

- Factory layouts and space available.
- Rates of product throughput.
- Hygiene requirements.
- Operating and maintenance requirements.
- Required reliability.

Manawatu beef packers have offered their facilities to GSL to use as a test bed for development of the closure system.

### **1.8 Consultation with MAF**

The proposed carton closure system has been outlined to MAF representatives and they have endorsed the closure system as a panacea to the tamper evidence problems the New Zealand meat export industry is experiencing. (See Appendix A.9 Pgs 80).

### **1.9 Potential market for the system**

This section clarifies the number of “20kg cartons of sheep and beef meat” (export product) to be closed for export annually and hence the required amount of adhesive tape.

Carton size will vary for different cuts and types of meat but the assumption has been made that spreading the annual tonnage of non carcass meat exported from New Zealand (NZ) into 20kg cartons will give a good conservative indication of the overall length of tape required to make these closures.



It is anticipated that initially 40% of the closures will be by the proposed taping method with this percentage increasing as time goes on.

These figures have been furnished by Meat NZ and AFFCO NZ Fielding. The Meat NZ figures are provisional and represent all sheep and beef product exports by all NZ exporters.

The AFFCO NZ Fielding figures are used to calculate the ratio of tape application machines to tonnes of sheep and beef meat, required to close export product.

It is acknowledged that the AFFCO Fielding plant, used as the model for this calculation, is a mid sized plant and many smaller plants throughout NZ will have a larger ratio of machines to tonnes of export product closed. Likewise fewer larger plants will have a lower ratio of machines to tonnes of export product closed. Thus the calculated 96 machines required for national export product closure is an absolute minimum figure.

However, the number of product closures remains the same requiring the same amount of tape regardless of the ratio of closure machines per tonne.

The amount of sheep and beef meat exported from NZ for the period Oct 2000 – Sept 2001 was 1,091,771 tonnes (provisional) consisting of 356,813 tonnes of sheep meat, 376,756 tonnes of sheep offal and 358,202 tonnes of beef meat including offal. 35,798 tonnes (representing 3.3% of total exports) of this is exported in carcass form leaving 1,055,973 tonnes of meat for export product closure by the proposed method.

Given that each export product closure requires 1.8m of adhesive tape, and that 1,055,973 tonnes equates to 52,798,650 export product closures, the resulting potential annual adhesive tape requirement is 95,037,570m or some 95,000km of tape annually. It is expected that 40% of this potential will be realized initially i.e. 38,000km of tape applied by 38 or more closure machines. These figures by MAF figures based on the number of carton seals allocated during the same year. Further study to clarify these figures, on a works by works basis, is currently underway. (See Appendix A.8 Pgs 78).

## 1.10 Current methods of carton closure

### 1.10.1 Current adhesive taping systems

#### Method outline

1. This system is used mainly to close RSC type cartons. These are identified by closure flaps both top and bottom that fold together to meet at the longitudinal centre line of the carton. The seams are then taped for closure.

Table 1 : Advantages and Disadvantages of Adhesive Taping Systems

Current Adhesive Taping Systems	
Advantages	Disadvantages
Environmentally friendly	Currently used only on level surfaces
Good carton structural integrity	Bottom closure seam is subject to failure
Extra substrate easily recycled	MAF seals are vulnerable and are easily damaged in transit.
	Erected flaps hinder carton loading

This method of closure is considered unsuitable for meat packaging as:

1. Carton structural integrity is poor with regard to meat product.
2. The erected flaps hinder carton loading.

The bottom carton closure seam is likely to fail due to the nature of the contents.

### 1.10.2 Hot Melt Gluing

#### *Method outline*

A bead of hot melt glue is applied to the lid flap or side of the carton. The lid flap is contacted with the side of the carton before the glue is cured and is held in position until the glue sets.

Table 2 Advantages and Disadvantages of Hot Melt Gluing

Hot melt gluing	
Advantages	Disadvantages
Environmentally friendly	High energy use to heat glue
Good carton structural integrity	Slow curing time
	Expensive system
	MAF seals are vulnerable and are easily damaged in transit.
	High maintenance and messy system
	Extra substrate to separate for recycling

### 1.10.3 Polypropylene Strapping

#### Method outline

The carton is filled and closed. To complete closure, four polypropylene straps are tightened around the carton (one each end and one each side), are heat sealed and released. Table X outlines key advantages and disadvantages for this method of closure.

Table 3 (Advantages and Disadvantages of Polypropylene Strap)

Polypropylene Strap	
Advantages	Disadvantages
High strength	Environmental issues
Useful for handling cartons	Cuts into carton
Inexpensive	Distorts carton
Simple to apply	MAF seals difficult to apply and are easily damaged in transit.
	Manual operation
	Extra substrate to separate for recycling

The three current systems closure addressed here are commonly used in the packaging industry. These closure methods have been investigated in order to make certain that they cannot be used or modified to achieve the same ends as the HATS project. The hot melt gluing and strapping systems fail to address the issues of tamper evidence and this alone precludes further development. The current system of taping closure applies to a type of carton that is widely considered unsuitable for the meat packaging industry and further development for this purpose is not useful. This system of closure may still use the specially marked tape for closure in other export packaging industries where the nature of the contents is suited to this type of carton.

#### **1.11 Objectives of the thesis study**

1. Identify a method of carton closure for the New Zealand meat export industry that offers security and tamper evidence that will significantly reduce the amount of export product that is returned, due to perceived evidence of tamper.
2. Analysis and development of GSL infrastructure according to the execution of the development of the carton closure project.
3. Design, specification and manufacture of a prototype carton closure machine.
4. Installation and commissioning of the prototype machine and development of a production model.

### **1.12 Summary of Thesis research outcomes**

A new system of carton closure has been identified that will significantly reduce the incidence of export product-shipments being returned to New Zealand due to evidence of tamper. The system is based on preliminary design ideas that have been identified and developed in consultation with MAF and the NZ meat processing industry. The basis of the system is the Horizontal Application of Tape System (HATS) to the seam, created between the lid and the base of a carton.

- This system precludes entry to the contents of the carton by way of delamination of the cartons surface upon removal of the tape (clear tamper evidence).
- It has the added advantage of being more robust, than other closure methods, under all handling conditions significantly reducing instances of perceived tamper.
- Recyclability of packaging substrate is significantly improved allowing increased compatibility with end markets and, subsequently, reduced costs to the NZ export industry.

MAF and the NZ meat industry have given approval in principal to the system and one major NZ meat exporter has formally ordered the installation of one such system for mid 2003. This will consist of a two prototype machines to swap in and out of production as assessments and modifications are made to the machines.

Design and specification has proceeded in a modular fashion. The head design was first proven by design and manufacture of a hand held application head. Documentation was prepared and a patent was applied for. This head has been used to demonstrate the HATS principle. A system model has been designed and awaits manufacture. This will incorporate a stand alone control

system to be later integrated into an overall modern multivariable control system for the complete production model of the machine.

Carton handling has been addressed and preliminary designs exist based on a rotary handling system. Again, this will incorporate a stand alone control system to be later integrated into an overall modern multivariable control system for the complete production model of the machine.

A prototype is yet to be built but the existing design material has been handed over to a facility in Finland with the infrastructure and in-house design and manufacturing ability to complete two prototype machines to meet the mid 2003 deadline for installation and testing.



## **2 Conceptual design and functional analysis of HATS**

### **2.1 Introduction**

This section lays out the functional requirements for the first 2 prototype HATS (Horizontally Applied Taping System) machines.

The HATS machine is intended to close cardboard cartons containing perishable NZ product for export markets. The initial market targeted is the sheep and beef meat industry. The prototype machine is being developed primarily to address this industry.

### **2.2 HATS Project**

The HATS project is to develop the first working prototype and install it into a meat processing chain. A second machine will also be assembled and used to swap out components in the first prototype. This will enable enhancements to be made without significant downtime being experienced.

#### *Machine dimensions*

- footprint < 1.5m x 2.0m.
- overall height < 3.0m.
- conveyer height >0.65m <1.15m.
- Machine will be able to horizontally apply tape a carton 0.525m long, 0.35m wide and 0.17m high.

#### *Machine electrical*

- Single phase, or three phase power input.

#### *Carton dimensions*

- The carton is two-piece (a separate lid and a separate base) or one piece with the lid hinged on one side.



- Board thickness ranges from 1.5mm to 9.0mm.
- Box and contents weigh no more than 30kg.
- Machine will be able to horizontally apply tape a carton 0.525m long, 0.35m wide and 0.17m high.

The machine will handle a range of different box sizes within a sub-range.

A number of different platen sizes will give the number of sub-ranges.

#### *Reliability*

- 1 closure fault / 70,000 cartons (i.e. 1/week).
- MTBF machine – 2,500 operating hours (i.e. 6 months).

#### *Machine Operating Speed*

- Machine to process < 15 boxes per min.
- Ave rate (@ 12 boxes/min.
- Continuous cycle <24 hrs/day duty.

#### *Materials*

- Must measure up to hygiene standards (no horizontal flat surfaces, easily able to be cleaned and etc).
- Machine to be covered for operator safety.
- Protective covers (High pressure wash down of machine likely).
- 308 grade stainless steel, plastics.

#### *Operation*

- Ergonomics: Appliance Like, Operator Friendly, Simple to operate.
- Operators manual.
- Current technology used.
- Electrically driven – 1 phase (if possible, no pneumatics).
- Machine to apply lids to cartons.

- Integrated feed and delivery system.
- Platen pressure forms carton shape.
- Aim for a carton seal that will minimize freezer burn and eliminate the need for plastic liners.
- Tear tab to be formed at end of tape for end user convenience.
- Acknowledged difficulty in taping around the corners leaving a neat finish.

#### *Service*

- Service manual.
- Parts manual.
- Accessible design.
- Uncluttered design.

#### *Functional Requirements for the Adhesive Tape in the HATS Project*

- A Pressure Sensitive Adhesive type tape.
- Have a width of  $< 60\text{mm}$ .
- Clear or coloured tape, thickness still to be decided.
- Be functional between from 20 to  $-26\text{ }^{\circ}\text{C}$ .
- Have security/ tamper evident features.
- A strong adhesive bond between tape and corrugated paperboard for airtight seal.
- Have suitable values of tensile strength and peel strength.
- Have a logo printed on the tape using suitable ink (position still to be decided), and a numbering system for traceability.

*Conceptual design and selection*

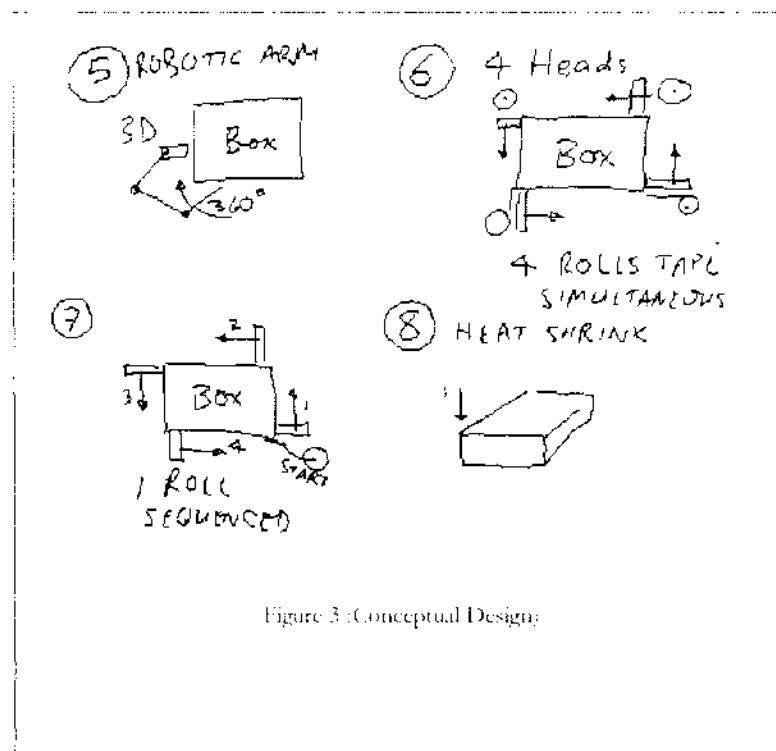
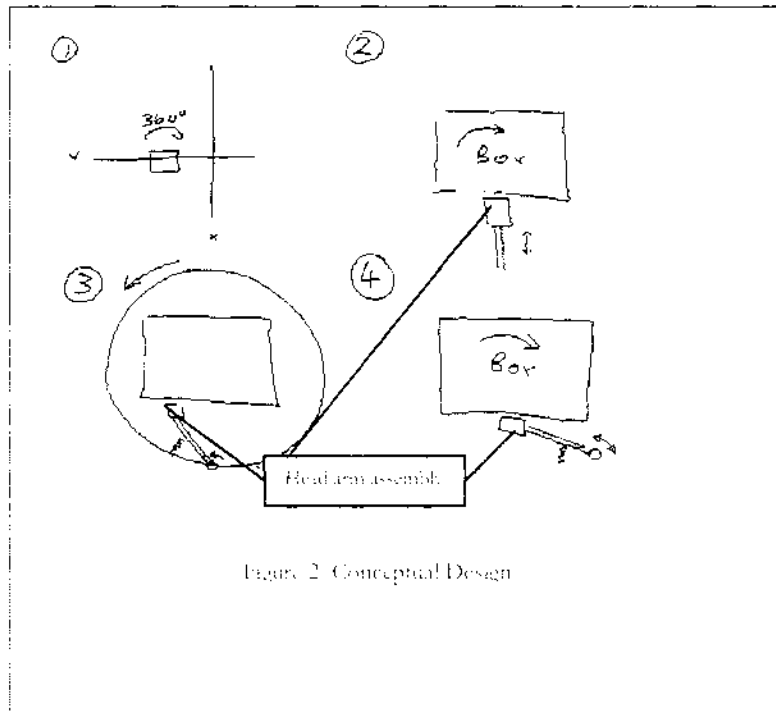


Table 1 (Outline of closure methods)

1 Swivel					
2 Rotate box with head on in/out arm					
3 Following arm for driving tape around box					
4 Mix of 2 & 3					
5 3D robotic hand					
6 4 heads 2x & 2y simultaneous					
7 4 heads one tape roll					
8 Heat shrink	No adhesive, recycle problems, temp?				
9 Clingfilm					

Closure systems were conceived according to the functional requirements.

Key areas of the functional requirements were chosen as criteria for assessing the value of the proposed closure systems.

Figures 2 and 3 illustrate the eight preferred closure systems developed. Table 1 gives a brief outline of each closure method and in addition, the cling film option (wrapping the carton entirely with cling film).

Table 2 scored the options according to the criteria given in the criteria given in column one. Table 3 applied weightings, given in the rank column, to the criteria scores given in table 2 (repeated here). The final scores in table 3 indicate the overall value of each closure system.

Table 2: High pressure closure systems

Items for comparison	Closure Methods									
	1	2	3	4	5	6	7	8	9	10
Cost										
Moving parts	4	4	4	4	2	1	1	2		
Tape handling	1	4	2	4	1	4	1	3		
Cable feed into feed	4	5	4	5	4	5	4	5		
Size height	5	4	3	4	5	3	3	5		
minimum horizontal surfaces	5	4	4	4	5	4	4	5		
Variable box size										
compression	5	4	5	4	5	5	5	2		
tape head	4	5	3	4	4	1	1	3		
Throughput	4	4	3	4	4	5	4	4		
Removing boxes	5	5	5	5	5	2	2	5		
Tape loading	1	5	5	5	1	2	3	3		
Integration with gating/compression	5	2	5	2	5	5	4	5		
Printer integration	2	4	4	4	2	1	4	1		
Ink loading	5	5	5	5	5	4	5	5		
Totals	50	55	52	54	48	42	41	48		
Scale 1-5	1 neg									
	3 neutral									
	5 Pos									

Table 3 (Applied weightings)

Items for comparison	Closure Methods								
	Rank	1	2	3	4	5	6	7	8
Cost									
Moving parts	5	20	20	20	20	10	5	5	10
Tape handling	3	5	20	10	20	5	20	5	15
Cable feed into feed	1	20	25	20	25	20	25	20	25
Size height	3	25	20	15	20	25	15	15	25
minimum horizontal surfaces	2	25	20	20	20	25	20	20	25
Variable box size									
compression	4	25	20	25	20	25	25	25	10
tape head	5	20	25	15	20	20	5	5	15
Throughput	4	20	20	15	20	20	25	20	20
Removing boxes	2	25	25	25	25	25	10	10	25
Tape loading	3	5	25	25	25	5	10	15	15
Integration with gating/compression	4	25	10	25	10	25	25	20	25
Printer integration	3	10	20	20	20	10	5	20	5
Ink loading	2	25	25	25	25	25	20	25	25
Totals		250	<b>275</b>	260	270	240	210	205	240

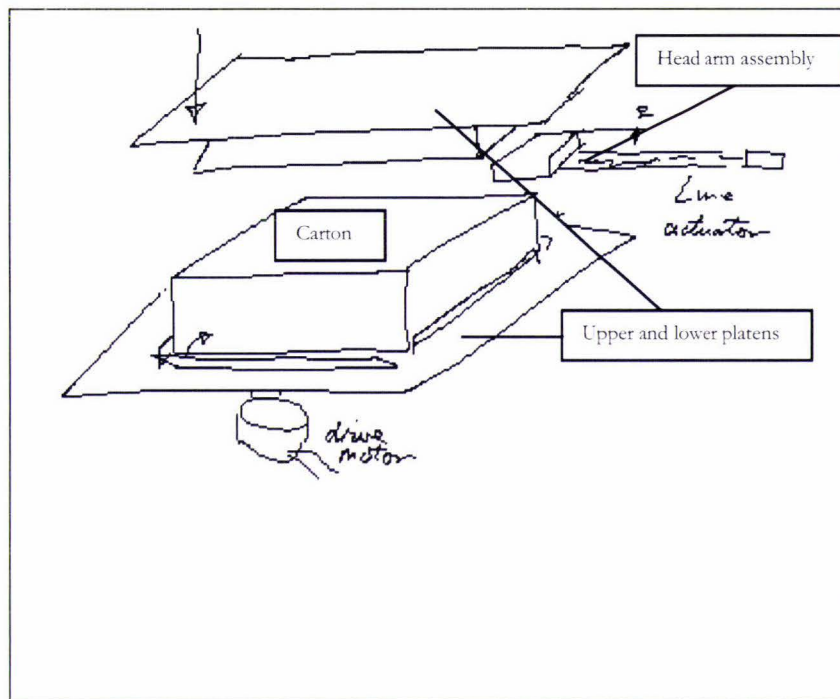


Figure 4 (Chosen conceptual design)

Figure 4 is a conceptual drawing of the elected carton taping system. The carton is rotated while the head is maintained in a relatively stationary position against the side of the box.

### 2.3 Project Plan

A copy of the project plan is included in the body of the thesis as it highlights the scale of this project and lists the key tasks and activities required to complete the project.

The plan was developed with the aid of a consultant project manager and has been useful in highlighting the benefits, to GSL, of the modern management tools available.

*Task Data*

Table 4

ID	Task Name	Duration	Start Date	Finish Date	Predecessors	Resource Names
1	<b>Machine Design</b>	42 days	Tue 29/10/02	Tue 24/12/02		
2	Overall machine architecture design	20 days	Tue 29/10/02	Sun 24/11/02		
3	Industrial Design	20 days	Wed 27/11/02	Tue 24/12/02		
4	<b>Platen Drive</b>	109 days	Fri 8/11/02	Tue 8/04/03		
5	Specify platen drive control system electronics	10 days	Fri 8/11/02	Thu 21/11/02		
6	Design platen drive control system	40 days	Wed 27/11/02	Tue 21/01/03		
7	Platen drive investigation (F&P, PDL)	20 days	Sun 24/11/02	Thu 19/12/02		
8	Design Carton compression unit including ladder	30 days	Thu 21/11/02	Tue 31/12/02		
9	Design feed delivery system	30 days	Sun 24/11/02	Thu 2/01/03		
10	Buffer 1	5 days	Fri 3/01/03	Thu 9/01/03	8,9	
11	Design platen system	30 days	Wed 15/01/03	Tue 25/02/03	10,2	



12	Prototype platen system	30 days	Wed 26/02/03	Tue 8/04/03	11	
13	<b>Operator Controls</b>	53 days	Fri 20/12/02	Tue 4/03/03		
14	Prototype operator control	40 days	Wed 25/12/02	Tue 18/02/03	3	
15	Define protocol specification	20 days	Wed 8/01/03	Tue 4/02/03		
16	Prototype protocol (bar coding, databasing, LAN etc)	20 days	Wed 5/02/03	Tue 4/03/03	15	
17	Design operator control system	5 days	Fri 20/12/02	Thu 26/12/02	2	
18	<b>Head/Arm Integration</b>	128 days	Mon 2/12/02	Wed 28/05/03		
19	Design head arm	40 days	Mon 2/12/02	Fri 24/01/03	2	
20	Build head/arm assembly prototype	30 days	Fri 31/01/03	Thu 13/03/03	19	
21	Test and modify tape tension system	30 days	Fri 21/02/03	Thu 3/04/03		
22	Prototype feed and delivery	30 days	Fri 21/02/03	Thu 3/04/03		
23	Design carton feed control system	5 days	Tue 4/03/03	Mon 10/03/03		
24	Build, test and modify platen drive control	20 days	Fri 21/02/03	Thu 20/03/03	6	
25	Buffer 2	30 days	Thu 17/04/03	Wed 28/05/03	16,14,20,21,22,23,24,12	
26	Second prototype head (milestone)	0 days	Wed 28/05/03	Wed 28/05/03	25	

27	<b>Final Assembly</b>	76 days	Wed 26/02/03	Wed 11/06/03		
28	Build prototype machine and mount head assembly	10 days	Thu 29/05/03	Wed 11/06/03	25	
29	Design machine cover (depends mainly on completed platen system prototype)	30 days	Wed 26/02/03	Tue 8/04/03	3	
30	Build prototype covers	20 days	Mon 14/04/03	Fri 9/05/03	29	
31	Second prototype machine (milestone)	0 days	Wed 11/06/03	Wed 11/06/03	28,30	
32	Prototype HATS machine final test review (Milestone)	0 days	Wed 11/06/03	Wed 11/06/03	30,28	
33	<b>Tape Development</b>	60 days	Mon 28/04/03	Fri 18/07/03		
34	Design tape splicing subsystem	40 days	Mon 28/04/03	Fri 20/06/03		
35	Prototype tape splicing subsystem	20 days	Mon 23/06/03	Fri 18/07/03	34	
36	Third Prototype machine (Milestone)	0 days	Fri 18/07/03	Fri 18/07/03	35	
37	<b>Documentation</b>	540 days	Wed 23/07/03	Tue 16/08/05	36	
38	Final revision drawings	40 days	Wed 23/07/03	Tue 16/09/03		
39	Service manuals	40 days	Mon 25/08/03	Fri 17/10/03		
40	Operator Manuals	40 days	Tue 23/09/03	Mon 17/11/03		

41	Thesis	300 days	Wed 23/06/04	Tue 16/08/05		
42	<b>Setup production facility</b>	127 days	Mon 3/11/03	Tue 27/04/04		
43	Research and determine facility requirements	30 days	Mon 3/11/03	Fri 12/12/03		
44	Design production layout	60 days	Mon 1/12/03	Fri 20/02/04	38	
45	Source materials and preferred suppliers	30 days	Mon 2/02/04	Fri 12/03/04		
46	Ascertain lead times etc	20 days	Mon 9/02/04	Fri 5/03/04		
47	Buffer3	32 days	Mon 15/03/04	Tue 27/04/04	45	
48	Full set of manuals and drawings (Milestone)	1 day	Wed 28/04/04	Wed 28/04/04	40,47	
49	<b>Begin Production</b>	60 days	Thu 29/04/04	Wed 21/07/04	48	
50	Setup production facility	60 days	Thu 29/04/04	Wed 21/07/04		
51	Action shipments	20 days	Tue 18/05/04	Mon 14/06/04		
52	First production appliance	1 day	Fri 9/07/04	Fri 9/07/04	51	

## 2.4 Synopsis of operation

- Filled carton is delivered onto the lower platen.
- Lower platen sides move into position and hold the filled carton.
- Pick and place moves the flat carton lid from the stack into position beneath the upper platen.
- Vacuum cups lower through the upper platen and attach to the lid.
- Vacuum cups retract with the lid attached.
- Lid sides are forced to conform to the upper platen profile during retraction (i.e. folded down).
- Upper platen and lid lowers to meet the top of the filled carton.
- Upper platen continues to lower until a set-point pressure is met.
- Taping head assembly is introduced to the side of the carton lid assembly.
- Taping head is attached to the end of a rodless cylinder.
- The rodless cylinder applies pressure to the side of the carton lid assembly, via the taping head, until a set-point pressure is met in the rodless cylinder.
- Set-point pressure is applied to the leading and trailing rollers of the head thus applying pressure to the carton. This pressure is less than the pressure applied by the rodless cylinder to maintain contact between the seam wheel and the carton.
- Start/cut-off/fold mechanism cycles and applies the end of the tape to the carton.
- Platen and carton assembly rotates until end of tape has passed beneath leading roller of tape head.
- Tension roller applies set-point tension to the tape between point of contact with the carton and the tension roller.



- Tension is less than will lift the leading roller from contact with the carton.
- Platen and carton assembly continues to rotate until the tape application overlaps the initial contact point of the tape and carton (some 370 degrees).
- Rotation is controlled to slow for the carton corners due to the larger radius from the axis of rotation.
- Tape tension is removed.
- Start/cut-off/fold mechanism cycles and cuts of and folds the carton end of the tape.
- Start/cut-off/fold mechanism retains the roll end of the tape for start of next cycle.
- Carton platen assembly rotates in order to buff down the end of the taping.
- Roller pressure is removed (rollers return to retracted or home position).
- Head arm assembly retracts away from the carton.
- Platen/carton assembly rotates to delivery position.
- Taped carton is delivered to conveyance.
- During the entire cycle, a tape feed roller feeds tape from the roll to a pre-tensioned dancing roller tape buffer system. This provides a buffer of tape quantity for the next taping cycle eliminating the need for direct peel of tape from the roll as the taping cycle occurs.
- The next carton is fed and the taping cycle begins again.

## 2.5 Overall control detail

### *Tape application head*

- Roller pressure is applied to either roller independently.
- Each roller is fixed to the end of an arm.
- Axes of rotation of the arms are driven by electric motors, via gears, operating in torque mode or by a lever /spring system for early less precise control.
- Set-point pressure is calculated from the current flowing through the motor (directly proportional to torque).
- Head floats about an axis laterally providing parallel orientation of the arms to the sides of the carton thus the roller pressure is controlled with a high degree of precision.
- Independent control of roller pressure is used to maintain parallel orientation.
- Cartons size is known therefore predictive control can be used here.
- Angle of the seam wheel contact point to the carton seam needs quantifying.

### *Tape head Start/cut-off/fold mechanism control detail*

- Mechanism consists of three vacuum pads.
- Two fixed and one hinged.
- One mount for the pads.
- One knife.
- Chassis.



- Guide roller.
- Two control actuators (electric motors).
- Vacuum source and switching.
- The pad mount rotates from an axis at the taping head end enabling contact with the side of the carton.
- The guide roller moves with the pad mount assembly (having two positions relative to this datum).
  - Position 1: maintaining a clearance between the tape and the pads during the taping cycle.
  - Position 2: removing the clearance during the Start/cut-off/fold cycles.
- The pad mount is operated by an electric motor rotating once for each cycle.
- The knife is fixed to the chassis, which, in turn, is fixed in relation to the pad mount assembly.
- The single pad is mounted at the maximum radius from the axis of rotation.
  - As the taping cycle occurs, the pad with vacuum applied is holding the end of the tape and the pad arm rotation cycle introduces the tape to the carton.
  - The tape is released by the pad (vacuum switched off) and the locating roller moves into clearance position.
- The other two pads serve to fold the end of the tape providing a “tear Tab” for end-user tape removal.
  - The pad closest to the axis of rotation is fixed in relation to the pad arm.
  - The other pad is hinged to the first allowing 180 degrees around the hinge axis thus folding the tape back onto itself
  - The hinged pad is rotated by means of a small electric motor and crank assembly passing through one revolution for a folding cycle.

- Before the folding cycle begins
  - The locating roller moves to the no clearance position.
  - Vacuum is applied to all three pads securely holding the tape.
  - The pad arm assembly cycles exposing the fixed knife between the single pad and the hinged pad and cutting the tape at this point.
  - Immediately the tape is cut, the folding cycle is begun.
  - Upon completion of the folding cycle, the vacuum to the hinged pads is switched off and the tape is released.
  - The vacuum to the single pad is maintained until the next taping cycle has begun.

*Tension control: (Independent PID fast)*

- Consists of a knurled plastic roller.
- Contact with adhesive side of tape.
- 180 degrees angle of lap for minimal slippage.
- Torque applied by roller applies tension to tape.
- Torque applied to roller by electric motor running in torque mode.
- Tension control is by way of varying current to motor to maintain a current set-point (calculated to required torque and resultant tension).
- As current deviations, due to fluctuations in speed of tape application, from the set-point are measured, PID or similar control is implemented to return the current to set-point.
- Tension set-point is altered to compensate for reduced tension requirement during feed, delivery and start/cut-off/fold cycles.

*Tape feed (Independent Feedback on/ off or bang bang)*

- Another Knurled roller to strip tape from the roll in preparation for the impending taping cycle.
- Maintains a fully loaded dancing roller system.
- Ramp up and ramp down.
- Some dead band for switching on and off.
- Switch off when dancing roller system is full.
- Switch on when dancing roller system is half empty.

*Arm control and head/ arm integration*

- The arm consists of mounted guided rodless pneumatic cylinder.
- This is a simple prismatic joint of 1 degree of freedom.
- The head assembly is pin-jointed laterally to the end of this arm.
- The arm provides a set-point force linearly along the axis of operation.
- Uses regulated air pressure.
- Precision control around the set-point is deemed only adequate for the specification of the machine in terms of tape application. For more precise application, faster actuation is required. Other linear actuators should be considered.
- The arm will contain position sensing for feedback to the platen rotation control system.
- Arm mounted to upper platen carrier assembly. Datum set by upper platen vertical position – therefore the head will be aligned to the lower edge of the lid side.

### *Platen control*

- On/off bang bang control for lower platen gates to be synchronized with feed and delivery.
- Bang bang control for lid handling into upper platen.
- PID control around set-point pressure to be applied by upper platen to carton/lower platen assembly.
- Upper actuator applies vertical pressure.
- Lower platen provides actuator for gates and rotation.
- Upper platen rotates freely in sympathy with the lower platen.
- Lower platen rotation control by PID. Set-point - circumferential speed of carton calculated from radius of head sensed from position sensor on arm.
- One cycle complete after backing up to 360 degrees from a 380-degree rotation. Adjustable parameters here in the interest of optimizing tape consumption.

### *Lid Handling*

- Typical pick and place unit with pile lifter for lid supply.
- Synchronized with system.
- Sensor to sense returned or home position for rest of cycle to begin.
- Low lid stack sensor.
- Failsafe stop for no lid pickup.

## 2.6 Summary

It is again concluded here that due to the nature and size of the project, that design and build should take a modular approach. Each module will be addressed in turn with proprietary programmable logic controllers (PLC's) used for prototyping and testing. The final stage in the development of the full production model will include the institution of an overall 'control model' for the machine. This will be a significant development in itself.



## *Chapter 3*

### **3 Analysis and design of the tape applying head mechanism**

#### **3.1 Evaluation of Historical Prototype**

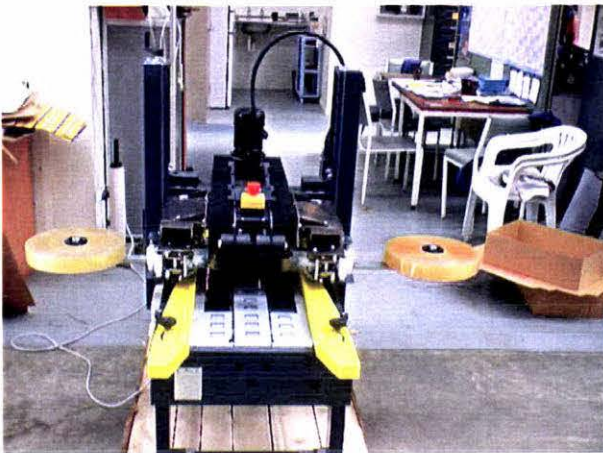


Figure 5 (Historical prototype)

The original prototype consisted of a conceptual drawing of the machine and drawings for the annular ring roller and a deforming shoe. The annular ring roller and deforming shoe system was the subject of the original patent for the taping system.

Two significant alterations were made to a SIAT taping machine (see figs 5 & 6) to demonstrate the effectiveness of the new taping system. Firstly; mounts were constructed in order to mount the existing taping heads horizontally on both sides



Figure 6 (Operating)

of the machine instead of vertically top and bottom. Secondly: the deforming



shoe and the annular ring roller were mounted in place of the buffing roller within the head.

The tape was first stretched, beyond yield stress, by the deforming shoe along the longitudinal axis on the seam line. This resulted in a stretched area of tape that was buffed into the lip area of the carton/lid assembly by the annular ring roller. The deforming shoe overcomes the difficulty of the tape bridging the contour between the lower edge of the lid and the base of the carton. It is observed here that weakening of the tape, due to the deformation, occurs in this region resulting in reduced structural integrity of the package.

The annular ring roller consists of three basic parts mounted on an axle. (See fig 7)

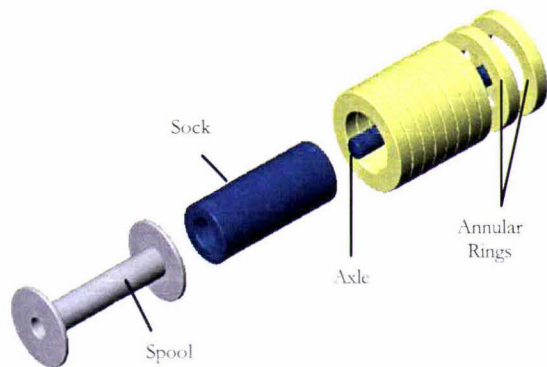


Figure 7 (Annular ring roller exploded)

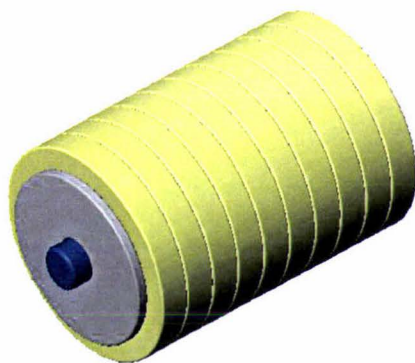


Figure 8 (Collapsed)

A soft foam nitrile rubber sock, (See appendix A.10 Pgs 83) is mounted over the rigid plastic spool with the annular rings (rigid plastic) mounted over the sock. This assembly uses the axle to mount to the carrying arm that is, in turn, mounted to the head. (See fig. 8)

Each annular ring roller is able to move independently of the others thus the roller is able to track the contour of the seam where the bottom of the lid meets the base of the carton (see fig 9). This annular ring roller was the core component of the new taping system and remains the most effective method of negotiating the contour of the seam. It is necessary to buff the

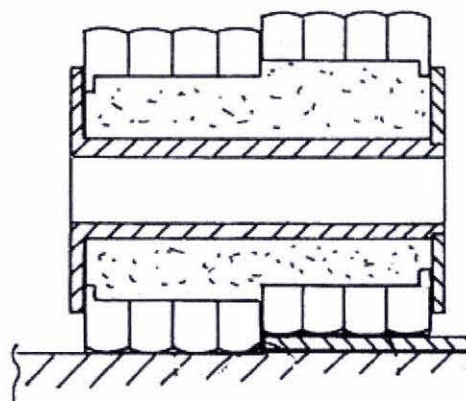


Figure 9 (Operation of roller)

tape after the application in order to ensure that the adhesive has made thorough contact with the carton substrate and the adhesive curing process can occur.

The overall system poses one significant problem. The system is only able to tape two sides of the carton simultaneously. To tape the two remaining sides, the system must either be reset for the orthogonal side dimensions of the carton and the carton is passed through the machine a second time. Or a second machine is introduced subsequent to the first, orthogonally, and the carton passes through both to complete taping on all sides.

An inherent problem with the first option is constant resetting of the machine to complete taping of predominantly rectangular cartons in current use. It also requires the carton to be reloaded into the machine resulting in excessive handling of the carton. The speed at which the cartons are required to be taped (15 per minute) immediately precludes the pursuit of this option.

The second option results in machinery with a footprint too big to fit within production lines.

It was concluded that this system was unsuitable for most situations due to excessive floor space requirements, but is still useful for demonstrating the principles of the system.

Furthermore, weakening of the tape occurs due to the deformation by the shoe. This reduces the structural integrity of the package. It also causes deformation of the print on printed tape.

### **3.2 The functional requirements for the head**

Based on the overall machine architecture and the finished package requirements, the following functional requirements were developed for the head:

- The head must apply tape continuously around the corners of the carton due to the rotation of the carton.
- Tape tension at the point of application to be precisely controlled.
- Tape is to be cut off and folded at the end of the cycle to give a tab to aid in removal of the tape by the end user.
- The head must track the seam to be taped precisely – a datum will be set to the upper surface of the lid of the carton through the head/arm integration.
- Heated ionised air is to be used to remove moisture and warm the surface to be taped; therefore room for an air nozzle is to be included in the design. This also serves to reduce static electricity build-up.
- Tape to be used is  $\leq 70\text{mm}$  wide.
- Design must use current technology.
- Uncluttered design.
- Rate of application of tape  $< 15$  cartons per minute.

- The tape must have an effective adhesion rate of  $> 95\%$ .

### **3.3 The three step tape application process**

This process was conceived to overcome the weakening of the tape by the deforming shoe. The process is as follows:

1. The tape is first applied to the side of the lid of the carton.
2. It is then folded under the lip at the bottom edge of the lid.
3. It is then applied to the side of the base of the carton completing the joint.

This system could be reversed i.e.

1. The tape is first applied to the side of the base of the carton.
2. It is then folded under the lip at the bottom edge of the lid.
3. It is then applied to the side of the lid of the carton completing the joint.

The leading application roller would be required to track the underside of the lip introducing a further unnecessary control parameter. The given sequence allows a less precise degree of control than is required by the seam wheel and will therefore remain within the required constraints.



### 3.4 Rotating the carton

Due to the constraints regarding the footprint of the machine, (1m x 2m) it was concluded that the carton should either remain stationary with the application head moving around the carton or the carton should rotate with the head mounted with a degree of freedom to negotiate the change of radius of the rectangular package due to the rotation.

Various models were considered (refer to figures 2, 3 & 4; Pgs. 23 & 27) and the model selected consists of an arm with one degree of freedom, maintaining application head pressure to the side of the carton during rotation through 380° providing an overlap of tape at the start/finish of the taping process. It is also noted that the circumferential velocity of the carton will also vary given a constant rotational velocity. This is due to the rectangular shape of the carton and the changing radius.

The dynamics of the head must adapt to this feature or the rotational velocity of the carton must change to accommodate the limitations of a simplified head. Stepper motors are freely available and are well suited to driving carton rotation. A suitable stepper motor can be supplied and the assumption has been made that rotational velocity will be precisely controlled to accommodate any design limitations of the head. This simplifies the design of the head significantly allowing the use of more commonly available elements within design.

It is also observed that time must be allowed for feed and delivery, to and from, the taping section of the overall process. The rate of the cycle is given at 15 cartons per minute. Observation of existing tape systems indicate that rates of tape peel from the tape roll, acceleration of tape peel and static electricity generated will present no problem. The assumption has been made that only 50% ( $60\text{s}/15\text{cartons} = 4\text{ s pr carton}$ ) of the overall cycle time is available for the taping part of the cycle.

Thus a typical carton with a taped circumference of 1.8m requires that the tape be applied in two seconds or less. This gives a linear application rate of 0.9m/s. This rate is well below linear rates observed in tape manufacture at the Sellotape factory and observation of current taping systems. If problems should arise, a second head is easily included into the overall machine architecture, 180° to the first, and it will effectively halve the linear application rate.

It is concluded here that the given rate of application will pose no problem with the identified system dynamics.

### **3.5 Application of pressure by head components**

Four existing taping heads (two Siat and two 3M Accuglide) were selected and the pressure applied by the rollers was measured using a spring balance scale. The pressure is applied by a single spring that operates both the leading and trailing rollers by means of a lever system. As the two rollers operate using a common spring, the measured pressure reflects the pressure applied by the rollers as a pair.

As the torque arms of the lever system change (due to rotation) so to does the tension in the spring as it is extended. The spring (with part number and supplied by the head manufacturers) constant is matched with the torque arm characteristics to provide a constant pressure by the rollers in all positions during operation.

The pressures measured (orthogonal to the carton surface) ranged from 1.5kg to 3.75kg and it was concluded that this range of pressures would be used in the new design. (See Appendix A.5 Pgs 75). All these heads tested were fully operational and the assumption was made here that the variation in pressure application was due to varying states of spring fatigue and general wear and tear on the mechanism.



Three methods of pressure application were considered for the new head:

- 1) By rotary solenoid via a geared or belt driven system. This had advantages of;
  - a. a high degree of control precision allowing a very high degree of accuracy in tracking the cartons surface at speed. This is due to the direct application of electrical control for actuation.
  - b. escaping the use of a relatively complex lever system to overcome torque changes due to rotation and provides constant pressure at the point of application.

- 2) By the existing spring system.

This method was seen as less than ideal due to the gradual fatigue and eventual failure of the spring. This results in imprecise pressure application and difficulty with the integration of the head and arm. It has also been observed that during regular existing head servicing that the spring requires replacement at intervals less than that set in the mean time before failure (MTBF), 2500 hours, as laid out in the functional requirements.

- 3) By pneumatics.

This system comprises a small linear pneumatic actuator supplied by an air reservoir large enough to minimise pressure changes due to the volume change as the actuator extends and retracts. This pressure change is easily kept within the limits measured in the spring operated systems. The system is compact and the air reservoir can be mounted remotely. Pressure is conveniently preset by regulator adjustment and remains relatively (when compared to the spring system) constant throughout the cycle.

### 3.5.1 *Calculation of leading and trailing roller pressures and overall application head pressure*

Leading and trailing roller pressures measured from existing head technology:

- 2.5kg or 10N.
- Torque arms for both leading and trailing rollers 0.046m.
- Torque = force x distance

$$\Rightarrow 1.127 \text{ Nm} = 24.5\text{N} \times 0.046\text{m}.$$

- Reaction speed of roller with respect to carton surface undulation during tape application:

- Max linear application rate = 0.85m/s.
- Tangential velocity ( $V_{\text{tan}}$ ) of the roller at the end of the torque arm to match linear application rate. I.e. 0.85m/s.  
Convert to rotational velocity ( $\omega$ ):

$$\blacksquare \quad \omega = \frac{V_{\text{tan}}}{r} = \frac{0.85}{0.046} = 18.48_{\text{rad/s}}$$

- Power required for roller pressure actuation

$$\circ \quad P = T \times \omega = 1.127 \times 18.48 = 20.83\text{W}.$$

One rotary electric actuator @30W operating through an electrically controlled particle clutch geared to both inner pivots of the torque arms will produce the required roller pressures to activate the tape adhesive. (See Appendix A.6 Pgs 75, 76).

### 3.5.2 Range of motion of torque arms and rollers

Continuous negotiation of the carton corners immediately precludes the use of existing head designs in this system. The rotating system requires that the head be starting to tape the next side of the carton as the previous corner is being completed. With existing systems, the corner is the finishing point of

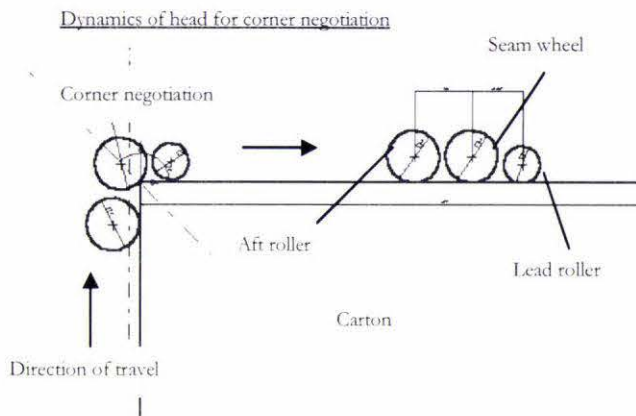


Figure 10 (Head dynamics)

the taping process and the leading application rollers are not required beyond this point. It is therefore necessary that all of the components of the head (in contact with the carton) tape to contact it with the carton, and must do so continuously throughout the taping cycle. (See fig 10).

Fig 11 shows the arm positions while the head is taping the flat side of the carton.

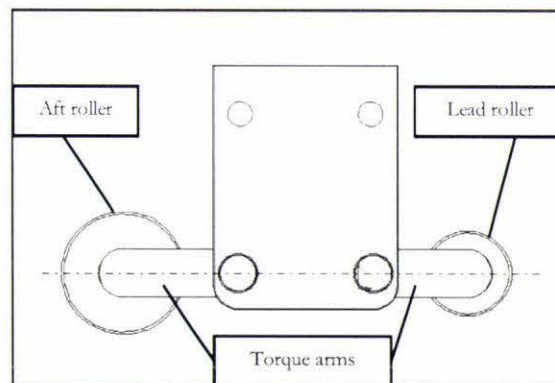


Figure 11 (Head dynamics)

Fig 12 indicate the arm and roller positions at the point where the corner taping occurs

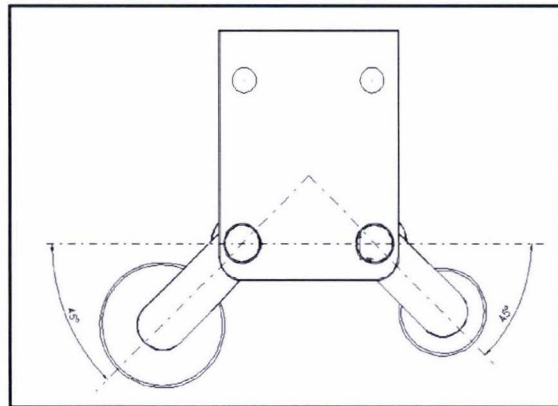


Figure 12 (Head dynamics)

### 3.5.3 Tape tension control

Tape tension control was initially determined as a component of the head. Due to the decrease in size (radius and circumference) of the tape roll during use, significant changes occur in both torque and rotational speed of the roll during tape removal. This results in a gradual increase in tape tension as roll size decreases when the tape is supplied directly from the roll to the head. To keep the tension constant, the tape should be supplied to a fixed dancing roller system independent of the head. This allows head movement independent of the tape supply system while maintaining constant tape tension.

The dancing roller system (See Appendix A.4 Pgs 73, 74) also contains a buffer of tape that can be refilled during the non taping part of the cycle. An electric motor with a knurled roller to remove the tape from the roll is used to feed the dancing roller system keeping it within determined boundary's using on/off control triggered by measuring the amount of tape in the buffer. It also provides the necessary buffer for movement by the head with respect to the tape supply.

It is concluded here that in interests of maintaining a lightweight and compact head, that this system will be included as part of the tape supply and magazine system. Apart from determining the overall machine architecture, this module is a subject of further study.



### 3.6 Hand held applicator

To prove the patent and demonstrate the “Three step process” a manual hand held demonstrator was developed. The demonstrator (see fig 13) consists of:

- A leading guide roller (1) feeds the tape to the application components and maintains even removal of the tape from the roll.
- An application roller (2), to apply the tape to the lid of the carton.

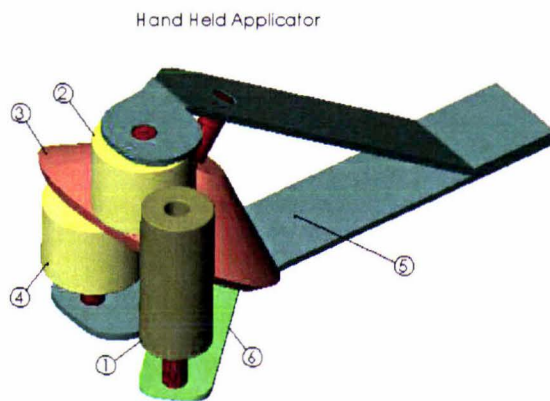


Figure 13

- The seam wheel (3), to fold the tape under the lip of the lid,
- A following roller (4), to apply the tape to the side of the base of the carton.

These components are mounted on a one piece bracket (5) incorporating a handle and a tape dispenser (not shown). The leading guide roller (1) is mounted on a spring loaded arm (6), to absorb any shock caused by a sudden take-up of tape due to a sudden change in taping speed.

The conical seam wheel (3) was developed in the interests of the compactness required with a hand-held model, and allows rollers (2) and (4) to be mounted in close proximity with the seam wheel.



Figure 14 (Hand Held Applicator)

All the parts were manufactured on site at GSL. Some of these parts have been modified due to shop floor constraints and the finished demonstrator appears as in fig 14. Trials have proved that the three step application process is effective.

### 3.7 Production head development

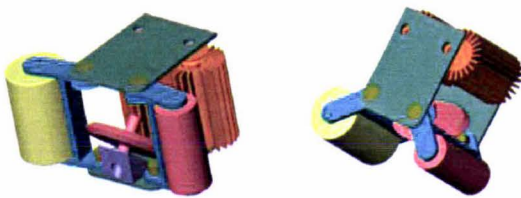


Figure 15 (Production Head)

The production head has less restriction on compactness than the hand held model. The conical seam wheel was dispensed with and the leading and trailing rollers were placed

fore and aft, respectively. Both rollers are able to accommodate the full width of the tape and are mounted on swinging arms to aid negotiation of the corners. Two positions are shown in fig 15. This allows the head to negotiate the corners of the carton. It can also be seen here the modifications that were made to simplify the seam wheel.

The finned devices at the rear of the assembly are intended as rotary solenoids that drive the roller arms to apply the required pressure to the tape. These are shown with a pulley system for power transmission to the arms. A 1:1 gear ratio driven system is a superior alternative system. The arms are limited in their rotation by stops at the extremes of required travel.

The application of force is preset and calculated from a measurement of current flowing through the solenoids. This opens the door to extremely precise and fast electronic control of roller pressure. This will also allow for precise stretching of the tape to neaten the corners as they are taped. However, these rotary solenoids were unable to be specified and it was



concluded that the untidy corners were insignificant in terms of the 95% adhesion rate required. The system also overcomes the complexities of a lever system with its inherent torque variation due to the changes in the moment arm during rotation.

A known available single pneumatic rotary actuator will be specified as a replacement. This will be geared to both arms and will be driven from a compressed air reservoir to provide a constant pressure at all roller arm angles. The roller arms will each mirror the other in position and maintain the operating surface of the head, orthogonal to all points along the relevant sides and corners of the carton throughout the taping cycle.

#### *Tape cut-off and fold mechanism*

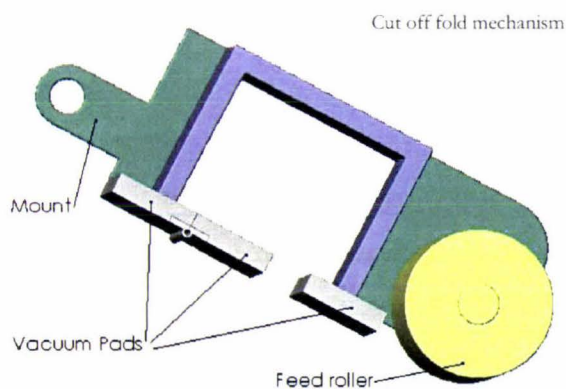


Figure 16

The final stage of the taping cycle requires the tape to be cut and the end to be folded in order to give a tear tab for the end user to remove the tape. The system developed is shown in fig 16. The tape passes around the

feed roller and across the surfaces of the three vacuum pads. The mount

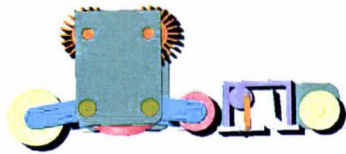


Figure 17 (Start of cycle)

rotates around the axis of the shown hole which is coincidentally mounted with the axis of the lead roller of the head. This lead roller axis is coincident only in the fully retracted position and this is the case when the cut-off and fold mechanism cycles at the end of the taping cycle.

The pair of hinged vacuum pads performs the fold operation while the third single vacuum pad retains the end of the tape for the start of a new taping cycle.

At the start of the taping cycle (see fig 17), the assembly rotates around the axis described and the single vacuum pad only, holding the tape by its non adhesive surface, comes into contact

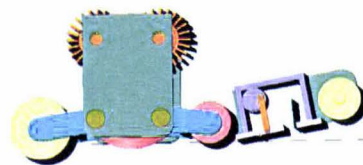


Figure 18 (Home position)

with the side of the carton lid. Pressure is applied to activate the adhesive, the vacuum is released and the assembly returns to the home position (see fig 18) leaving the tape attached to the side of the carton. The taping cycle then completes.

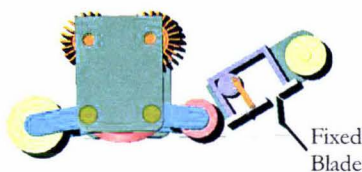


Figure 19 (Cut position)

At the conclusion of the taping cycle, vacuum is applied to all three vacuum pads and the tape is drawn against these. The assembly then rotates around it's axis in the opposite direction to the start cycle and draws the tap across a fixed blade (see fig 19) positioned between the hinged pair and

single vacuum pads. The tape is cut and the inner vacuum pad rotates around

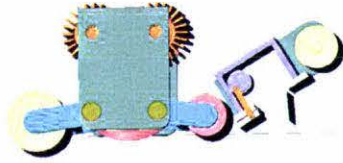


Figure 20 (Fold position)

the axis of the hinge to fold the finished end of the tape back on itself (see fig 20). The vacuum is released to the hinged pair only, and the pad returns to its home position (shown see fig 21). The carton rotation then continues, to buff down the end of the tape onto the carton.

This system serves three main purposes:

1. Ease of tape removal by the end user
2. Encourages the end user to remove the tape in such a way as to leave maximum delamination of the carton surface and hence maximum tamper evidence.
3. Start and cut-off of tape at respective parts of the overall taping cycle.

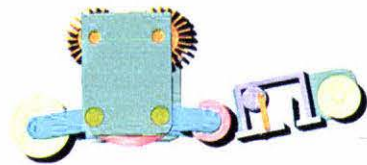


Figure 21 (Home position)

The tab must be produced at the end of the cycle so as to overlap the start application of tape and produce an accessible tab.

Vacuum pads grip the tape and these rotate as an assembly, about an axis that is common to the lead roller axis. This minimises the extension of the tape between the lead roller and the vacuum pads. Extension of the tape is still present within this process because the tape must accommodate the circumference of the lead roller. This is engineered as shown in fig 22 (Next page).

If the pivot point is at the arc and 15 degrees from vertical as shown, then when the arm travels through it's own arc to to a point where the tape leaves the roller surface at the point 49.14 degrees further on, the tape will shorten by an overall amount of 1.15 mm.  
This will require say 5mm of compensating head travel WRT the carton surface dictating the allowable time for the tape cutting and folding cycle. Else more tape should be released before cutting cycle. Alternatively, this could take up the amount of tape in the clearance between the hinged vacuum pad and the knife.

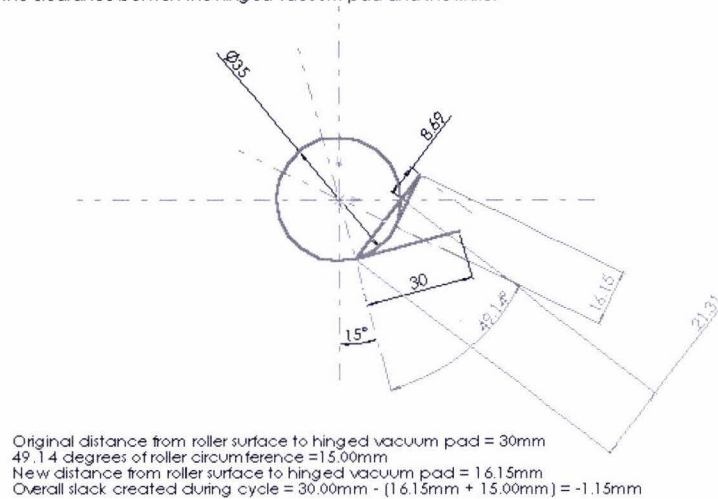


Figure 22 (Cut-off /fold dynamics)

A small DC electric motor is used to operate the hinged inner vacuum pad by means of a crank and connecting rod. The assembly movement is operated by a small stepper motor by means of a crank and connecting rod with the first half rotation for the start part of the cycle and the second half rotation completing the end cycle.

### 3.8 Manufacturing materials

The materials used in manufacture were chosen according to the following criteria:

- Easy cleaning characteristics (food processing hygiene requirements).
- Good machining qualities.
- Light weight.
- Toughness and long life.
- Availability.
- Reasonable cost.

These criteria were set to meet the prototyping nature of the project. Final design will require attention to:

- No flat surfaces, where liquid may settle and provide an environment for bacteria to develop.
- Ability to function in sub zero temperature (-14 C) conditions. Typical conditions for a meat packaging plant.
- Radiused edges for ease of clean down of machinery.
- Accessibility of parts for clean down and maintenance.
- Design for a wet environment; corrosion resistance.
- Design for a wet environment; electrical safety.



The materials chosen for the prototype include:

- Ultra High Molecular Weight PolyEthylene (UHMWPE). Properties include:
  - Superb machining qualities: Fast, low wear on tooling, reliable finishing and can be machined to a high precision level  $\pm 0.01\text{mm}$ .
  - Robust: Good toughness, tensile strengths and stress characteristics. (See appendix A.10. Pgs 80, 81 for more detail).
  - Low friction coefficient: inherent bearing surfaces.
  - Meets international hygiene requirements for food processing industries.
  - UHMWPE is used for the manufacture of the rollers, annular ring roller spool and the seam wheel for the hand held demonstrator.
- Flexible, closed cell, elastomeric nitrile rubber insulation. This material was developed for insulation of domestic hot water pipes. It is formed as a tube that is placed as a sock, over the hot water pipe. Desirable properties include:
  - Low moisture retention in a wet environment.
  - Suitable elasticity for the annular ring roller application. (See appendix A.11. Pgs 82 for more detail).
  - Can be used “off the shelf” and cut to length.



- This material is used for the foam sock in the manufacture of the annular ring roller for the hand held demonstrator.
- Aluminium flat bar was used to manufacture the frame for the hand held demonstrator. No particular specification was used apart from:
  - Low weight.
  - Corrosion resistance.
  - Availability.
  - This material requires further specification for production models.
- Cylindrical stainless steel, on hand, was used to manufacture the axles for the rollers. Again no particular material specification was used apart from:
  - Corrosion resistance.
  - Wear resistance.
  - Availability.
  - This material requires further specification for production models.

## **4 Results and Conclusions**

### **4.1 To date:**

- Market and data research for the development of the functional requirements of the overall machine
- The overall machine architecture has been established.
- A hand held tape application head has been designed, developed, built and tested. It has proven the principles of operation in the new design.
- Patents have been applied to protect the new taping principle.
- An overall project plan is now in place.
- There has been significant development of the production type tape application head (this is considered at the core of this thesis). This has included.
  - Working drawings and solid models for the head manufacture.
  - Manufacture of some parts for the head – these include:
    - Seam wheel and mounting blocks.
    - Rollers, both annular ring and solid, and bearing systems.
    - Mounting plates top and bottom.

- Working drawings and solid models for the tape cut-off and fold mechanism.
- Conceptual mounting systems for the two sub assemblies (tape application head and tape cut-off and fold mechanism). This will be finalised during head/arm integration.
- The modification of a standard SIAT taping machine to accept the horizontally mounted heads.
- Funding application and in some cases approval (See Appendix A.1 Pgs. 67 & 68).
- Risk analysis to project (See Appendix A.7 Pgs. 77).

## 4.2 Further and Future Developments

Testing of the hand held head has proven the principle of the three step taping process. Further development should include:

- Construction and testing of the production model head as designed.
- Completion of design, construction and testing of the rotary carton transport assembly.
- Design, construction and testing of the head mounting assembly.
- Design, construction and testing of a carton lidding assembly.
- Individual control systems design for each of the above.
- Integration of the above systems.

- Design of an overall modern multivariable control design model for the integrated system.
- Prototype build.
- Commissioning and testing of prototype.
- Design and build of the first and future production models.

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# Appendix

## **A.1 Funding**

### *A.1.1 Seeding finance*

Two main sources were approached for seeding finance. This type of finance relies on investment of capital by a source with a vested interest in the project. The project was outlined in presentation format and these were delivered using a computer and video projector to AFFCO NZ and Sellotape NZ executive staff. AFFCO reiterated their offer of test bed facilities but were unable to offer seeding finance. Sellotape NZ, in negotiation with GSL, is presently finalising detail for significant funding toward the project.

### *A.1.2 Venture capital finance*

Venture capital finance avenues were explored but in all cases, the amount of funding required meant that the financiers ended up with a controlling share in GSL. This was concluded as being unacceptable.

### *A.1.3 Business development trusts*

Business development trusts approached, so far, have displayed a more genuine interest in helping GSL in tackling this project. A formalised business plan is currently under construction for this purpose.

### *A.1.4 GPSRD*

This is a technology NZ source of finance for this type of project. Funding has been applied for, for the development of the Tape magazine and feed system module of the project. Funding has been granted and has encouraged progress in this area.

### *A.1.5 TIFF*

A second TIFF application was approved and a second masterate student began work in March 2002. The course of study here includes the development of the tape to be used within the HATS system.

Overall, significant time has been spent preparing documentation and presentations and in meetings in order to source suitable finance. The role has predominantly been to outline the scope and nature of the project. This is considered as ongoing work of a repetitive nature and it is necessary for the project to continue.



## A.2 General Agreement on Tariffs and Trade

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The General Agreement on Tariffs and Trade (GATT) was first signed in 1947. The agreement was designed to provide an international forum that encouraged free trade between member states by regulating and reducing tariffs on traded goods and by providing a common mechanism for resolving trade disputes. GATT membership now includes more than 110 countries.

Consideration of GATT's relationship to environmental policy is an emerging concern in trade and environmental policy circles. Until the recently concluded Uruguay Round of GATT negotiations, the word environment did not appear in the GATT text. Several provisions and sections of GATT may be relevant to environmental issues, however. The following sections of GATT are often referenced in the examination of trade-environment issues. The excerpts are from GATT as amended through 1966, originally digitized by the Multilaterals Project of the Fletcher School of Law and Diplomacy, Tufts University:

- Article I General Most-Favoured-Nation Treatment;
- Article III National Treatment on Internal Taxation and Regulation;
- Article XI General Elimination of Quantitative Restrictions;
- Article XIII Non-discriminatory Administration of Quantitative Restrictions;
- Article XVI Subsidies;
- Article XX General Exceptions;

The GATT Final Act Embodying the Results of the Uruguay Round contains several other relevant items:

- the Trade-Related Aspects of Intellectual Property Rights;
- an Agreement on Subsidies and Countervailing Measures that permits some environmental subsidies in section 8.2;
- And the Agreement Establishing the Multilateral Trade Organization.

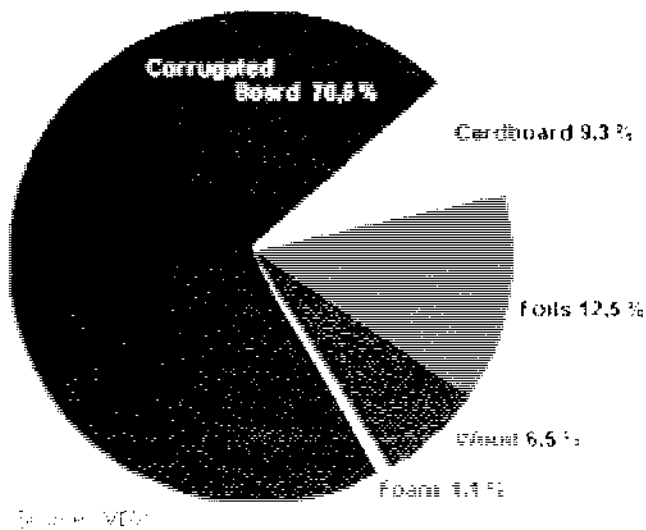
The complete Uruguay Round text is also available on-line. Explicit environmental concern related to GATT has grown in the last few years. Although formally organized in 1971, a GATT committee on environment met for the first time in 1991. Also in 1991 a GATT dispute-resolution panel made a ruling in the tuna-dolphin case, a dispute between the United States and Mexico over limiting imports based on fishing practices. Issues in the tuna-dolphin dispute are described by Cough (1993) in "Trade-Environment Tensions"; in the U.S. Office of Technology Assessment (1992) report *Trade and the Environment*; and in the GATT dispute panel report (1991) on the case. In 1992, GATT produced "Trade and the Environment," a report that offered GATT's recommendations on the relationship between international trade and environmental measures.

The recent cases, the 1992 report, and growing international consideration of the relationship between trade and environmental policy have focused attention on GATT's influence on international environmental agreements. In some ways, GATT is seen as potentially limiting or barring trade provisions in environmental agreements. Environmental, legal, and other experts have also called for reform of GATT to accommodate international concern for environmental issues.

Charnovitz (1992) examines the potential of GATT to limit trade-based implementations in environmental agreements in "GATT and the Environment." In "Free International Trade and Protection of the Environment," Schoenbaum (1992) evaluates the impact of existing GATT provisions and discusses when trade restrictions may be appropriate within environmental agreements. Weiss (1992) comments on Schoenbaum's article in "Environment and Trade as Partners in Sustainable Development," suggesting that global consensus on sustainable development as a guiding policy principle has added weight and priority to environmental concerns in relation to trade policy.

<http://www.ciesin.org/TG/PI/TRADE/gatt.html>

### A.3 RESY



ONE STEP IN FRONT OF  
LAW MAKERS!

The Packaging Regulation  
became effective in June  
1991. This regulation  
distinguishes between  
particular kinds of packaging:

Transport packaging  
Secondary packaging

Sales packaging

The Packaging Regulation defines transport packaging to 'serve the purpose of keeping goods on route from the manufacturer to the distributor from being damaged', which is to say, to guarantee that the transport is safe and secure in every respect.

This can be done with the aid of shipping containers /packaging, crates, pallets, sacks, kegs, canisters, foils or even foam shells. Public depots for transport packaging have been closed since 1 December 1991. Since this time, business and commerce have been obligated to accept returns of transport packaging and provide for material recycling.

Law-makers distinguish between secondary packaging and sales packaging with respect to transport packaging. Secondary packaging includes blisters, foils, cartons or similar containers which also make possible additional packaging either for the sale of products in a self-service format, in order to prevent shoplifting or for primarily advertising related purposes.

Sales packaging are all those containers or packaging of goods which are used by the end-consumer for the transport of goods all the way to their usage. It is difficult to distinguish among these in particular cases, as the border-line is fluid.

Transport packaging accounts for 20 % of total packaging volume. The most important material here is paper and cardboard: 80 % of all transport packaging is made of this raw material. It is expected that this percentage will continue to rise as the Packaging Regulation is implemented. This is due to its easy recyclability - 80 to 85 % of all transport packaging made of paper and cardboard was already being recycled prior to the entry of the Packaging Regulation into force.

The RESY GmbH (**R**ecycling **S**ystem) was established in June 1991 in order for this type of packaging to be completely recycled and for statutory stipulations to be met.

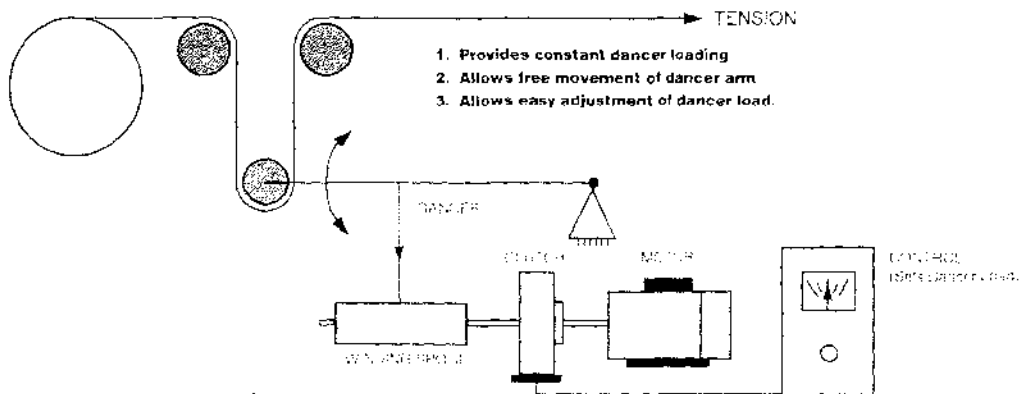
<http://www.resy.de/eng-sta.htm>

## A.4 Web Tension

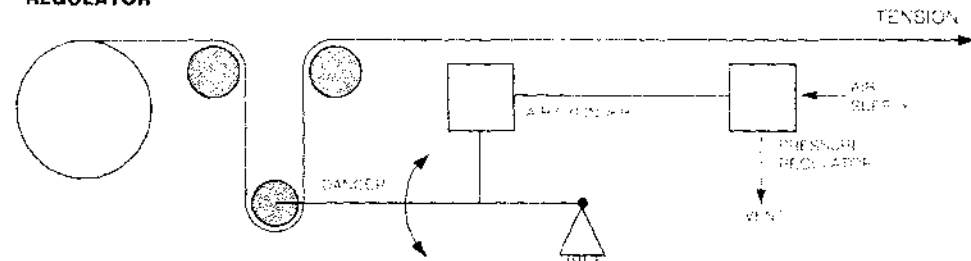
### ENGINEERING APPLICATIONS AND WEB TENSION INFORMATION

#### DANCER LOADING

##### CLUTCH AND CABLE ASSEMBLY



##### PNEUMATIC CYLINDER AND REGULATOR



##### Recommended:

1. Rolling diaphragm type pneumatic cylinder for its low friction characteristics.
2. A pressure regulator with high volume flow capacity and fast relieving vent to allow rapid movement of dancer.

##### Not Recommended:

1. Weights impede rapid dancer arm movement by adding mass to dancer arm.
2. Springs provide inconsistent loading, since spring force changes with deflection.
3. Shock absorbers resist changes in dancer position by dampening.

**TRAFLOW**



## WEB TENSION INFORMATION

### TYPICAL TENSIONS

Material	Thickness		Tension		Material	Thickness		Tension	
	(Inches)	(mm)	PLI	kg/cm		(Inches)	(mm)	PLI	kg/cm
<b>Foil</b>	0.0005	0.0127	0.5	0.09	<b>Paper</b> <b>15 pound weight</b> <b>20 pound weight</b> <b>30 pound weight</b> <b>40 pound weight</b> <b>60 pound weight</b> <b>100 pound weight</b>	0.001-0.002	0.0254 to 0.0508	0.5	0.09
	0.001	0.0254	1	0.18		0.002-0.003	0.0508 to 0.0762	0.75	0.135
	0.002	0.0508	2	0.36		0.003-0.004	0.0762 to 0.102	1	0.18
<b>Film, Mylar (Polyester)</b>	0.0005	0.0127	0.25	0.045		0.004-0.005	0.102 to 0.127	1.5	0.27
	0.001	0.0254	0.75	0.135		0.005-0.007	0.127 to 0.178	2.5-4	0.45-.72
	0.002	0.0508	1.5	0.27		0.007-0.010	0.178 to 0.254	3-5	0.54-.90
<b>Film, Polyethylene or Vinyl</b>	0.0005	0.0127	0.125	0.0225	<b>Copper Wire, 15000 psi</b> <b>Run</b> <b>Aluminum Wire</b> <b>at 1/2 to 2/3 these values</b>	#40 (0.003)	0.08	0.10 lb	.05 kg
	0.001	0.0254	0.25	0.045		#36 (0.005)	0.13	0.25 lb	.11 kg
	0.002	0.0508	0.5	0.09		#34 (0.006)	0.16	0.50 lb	.23 kg
<b>Acetate</b>	0.0005	0.0127	0.25	0.045		#30 (0.010)	0.25	1.25 lb	.57 kg
	0.001	0.0254	0.5	0.09		#28 (0.013)	0.32	1.75 lb	.79 kg
	0.002	0.0508	1	0.18		#24 (0.020)	0.51	4.5 lb	2.0 kg
<b>Polystyrene</b>	0.0005	0.0127	0.5	0.09		#20 (0.032)	0.81	8.0 lb	3.6 kg
	0.001	0.0254	1	0.18		#18 (0.040)	1.02	10.0 lb	4.5 kg
	0.002	0.0508	2	0.36		#16 (0.051)	1.29	12.0 lb	5.4 kg
<b>Cellophane</b>	0.001	0.0254	0.5	0.09		#14 (0.064)	1.63	15.0 lb	6.8 kg
						#12 (0.081)	2.05	18.0 lb	8.2 kg
<b>Thin Wax Paper</b>	0.001 to 0.002	0.0254 to 0.0508	1 to 2	0.18 to 0.36		#10 (0.102)	2.59	20.0 lb	9.1 kg
						#8 (0.128)	3.26	25.0 lb	11.3 kg
<b>Newspaper</b>	0.002 to 0.003	0.0508 to 0.0762	0.25 to 0.75	0.045 to 0.135					
<b>Kraftpaper</b>	0.005 to 0.01	0.127 to 0.254	1.5 to 4	0.27 to 0.72					
<b>Paperboard</b>	8 pt	105 g/m <sup>2</sup>	3	0.54					
	12 pt	157 g/m <sup>2</sup>	4	0.72					
	15 pt	196 g/m <sup>2</sup>	5	0.9					
	20 pt	262 g/m <sup>2</sup>	7	1.26					
	25 pt	327 g/m <sup>2</sup>	9	1.62					
	30 pt	393 g/m <sup>2</sup>	11	1.98					

Laminates are generally processed at tensions equal to the sum of the individual webs.

PLI = Pounds per linear inch of web width

kg/cm = Kilograms per centimeter of web width

Paper "weight" is the weight of a ream of paper. A ream is 500 sheets of a given size. The tensions above are based on a 3,000 square foot ream (278.7m<sup>2</sup>)

**MAGPOWER**

### A.5 Roller pressure tests

	Unit 1	Unit 2	Unit 3	Unit 4
Kgs	2.8	0.75	1.5	3.75
	Two rollers operating on common spring system so with both rollers operating, there will be 1/2 the recorded value per roller. Four heads tested 2 x Siat and 2 x 3M.			

### A.6 Specify actuator for applying roller pressure:

Need:

- Torque arm: 0.046m /axis to axis roller mount.
- Required pressure: 5 – 30N.
- Need to spec required rotary actuator speed. Say same as max roller speed (Radius (r) = .025m)? : Circumferential velocity (C) of roller:
  - $C = 1\text{m/s}$
  - Assume linear pressure applied at lever arm of .046m requiring speed of “C” 1m/s giving circumferential velocity of lever arm (C<sub>1</sub>):
    - Want C<sub>1</sub> at 0.046m  $\approx$  0.05m:  $C_1 = A \times r$  so  $A = C_1 / r$   
 $= 1\text{m/s} / 0.05\text{m} = 20\text{rad/s}$
- Actuator rotational speed:  $\approx 191\text{rpm} = 20\text{rad/s}$  (say 200rpm)
- Required torque (rotary actuator)  $30\text{N} / 0.046\text{m} \approx 30\text{N} / (1 / 0.046\text{m}) = 1.38\text{Nm}$

- Rotary actuator power:  $1.38\text{Nm} \times 20\text{rad/s} = 27.6\text{W}$  + heat, coil and core losses etc (say 10%)  $\approx 30\text{W}$
- Duty cycle:  $\leq 75\%$
- Dimensions:  $\leq 65\text{mm}$  diameter (prefer 50mm),  $\leq 80\text{mm}$  long. A 'pear shaped' actuator with slightly larger cross section dim may fit. Output shaft diameter: 7mm –10mm.
- Wiring must be dynamic.
- Rotary actuator will be running at, effectively, 'start up torque' for the duration of duty so more heat sinking may be required.
- Voltage range: 24 – 240VAC or 24 –100VDC
- Phasing: Doesn't matter but as simple as possible – control can be found to suit.

## A.7 Risks:

1. Comparative product on market:
  - i. Research (meat NZ and processors) Fish?
2. Project time blow out:
3. Sellotape take hats to SIAT: - research SIAT capability]
  - i. Could be an opportunity for export market.
4. Loss of Key Personnel: - Careful documentation
5. Confidentiality of product
  - i. Data security.
  - ii. Confidentiality agreements.
  - iii. Project team.
6. Outsourcing project activities:
  - i. Choose suppliers who are not in industry.
  - ii. Spread components across many suppliers.
  - iii. Accurate specification of outsourced jobs.
7. Head operation on corners: - Test early.
8. Tape Cutting and starting: - Test early.
9. Delays introducing the HATS machine into the market.
  - i. Alternative sources for funding.
  - ii. Develop and plan product introduction.
10. MAF compliance time too soon: - Keep MAF informed.
11. Ability to fund.
  - i. Continue to investigate possible sources.
  - ii. Refine budget for hats project.
  - iii. Prepare budget for hats product information.
  - iv. Prepare budget based on PEC manufacture.

#### **A.8 NZ annual carton closures for the meat industry**

This document clarifies the number of “20kg cartons of sheep and beef meat” (export product) to be closed for export annually and hence the required amount of adhesive tape.

Carton size will vary for different cuts and types of meat but the assumption has been made that spreading the annual tonnage of non carcass meat exported from New Zealand (NZ) into 20kg cartons will give a good indication of the overall length of tape required to make these closures.

It is anticipated that initially 40% of the closure will be by the proposed taping method with this percentage increasing as time goes on.

The figures in this report have been furnished by Meat NZ and AFFCO NZ Fielding. The Meat NZ figures are provisional and represent all sheep and beef meat exports by all NZ exporters.

The AFFCO NZ Fielding figures are used to calculate the ratio of tape application machines to tonnes of sheep and beef meat, required to close export product.

It is acknowledged that the AFFCO Fielding plant, used as the model for this calculation, is a larger plant and many smaller plants throughout NZ will have a larger ratio of machines to tonnes of export product closed. Thus the calculated 96 machines required for national export product closure is an absolute minimum figure.

However, the number of product closures remains the same requiring the same amount of tape regardless of the ratio of closure machines per tonne.

The amount of sheep and beef meat exported from NZ for the period Oct 2000 – Sept 2001 was 1,091,771 tonnes (provisional) consisting of 356,813 tonnes of sheep meat, 376,756 tonnes of sheep offal and 358,202 tonnes of beef meat including offal. 35,798 tonnes (representing 3.3% of total exports) of this is exported in carcass form leaving 1,055,973 tonnes of meat for export product closure by our proposed method.

Given that each export product closure requires 1.8m adhesive tape, and that 1,055,973 tonnes equates to 52,798,650 export product closures, resulting in a



potential annual adhesive tape requirement of 95,037,570m or some 95,000km of tape annually. It is expected that 40% of this potential will be realized initially i.e. 38,000km of tape applied by 38 or more closure machines.

A number of assumptions have been made.

- AFFCO NZ Fielding has been used as a model to ascertain the ratio of closure machines per tonnage of export product closed.
- The division of the total NZ sheep and beef meat export into 20kg cartons is representative of the number of cartons exported and hence the amount of tape required for closure. An informal quotation by the ministry for agriculture and forestry (MAF) of around 59,000,000 cartons (conservative) closed annually for export is based on the usage of official MAF export seals. Allowing for some smaller cartons – hence more of these – indicates that the calculated 52,798,650 export product closures to be both robust and conservative for the purposes of this report. Also, some export markets do not require MAF certification.
- As the smaller cartons maintain the aspect ratio of the standardised 20kg carton, it is expected that, on a per tonnage basis, somewhat more tape would be used to close the smaller cartons due to more starts and finishes in the taping process.
- All beef and sheep meat that is exported as carcass is not cartoned. This amounts to 3.3% of total exports.
- All offal is cartoned.

The Meat NZ figures quoted in this document were obtained by phone and are more up to date than those given in the appendix obtained from the Meat NZ website. Nor is the sheep offal included in this table.

## A.9 Endorsement by MAF



Ministry of Agriculture and Forestry, New Zealand

Te Manatu Ahuwhenua, Ngaherehere, Aotearoa



8 June 01

John Bradley



Dear John

### Carton Taping Machine

Further to our discussion in Palmerston North on the 23<sup>rd</sup> May regarding the carton taping machine and its potential for incorporation of the MAF security mechanisms.

The traditional means of officially sealing cartons, ie a seal of approx. 150mm x 50 mm placed over the carton joints is not particularly satisfactory. There are ongoing problems with application, numbers of seals used per carton depending on design, and rough handling during loading and transport. Foreign governments periodically reject product for faulty sealing, with the latest incident involving four containers of product taking place this week.

Several years ago, MAF asked the meat industry and the carton seal manufacturers to submit suggestions for a new seal of more robust design. There was none.

MAF recognises the potential of your carton tape serving a dual function as an official seal. The tape would have to display official information along its length. This information must remain legible as the tape moulds to the carton surface.

We are keen to see further work done particularly with cartons of different designs. Success in this endeavour would provide us with the first opportunity we have had in twenty years to rationalise the mechanisms and procedures for the official sealing of cartons.

Yours sincerely

A handwritten signature in dark ink, appearing to read 'P.A.R. Ward'.

P.A.R. Ward  
Technical Policy Manager

MAF FOOD ASSURANCE AUTHORITY

ASB Bank House, 101-103 The Terrace, PO Box 2526, Wellington, New Zealand.

Telephone: 64-4-474 4100 Facsimile: 64-4-474 4239



## A.10 Plastics

*MatWeb.com, The Online Materials Database*

*Overview - High Density Polyethylene (HDPE), Ultra High Molecular Weight*

**Subcategory:** HDPE; Polyethylene; Polymer; Thermoplastic

**Close Analogs:** Click the button to view the proprietary polymer grades listed in MatWeb that belong to this class. Please be aware that some proprietary polymers may not be listed because they fall into more than one class or because of ambiguity in manufacturer's information.

**Key Words:** UHMWPE; Plastics, Polymers

The property data has been taken from proprietary materials in the MatWeb database. Each property value reported is the average of appropriate MatWeb entries and the comments report the maximum, minimum, and number of data points used to calculate the value. The values are not necessarily typical of any specific grade, especially less common values and those that can be most affected by additives or processing methods.

Physical Properties	Metric	English	Comments
Density	0.934 - 0.954 g/cc	0.0337 - 0.0345 lb/in <sup>3</sup>	Average = 0.945 g/cc; Grade Count = 5
Water Absorption	0.01 %	0.01 %	Grade Count = 1
Environmental Stress Crack Resistance	500 hour	500 hour	Grade Count = 1
Melt Flow	2 - 12 g/10 min	2 - 12 g/10 min	Average = 8 g/10 min; Grade Count = 3

### Mechanical Properties

Hardness, Shore D	63 - 68	63 - 68	Average = 65.2; Grade Count = 5
Tensile Strength, Ultimate	40 MPa	5800 psi	Grade Count = 1
Tensile Strength, Yield	20 - 27.6 MPa	2900 - 4000 psi	Average = 23.4 MPa; Grade Count = 5
Elongation at Break	300 - 850 %	300 - 850 %	Average = 590%; Grade Count = 5
Tensile Modulus	0.5 - 0.85 GPa	72.5 - 123 ksi	Average = 0.68 GPa; Grade Count = 2
Flexural Modulus	0.7 - 1.45 GPa	102 - 210 ksi	Average = 0.996 GPa;



Izod Impact, Notched	4 - NB	7.49 - NB	Grade Count = 5 Average = 9.5 J/cm (NB computed as 15 J/cm); Grade Count = 5
Tensile Impact Strength	710 - 1900 kJ/m <sup>2</sup>	338 - 904 ft-lb/in <sup>2</sup>	Average = 1300 kJ/m <sup>2</sup> ; Grade Count = 2
Coefficient of Friction	0.15	0.15	Grade Count=1

### Electrical Properties

Electrical Resistivity	1e+016 ohm-cm	1e+016 ohm-cm	Grade Count = 2
Surface Resistance	1e+016 ohm	1e+016 ohm	Grade Count = 1
Dielectric Constant	2.3	2.3	Grade Count = 1
Dielectric Strength	28 kV/mm	711 kV/in	Grade Count = 1
Dissipation Factor	0.0002	0.0002	Grade Count = 1
Dissipation Factor, Low Frequency	0.0002	0.0002	Grade Count = 1

### Thermal Properties

CTE, linear 20°C	125 - 200 µm/m- °C	69.4 - 111 µin/in-°F	Average = 160 µm/m- °C; Grade Count=2
Melting Point	130 °C	266 °F	Grade Count = 1
Maximum Service Temperature, Air	67 - 82 °C	153 - 180 °F	Average = 74°C; Grade Count = 4
Deflection Temperature at 0.46 MPa (66 psi)	67 - 79 °C	153 - 174 °F	Average = 73.2°C; Grade Count=4
Deflection Temperature at 1.8 MPa (264 psi)	46 °C	115 °F	Grade Count=1
Vicat Softening Point	129 - 139 °C	264 - 282 °F	Average = 130°C; Grade Count = 4
Minimum Service Temperature, Air	-30 °C	-22 °F	Grade Count = 1
Brittleness Temperature	-75 °C	-103 °F	Grade Count=3

### Processing Properties

Processing Temperature	450 °C	842 °F	Grade Count = 1
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*Foam sleeve for annular ring roller (Armaflex)*

**Description**

Flexible, closed cell, elastomeric nitrile rubber insulation

**Material**

Foamed nitrile rubber

**Application areas**

Process work, hot and cold water services, chilled water lines, heating systems, air conditioning ductwork, refrigeration pipework and ancillary equipment

**Delivery programme**

Tube 2m lengths

Flat sheets 2 m x 0.5m

Continuous sheet 1m wide

All sheet material available with a self adhesive backing

Self adhesive tape

<b>Temperature range</b>	<i>Minimum line temp.</i>	- 50°C
	<i>Maximum line temp.</i>	+105 °C +85°C for flat surfaces and tape
	<i>Notes</i>	If lower temperatures, down to -200°C, are involved please consult our Technical Department Tel: 0161 287 7100 or Fax: 0161 633 2685.

<b>Thermal Conductivity</b>	<i>at mean temperature 0°C : 0.035 W/(m x K)</i>	
	<i>at mean temperature +20°C : 0.037 W/(m x K)</i>	
	<i>at mean temperature +40°C : 0.039 W/(m x K)</i>	
	<i>Notes</i>	Test method BS874 Part 2 1986

<b>Water vapour permeability</b>	<i>Moisture resistance factor <math>\mu</math></i>	$\mu > 5,000$
	<i>BS EN ISO 9346: 1996</i>	$3.6 \times 10^{-14} \text{ kg/(m.s.Pa)}$
	<i>BS4370 Part 2 1973</i>	0.13 $\mu\text{gm/(N.h)}$

<b>Water absorbtion</b>	<i>by volume after 28 days</i>	0.9% average, 1.5% maximum
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## **A.11 Errata.**

In response to examiners report.

The three step tape application process represents cutting edge technology within the meat packaging industry. As such, an assumption was made early in the project that a line of development would be undertaken independently due to a lack of available information.

It is acknowledged that similar development work is likely, underway elsewhere. GSL's own protection of this technology includes patents, confidentiality agreements and trade secrecy. Again, a further assumption notes that the aforementioned technology protection is also employed by any parallel development of any similar technology and is thus hidden for purposes of the author's literature review in this area.

There has also been a balance struck up between the speed to market of this technology and the academic analysis of the technology, which has precluded some of the more traditional academic approaches to this type of development in favour of a trial and error approach.

The GSL staffs have worked as a team on this project and as a team; a vast resource of practical knowledge has been applied to the project. GSL is a very small company of five full time equivalent staff including six people. The infrastructure and financial resources have been ill equipped to deal with a project of this nature and size.

Certain aspects of the overall technology are based on existing component technologies that are regarded as second nature to members of the GSL staff. These have been suitably developed, by these staff, to meet lead times otherwise unattainable. However, the overall technology is innovative and provides a solid



solution to issues raised by the NZ meat export industry and associated regulatory bodies.

In short this thesis embodies the process that a small New Zealand business has employed to provide an overall integrated solution to significantly reduce instances of tampering with New Zealand export product. The author acknowledges that certain areas of development are less than academically sound but these areas of development have been delegated to practical development based on the abilities of trade staff that have succeeded in providing expedient and suitable solutions, better able to meet deadlines.

The author's direct contributions to this project include:

- Conception, conceptual design, drawings and documentation for the preparation of patent application for the three step tape application process.
- Full design and supervision of the fabrication of the hand held demonstrator.
- Conception, conceptual design, drawings and documentation for a rotary carton handling mechanism.
- The development of the synopsis of operation of the overall system of carton closure with respect to rotary carton handling system integrated with the three step tape applying head and the initial control architecture.
- Infrastructure development for the project including:
  - Introduction of suitable computer software to GSL.

- Tech NZ TIFF funding application and acquisition of funds to fund two masters' degrees for the project.
- Pushed the barrow for the institution of a formal project plan and compilation of the initial project plan using suitable software. Design of the project plan was in collaboration with "Pyxis" consulting.
- Day to day administration and chargeable hours to help sustain company income to help finance the project.
- Marketing of the closure system:
  - Authoring and delivery's of a presentation in various forms to describe the system.
  - Liaison with various involved parties.
- Scoping functional analysis of the overall closure system in collaboration with consultants "R & D Solutionz Ltd".

As of the 1<sup>st</sup> of June 2003, GSL exhausted its financial resources due to the heavy investment in the development of this project and was sold. A holding company was instituted and new investors brought in to pursue the HATS project. A final design has been signed off and a first prototype is under construction in Finland. Delivery is expected in September 2003 for a firm order placed by a major NZ meat processing and exporting company. The author is currently managing GSL for the new owners and hopes to pursue further study in the HATS project when possible. The overall control architecture has been addressed and, at the time of writing this dissertation options were still under debate. The subject of debate being: a slightly less functional and existing (cheaper) technology, versus an integrated, machine specific control architecture

for the closure system. Again, the commercial realities of the project have dictated terms and the latter control architecture will become the subject of future study.

The author notes the technical report nature of parts of this dissertation.