SCIENTIFIC RESEARCH AND EXPERIMENTAL DEVELOPMENT

PLASTICS MATERIALS, PROCESSING, EQUIPMENT & TOOL MAKING CASE STUDIES

DATE: August 2005

Index

1 Plastics / metal hybrids 2
2 Change in Direction 4
3 A Tale of Three Stakeholders 7
4 In-line compounding 12
5 Bottle Filling - Product Range Extension 14
6 Bottle Filling - Production Problems 17
7 Ejection Detection 19
8 Compression moulding of abrasion resistant liners 21
9 Material Substitution 23
10 Dual Injection 25
11 Different Equipment 27
12 Extrusion 29
13 Screw Design 32
14 Development of an UHMW-PE Abrasion Resistant Sheet Formulation 36
15 Large Compression Moulded Parts 38
16 The bevel gear 43
17 Cast figurines 48
18 Reaction Injection Moulding (RIM) 52

1 Plastics / metal hybrids

1.1 Background – the business context

This work concerns a proprietary Plastics / metal hybrid technology in which nylon is bonded to a metal stamping, to give better strength and structural integrity than can be achieved with the metal stamping alone.

Our company is a 'tier 1' supplier, which has licensed the base technology from the multinational corporation who developed it at a location outside Canada. This project covers subsequent work that was needed to adapt the technology for use it in a front-end module. The technology is not yet well established and at this point in time each application requires its own application development to accommodate the special features of the moulding process.

The initial design for the part had been carried out at our customer, a U.S. auto OEM[1]. The work that follows was required to advance the technology to a sufficient degree that we could design a process to manufacture the parts.

1.2 Project Description

1.2.1 Section A: Purpose

Development of the design details and process conditions for the manufacture an automotive front-end module.

1.2.2 Section B: Technological advancements sought

Since we were only provided with drawings, we needed to develop the required technology and know-how for the correct placement of the metal stampings (as part of the design details) and the process for injecting the plastic. Development of the product and process would increase our company's technology base for the manufacture of plastic / metal hybrids.

1.2.3 Section C: Technological uncertainty

The current base technology only gives an approximate position for the metal inserts.

The design details including the proper positioning of the metal stamping are crucial for good adhesion. Poor adhesion can lead to problems with variability on part geometry. The original drawings were based on rules of thumb developed by the resin supplier and we had to modify these with the results acquired from our experimentation. The experimentation was needed to provide the required finesse that was not provided by the rough theoretical guidelines available to us.

---

[1] Original Equipment Manufacturer

1.2.4 Section D: Summary of work carried out

1. The initial moulds were built using the drawings provided by our customer. Initial runs gave us parts that had adequate strength, but the alignment was poor.
2. The moulds were modified empirically in two iterations to give the required alignment

1.3 Comments

The base technology had clearly been developed outside Canada. Much of the final development was performed in Canada. The final design and production development[2] required further work to advance the technology and remove the technological uncertainty around the shrinkage of the materials in this process. As long as the work carried out in Canada meets the SR&ED criteria, it can form the basis for a valid claim, even though the underlying technology was developed outside the country.

[2] This term includes both product and process development

2 Change in Direction

2.1 Background – the business and technology context

Our company is a leader in the design and manufacture of plastic injection moulds, which make up the bulk of our business. We had won a contract to design and build tooling to produce complex moulded PVC housings that were over 57” wide, 12” high and had a wall stock of 3/8-1/2”. These very large parts had multiple internal cavities with internal and external flanges.

This example describes a project that began as an injection mould design that was expected to contain only a limited amount of work meeting the SR&ED criteria. At some point the direction of the project changed, when we realised that we had to develop the manufacturing technology needed to produce the extrusion dies.

After the initial design work it became apparent that injection moulding would not give parts that could meet the functional requirements for rigidity and impact resistance. We decided that the parts would have to be extruded. This would be our first attempt at designing and producing extrusion dies of this size.

The size of the available extrusion machines provided a constraint. This impacted on the size of the dies since only a limited amount of space was available for the plastic to expand from the 3” extruder head to the 57” product width. As a result the extruded material had to flow through an angle of 135 degrees, compared to the typical 10 to 20 degrees. There were also concerns that the moulding pressure might blow apart the dies. The dies were therefore designed with a single piece outer construction to obtain maximum strength.

Dies of this nature are normally wire-EDM (Electrical Discharge Machine) manufactured, but because of the complexity of the flow patterns, and the large size of the dies this was not possible. Since typical methods of manufacture would not work in this application, a new approach had to be developed. The compound angles of the receiving block and its four interior chambers would have to be separately manufactured. This could only be done using CNC (Computer Numeric Controlled) contoured milling of the outer single-piece receiving block.

2.2 Project description

2.2.1 Section A: Purpose

The initial purpose of the project was the design of an injection mould for the manufacture of unusually large PVC parts with a complex profile. The part had a thick exterior wall, four interior chambers and a flange on one end.

The project evolved into the development of extrusion dies and the technology required for manufacturing both the dies and the parts.

2.2.2 Section B: Technological advancement

- Development of the know-how required to design a PVC housing that would meet our customer’s functional requirements.
- The design of very large extrusion dies for shaping and forming the extruded parts.
- The development of manufacturing methods for large extrusion dies too large for wire EDM manufacture.
- To develop an understanding of the flow characteristics of extruding plastic and to apply this understanding to develop the processing parameters for large extrusion dies with multiple internal chambers, thick wall stock and external flanges.

2.2.3 Section C: Technological uncertainty

- We had to design a part that could be produced with the extrusion process and still meet the functional requirements of the customer. Our base technology did not allow us to be confident that this could be done, since our experience with extrusion was limited and as far as we knew, the dies would be the largest of this type in production in the industry
- The dies would have to be constructed of a single outer shell to prevent the die from blowing apart under extruding pressures related to flow requirement.
- Typically extrusion dies are produced with wire-EDM (electric discharge machining). The present dies could not be produced using conventional machining methods for two reasons:
    - the large overall size meant that the parts could not fit into any wire-EDM machine; and because of
    - the requirement for a 135 degrees angle over an 18” distance.
- We expected that extrusion of plastic from a 3” extruder head to 57” in a span of less than 18” would lead to poor flow and filling difficulties.

2.2.4 Section D: Summary of work carried out

- The finished product was made from a number of pieces. We designed these pieces and built models to ensure that the finished pieces would fit together to give a part that met our customer's requirements. We then designed the dies required to manufacture the parts.
- Upon completion of the design of the dies we realised that there were additional technical problems that we had not considered at the beginning of the project. The greatest of these was how to manufacture the dies. To produce the four interior chamber components, fixtures were built for each component. They were then manufactured using CNC contoured milling and sink EDM. These interior chamber components would then be mounted using flow

dividers to fasten them to the main receiving block. Finally the extrusion die, which was wire EDM and also had interior chamber components mounted with flow dividers, was assembled to the receiving block.

- Upon “first test” the dies functioned as designed, however there were problems with the receiving plate and in particular the flow of the plastic being extruded. The dies did withstand the high processing pressure, however the angles called for in the design were not sufficiently contoured to provide the required flow of plastic. It was necessary to rework the contoured shape of the receiving block many times over the next few months before finally obtaining a successful result. The problem was developing a shape that would force the material in a lateral direction.

2.2.5 Progress to date and summary

Material distribution and critical tolerances were finally achieved to give a part that met the needs of the mould maker's customer.

2.3 Comments

In the course of carrying out SR&ED, new information is often acquired that can have a significant impact on the scope, direction or duration of a project.

In this case resolving the technological uncertainties required to design the die, resulted in a die that could not be manufactured with routine techniques It was necessary to take a new approach to die manufacture and assembly.

Normally it is relatively easy to accommodate changes in scope or direction into an SR&ED claim, since the claim is written after the work has been done.

The additional technological advancements required and / or the associated technological uncertainties can be included, even if they were not obvious at the beginning of the project. In this case "a method to cut metal in complex shapes that are not possible with wire EDM" would be added to the list of technological advancements.

If the project is split in two and submitted in two or more tax years, then the changes will be made to the advancements and uncertainties in the second or subsequent years work, with an explanation as to what had generated the need for change.

This project provided an opportunity for the mould maker to design and manufacture unique extrusion dies, expanding their technology base from that required for the design and manufacture of injection moulds that formed the bulk of their business. They took a new approach to die manufacture and assembly, drawing on the experience of their designers to develop the die design, and to learn about the flow characteristics of extruded plastic.

3 A Tale of Three Stakeholders

3.1 Introduction

This example describes the shared effort of three groups to bring a new product to market for automotive exterior trim. This system is being developed to replace painted plastic parts used for exterior trim panels and moldings, with non-coated raw plastic parts that provide the same appearance and durability as paint. The resulting cost savings to the OEM will be significant if the project succeeds.

The three companies involved are Resin-Us Inc., the resin supplier, Mould-R Inc., the mould maker and Process-R, the company that will manufacture the parts.

3.2 Project Claimed by Resin-Us

Background

Resin-Us was asked by their customer, the processor for a resin that could be moulded to give a part that has the same high gloss appearance, abrasion resistance, surface durability and chemical environmental resistance as paint. The resin supplier has never supplied a material that meets these criteria before and therefore must create a new plastic that it hopes may be used in applications such as the exterior panels of automobiles. It was expected that the resin supplier would provide samples to the supplier.

3.2.1 Section A: Purpose

The creation of a new plastic that can be used in applications such as the exterior panels of automobiles.

3.2.2 Section B: Technological advancements Sought

Techniques to resolve the following issues:

- Obtain the required gloss level and surface consistency to provide an acceptable appearance.
- Achieve this at the same time as surface strength or impact resistance requirements are met.
- Ensure that the manufactured parts have the required long-term resistance to the elements.

3.2.3 Section C: Technological uncertainty

Plastic parts are used routinely for exterior panels of cars and other vehicles. They are usually painted to achieve the required gloss levels, surface strength and impact resistance. The challenge is to produce a compounded material that will give parts with the required mechanical properties, which has a uniform surface that will be durable enough to withstand the environment to which it is exposed.

3.2.4 Section D: Summary of work carried out

- The plastic was formulated based on what was known about the materials using the principles of chemical science and engineering combined with past experience.
- The supplier moulded it into sheet form for use in testing.
- A series of tests were then performed to satisfy the conditions spelled out by the OEM for vehicle exteriors. The results of these tests were analyzed and adjustments were made to the formula for re-testing.
- The resin was released to the plastics processor. Although it met only part of the required conditions for durability, it met most of the requirements for mouldability.
- The plastics supplier continues to work on the resin to complete all of its chemical requirements for things like weather resistance. Communication is maintained with the mould maker and the processor, and modifications are made to the formulation both to resolve weatherability issues and to contribute to resolving part appearance issues.

3.2.5 Documentation

- Literature from search
- Lab reports
- Customer visit reports including pictures
- E-Mail – meeting minutes & memos
- Time sheets – T4s
- Contracts
- Invoices
- Expense reports
- Purpose and Project description

3.3 Project Claimed by Process-R Inc.

Background

Process-R Inc.'s goal was to develop a process that will use the new resin to manufacture automotive body side mouldings. They worked with the resin supplier to develop specifications for the plastic and a process that can use this material to obtain a product that meets the technical specifications for the part.

3.3.1 Section A: Purpose

The creation of process technology that will enable our company to make exterior panels and other automotive parts from a new plastic.

3.3.2 Technological advancements sought

Technological advancements will be required so that:

- The new plastic can be processed in injection moulding applications.
- The properties of the plastic will facilitate the production of a part with the required geometry.
- New techniques can be developed for post mould handling of parts made from the new plastic.

3.3.3 Technological uncertainty

Plastic parts are used routinely for exterior panels of cars and other vehicles. They are usually painted to achieve the required gloss levels, surface strength and impact resistance. The challenge is to produce a part that does not need to be painted to obtain a uniform surface that will be durable enough to withstand the environment to which it is exposed and the required mechanical properties.

3.3.4 Summary of work carried out

- Sample parts of the new plastic were made utilizing existing moulds with geometry similar to the intended body side mouldings required for the specific application.
- The processing requirements were extrapolated from the indications of part appearance obtained in these initial tests.
- Part handling systems were developed and the initial parts were used to evaluate the process.
- The moulds utilized for these initial tests are set aside.

The plastics processor then waits for the new moulds to arrive from the mould maker. When they arrive:

- Tests are carried out on them, with changes being made to the processing system to obtain the best results. These results are recorded and copies are sent both to the plastics processor's engineering department and the mould maker's engineering department. The plastics processor analyses the data and prepares for the next test.

The moulds are then sent back to the mould maker. After some time the moulds are returned and:

- The plastic processor analyses the first sample part, and makes further changes to the processing parameters attempting to correct problems with part appearance.

The moulds may be returned the mould maker a number of times before it is determined that the requirements can or cannot be met.

3.3.5 Documentation

- Initial project description
- Test results / Lab books
- Process specifications (versions)
- Time records (employees / machinery)
- Invoices, work orders

3.4 Project Claimed by Mould-R Inc.

Background

Mould-R needs to take the part geometry and plastic material specifications and create a mould that will produce a part that will meet the conditions specified for use in automotive exterior trim.

3.4.1 Purpose

The creation of a mould that is capable of acquiring and maintaining the high level lens quality surface finish required to mould a “wet look” paint like part.

3.4.2 Technological advancements sought

- Can an SPI A-1 lens quality finish be applied to an automotive mould consistently over a large surface area?
- Is there a tool steel available to support this type of mould finish?
- If both tool steel and polish criteria can be met, will the surface last during the moulding process?
- How will the surface tension effects created by the smooth surface associated with the high finish effect the flow of plastic?
- Can a runner system be developed to compensate for any flow problems, and if so how?

3.4.3 Technological uncertainty

Plastic parts are used routinely for exterior panels of cars and other vehicles. They are usually painted to achieve the required gloss levels, surface strength and impact resistance. The challenge is to produce a mould that can be used with the new resin system to obtain parts with the required mechanical properties, which has a uniform surface that will be durable enough to withstand the environment to which it is exposed.

3.4.4 Summary of work carried out

- Candidate samples of tool steel were acquired for tests on surface polishing. The results of these tests were used to select a steel for the mould.
- Moulds were designed and built utilizing the chosen steel.

- The moulds were then tested under simulated production conditions.

The mould maker then released the moulds to the plastic processor for initial production mould process testing. They were returned to the mould maker along with sample parts and the data from the processor’s tests.

Further work was then carried out to:

- Analyze the test sample parts to determine what changes can be made to the mould or the handling system to correct problems in part appearance.
- Inspect the mould for a number of performance characteristics including surface finish, durability and determine coating requirements for surface protection.

3.4.5 Documentation

- Project plan
- Test results, analysis & conclusions
- Timesheets
- Supplier invoices
- Prototypes, moulds and parts
- Photographs
- Engineering reports
- Customer feedback reports

4 In-line compounding

4.1 *Background - the business context*

Normally, filled resins are precompounded prior to the injection molding process. There are limits to the length of the fibers that can be introduced and in many case better product performance would be achieved if longer fibres could be used. A company wanted to develop a capability for the direct compounding of a glass-filled polypropylene resin in an injection moulding machine.

4.2 *Project Description*

4.2.1 Section A: Purpose and project description

Develop equipment that will allow the direct compounding of a glass-filled polypropylene resin in an injection moulding machine.

4.2.2 Section B: Technological advancements sought

- Develop a capability for the direct compounding of a glass-filled polypropylene resin in an injection moulding machine.
- Improvements in the physical properties of glass-filled moulded parts by increasing the length of the glass fibers.

4.2.3 Section C: Technological uncertainty

Equipment

- The twin screw extruder, which was designed for continuous extrusion operation, was required to run discontinuously (start / stop). It was not known what effect this would have on the uniformity of the resin properties and the distribution of the glass fibers.
- The twin screw extruder normally experienced little or no resistance to the outflow of resin. It was not known how much backpressure would be created by transferring the compounded resin to a shooting pot and how this might affect the operation of the extruder. It was also not known if the extruder could exert sufficient pressure to fill the shooting pot.
- Shooting pots in two stage injection units are usually filled quickly at the end of the plasticizing cycle of the injection screw. It was not known how the continuous filling of the shooting pot during plastisizing by the twin screw extruder will affect the uniformity of the melt.

Process

- Relationship between throughput (operating speed) and fiber length.

- Relationship between throughput and uniformity (homogeneity) of fiber distribution.
- Relationship between the amount of glass and the uniformity of fiber distribution.

Material

- Compounded resin property changes resulting from increased length of glass fibers.
- Sensitivity of properties to glass fiber length distribution.
- Sensitivities of material properties to screw speed, injection speed, melt temperature, mould temperature and hold pressure.

4.2.4 Section D: Summary of work carried out

A concept was developed based on:

- design changes to the injection unit to allow the standard, single, injection moulding screw to be replaced by a standard intermeshing twin screw extruder intended for extrusion processing,
- redesign of the injection unit barrel head to interface with the extruder and feed in the continuous glass woven roving,
- design of a mechanism and structure to feed the glass woven roving from containers to the barrel head,
- modifications to the machine controls to control the operation of the twin screw extruder.

After the detail design was completed, a prototype was constructed and experiments conducted to measure:

- the influence of moulding process parameters such as the amount of glass fiber, resin melt temperature, screw speed, injection speed and hold pressure,
- measure the impact strength and heat deflection temperature of moulded parts,
- measure the glass fiber length distribution.

4.3 Comments

In this example the work carried out in the project meets the requirements of experimental development. The technological advancement sought is the “know-how” required to compound glass-filled polypropylene resin directly in an injection moulding machine. The technology involves both the development of machinery and process control.

This example also illustrates the relationship between technological advancement and technological uncertainty, i.e. the attempt at technological advancement, in this case the technological “know-how”, becomes obvious when the work is directed to resolve the technological uncertainties involved in the equipment, the process and the material.

5 Bottle Filling - Product Range Extension

5.1 Background - the business context

With the wider consumer acceptance of plastics containers in the food and beverage market, there is an on-going trend to replace glass containers with plastic. A plastics container company embarked on a program to develop a small single serve container that would be hotfillable and provide the required shelf life for juice, isotonic and sauce applications.

Hot filling is employed to sterilize the internal surface of the container and closure and not to reduce microbial counts in the product. Bottles from any reputable manufacturer will have very low microbial loads since the melt and reheat-blow processing sterilizes them. In most modern processes, the product with which the bottle is filed has already been pasteurized by a thermal treatment before filling. Subsequent handling should maintain this cleanliness.

In the filling process the hot liquid, typically at 185^{o}F (85^{o}C), is introduced into the bottle by a fill tube, which is withdrawn leaving a headspace, and the bottles are conveyed to a capper where more headspace is created by sloshing. Our industry specification is that bottles must be able to withstand a headspace of 15 mm depth.

After capping, the bottle cools and the water vapour in the headspace condenses contributing to a vacuum. The liquid also thermally contracts. The bottles must be designed to withstand the hot filling and the subsequent vacuum that forms when the liquid cools. The vacuum level also determines the amount of residual oxygen in the bottle, which impacts on the shelf life of oxygen sensitive products. The bottle generally has an industry standard finish (the threaded part of the bottle) of 43 mm[3], a size that imposes severe challenges on bottle design.

To withstand this partial vacuum, PET bottles are made with panels and domes. The panels are designed to flex on cooling and take up the vacuum, while the rest of the bottle remains rigid so as to meet topload, shrinkage and ovalization specifications.

Since the company had been manufacturing larger size (1L and 2L) hotfill containers for the beverage market for a number of years, the engineer who prepared the technical descriptions included in the company’s SR&ED claims was concerned because the project appeared to be a routine design and engineering procedure at first glance. Since he felt that there was a significant amount of technical uncertainty that would have to be resolved in order to

[3] This is the overall outside diameter used for 64, 32 and 20 oz. hotfill bottles.

successfully complete the project, he contacted his local CRA office for advice on how to prepare his claim.

5.2 Project Description

5.2.1 Section A: Purpose and project description

Development of a small single serve container that would be hotfillable and provide the required shelf life for juice, isotonic and sauce applications.

5.2.2 Section B: Technological advancements Sought

Determination of the relative impact of condensation and thermal contraction on vacuum formation in a single-serve hotfilled PET bottle.

5.2.3 Section C: Technological uncertainty

Without knowing the parameters that control the vacuum formed in the headspace of a hotfilled bottle, it is not possible to calculate the stresses on the bottle or to determine the shelf life of the product.

5.2.4 Section D: Summary of work carried out

- Several bottle and vacuum panel designs were evaluated using finite-element analysis to determine the optimize design for building a prototyping mould.
- Bottles made with the optimized design were filled at 85°C and tested using the standard hotfilled container procedures and specifications. Modifications were done on the panel design and material distribution to optimize the structural performance of the bottle.
- Overall volume change of the bottles was measured using the displacement method in a graduated cylinder. The change was compared to the calculated value of liquid contraction and vapour condensation. A series of experimental runs were carried out on the filling line to determine the major factors that impacted on the pressure and amount of the headspace gasses. These were two level factorial designs that looked at the impact of bottle shape (two potential designs with differences in geometry, finish size, filling liquid temperature, filling speed and two different types of nozzle. These runs were repeated during two separate shifts (one a day shift the other a night shift, to provide different cooling speeds due to different ambient temperatures).
- The pressure in the headspace was measured. The rate of oxygen transmission through the bottle wall was also measured using a proprietary method.

- The results were analyzed to determine the effect of each of the variables on pressure and product shelf life.

5.2.5 Section E: Project Status

The project was concluded successfully. The company had always believed that the major factor in creating vacuum pressure was the condensation in the headspace but closer examination reveals some surprises. The work showed that the major cause of vacuuming was simply from cooling the liquid from 85 to 23°C. The work showed that there is a significantly higher oxygen/liquid ratio in the headspace for the single serve containers when compared to the larger size containers; this has very serious implications for oxygen sensitive liquids.

Based on this study, it was concluded that smaller finish sizes are necessary if we are to design successful smaller-volume containers for hotfill applications. This will lead to lighter-weight (lower cost) containers and lower cost closures.

5.2.6 Section F: Documentation

- Drawings of container design
- Design of experiment planning documents
- Note books of the engineers involved in the work
- Run sheets showing process conditions
- QC logs generated during the runs

5.3 Comments

Work to extend a product line is not automatically SR&ED. In this case the work meets the criteria for SR&ED since a technological advancement is required and the work is carried out systematically.

The CRA R&T advisor recommended that the project description should be modified to clarify the number of experimental runs required to advance the technology, their length and the amount of material that was scrapped in these experiments. The review process was facilitated by this additional information.

6 Bottle Filling - Production Problems

6.1 *Background – the business context*

In the following example, our company had production problems with the manufacture of a bottle that had been developed in our plant.

In order to reduce material cost and improve cycle time during the preform injection process, the company had decided to reduce the weight of an existing plastics bottle by 5% for a juice application. Since it was uncertain whether the lighter weight container could still satisfy all physical properties and specifications, it was necessary to proceed with a prototyping injection mould to manufacture the new preforms. The lighter weight preforms were subsequently blown into the same juice container for testing. During the development of this lighter weight container, it was found that the bottle satisfied all the specified requirements, except the top load condition, i.e. the bottle was collapsing when the specified force was applied to the top of the container.

Using Design of Experiment techniques, the poor top load condition was eventually rectified with a new preform design to allow material to be distributed in the desirable area during the blow moulding process. The technology to produce the lighter weight preform and container was then transferred to a production plant.

6.2 *Summary of work carried out*

A few months after the bottle had been in production, the process operator found that the bottle had failed the specified top load requirement during his routine quality check. With the help of the Quality Assurance technician, the process operator was able to run several experiments and determined that the preform heating profile had drifted and had to be adjusted to achieve the original material distribution. The operator already knew that the bottle could achieve the top load condition when processed properly, so there was no technological uncertainty when the experiments were run.

6.3 *Comments*

The original work described in the previous example that was required to reduce the weight of the soft drinks bottle qualified as SR&ED.

When the operator later had problems with achieving the top load condition, she already knew that the bottle could achieve the required specification when processed properly, so there was no technological uncertainty when the experiments were run.

Although the work required to return the bottle making process to its original specified conditions was carried out in a systematic manner, it is not considered to be SR&ED, since there was no need to advance the technology. It was quite clear to all parties concerned that the work only required the application of known process technology.

If the operator had to develop the technology further in order to achieve the specified heating profile, a technological advancement would have been made and the work could qualify as SR&ED.

7 Ejection Detection

7.1 Background

Getting moulded parts out of the tool and "down the spout" is a critical part of any mass-production moulding operation, including the more esoteric processes like rotational moulding and hand lay-up. But in injection moulding, failure to eject reliably is more than an inconvenience.

The eight-cavity mould produced a dimensionally non-critical (this was before Six Sigma) small cylinder which was ejected conventionally then blown into a hopper which gravity fed into a small conveyor for the "second op" process. Sprues fell into a barrel where they could be carted away periodically.

The system worked well enough but every once in a while, mis-ejection would cause a “stoppage”. The operator would have to hit the panic button when the mould made that characteristic dull thud that suggested ejector pins that were not cycling in a straight line. If they didn't, it usually meant a crash, bent pins, and lots of expensive downtime.

After re-startup, the machine always checked out O.K. Run the process at or near an economically viable speed, however, and the problems reappeared.

7.2 Project Description

7.2.1 Purpose and project description

To correct a problem of frequent “stoppages” on an injection moulding machine by identifying its root cause.

7.2.2 Summary of work carried out

1. The first step was to manually check for binding or roughness. The parts slid freely.
2. Loading the cavity with spray-on mould release and adding a little heat showed there was no kind of build-up or gumming action.
3. The pins were removed for a visual check that showed that the heads had sufficient clearance to keep them floating behind the retainer plate.
4. There were no witness marks on the parts and ejection seemed trouble-free at moderate speeds. Use of a strobe or high-speed camera to watch the action was considered but there seemed to be no way to adequately see the pins cycle.
5. The short-term solution was simply to slow the machine down, since the investigation consumed production time too.

6. A little later the tool went back to the mould shop for a slight modification. After the mild rework, the mould behaved perfectly. It turned out that the bores for the worst offenders were short, very short, at what seemed like not much more than the diameter of the already slender pins.

7.2.3 Project status

At a later date the engineer noticed that serious bellmouthing on the parts had been ignored. This telltale sign should have given away the cause; "It came like that and the other shop says it made 1.2 million parts with no problem".

Rebushed, with new drylubed pins, the mould worked as advertised. Manually sliding those nails back and forth and wiggling side to side failed to produce the lash that was not noticed because at the extremes of the pin's motion, the head gave it extra lateral support, which isn't a realistic operating condition.

7.3 Comments

Despite the engineer's oversight, the work described here is clearly carried out in a systematic manner, meeting one of the criteria for SR&ED eligibility. The problem was solved using existing technology so there is no technological advancement and the work does not qualify as SR&ED.

Again, as in the previous example, if the operator had had to develop the technology further in order to solve his problem, then the work could have qualified as SR&ED.

8 Compression moulding of abrasion resistant liners

8.1 Background - the business context

In an attempt to expand its market share and better meet its customer's needs by offering a broader product line, the plastic company embarked on the development of a new steel filled UHMW-PE[4] for use as an abrasion resistant lining material in the pulp and paper industry.

8.2 Project Description

8.2.1 Section A: Purpose and project description

Development of a steel filled UHMW-PE abrasion resistant liner for the pulp & paper industry.

8.2.2 Section B: Technological advancements Sought

- To use steel powder as a filler in a UHMW-PE sheet intended as an abrasion resistant liner.
- To develop a mixing process for high density fillers such as steel powder.
- To control the thickness of steel filled UHMW-PE liners and meet the tolerance requirements through the use of process conditions (temperature, pressure) to control the shrinkage.

8.2.3 Section C: Technological uncertainty

- The addition of even a small quantity of an additive to UHMW-PE can have
  large unpredictable adverse effects on the properties and processing of the polymer.
- Steel powder is extremely dense and has very different properties from any filler that we have previously used with this polymer.

8.2.4 Section D: Summary of work carried out

1. A set of designed experiments were conducted on small scale compression moulding equipment to determine the effects of the addition of several types of metal powders (material and morphology) on the properties of UHMW-PE.

---

[4] Ultra High Molecular Weight Polyethylene

2. Once a material was selected that could be added to UHMW-PE to give the required properties and economics, another series of experiments were carried out to evaluate the processing requirements.
3. During production trials several processing problems were encountered. The
unusually high bulk density of the additive gave rise to mixing problems that had to be overcome.
4. The new formulation had a much lower coefficient of thermal expansion and therefore did not shrink as much as standard UHMW-PE material would upon cooling. This made it difficult to remove the product from the moulds. We therefore had to experiment to find a way to remove the finished product from the moulds. This was achieved by modifying the temperature profiles.
5. To obtain the required thickness, standard practice is to mill the material down. This new product could not be milled as it quickly wore the carbide tipped milling blades away. Experimentation was initiated to determine how to meet the thickness specification.

8.2.5 Section E: Project status

The required thickness tolerances were not met for this type of steel filled UHMW-PE lining material. It was not possible to mill the material even with carbide tips. Currently modifications to the compression molding process are being developed to allow processing of tighter tolerance sheet. This would eliminate the need for subsequent milling to meet the thickness tolerances.

8.2.6 Section F: Documentation

- Lab reports and research notes.
- Production trial documentation.
- Samples

8.3 Comments

This experimental work to produce steel filled liners is carried out in a systematic manner in an attempt to remove uncertainty and advance the technology. It is thus SR&ED.

In this case one business project is presented as a sequence of technological problems. In other cases it may be more appropriate to break the project into a number of sub-projects.

9 Material Substitution

9.1 Background – the business context

Our company is producing extruded profiles for the appliance market from ABS[5] produced with compounding technology. As a result of cost pressures in this extremely competitive market, the company was looking for alternative materials, which would provide a similar property balance at a lower price. After looking at several alternatives, and talking to our suppliers we decided to investigate the possibility of using a mass polymerisation grade of ABS.

Since a similar grade was chosen, the initial expectation was that the resin switch would be seamless. As part of the manufacturing routine the new profiles were put through the testing procedures to ensure performance was achieved. Although the resins had almost identical specifications, the shrinkage behaviour of the parts made from the new resin was different.

9.2 Project Description

9.2.1 Section A: Purpose and project description

Identify a lower cost alternative to ABS as part of our cost reduction program.

9.2.2 Section B: Technological advancements sought

To develop a process that produces extruded profiles for the appliance market[6] using lower cost mass polymerized ABS in place of ABS produced by compounding technology.

9.2.3 Section C: Technological uncertainty

We are presently using ABS produced via compounding technology to manufacture extruded profiles for the appliance market. Our supplier has suggested that we can obtain similar results with ABS produced in a different process (mass polymerisation). Although we chose a material with similar specifications, as in this case, they will often behave differently.

9.2.4 Section D: Summary of work carried out

The new ABS was chosen because it had a similar molecular weight and was expected to have similar thermal properties (die swell, thermal conductivity, shrinkage, flow)

---

[5] Acrylonitrile-butadiene-styrene

[6] The initial application was for a breaker strips for a refrigerator. Decorative extruded profiles can be manufactured in a similar process.

400 meters of product were produced in an experimental run that took four hours. This time was required to stabilise the line and allow the production of consistent material.

Testing of the parts produced showed that they met the mechanical requirements, but that the shrinkage was different from that which was predicted and hence the size of the parts was not correct.

The dies had to be modified by trial and error, since there was no way to predict the shrinkage with the accuracy required.

In the third trial, parts were obtained which consistently had the correct dimensions.

9.3 Comments

Replacement of one resin by another or using the same resin produced in a different process will often require experimental development. Substituting a resin for a competitive material produced by a different supplier (or manufactured by the same supplier at a different location) can require SR&ED but is much less likely.

In this case SR&ED was required. In the absence of scientific predictions, a systematic process of trial and error was used to modify the extrusion dies.

The project claim should include the labour required to run the trials and carry out the product testing. The resin used in these trials should also be part of the claim as “materials consumed”. Disposal costs of scrapped material might also be included in the claim.

Whether or not the project is successful work on the dies can be claimed as part of the project. Any dies that are scrapped as part of the SR&ED work can also be included in the claim as “materials consumed”. If the dies themselves are used in production then they become “materials transformed”.

10 Dual Injection

10.1 Background - the business context

A company wished to make use of a new technology called dual injection, which they had never used before. They believed that this technology would allow them to use recycled polymer in the core of a product, and virgin material on the outside. Performance requirements are that the outside material must be of sufficient quality to pass impact tests without surface blemish or cracking.

10.2 Project Description

10.2.1 Section A: Purpose and project description

Develop the capability of using dual injection technology to increase the amount of recycled material in a product.

10.2.2 Section B: Summary of work carried out

In order to assess the technical and commercial feasibility of this new technology, the company needed to determine the necessary machine parameters to obtain an acceptable product at minimum cost.

- A number of trials were performed in a standard format for designed experiments; in this case a Taguchi L9 (a statistical experimental design technique) was used.
- Optimum conditions were estimated and used in a final confirming experiment.
- A 300-piece trial was conducted at the optimum conditions to determine process capability. All 300 pieces were scrapped after the trial.

10.2.3 Section C: Technological advancements sought

- Develop the capability of dual injection to allow the use of recycled polymer in the core of a product, and virgin material on the outside.
- Develop an understanding of the capabilities and limitations of dual injection technology.

10.2.4 Section D: Technological uncertainty

We did not know how to achieve our objectives with our present technology

10.3 Comments

This example illustrates how the use of new technology enabled the company to reach its technical objectives and such work often involves technological uncertainty. The work was driven by a need to reduce costs. A systematic process of experimentation was used to carry it out.

If a company is using a technology for the first time it does not automatically mean that they are carrying out SR&ED. When describing a project like this one, it is therefore important to identify the parts of the technology that are general available and distinguish these from the “know-how” that the company needs to develop experimentally.

In this case the technical content requirement was satisfied with the performance of a designed experiment using accepted methods, and the completeness of the work in performing the 300-piece process validation.

11 Different Equipment

11.1 Background

One of the critical issues in the manufacture of blow-moulded containers is ensuring that any fill lines on the finished container are correctly located to control the volume of the product in the container with sufficient accuracy.

A blow mould company has been supplying blow moulds for bottles for many years and is now expanding into international markets. Their new customers are expecting moulds of similar configuration to conform to strict packaging criteria, regardless of where in the world the tool is produced. The company must develop methods to design and manufacture moulds that can be used to produce bottles with consistent dimensions.

11.2 Project Description

11.2.1 Section A: Purpose and project description

The purpose of the project was to develop procedures that can be used to design and manufacture blow molds for the production of bottles that have a fill line to indicate the amount of product to be sold in them. These bottles need to have the same dimensions when produced in North America, Europe or South East Asia. The critical requirements were stable and consistent vertical and horizontal wall dimensions as well as consistently located fill lines.

11.2.2 Section B: Technological advancement

The technological advancement was the establishment of design and manufacture parameters which would ensure that the strict dimensional requirements would be obtained in production, regardless of where either the mould or the bottle was produced. The technological advancement identified the critical parameters and provided a means of determining the variables that were used during the design of the mould to control its volume. The experimental work would provide improved “predictability”.

11.2.3 Section C: Technological uncertainty

Blow moulding machines can produce difference results with the same mould. Humidity, temperature, cooling, cycle, resins and settings parameters can all impact on the shrinkage factors of the material, and hence the dimensions of the plastic products produced in them. It was not certain that verifiable design and manufacturing parameters could be identified that would allow sufficient control over the process to provide products that would meet the strict requirements, independent of the location, the blow mould machine used for production, the resin supply, as well as the local technological capabilities and the climate.

11.2.4 Section D: Summary of work carried out

The project began with the design and manufacture of a prototype mould. The mould design was based on the final product design. However it was modified to include measurement indicators, which during test runs could provide precise data about vertical and horizontal shrinkage as well as changes in volume.

The prototype mould was built and sent to the first site for testing. Data gathered included information about the resin and the machine used, the resin as well as processing temperatures and other processing parameters. This data was analyzed along with test results from the samples produced.

The mould was then returned to Canada and modifications were made to the mould based on these results. The modifications included changes to the design indicator locations and cnc machining. The mould was retested at the same Canadian site with the same conditions. Further data was collected during the production of samples. The samples were again analyzed and variables determined based on the results of this second test. A third iteration was carried out before satisfactory results were obtained.

Mould tryouts in this experiment were conducted at 4 locations in North America, Europe and Asia as identified above, although all design, machining work and preliminary testing was completed in Canada. Each time the data was collected and modifications made to establish the reliability of the predictions. It was learned from these experiments that variations inherent to processing of a product in various locations through out the world could be predicted in advance with the help of a number of parameters.

11.2.5 Section E: Project status

The data collected from the prototype helped to develop a database for model classification based on location, equipment application and material supplied. Much was learned from the project, and the data now provides the ability to predetermine what variables must be applied prior to the design of new tooling.

11.2.6 Documentation:

- Design variable Database;
- Prototype and part drawings;
- Job cards;
- Technical specifications;,
- Test reports and
- Transit reports.

11.3 Comments:

The description of the work carried out explains how the experimental mould was modified and reused for experimentation in the establishment of the dimensional variation database.

The development of design procedures can be SR&ED, although only the work carried out in Canada can be claimed. The use of these procedures in subsequent projects to design production moulds may not be SR&ED.

In this project the prototype mould met the CRA definition of a prototype. It was a piece of equipment designed and built for the sole purpose of experimentation and data collection. Upon completion of the experiment it was not usable for commercial production.

12 Extrusion

12.1 Background

Extrusion processes are used to produce a wide variety of products, such as coated wire, blown film, extruded sheet, pipes, tubes and extruded profiles.

The components of the extrusion process usually consist of an extruder (drive, gearbox and screws), the extrusion die, a cooling medium, calibration units, haul-off equipment, a saw or other cutting device and finally devices that provide any treatment required for final finishing.

In the extruder, material is added to the hopper as either powder or pellets. The hopper continuously feeds the material to a heated barrel, which contains a rotating screw. This screw simultaneously heats, mixes, pressurises and meters the material as it transports the polymer to the die head. At the die, the polymer takes up the approximate shape of the part and is then cooled either with water or air to give the final shape. As the polymer cools, haul-off devices draw it along so that the product can either be coiled or cut to length

The material selection process requires balancing a number of properties of the resin. These might include density, tensile strength, flexural modulus, UV Stabilizer levels, coefficient of thermal expansion, coefficient of friction, melt index, shrinkage and gloss levels. At the start of the project it is not always clear what are the important performance criteria and the levels of these are required. Experimentation is often required to determine these.

The performance of the product usually depends on the conditions under which the material was processed. Relevant process parameters can include melt temperature, barrel temperatures, die zone temperatures, back pressure, velocity and mass flow rate.

The type of equipment used to process the polymer can also impact on product performance. For example the cooling bath, its inlet and outlet temperatures and flow patterns, can modify the product performance.

After extensive market research and an economic trend analysis, the company has decided to produce a polypropylene (PP) sheet product which they hope will fulfill its customers' needs and allow them to expand their market share. Since they had no experience of the use of PP in this type of application, extensive experimentation is required so that they can to develop a viable manufacturing process and gain control the many parameters and their interactions.

12.2 Project claim

12.2.1 Section A: Purpose and project description

The development of technology that will provide a process to produce PP sheet that meets the technical requirements for a number of novel applications.

12.2.2 Section B: Technological advancement

- To identify a grade of polypropylene that can be processed to produce a performing product.
- To modify the processing equipment so that a product can be obtained that meets all critical dimensional requirements
- To develop a dependable process to produce PP sheet that will consistently meet customer requirements.

12.2.3 Section C: Technological uncertainty

The resin system and process conditions that were chosen based on previous experience gave a product that was too variable. The process was unstable

12.2.4 Section D: Summary of work carried out

- In conjunction with material suppliers, several experiments were conducted on the production line with various compositions and melt index to identify a grade that could meet dimensional criteria at an acceptable mass flow rate.
- Traditional processing techniques were not satisfactory because variations in melt strength and coefficient of thermal expansion caused freezing of the material, variation in hardness of the material and irregular shrinkage. These variations gave an inherently unstable process
- Rolls were replaced with flame hardened rolls that were annealed at higher temperatures to prevent damage caused from the freezing of the new material on the rolls.
- The corona treater roll was replaced with a smaller roll to allow for the higher shrinkage of the new material and the amperage of the treater was increased as the PP material proved to be more difficult to treat than the conventional material run on these lines.

12.2.5 Section E: Project status

The processing issues have been resolved and the first product in the new range has been accepted in the marketplace. Further SR&ED work is anticipated in order to produce sheets with different thickness for similar applications.

12.3 Comments

This experimental work to develop a process to manufacture polypropylene sheets meets the criteria for SR&ED since it is carried out in a systematic manner attempting to remove uncertainty and advance the technology.

Simple selection of materials without the development of new technology is not SR&ED. In this case the required know-how is not available in the public domain and must be developed by the claimant.

The claimant correctly recognises that the market research and an economic trend analysis (which are certainly an essential part of the business project) are not part of the SR&ED project.

Although there are three separate technological advancements required, the interactions between the materials, the equipment, the process conditions and the final end product properties means that this work must be treated as a single project. This does not however mean that all expenses will be accepted as eligible.

The labour required to identify the best grade of PP is clearly a part of the SR&ED project; the material that is scrapped as a result of the trials and which cannot be recycled is “consumed”.

The work on the rolls is also a part of the SR&ED project, but the rolls themselves will be used in production and so cannot be claimed as part of the SR&ED project. An exception would be if experimental rolls are ordered for a trial and are scrapped after the trial.

13 Screw Design

13.1 Background - the technical and business context

Mixing plays a critical role in plastics processing. At low stress, distributive mixing occurs. When more stress is applied, dispersive (intensive) mixing occurs. Dispersive mixing ruptures the cohesive forces that cause components to agglomerate into droplets or particles and thus gives more uniform distribution of the components.

The use of all polymers requires the addition of materials that confer the required performance properties. These can include thermal and UV stabilizers, plasticizers, organic or inorganic pigments, regrind or even physical blowing agents to produce evenly distributed uniform cell structures. To be as effective as possible, these additives need to be dispersed as evenly as possible within the polymer matrix. The technological challenge of uniform pigment and additive dispersion can be addressed by systematically modifying screw designs.

Design of a screw for a specific application will depend on the requirements, which will vary according to the composition of the compound, the equipment and the end application. A host of technological uncertainties may arise during this design process. For example if we need to introduce new mixing elements into a screw designed for an injection machine, special challenges can arise because the plasticating unit –(the plastic melting and conveying section) of an injection machine is relatively short. Moreover, the new screw design may fail to produce the expected dispersion, to the detriment of the end product.

Screw designs must provide the best combination of distributive and dispersive mixing in order to produce the required properties in the product. The screw of an injection-moulding machine is typically a single stage and single flighted conveying screw. Studies have shown that the shear flow generated by screws of this type is inefficient for dispersive mixing. Instead, generation of elongational flow, in which particles such as filler agglomerates undergo a stretching type of deformation without rotational movement, helps in efficient dispersive mixing.

The company is using injection moulding to manufacture a product for the construction market. If a product can be made with a higher impact resistance, then a new application would be possible, which would result in a new product line and increased sales.

13.2 Project description

13.2.1 Section A: Purpose and project description

The development of an improved screw design that will allow us to increase the impact resistance of the product and at the same time increase productivity without increasing production costs.

13.2.2 Section B: Technological advancements Sought

A new screw design that will offer:

- Improved dispersion, without changing the process conditions.
- Consistently improved impact properties.
- Shot repeatability, with reduced variations in part weight.
- The ability to include a higher percentage of regrind materials without sacrificing performance properties.
- Enhanced particulate dispersion without irregularities of colour.

13.2.3 Section C: Technological uncertainty

- Our new product line demands parts with better impact resistance. This means that a new ingredient must be mixed efficiently. For this injection moulding application, we would like to insert the mixing elements into the screw of the injection moulding machine. Although this new design might improve mixing, the process conditions could thereby be changed, giving a process window that might not allow cycle time adjustments. The use of regrind use might be restricted and costs might rise.
- The current process produces a commercially viable product, but variations in part weight and inconsistent impact properties have been reducing productivity. Mixing elements are available that can improve the relative amounts of dispersive and distributive mixing. The available technology allows us to make directional predictions, but the science is not available to make quantitative predictions. Thus experimental development work is required to improve the performance of the screw in this application.

13.2.4 Section D: Summary of work carried out

- The output of the injection screw was found to be much less than its theoretical (calculated) output. Possible reasons for this discrepancy included:
    a. A feed problem
    b. Wear of the screw or barrel, or
    c. Insufficient melting of the ingredients at high screw speeds.
- Measurements of the barrel and screw did not uncover any wear related issues. Changing the barrel temperature settings did not improve the output or the variability of the parts.
- Different chemical measurements (viscosity, solvent extractions and thermo-gravimetric analysis) and measurements of surface properties on different sample parts showed that the dispersion of solids was not uniform. Un-melted resin pellets were even observed occasionally.

- Based on the above investigations, two strategies were undertaken to advance the technology:

1. The design of the non-return valve (NRV) was changed to improve mixing. This was achieved by adding a CRD[7] mixing element to an injection screw as follows: mixing pins were placed inside the slide ring of the NRV. The pins were elongated in the axial direction in order to accelerate of the melt fluid as it passed between two pins. This gave elongational flow, which resulted in effective dispersive mixing. Adding similar pins to the outside of the stop subjected the mixture a second time to elongational flow. The large number of pins induced many splitting and reorientation events and the result was efficient mixing.

2. Instead of ground calcium carbonate (GCC), precipitated calcium carbonate (PCC) was used in the composition. Although PCC is costlier than GCC, PCC's particles are much finer and their high specific area and controlled structures make them more effective nucleating agents.

   - A set of experiments was designed and carried out, in which the percentages of PCC and GCC were varied in a systematic way to discern their effects on product properties.
   - After incorporating the CRD mixer onto the NRV, several runs were carried out and the resulting impact properties were measured. Using more pins allowed the proportion of regrind to be doubled and surface gloss improved considerably.
   - To check weatherability, specimens were placed under QUV panel and their impact properties determined after various exposure times. Samples containing GCC showed marked loss in impact properties while samples containing PCC did not.

13.2.5 Section E: Project status

As a result of this work we were able to improve the impact resistance of parts. In addition we produced less scrap and regrind content was doubled from 5 to 10%. Since the work has taught us that mixing can be improved, we anticipate continuing this work in the next year to further increase the regrind cycled content.

13.2.6 Section F: Documentation

- Screw design
- Test results from experimentation
- Literature

[7] Chris Rauwendaal Device

13.3 Comments

The description shows that work was carried out in a systematic manner to advance both screw design technology and to improve the technology available to use regrind in our processes.

The work meets the criteria for Experimental Development.

14 Development of an UHMW-PE Abrasion Resistant Sheet Formulation

14.1 Background - the business context

A company launched a new cross-linked sheet to meet their customer's need for improved abrasion resistance. After launching the product the company received a customer feedback indicating a liking for the abrasion resistance and impact resistance of the new material but a higher flexural modulus was desired. The company decided that it was necessary to try to develop a product that would maintain the abrasion resistance and impact resistance achieved through crosslinking as well as meet this new primary requirement of an increased flexural modulus.

14.2 Project Description

14.2.1 Section A: Purpose and Project description

The development of a new product, which maintains abrasion and impact resistance while offering increased flexural modulus.

14.2.2 Section B: Technological Advancements Sought

To find a way to increase the flexural modulus without loss of abrasion resistance and impact resistance.

14.2.3 Section C: Technological Uncertainty

Increasing the cross-linking of a polyethylene resin increases both the abrasion resistance and the impact resistance. At the same time this increased cross-linking will reduce the flexural modulus of the polymer. The obvious way to provide the customer with a less flexible product (by reducing the cross-linking) cannot be used since this will reduce abrasion resistance and impact resistance of the product. Hence a more creative solution must be found to meet these seemingly contradictory requirements.

14.2.4 Section D: Summary of work carried out

- The company carried out an extensive series of small scale laboratory experiments to determine what effect a variety of additives have on the flexural modulus of the cross linked product. Several additives were found that increased the flexural modulus of the product to the required levels.
- The flexural modulus, abrasion resistance and all of the other secondary properties including: tensile strength, izod impact strength, coefficient of thermal expansion and coefficient of friction were tested

on several blends of each of these additives at a variety of loading levels. These experiments provided an optimum blend.

- A production trial was carried out to determine what effect this formulation had on the processing of the product. Using standard processing parameters problems were encountered during both the mixing of the blend and compression moulding of the new material formulation. Laboratory experimentation in addition to several production trials were carried out to determine how to obtain thorough mixing of the product and what the optimum pressure and temperature cycles are for the new formulation.

14.2.5 Section E: Project Status

Through these trials & experimentation we developed the knowledge that allowed us to develop a product that met both the primary property requirements of improved abrasion resistance and higher flexural modulus as well as the secondary property requirements of maintained tensile strength, izod impact strength, coefficient of thermal expansion and coefficient of friction.

14.2.6 Section F: Documentation

- Lab reports & research notes
- Production trial documentation
- Samples

15 Large Compression Moulded Parts

15.1 Background - the business context

An American company had requested that we develop, design and build moulds that would produce plastic road gratings. These gratings were meant to replace the wooden planks used to construct temporary roads in construction sites.

The parts would have to be strong enough to withstand dynamic loads over 40,000 kg from construction machinery. Each plastic part would measure 84" wide by 156" long and weigh over 500 lbs, and would have to be made from plastics that could be recycled. Right at the outset, we realised that plastic parts of the required size and strength could not be moulded with current technology. The moulds for these parts were larger than any that had been manufactured before and as a result, the presses had to be redesigned around our new moulds. Our challenge was to design parts that would have the necessary properties, to build the moulds for these parts and to work with our client to develop a process that would enable our customer to manufacture these parts. This had to be done in a way that gave a finished product, materials and processes that met the cost constraints.

15.2 Project Description

Project duration: August 1997 to September 1998

15.2.1 Section A: Purpose and project description

Development of compression moulding tooling for thermoplastic material to produce ELCMP[8] for road grading plates to withstand up to 40,000 kg dynamic load.

15.2.2 Section B: Technological advancements Sought

- To fill larger moulds than anyone had ever used before. These moulds would be used to make parts that were twice as big as any that our company has ever made.
- To use thermoplastic materials in compression moulding. Most compression moulding is carried out with reinforced and thermoset materials. We were using thermoplastic materials so that the resultant parts could be recycled. As a result a completely different process was required.
- To develop a manufacturing process with a commercially acceptable cycle time. Our initial attempts to make these parts gave a process

[8] Extra Large Compression Moulded Parts

with a cycle time of more than one hour. In order to have an economically viable process, we had a target of 2 minutes cycle time per part.

- To design plastic parts that would withstand 40,000 kg dynamic load strengths to which they would be subjected during their use.
- To develop techniques to prevent uncontrolled shrinkage of these parts
- To develop lifting and handling techniques that would allow the assembly of these very large parts at the construction site. The design required screwing two identical parts together; this required that the slots in the parts were aligned. The two parts then needed to be welded along the 4 sides to produce a watertight weld.

15.2.3 Section C: Technological uncertainty

- Compression moulding is usually carried out with filled and thermoset materials. These materials are available as either bulk moulding compound (BMC) or as sheet moulding compound (SMC). Since we wanted a system that was neither thermosetting nor filled, we had to develop a way to handle thermoplastics for compression moulding. Filling the mould with liquid plastic was not feasible since commercially available equipment could not provide an adequate shot size. We developed a technique whereby the mould was filled with granules, and then heated to melt the plastic; uneven filling resulted in voids in the parts, that would in turn cause stress points and low strength. Thus, we would have to overcome the problem of uneven filling of these extremely large moulds.
- Heating and cooling the mould in order to liquefy the plastic required that the mould be rapidly cycled through a wide range of temperatures. This was causing damage to the high grade of aluminium used in the mould. We then had to design and add special wear plates and determine if these could resolve this problem.
- Shrinkage of the parts resulted in an unexpected locking of the part into the mould. A traditional compression mould contains a knockout box containing knock out pins and plates that move in unison. Since this could be incorporated into the moulding machine without a complete redesign and rebuild, we had to design and build a series of self-contained individual spring loaded mechanisms. The challenge was to design and locate these knockout pins so that they would move together and avoid cracking of the parts.
- The part has a honeycomb pattern on its underside. Initial computer design of the honeycomb pattern showed us that this approach should give parts with the required strength. The initial parts had dynamic load strength of less than 20,000 Kg because of the interaction between the process and the material. The size of the hex pattern, its wall thickness

and the depth of its ribs had to be optimised to withstand the extreme dynamic loads without cracking.

- The design of the parts would have to be amenable to easy assembly at the construction site. We did not know how to control the shrinkage to ensure that the locking slots would coincide with each other. Lifting the large parts gave a number problems and experimentation was required before we found a way to resolve this problem by introducing grooves onto the surface of the parts.

15.2.4 Section D: Summary of work carried out

1. Literature, patent and Internet searches as well as discussions with IRDI did not provide us with either technical information or scientific papers that could assist us with the project planning.
2. Based on our technological experience and our cost calculations, we concluded that a blend of thermoplastic plastics should be used to meet the strength requirements in a part that could be recycled.
3. A prototype mould was built to produce parts with the same thickness as the final product, but only one foot square. The parts produced were subjected to mechanical testing which showed that the strength properties were significantly different from the predictions. The mould was systematically altered until it yielded parts that met the design criteria.
4. In order to deal with challenges of making the plastic parts economically feasible, we designed a process whereby large parts measuring 84" x 156" would be moulded. The pieces were designed to allow easy assembly at the construction site by screwing them together in an overlapping fashion. Each assembled unit weighed over 1000 lbs.
5. We had to develop a way to handle thermoplastics for compression moulding. We soon found that melted plastic could not be injected rapidly enough into a mould this large. We therefore developed a process wherein plastic granules would be laid into the mould, which was then be heated until the plastic liquefied and filled the entire cavity of the mould. The mould was then cooled.
6. In order to minimise the heating and cooling time we investigated the use of aluminium moulds. We determined that high grade aircraft aluminium provided the required tensile strength and thermal conductivity, while being commercially available with an acceptable delivery time for the width required.
7. At this point, the cycle time required to fill, heat, cool and eject the part was economically unfeasible—nearly one hour. We designed and built a system of 12 identical moulds in three carousels of stack presses four moulds high. As the first carousel was heated, the second would be cooling while the third was ejecting parts and being refilled with fresh resin. This process had to be developed using all twelve moulds, since the

cooling rate of an isolated mould would be different, and we could not accurately assess shrinkage effects and warping.

8. The next problem to be overcome was locking of the part into the mould because of shrinkage. We therefore had to determine how parts this heavy could be removed from the moulds without damaging the moulds or cracking the part. We had to develop a series of spring-loaded knockout mechanisms that were built into each mould to avoid redesigning and rebuilding the presses. A moving machine platen would push the knockouts forward, thereby ejecting the part.
9. The scaled up parts did not shrink as predicted from the results of the prototype testing and experimentation. A large L-shaped design ran the length of two sides of the part and the resulting difference in cross-sections caused the part to twist. The L-shape was integral part of the design that allowed us to mould the mats with a honeycombed interior and solid edges needed to withstand the stresses and provide a means of joining the two sub-assemblies together. The edges with the L-shaped design shrank over 1.5” more than the rest of the part. Once again, we had to redesign and test alternative processes that would give us a part that remained square and flat during shrinkage.
10. The two halves of each mould did not have the same thickness and cross section, since one half had to accommodate the ribbing required for the honeycomb. The base was machined into an aluminium plate 3.7” thick, but the lid was only 1.75” thick. As the two halves of the moulds were heated and cooled, they expanded and contracted at different rates. The thinner lids expanded more quickly, and this interfered with the closing of the halves. We therefore had to design and build a series of wear plates to eliminate damage to the aluminum of the mould. Our design used lids with hardened O-1 inserts built into the four outer edges, and bases with built-in Ampco 21W inserts to mate with its O-1 partners. Ampco 21W was selected for its high lubricity properties.

15.2.5 Section E: Project status

The project is not complete. The parts are currently undergoing extensive field-testing. The latest reports shows that the parts are still cracking and therefore do not have the required strength. The moulds have been altered so many times during initial testing that new tooling will likely be required for the commercial moulds. There is still a reasonable likelihood that the entire project will have to be scrapped.

15.2.6 Section F: Documentation

Documentation, samples and drawings are available. These include:

- The initial letter requesting a bid for the parts.
- The results of the search for relevant technical publications or patents

- The specifications for the press, and the closest commercially available machine
- Test reports / photographs
- Shrinkage results / photographs
- The E-Mail to supplier requesting high lubricity materials

15.3 Comments

This project meets the SR&ED criteria.

Project descriptions can be presented in a number of ways. The above approach often works well for the kind of experimental development projects that occur in plastics and in other manufacturing sectors.

After an introduction of the commercial and technical objectives of the project, the description identifies the technological advances that were needed for the project to be successful. The technological uncertainties that had to be resolved to make those advances are described next; this is achieved by comparing what was known at the beginning of project with what was known at the end of the project. The summary of the work then provides an overview of how this was achieved, illustrating a systematic approach to resolving the technological issues.

16 The bevel gear

16.1 Background – the business and technology context

Our Company was incorporated in 1990. It is a recognized leader in designing and producing complex and innovative moulded plastic parts for several OEM industries.

The company was approached by a potential customer who wanted to purchase a mould that would produce a plastic bevel gear set that would match the performance of an original metal straight bevel gear set. The gear set included a 2-inch diameter, 16-tooth gear and a 1-3/8 inch diameter, 11-tooth pinion.

The customer offered us an opportunity to design and build the required mould. This potential customer was not contracting us to perform SR&ED. However, we had to perform SR&ED to satisfy the customer and win the business.

We decided to mould the gear set out of 6,6 nylon with a 33% glass fill. For the project to be economically viable, we needed to create a single mould with two cavities, allowing the gear and the pinion to be produced at the same time. Producing gears out of plastic provides considerable benefits in several areas such as drive smoothness, low noise in operation, durability, balanced tooth strengths for both pinion and driven gear, and freedom from interference in meshing.

Conventional bevel gears are machined with special machine tools. In the present example the specified tooth type is Gleason straight bevel, with a 20-degree pressure angle. This modified tooth form is automatically produced on the Gleason machine and is difficult to reproduce by other methods. The complex geometry of the Gleason gear cannot readily be described by simple equations.

16.2 Project description

Project duration: February 1999 to December 1999

16.2.1 Section A: Purpose and project description

To develop a manufacturing process to produce small, plastic injection-moulded precision straight bevel gears to replace conventional machined metal Gleason gears.

To demonstrate this technology by moulding a paired set of two trial gears and verifying their dimensional accuracy and their meshing performance using a special test fixture.

16.2.2 Section B: Technological advancements sought

The main technological advancement sought and achieved in this project was the development of a moulding process to produce small, precision straight bevel plastic gears. Being of glass-filled nylon, these alternative gears offer superior toughness, durability, low operating noise, and freedom from lubrication while still having a performance matching metal gears. Being injection moulded, they can also be produced rapidly in large volumes.

Parts shrink after they have been moulded. The normal manufacturing process for injection moulding requires that the shrinkage be estimated with the help of a mathematical model. The model requires the input of equations that describe the geometry of the part; in the case of the Gleason gear the shape is complex and the needed equations are not available.

A process must be developed to provide a part with the required tolerances without the use of these shrinkage predictions. This work resulted in an increase in the company's technology base, giving them the capability to mould complex geometric parts.

16.2.3 Section C: Technological uncertainty

From the very outset, the following technological problems were identified, and project activities were planned accordingly:

(a) Gear tooth geometry

The information provided to the company or available through technical reference sources was not enough to establish the data needed to cut the tooth forms in a mould through processes applicable to building a mould (as opposed to cutting teeth on a gear blank with a Gleason machine).

(b) Manufacturing process

In conventional bevel gear manufacturing, handbook references are available to specify the critical gear blank dimensions, cutter parameters, and the appropriate Gleason machine settings required to produce the required bevel gears. However, this approach was not applicable to mould manufacture. Hence the first problem in this example was to determine the absolute 3-D tooth geometry and related dimensional data for both pinion and gear in terms of spatial co-ordinates, which could then be used to generate data to CNC machine the (mould) surfaces.

For mould dimensioning, compensation would have to be provided for material shrinkage, draft angles (if applicable), etc. Completely unknown were the distortions that would arise through the moulding process and how to correct for them. Tight tolerances were specified for backlash, TIR runout, etc. on the finished gear set. All of these were inter-related to the integrity of the tooth form and the roundness and face perpendicularity of the gears after moulding. Large local mass variations in material existed in the tooth areas, and it could not be foreseen how much, and where, sinking and other moulding-related distortions would appear to cause still further difficulties in the performance of the meshed gear set.

Furthermore, glass-filled nylon is a highly abrasive moulding material that flows only with difficulty. It was clear that an even filling of the mould would be problematic to achieve in any event, let alone with all the complex part geometry features discussed above.

16.2.4 Section D: Summary of work carried out

Experienced engineers and technicians studied the crude samples and incomplete data made available to us by the potential customer They developed alternate scenarios and preliminary strategies on how the two gears could be produced via a moulding process.

Extensive literature searches and professional contacts were initiated to discover what means could be employed to precisely determine the gear geometry, tooth profiles, and related dimensional data, so as to establish baseline information for designing the mould for each gear.

Computer modelling of tooth geometries and dimensions was performed. Simulated meshing of the gear pair was studied for engagement and disengagement action.

In parallel, an instrumented test fixture was designed and fabricated for a physical evaluation of the actual meshing behaviour of the supplied sample gear pair, and later of trial gears.

When a preliminary workable set of 3-D dimensional data appeared to have been finally evolved, a trial pair of aluminum gears was cut using this data on a CNC Wire-EDM set-up at a specialist shop. Meshing trials of the experimental aluminum gears were conducted on the test fixture. This generated information that could be used to correct the electronic 3-D data.

A second set of experimental aluminum gears was cut using the corrected data, and meshing trials were repeated on the test fixture. Another iteration of electronic 3-D data correction was performed. Final corrections were determined using information based on actual tooth contact signatures obtained by using "machinists' blue" on gear tooth engagement areas.

The electronic data was adapted to CNC Wire-EDM cutting a set of electrodes for a Plunge-EDM process to make the mould cavities. This required extensive work with Solids and Surface programs for developing precision cutter paths to achieve the desired accuracy and finish.

In the mould design, a deliberate strategy was adopted to place the bulk of the critical areas of one gear as a core detail, and that for the other gear as a cavity detail. This would enable a comparative determination to be made on which approach was better for making the final, exact adjustments to achieve the minute details required.

A trial injection mould was made and experimental plastic gear samples were produced. Evaluation with the test fixture showed that corrections were required to local mould tooth geometry/dimensions to minimize backlash.

After the injection moulding trial and a detailed gear sample evaluation, corrections were made to both core and cavity in the mould, and moulding trials were repeated.

1. With three iterations of this procedure, it was found that the process would deliver parts with the required precision, and sample gears were then shipped to the OEM customer for approval.

16.2.5 Section E: Project status

The potential customer granted approval after extensive inspection and tests, and the mould stands were accepted for regular part production in an offshore factory.

16.2.6 Section F: Documentation

Project Definition and SOW (Statement of Work), Project plan with timeline, Work Analysis, Meeting minutes, task breakdown structure, and activity assignment chart. Preliminary list of activities identified as SR&ED.

Weekly project team meeting minutes.

Individual engineer/technician dated technical work logs.

Collated binder containing information on gear geometry and Gleason generating process, created from literature searches and material received from professional contacts.

Minutes of discussion meetings with the potential customer regarding critical technical requirements and minutes of internal meetings tracking experimental development activities.

Selected printouts from electronic solid model development and 3-D co-ordinate data development. Electronic logs of all iterations performed are available.

File on design, construction, and approval of gear mesh test fixture.

Measurement and mesh test data on sample gears provided by the potential customer.

Cutter path development and CNC data for machining aluminum trial gears: selected printouts and full electronic records.

Measurement and mesh test data on aluminum trial gears for all iterations.

Minutes of project team meetings, sketches, preliminary drawings, and notes on mould development for plastic gears.

Mould tryout logs for plastic gears, for all iterations.

As in (6), (9), and (10) above, but for trial moulded plastic gears, for all iterations.

1. Acceptance test results from customer on shipped plastic gear samples, and related correspondence.

Time records related to project (personnel time sheets).

2. Name list, summary of contribution, and resumes for all project personnel.

Retained physical evidence includes: trial gear samples (aluminum and moulded plastic), test fixture, rejected plunge EDM electrodes, rejected mould components, dated photographs of moulds and internal details (illustrating iterations).

16.3 Comments

This project is an example of a case in which the need for a technological advancement is identified at the outset. A significant amount of effort is required in steps 1-8 in preparation for "first try-out." This work meets the definition of SR&ED. The subsequent work in steps 9-11 is also eligible since it is required to achieve the technological advancement.

Accordingly, all work in the actual claim was deemed eligible, other than a few initial business meetings between the claimant and potential customer when non-technical matters were discussed.

This case is a good example of why in many (if not most) situations the "first try-out" is a poor indicator of project eligibility.

Since the designing and building of the mould involved experimental development, the portion of the costs incurred for SR&ED would be allowed. The costs incurred for the experimental development, in this case, could include the costs of labour and materials.

The costs of any materials that were destroyed or rendered virtually valueless as a result of the SR&ED may be claimed as costs of materials consumed.

The costs of materials that were incorporated into the mould as a result of the SR&ED may be claimed as costs of materials transformed. If the mould is sold, converted to commercial use, or used for demonstration purposes, the costs of the materials transformed would be subject to recapture.

17 Cast figurines

17.1 Background – the business context

Our company was incorporated in 1985. It produces complex and innovative moulded plastic parts for several OEM industries. The business initially concentrated on the decorative figurines market sector and has achieved considerable success over the years in this specialized area. Over time, as consumer tastes have become more sophisticated, figurines have come to require an increasingly finer level of detail. Until recently, the manufacturing techniques established by the company had been able to sustain this increasing product refinement.

This example looks at the scenario created when a dealer in collectible figurines approached the company to develop a line of highly realistic sports and military miniatures. Extremely detailed features were to be reproduced, and the postures of the figurines were to accurately show examples of action movement (such as shooting a hockey puck, kicking a soccer ball, parrying a sword thrust, leading a bayonet charge or riding a horse into battle).

This requirement for extreme detail meant that the facial expressions, drape of the clothing, body stance, tensing of muscles, and all other visual cues had to be completely faithful to the action being represented. The new figures were 5cm tall and included details that were less than 1mm across; some of the more demanding details included a gun site on the end of as rifle, collar buttons and buckles and holes on a belt. The level of detail was far in advance of anything the company had attempted before

Handcrafted specimens of the figurines were made available by the company.

The technology

Sample handcrafted figurines are used as patterns for making the moulds. The moulds are cavities in a block of silicone rubber, and are created by pouring a liquid silicone compound over the patterns. The compound sets into a shape that conforms to the outer contours of the pattern. The pattern is removed and the hollow cavity then becomes the mould for producing a cast figurine. Liquid casting resin is then poured into the moulds to produce the figurine.

The company believed that the basic method would work for the new line of figurines as well. However, as discussed below, trials revealed that the standard techniques could not reproduce the level of detail that was demanded.

The company did eventually succeed in establishing a suitable process for making this new line of highly-detailed figurines, but only after a considerable effort in experimental development.

17.2 Project description

Project duration: January 1999 – December 1999

17.2.1 Section A: Purpose and project description

- To develop a manufacturing process that produces small, highly-detailed cast plastic figurines faithfully reproducing fine surface detail and geometrical features
- To demonstrate this technology by producing samples covering a range of figurines representing a range of action movements

17.2.2 Section B: Technological advancements sought

The main technological advancement sought and achieved in this project was to develop a casting methodology and technique to produce a range of highly-detailed miniature cast plastic figurines with an unprecedented level of surface detail and delicate geometrical features. The technology also had to be compatible with a high rate of production.

Achieving this objective would open up a technical capability to reproduce levels of fine detail and geometry in cast figurines that was previously unobtainable in the industry

17.2.3 Section C: Technological uncertainty

The technological uncertainty stems from the inability of the previous established company techniques to achieve the results that were needed in the as-cast figurines. In other words, standard practice was inadequate.

Specifically, the technological problems were:

- The ability of the mould material (silicone compound) to faithfully conform to the surface detail and delicate geometry of the figurine.
- The choice of a parting surface for the mould that would allow the cast figurine to be extracted without damaging the delicate features.
- Choosing a casting resin related to its fluid flow properties, and then to the cure regime, outgassing, and as-cured mechanical properties.
- The ability of the liquid casting resin to actually reach all the extreme delicate features in the mould and properly fill the mould cavity, and any external arrangement to assist the mould-filling process.
- The gating and feeding arrangements for sustaining multiple-cavity moulds to suit volume production.
- The curing process – Would a room-temperature cure be adequate, or would a heating arrangement be required?
- The possible need for mould release agents to facilitate part release – Would these be compatible with the mould material and the casting material (in its initial liquid and cured stages)?

17.2.4 Section D: Summary of work carried out

1. Engineers and technicians studied the sample figurines and made a preliminary selection of an item for try outsee whether the company's existing casting method would succeed.
2. A single cavity trial mould was made.
3. Trial castings were made. Results were very far from acceptable. Facial and clothing details were not adequate and the extremities were not filled.
4. Internal meetings were held, and it was realized that the problems revealed by the first try out failures could not be solved with knowledge that existed in the company.
5. Discussions were held with casting resin suppliers and mould material suppliers, to find better materials for filling the moulds. Special choices were made, particularly for low-shrinkage casting resins.
6. Several trials were conducted with these low shrinkage casting resins, but the extremities of the moulds were still not filled.
7. Centrifugal assist was employed, using a motorized turntable to rotate the mould.
8. Difficulties were still encountered with mould filling, along with new problems caused by venting and outgassing.
9. A vacuum draw was added.
10. Eventually, after several iterations to adjust the cooling conditions, satisfactory castings were obtained.
11. To define limits to the process, the method was extended to selected figurines in the dealer-requested range.

17.2.5 Section E: Project status

Through the extensive experimental development work described above, the company did achieve the capability to cast a completely new class of highly-detailed figurines, and it established a technology base that could be applied to other figurines with similar levels of fine surface detail and complex geometrical features.

17.2.6 Section F: Documentation

The following dated records exist in company project files:

1. Minutes of internal meetings recording discussions on dealer-supplied handcrafted samples and decisions on initial choices to develop castings.
2. Minutes of meetings that discuss poor test results. Action items on individuals to investigate parameters.
3. Records of phone discussions, faxes, and brief notes based on supplier information on mould materials and casting resin issues.
4. Experimental records on tests with different combinations of mould and casting materials.

5. Records of experiments that show formulations and cure times
6. Record of further discussions on unsatisfactory test results.
7. Meeting minutes laying out experimental plan specifying figurine type, mould design (sketch), venting arrangement.
8. Test results (still unsatisfactory) – notes on verbal discussion with plant manager.
9. Minutes of meeting discussing vacuum assist and motorized turntable. Sketches of possible alternatives.
10. Further experimental test results. Some improvement noted.
11. Meeting minutes with sketches of finalized vacuum draw and turntable arrangement. Aluminum feed runners suggested for incorporation in next test run.
12. Meeting minutes on further experimental test results. Samples apparently almost satisfactory. Heated curing suggested.
13. Further test results and minutes of meeting to discuss and finalize heating chamber.
14. Test results now satisfactory. Meeting suggests heater controls to refine process.
15. Final experimental casting ad test results, with material formulations, weight and viscosity of casting resin used, vacuum draw level, cure time and temperature, technician name, Q.C. visual assessment, and photographs. Meeting minutes record decision to send samples to dealer.
16. Dealer response (fax). Approved.

17.3 Comments

In most real-life examples, eligible work can be found before the first-tryout event. However, in this case, the SR&ED project actually did commence only after the first try-out, because that is when the company established that its existing technology base was inadequate to handle the complex new requirements and therefore began an experimental development process.

In this case the work described after the first try out was found to be eligible.

SR&ED is not required for every new figurine. It was required for the first example and then for any others that had special requirements such as finer details than any previously produced or for figurines with longer narrower parts.

18 Reaction Injection Moulding (RIM)

Scenario 1, which does not involve SR&ED

18.1 Background

ABC is a company that routinely uses injection moulding to produce plastic parts for the auto industry. In 2003 they decided to expand their product line so that it would include thinner, lower weight parts. They acquired new moulds for this purpose but were unable to manufacture the parts using their existing technology. ABC's engineering department prepared a proposal to evaluate the use of Reaction Injection Moulding (RIM), a technology that promised to provide parts with better performance than that achievable with their traditional thermoplastic materials, allowing them to mould the thinner, lighter weight parts that they wanted. ABC's purchasing department conducted a search and found a potential supplier, XYZ, who had a commercially available RIM technology that they expected would work with ABC's moulds and equipment. In 2003, an agreement was made with XYZ to demonstrate the feasibility of producing the required parts with this polyurethane RIM process. A sample part was produced that had the required dimensional tolerances, strength and surface finish.

The present scenario covers the additional work carried out in 2004 to further develop the process to manufacture these parts on a routine basis.

18.2 Detailed Project Description

ABC's RIM project continues in 2004 to demonstrate that the RIM technology evaluated in 2003 can be used to produce automotive parts in an economically viable process.

A. Scientific or Technological Objectives

ABC is working to develop a new process using Reaction Injection Moulding Technology (RIM) that will allow it to enlarge its product line, meeting its customers' new specifications, with thinner lower weight parts than those it can manufacture using its existing injection moulding technology.

B. Technology or knowledge Base Level

Prior to 2003, the company ABC had no knowledge of RIM technology. ABC's VP of Marketing and VP of Technology consulted with potential customers on the requirements for parts that might be required in the near future, developing specifications for shape, dimensional tolerance, strength and surface finish. In 2003 ABC's Engineering Department developed a plan, identifying the type of plastics that might do the job. Reviews of the trade literature and discussions with potential suppliers suggested that RIM technology should provide a viable approach. Initial tests on their existing injection moulding equipment failed. A potential supplier, XYZ, provided a 2 kg/min RIM unit that was used to produce a part in ABC's mould, demonstrating the feasibility of RIM technology to meet the needs of this application.

C. Advancement (2004)

(Please note that as discussed below this is not a technological advancement)

Demonstration of the capability of RIM technology to produce automotive parts that consistently meet the specifications of the buyer, i.e. to scale up the process that uses RIM technology to produce thinner, lighter parts. Mastering RIM technology through this project increased ABC's knowledge of injection moulding technology.

D. Description of the Work in this Taxation Year

- ABC purchased a 40 kg/min RIM injection moulding machine designed by XYZ.
- Commissioning was followed by a validation trial of 300 parts. The conditions used in these trials were extrapolated from the conditions used in the previous year to produce the sample. ABC expected these conditions would enable them to manufacture acceptable parts at a viable cost.

  This run demonstrated that the parts produced using the RIM technology were measurably consistent (dimensional tolerance 98% based on 100 points), strength and surface finish were also well within specifications. Variations followed a normal distribution. The Chief Engineer agreed that the RIM technology was statistically reproducible and that ABCs process capability requirements were met. The standard deviations provided by the data were used to demonstrate to senior management that the RIM process was capable of manufacturing the parts with the required level of consistency to meet the customer specifications.
- The parts from these trials had no commercial value and were scrapped.

E. Supporting Information

- Computer generated worksheets, with hand-written experimental parameters and results
- Instron charts from strength tests
- Engineering notebooks with notations on part and machine parameters
- Photographs of parts and RIM processing equipment
- Shipping documents for disposal of 317 parts
- Material invoices

18.3 Comments

The work described in this example does not meet the requirements of SR&ED.

In this scenario ABC carried out work required to learn how to use commercially available technology in the way that it was designed.

While "a series of experiments were carried out in a field of technology in a systematic manner" as required by the SR&ED definition in the Income Tax Act, the work does not fulfil all of the requirements of the definition. The test demonstrated the feasibility of producing parts with RIM technology that was available through their supplier, who provided the processing expertise. They were using a commercially available process to do things that were within the range of applications that had already been developed. ABC gained a process that was new to them but no new technology was required for this. They did not contribute to the advancement of the underlying technology.

So although this work contains most of the elements of SR&ED the work is not SR&ED.

Since there was no SR&ED project, none of the costs associated with the validation work carried out in 2004 could be included in an SR&ED claim.

Scenario 2, which involves SR&ED

18.1 Background

ABC is a company that routinely uses injection moulding to produce ***thermo***plastic parts for the auto industry. In 2003 they decided to expand their product line so that it would include thinner, lower weight parts. They acquired new moulds for this purpose but were unable to manufacture the parts using their existing ***thermoplastic*** technology. ABC's engineering department prepared a proposal to evaluate the use of Reaction Injection Moulding (RIM), a technology that promised to provide parts with better performance than that achievable with their traditional thermoplastic materials, allowing them to mould the thinner, lighter weight parts that they wanted. ABC's purchasing department conducted a search and found that XYZ had a commercially available RIM technology that they expected would work with ABC's moulds and equipment. In 2003, an agreement was made with XYZ to demonstrate the feasibility of producing the required parts with this polyurethane RIM process. ***XYZ provided ABC with a 2 kg/min RIM unit that was intended for the production of a sample part with ABC's mould.*** **Initial attempts to *use the RIM technology failed as the RIM unit did not function well with ABC's mould and the available urethane systems. XYZ did not have sufficient expertise to help ABC solve the problems. ABC overcame the problems with a radically redesigned mixing***

head with a variable temperature control. A sample part was ***eventually*** produced that had the required dimensional tolerances, strength and surface finish.

The present example covers ***a claim for*** the additional work carried out in 2004 to further develop the process to manufacture these parts on a routine basis.

18.2 Detailed Project Description

ABC's RIM project continues in 2004 to demonstrate that the RIM technology evaluated in 2003 can be used to produce automotive parts in an economically viable process.

A. Scientific or Technological Objectives

ABC is working to develop a new process using Reaction Injection Moulding Technology (RIM) that will allow it to enlarge its product line, meeting its customers' new specifications with thinner, lower weight parts than those achievable with its existing injection moulding technology.

In 2004 ABC's business objective was to demonstrate to its customers the capability of RIM technology to produce automotive parts that consistently meet their specifications. To do this they needed to scale up the RIM process and show that they could produce parts that met the tolerance requirements for these parts.

B. Technology or knowledge Base Level

Prior to 2003, the company ABC had no knowledge of RIM technology. ABC's VP of Marketing and VP of Technology consulted with potential customers on the requirements for parts that might be required in the near future, developing specifications for shape, dimensional tolerance, strength and surface finish. In 2003, ABC quickly learnt that their current thermoplastic technology could not produce parts that met these needs. ABC's Engineering Department developed a plan that identified the plastics that might be suitable for manufacturing these parts. Reviews of the trade literature and discussions with potential suppliers suggested that RIM technology should provide a viable approach. Initial tests on their existing injection moulding equipment failed. ***ABC worked unsuccessfully with company XYZ to adapt a commercial system to their needs. ABC then made substantial modifications to the commercial machine, making major changes to the mixing head and equiping it with variable temperature control. They used this modified mixer with the original mould to demonstrate on a small scale that RIM technology could meet the needs of this application.***

This work was accepted as SR&ED in ABC's 2003 claim.

In order for the company to develop a commercially viable process, it had to scale up their partially developed RIM technology from 2 kg/min to 40 kg/min.

As described below, many technical and technological uncertainties had to be overcome during this scale-up.

Changing the mixer on any urethane machine can have a major impact on the kinetics of the process and hence on the performance and consistency of the resultant parts. The ingredients of these fast setting formulations are mixed rapidly in a turbulent non-equilibrium environment. The kinetics are complex, since we have a mixture of non-Newtonian liquids, whose viscosity changes rapidly over time with the changes in composition and temperature.

Despite this, the reaction mixture must enter the mould cavity in a laminar flow, not in a turbulent condition. The liquid flow front must not be separated and should maintain its integrity to ensure that the air is forced out of the mould, ahead of the front; this liquid flow front must also enter the mould as a stable solid wave front to prevent viscosity build-up and fast gelling.

To scale-up the process, the mixer dimensions must be changed and a modified formulation developed.

The presently available technology permits general statements to be made about these systems and qualitative directional predictions to be made. It is not possible to simulate the non-linear effects of changes in the geometry of the mixer, the composition of the mixture, the changing temperatures and the way that these interact together to determine the part properties without the extensive experimental work that was carried out to produce the sample parts. The present knowledge base also does not provide any means to predict process consistency.

In 2004, work was therefore required to determine the impact of mixer speeds, mixer configuration, temperatures, flow rates and component ratios on the performance of the resultant properties of the product. The experiments were designed based on data obtained with the 2 kg/min unit. This work provided predictions as to how the process could be run; a final 300 piece run was required to confirm that these predictions were correct and establish the parameters of a process that would produce consistent parts.

C. Technological Advancement (2004)

To develop a proprietary RIM technology through resolution of the technological uncertainties inherent in the scale up of the RIM process from 2 kg/min to 40 kg/min. These uncertainties result from the complex non-linear relationships between the mixer geometry, mixture composition and process conditions that will determine the dynamic viscosity, rate of heat generation and changing heat transfer characteristics of the mixture, all of which impact on the performance and consistency of the resultant parts.

D. Description of the Work in this Taxation Year

- ABC purchased a 40 kg/min RIM injection moulding machine designed by XYZ. ***<u>ABC built the initial mixing head based on the design they</u>***

<u>had developed for the small unit. A total of three differently designed mixing heads were used during the scale-up[9].</u>

- In order to commission the RIM technology and establish operational parameters ABC's Chief Engineer setup a series of experimental trials using standard statistical experimental design techniques. A 2-level factorial screening design was followed by a confirming 3-level response surface design. From these experimental trials, optimum processing conditions were estimated for use in the final process validation. It was expected that this set of optimized machine parameters would enable ABC to manufacture acceptable parts.
- A validation trial was conducted using the optimized machine parameters for a simulated production run of 300 parts.

  The experimental trials had provided estimates of the process variance, expressed as standard deviations. The 300 parts sample size was determined by comparing this variability with the part tolerance requirements that the technology must deliver.

  This run demonstrated that the parts produced with the RIM technology were measurably consistent (dimensional tolerance 98% based on 100 points), strength and surface finish were also well within specifications. Variations followed a normal distribution. The Chief Engineer agreed that the RIM technology was statistically reproducible and that ABC's process capability requirements were met. The standard deviations provided by the data were used to demonstrate to senior management that the RIM process was capable of manufacturing the parts with the required level of consistency to meet the customer specifications.
- The parts from these trials had no commercial value and were scrapped.

E. Supporting Information

- Computer generated worksheets, with hand-written experimental parameters and results
- Instron charts from strength tests
- Engineering notebooks with notations on part and machine parameters
- Photographs of parts and RIM processing equipment
- Shipping documents for disposal of 317 parts

---

[9] The description of the work with the mixing head was more extensive than described here. This was done so as not to allow us to focus on the validation issue.

- Material invoices
- Scheduling records for RIM equipment

18.3 Comments

In contrast to the previous example, in 2003 ABC found that the best available technology did not meet their needs and that work was required to modify it. The company did not have access to any other application in which this type of plastic had been used to make a comparable part designed to meet similar criteria.

The work carried out in the previous year (2003) is described in the **Technology or Knowledge Base Level** section of the example. In this scenario SR&ED was required to scale-up a RIM mixing head to make automotive parts.

Continuation of the work was required in 2004 to develop the necessary process technology and advance the company's knowledge of RIM. It resolved technological uncertainty around the process capability, in particular allowing the company to develop the technology required to scale up from 2 kg/min unit to 40 kg/min. The many uncertainties present in this scale-up are described in the example.

This work, in the area of RIM mixing technology, was carried out in 2004. It has been carried out in a systematic manner using statistical experimental design techniques. The work was required to increase the understanding of the impact of process parameters on the performance of the resultant products, providing ABC with an advance in the underlying technology that allowed them to develop an improved process that has the capability to consistently make a range of thinner, lower weight parts. Thus the work meets the SR&ED criteria. The costs of labour and materials consumed in the work to modify the mixing heads and to validate their performance would be allowed.

The supporting information listed helps by substantiating the activities that have been included in the claim and showing that the appropriate labour and materials costs are included.

The 300 parts were experimental production, necessary for the validation of the process, to confirm that the process is in control and that the process variability is sufficiently small that substantially all of the parts produced in the process will meet the dimensional tolerance requirements. The number of parts is justified by comparing the inherent variability of the process (in this case measured during preliminary experimental runs) with the part tolerance requirements. The parts were not sold and had no value to ABC. Hence the costs of labour and materials consumed in the production of these parts can be included in the SR&ED claim.

During the scale up from the 2 kg/min to 40 kg/min RIM injection moulding machine, the claimant developed and built three mixing heads for SR&ED purposes. The first two mixing heads were destroyed during the tests as a result of build up during their use. The damaged mixing heads were available for inspection by the CRA reviewers. The third mixing head was converted to commercial use and used in production.

The costs of materials incorporated into the three mixing heads would also be allowed. However, since the third mixing head was converted to commercial use, there would be a recapture of investment tax credit (ITC)[10,11].

[10] Further information on the ITC recapture rules can be found in Application Policy SR&ED 2000-04R2 "Recapture of Investment Tax Credit" (http://www.cra-arc.gc.ca/taxcredit/sred/publications/sr0618-e.html)

[11] Instead of developing and building the three mixing heads, the claimant purchased three mixing heads for SR&ED purposes during the scale up of the RIM injection moulding machine. The first two mixing heads were destroyed during the tests as a result of build up during their use. The third mixing head was converted to commercial use and used in production.

Since the three mixing heads were purchased to be used in SR&ED, the all or substantially all (ASA) test would have been met [See section 5.3.5 Expenditures for capital equipment of the plastics guidance document]. As a result, the costs incurred to purchase the three mixing heads would be allowed as capital expenditures for SR&ED. However, since the third mixing head was converted to commercial use, there would be a recapture of ITC.