

## *Contractor's Report to the Board*

# Postconsumer Resin Quality Assurance and Testing Protocol: Quality Assurance Guidelines

*June 2004*

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Chico, California*



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## **Executive Summary**

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The research in this report is the third phase of a six-phase research project that establishes a quality program for post consumer resins (PCR). The objectives of the overall research are to evaluate the post consumer plastic processors in California and their respective quality assurance programs, and to propose a model quality assurance programs for post-consumer resins. The scope of this phase of the research is to develop a quality protocol for PCR based upon results of a survey of PCR manufacturers from the second phase of the research. This research, also, creates an optimum set of guidelines for quality assurance in post consumer resins. In our survey, the larger companies report having a quality assurance program, while the smaller companies do not. Quality control procedures from large PCR manufacturing companies provide the framework of our Quality Management System (QMS). The best practices from other sources in the United States and Europe were added to our quality management system in order to be applicable to the major recycled plastics, e.g., LLDPE, HDPE, PP, and PET. The QMS is also expanded to include a range of products, including, trash bags, rigid packaging, and plastic lumber. The QMS for PCR is broken down into three major areas during the PCR manufacturing operation: Part 1 - Receiving of incoming plastic material, Part 2 - Process control during the manufacturing operations, and Part 3 - Final product specifications. The new standards include documentation and testing. Different grades of PCR will have different levels of documentations, specifications, and testing requirements. The QMS recommends five grades of post consumer resin (PCR), ranging from grade 1 for near virgin plastic quality to grade 5 that has unacceptable quality for trash bag manufacturers but acceptable quality for some rigid packaging and for plastic lumber manufacturers. Trash bag manufacturers can use PCR with from grades 1, 2, and 3. Rigid packaging manufacturers can use PCR with grades 4 and 5. A key quality characteristic of grade 4 PCR is improved environmental stress cracking resistance. Plastic lumber manufacturers can use materials from grades 4 and 5. The quality management system will encompass all five grades of PCR materials, though different grades will have different testing standards, material specifications, and process control. The quality management system will be implemented during three areas of PCR manufacturing, e.g., incoming material specifications, process control of manufacturing operations, and final product specifications.

## **Introduction**

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The research in this report is the third phase of a six-phase research project that establishes a quality program for post consumer resin (PCR). The objectives of the overall research are to evaluate the post consumer plastic processors in California and their respective quality assurance programs, and to propose a model quality assurance programs for post-consumer resins. The scope of this phase of the research is to develop a quality protocol for PCR based upon results of a survey of PCR manufacturers from the second phase of the research. This research, also, creates an optimum set of guidelines for quality assurance in post consumer resins based upon the responses from the second phase. Best practices from each PCR manufacturing company will be compiled to help produce an effective Quality Management System (QMS).

## **Literature Review**

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Research in quality assurance methods for PCR plastics in Europe and the United States are much more limited than for quality standards of virgin plastics. Typically, virgin plastics are produced by very large multinational companies, who require very high quality control standards and practices. All virgin plastic manufacturing companies are ISO 9001 compliant. Alternatively, post-consumer resins are produced by small to medium-sized companies that generally do not have the capital investments to institute high-level quality control procedures. The lack of quality standards, though, can limit the use of materials. The California Integrated Waste Management Board defined standards of PCR quality for use in trash bags. The standards require PCR manufacturers to meet specifications for moisture, pellet uniformity, contamination, specific gravity, and melt index.<sup>1</sup> Two companies developed quality standards for HDPE PCR<sup>2</sup> and PP PCR<sup>3</sup> that are similar to quality characteristics of virgin plastics. The first researcher presented a quality system that includes quality testing of raw materials, monitoring of melt index, statistical process control of the extrusion process, color analysis, and contamination control. The researcher determined that an effective method for quality control of a HDPE film is to produce a 2-mil test strip and compare it to strips that have a predetermined quality grade. Other key elements of the quality system are the development of a quality check sheet for incoming materials, color analysis with CIE L-a-b color scale, use of a tight screen pack to trap larger contamination particles, back pressure measurements across the screen pack, and addition of antioxidants to the PCR.<sup>2</sup> The second researcher demonstrated quality assurance in plastics recycling with a scrap battery recycling plant.<sup>3</sup> The researcher developed a quality system that includes testing of raw materials for impurities and melt index, quality control on process parameters, and after-sales service on the recycled materials.

European countries are also concerned with quality control with recycled plastics because it can reduce the amount of plastic waste in landfills. The European Union Packaging and Packaging Waste Directive of 1994 called for the recovery of 50% to 65% by weight of total packaging waste with an overall target of 25 to 45% recycling and a specific target of 15% recycling for each packaging material by July of 2001.<sup>4</sup> The directive resulted in a British law that opted to recover 50% and recycle 25% of packaging by 2001, with a 15% minimum recycling rate for each material. Recycling of post-consumer PET, PVC, and HDPE in the U.K. has made significant contributions to meeting the national target of the recycling directive, but more work is need to improve the quality of post consumer materials. A not-for-profit company, *Waste and Resources Action Programme*, that works to promote efficient markets for recycled materials and products in the U.K., published a research report to improve the quality of recycled plastics.<sup>5</sup> The research identified barriers that are directly related to quality standards or specifications that discriminate against greater use of recycled materials. The barriers were identified based upon a telephone survey to thirty-seven companies who are involved with U.K. plastics recyclers. Nine companies were classified as large recyclers. Twenty-two recyclers are considered small recyclers. Six respondents were government agencies. The survey results found that the responses can be split into two categories, one made up of large recyclers (greater than 10,000 tonnes per year) and one of small recyclers. Standards were more important and have more of an impact on the businesses to the large recyclers than to the small recyclers. The report recommended standards and test specifications for refuse sacks. The standards limit the recycled content to a maximum of 25% and have specifications for dart impact, tear strength, and tensile strength. Some recyclers in the U.K. are using 98% recycled content for the refuse sacks, but no

standards or specifications have been developed. Representatives from the smaller companies reported in the study identified a business concern due to their inability to perform quality testing. They, also, reported that they do not have the capacity to finance the extra burden of new quality test equipment due to very thin economic margins in the recycling business. Representatives from the larger companies reported that testing facilities on-site are a basic pre-requisite for sustainable involvement in the recycling market. Many respondents to the survey expressed the view that tracking recycled materials from the receipt of incoming materials to processing into PCR pellets of flakes, and then packaging of final approved product is essential to any quality assurance system. Most of the respondents from the large recyclers felt that if they were provided with good quality control and testing standard regimes, a competent technician could produce a compound of similar quality tolerance to most virgin materials. Many respondents to the survey warned that almost no quality control exists with many companies even though there are ISO quality management standards to which recyclers could become accredited. Lastly, the survey revealed that there exists a lack of general culture of quality management within the recycled plastics industry even though an excellent quality management culture exists within the mainstream plastics industry.

In the United States, the lack of quality standards and material standards when compared to virgin resins was determined to significantly hinder the use of recycled materials in the electronics industry.<sup>6</sup> A forum, created from electronics manufacturing companies, developed recommendations for improving the quality of recycled materials by providing classifications of recycled plastics and to have grades within the classifications. For each grade of material the standards specify a set of material quality variables or properties, e.g., weight, color, plastic type, contaminants, and physical properties. The quality management standards also specify ranges of values for each material quality variable and standard test protocols for measuring quality. The standards also include an inspection process for incoming materials and a process for the manufacturing operation.

## **Background**

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The typical process to convert recycled plastics to plastic pellets involves sorting, shredding, washing, drying, and pelletizing. The most common processing steps include granulation, air classification, washing, separation, rinsing, and drying.<sup>7</sup> The post-consumer plastics are sorted by either manual or automated identification methods. Efficient sorting of plastics is an essential component of an effective quality management system. The manual method is labor intensive and requires operators to monitor an assembly line and sort out clear plastic bottles (PET) from the milk containers (HDPE) and colored plastic containers (LDPE, PP, PVC). The automated method can employ one of several analytical techniques, including x-ray fluorescence, mass spectroscopy, Fourier Transform Near Infra-red (FT-NIR) spectroscopy, Fourier Transform medium Infra-red (FTIR) spectroscopy, or tribo-electric analysis, on the recycled plastic materials. The automated sorting method efficiently and quickly sorts the plastic and can lead to a higher quality PCR. Several of the automated methods are able to sort the plastic at high rates with over 99% accuracy.<sup>8,9,10</sup> The sorting efficiency can be improved with an automated sensor cleaning system. An on-line sorting method can dramatically improve the quality of PCR. One company<sup>11</sup> developed a rugged analytical system for on-line quality control that continuously monitors PCR samples from the recycling process materials stream for real-time levels of contamination.<sup>12</sup> The company has made the equipment commercially available. Once the material is sorted, contamination of the plastic with paper and other debris is a significant quality concern. Washing of the recycled plastics is a very effective method of removing excess detergents from detergent bottles, adhesives from labels, paper and dirt contamination. The presence of contaminants can lead to discoloration of the PCR. The washing methods vary from one reclamation facility to another. Over the years several washing facilities were built with great expense. Only two of the PCR manufacturers that responded to the survey in the second phase of this research reported having a wash line due to the high capital cost. Most of the PCR manufacturing companies do not wash the plastic in a wash line. The last step in the post-consumer recycling process is melt processing, where the clean plastic material is heated in an extruder, shaped into a rod, cooled in a water bath, chopped into a pellet, dried, and placed in containers for shipments. The processing operation involves many processing parameters that affect quality and need to be monitored for effective quality control. The final pellet characteristics need to be evaluated with a series of quality control tests.

## **Phase 2 Survey Results**

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The first phase of this research created a detailed work plan that described the scope and defined the quality problems associated with using recycled materials. The second phase of the research conducted a survey of the quality assurance practices at eight post-consumer resin manufacturers in California and one in Illinois. Our survey found results similar to the U.K. survey in that the responses were divided into groups based upon size of the company. In our survey, the larger companies report having a Quality Assurance program, while the smaller companies do not. The largest four companies each produce over 20 million pounds of plastic each year, have well defined quality procedures, and perform quality tests on a regular basis. The other five companies each produce between 1 and 10 million pounds of PCR and perform quality tests on an “as needed” basis. Both groups rely upon visual methods to sort and evaluate the incoming recycled material before it is sent into the processing operation.

One of the most efficient methods to check the quality of the PCR is with a small extrusion blown film line. This enables the PCR materials to be blown into a film and then checked for bubble stability, color, odor, strength, and other quality measurements. If the quality is poor then the material can be discarded or blended with conforming material. This technique significantly reduces the risk of material failure at the blown-film production operation. The technique is used at a large PCR manufacturing facility that I visited and as a result produces a high quality PCR that is used in LLDPE trash bags. The difference between the large and small PCR manufacturing groups is most pronounced during the compounding process of converting the recycled plastic into post consumer resin pellets or flakes. Based upon the survey results from phase 2 of the research, the larger PCR manufacturing companies have a documented quality operation that tracks the manufacturing process with inspection sheets that are included with every lot of material. The smaller companies only document the quality control if problems arise. After the PCR is produced the larger companies test the material for color, odor, melt index and density. Most of the smaller companies visually test for moisture and contamination and only perform quality tests if required by the customer. Several of the smaller companies do not perform any quality tests on the outgoing PCR product. I visited two PCR manufacturing companies, one in California representing the smaller companies and one in Illinois representing the larger companies. Six other companies rejected my request for a plant visit. The larger company produced a high quality LLDPE PCR and provided me with a tour of the manufacturing operation at the facility. During the plant visit the company provided me with copies of the quality documentation used at the manufacturing facility. The documentation included Post Consumer Material (PCM) bale specification, incoming PCM bale quality control, typical causes for rejection, PCM pellet specification, and PCM processing issues. The quality control documents are provided in the Appendix. The large PCR company demonstrated an effective quality control procedure that has many characteristics of an effective quality assurance program and many of the elements that are included in an ISO 9001 certification. None of the companies that participated in the survey are ISO 9001 compliant and none are willing to spend \$5,000 to be compliant. ISO certification would dramatically improve the processing efficiencies at the companies and improve the quality of the PCR. Successful quality programs focus on the customer and document all aspects of the manufacturing process.<sup>13</sup> The quality principles establish ways to track nonconformance in materials and identify and then remove quality problems its source. The ISO 9001 standard was updated in 2000 to focus more on the customer. The new ISO standard expects companies to communicate with customers and monitor customer satisfaction. ISO 9001 evaluates the effectiveness and suitability of the quality management system and implements continuous improvements. A list of key ISO9001 items is provided in the Appendix.

The survey of the PCR manufactures illustrated inconsistent quality control from company to company. The quality of PCR can be significantly improved without requiring very expensive equipment by improving the monitoring of recycled plastic as it is converted from plastic to PCR, documenting the process parameters, and keeping quality records associated with lot numbers of PCR. An efficient quality control will enable the processors to identify manufacturing concerns before they manifest themselves as quality problems. A key component of successful PCR manufacturing is the development of a quality assurance system that includes inspection of incoming product, monitoring melt index, measuring contamination, and meeting quality targets for the final PCR product. The quality of the PCR can be

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measured with a variety of test methods, including, melt index, density, colorimetry, differential scanning calorimetry (DSC), infrared spectroscopy, and tensile testing.<sup>14</sup>

The survey from phase two of the research identified three problem areas, e.g., poor documentation, incomplete process control, and inconsistent testing of final product. The poor documentation begins with inconsistent quality control of incoming recycled plastic to the PCR manufacturer. The incoming plastic should be inspected and meet a set of material standards. Thus, quality problems can be identified at its source and removed from the process. Additional quality standards are needed to improve the quality of the incoming recycled plastic. The incoming plastic can be contaminated with wood, paper, cardboard, metal, PVC, PVDC, and organic items that need to be removed before processing. The improved quality in the plastic used at the beginning of the PCR processing operation will greatly improve the quality of the PCR product. If most of the contaminants and non-plastic object are removed from the recycled plastic bales then the contamination can be reduced to the paper packaging products in the bale. Once the contamination is better controlled at its source, then better process control on the manufacturing process can yield dramatic improvements in the quality of the PCR. One of the biggest contaminants for trash bags manufacturing from PCR is the paper cardboard that is present in the incoming bales of recycled plastic. The paper can be trapped in the plastic as it is converted to pellet causing a burnt wood odor in the plastic and a brown color (from light to dark) to the pellet. The paper contaminant prevents the PCR from being used in white trash bags and causes impurities in the melt that can disrupt the bubble formation during extrusion blowing. Most of the paper can be removed by washing the plastic in a series of wash lines. Alternatively, some of the wood can be removed by melt filtering with screen packs. The wash line is much more effective separation process than melt filtering, but is time consuming and expensive to operate. In the future, a more efficient method should be developed to remove paper and cardboard products from the recycled plastics, which would significantly improve the quality of the PCR. If the contaminant can be removed the PCR color would be brighter and the properties of the trash bag would significantly increase. Removing the paper and cardboard from the input stream is a complex technical challenge. Paper, like polyethylene plastic, has a specific gravity of less than 1 and, as such, will float in a water bath with the plastic. The paper contaminant can be reduced if standards are developed to require a plastic strapping made with either LLDPE or with a plastic that has specific gravity greater than 1, i.e., PET or PBT, for the bales instead of paper products, then, the heavier strapping material will sink and the polyethylene will float in the wash lines. The PET and PBT can be removed in a wash tank or in the melt filtering operation. If LLDPE strapping is used and is compatible with the PCR it may be included in the PCR used for trash bags.

The second problem with current quality practices at post consumer plastic processing companies is incomplete quality control at many of the smaller PCR producers and some of larger ones. The companies did not appear to have a quality culture wherein quality is a valued and essential business component. The smaller companies and most of the larger companies did not demonstrate a practice of measuring the quality of incoming recycled plastic, nor measuring the quality of the plastic during the manufacturing operation. Some of the companies reported measuring the quality of the PCR if the customer required it.

The third quality area of concern is the testing methods for the final PCR product. Standard tests are needed to characterize the PCR by, at a minimum, melt flow and density. The testing will enable the customer to better blend the PCR with other similar types of plastics. Other quality tests can be used to better characterize the quality of the PCR if required by the PCR customer. The tests include moisture, residual additives, odor, and contamination. The quality of PCR can be improved with an establishment of a quality management system that features the use of control documents, control of records, internal audit, control of non-conforming product, corrective action, and preventative action. The control documents define the quality system and are used in all manufacturing phases of the PCR. The proposed quality system includes these items and will enable the demonstration of effective quality improvements during later phases of the research project.

## Quality Management System (QMS)

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A model quality management system can be developed based upon the best practices in quality assurance from PCR manufacturing companies who participated in our survey and from published results of the research work in Europe and the United States. Our survey from phase two of the research found that quality control standards are needed to improve the quality of PCR for small and large PCR companies, even though they have different approaches to quality control. Also, PCR manufacturing companies do not have the same quality culture as virgin plastics manufacturing companies. The survey results and literature review indicate that quality control is needed throughout the PCR processing operation, including receipt of incoming recycled materials, processing of the recycled plastic into PCR, and inspection of final PCR product. Differences exist in quality control between the various companies in our survey and those listed in the published research. Kepner-Tregoe *Decision Analysis*<sup>15</sup> techniques are used to compare the different methods of quality control based upon our survey and the European survey. The quality methods are evaluated by identifying several factors that are needed in order to achieve high quality PCR. Table 1 illustrates the differences between the European PCR companies and domestic large and small PCR companies. The European information is limited due to the limited amount of published research on quality methods for PCR manufacturing. The information for the large and small companies is obtained from the results of the survey in phase two of this research.<sup>16</sup>

The results from the table demonstrate the fact that larger companies have more thorough quality procedures than smaller companies. Larger companies can evaluate incoming product per specifications and remove any contaminants from the incoming materials. If the incoming material has too many violations it is rejected and returned to the recycling source. Most of the PCR companies perform similar evaluation procedures. The second important area for testing is during processing. One large PCR manufacturing company has, in place, effective inspection procedures and documentation of incoming materials, excellent process control and documentation of the manufacturing process, and efficient and effective product testing of the manufactured PCR. The large PCR manufacturer produces a sample plastic product from the PCR with an in-line small extruder that produces a plastic film. The film is evaluated for quality. If the quality is acceptable, the PCR material is boxed and labeled as acceptable product. If the material is out of specification then the material is rejected and the production operation is halted and the incoming material removed. This procedure was similar to the one recommended with HDPE.<sup>2</sup> No other PCR company that responded to our survey performs as similar quality procedure. The last testing step is testing of the final product. Most of the large PCR companies evaluate the PCR plastic for melt index, density, and color. None of the smaller PCR companies perform quality testing on final product. None of the companies that participated in the survey reported any chemical testing on the plastic product. Some of the companies did report that antioxidants and virgin plastics are added to enhance the properties of the PCR.

The best practices from the large companies and information from the literature review are captured in our quality management system. Best practices from quality control of virgin plastics<sup>17</sup> can also be included in the quality management system. Quality control procedures from the large PCR manufacturing company that I visited provided the framework of our QMS. The best practices from other previously mentioned sources were added to our quality management system in order to be applicable to the major recycled plastics, e.g., LLDPE, HDPE, PP, and PET. The QMS is also expanded to include a range of products, including, trash bags, rigid packaging, and plastic lumber.

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Table 1. Kepner-Trego Analysis of European and American Quality Tests

<b>Decision Attributes</b>	European companies	CA Large Companies	CA Small Companies
<b>Needs</b>			
Inspection of incoming plastic	Yes	Yes	Yes
PCR certification documentation	Unknown	Yes	Yes
Test on PCR product. MI, Density	Some companies	Yes	No
<b>Wants</b>			
Tests on incoming product	Some companies	Some companies	No
Moisture, MI, Density			
Tests during processing	No	Some	No
Tests after sample production	No	Yes	No
MI, Density, Contamination, color			
Tests on PCR	Some	Yes	No
Melt Flow, Moisture, Color			
Manufacturing Quality cost	Low	Moderate	Low
Material type	All plastic	All	All
Environmental impact	Good	Good	Good
Quality Control on PCR	No	Yes	As needed

## Quality Control Protocol

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Each of the manufacturing steps requires quality control. The quality control will vary depending upon the type of PCR that is produced. PCR can have several different types of customer requirements depending upon the intended use of the PCR materials. Trash bag manufacturers who use PCR will have a different set of requirements than manufacturers of rigid packaging or plastic lumber. Each of the customers of PCR must be assured that the PCR materials are certified for the post consumer content. Then, the different end-users should be able to get the PCR that meets the needs of their product. I recommend that an additional certification be created to classify the material into several quality categories. I recommend five grades of post consumer resin (PCR), ranging from grade 1 for near virgin plastic quality to grade 5 that has unacceptable quality for trash bag manufacturers but acceptable quality for some rigid packaging and for plastic lumber manufacturers. Trash bag manufacturers can use PCR with from grades 1, 2, and 3. Rigid packaging manufacturers can use PCR with grades 4 and 5. A key quality characteristic of grade 4 PCR is improved environmental stress cracking resistance. The specifications for grade 4 PCR will improve the reliability of the PCR and minimize the stress cracking when the rigid packaging container is produce with some PCR and is exposed to oils, paints, and adhesives. Plastic lumber manufacturers can use materials from grades 4 and 5. The five PCR grades are further explained

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in the Appendix. The quality management system will encompass all five grades of PCR materials, though different grades will have different testing standards, material specifications, and process control. The quality management system will be implemented during three areas of PCR manufacturing, e.g., incoming material specifications, process control of manufacturing operations, and final product specifications. The three areas will include data collection with quality records throughout the manufacturing process and material testing procedures during selected phases in the manufacturing process. The testing procedures and frequencies will vary between the five grades of PCR. The PCR manufacturer can establish which grade of PCR they produce as they select the recycled plastic and pay close attention to the source of the recycled plastic. The manufacturing operation for PCR will be required to maintain quality standards to produce the selected grade of PCR. Appropriate quality tests and procedures will also follow the recycled plastic as it is transformed into PCR. The PCR then can be certified as to the grade of PCM and to the level quality. The certification is based upon documentation that will follow the plastic as it is converted to PCR. The quality control data sheets and material testing procedures can be automated with web-based technology to improve the flow of data.

The QMS for PCR is broken down into three major areas during the PCR manufacturing operation: Part 1 - Receiving of incoming plastic material, Part 2 - Process control during the manufacturing operations, and Part 3 - Final product specifications. The new standards include documentation and testing throughout the process in all three areas. Different grades of PCR will have different levels of documentations, specifications, and testing requirements. The quality system will include the use of sampling plans, data control charts for process conditions and control of contaminants, final product testing for conformance, PCR quality certification for grade level, and customer feedback questionnaire. The quality system will be implemented with the establishment of a quality management system at each PCR production facility. Each company will institute a quality policy that fits its company needs and production requirements and documented in the quality control manual. The policy will include various degrees of statistical quality control methods, inspection sheets, final product testing, lot trace-ability, and quality audit procedures.

Quality control of the incoming post-consumer recycled plastic is the first step in a successful quality assurance program. The incoming plastic must be evaluated per specifications to determine the grade level. The material must be identified and recorded by lot number and tracked through the manufacturing operations through the production of a PCR product. The incoming plastic must be evaluated for quality using an inspection sheet that is included in the Appendix. The post consumer bale specifications include characteristics for the size and dimensions of the pallet, resin type identification, commercial source, bale properties, strapping characteristics, evaluations for contamination, moisture, and hazardous materials. Once the quality of the incoming plastic is evaluated, it is recorded on a quality control sheet that is included during the processing operations. If the recycled plastic does not meet the specifications, the baled recycled material is rejected and returned to the material supplier. The PCM grade level is established with an intended product use. PCR manufacturing for trash bags have the most demanding quality control requirements. The PCM characteristics are tracked by lot number through the next phase of PCR manufacturing. Testing of the post-consumer plastic is limited to the Grade level 1, 2, and 3. The plastic is tested for melt index, density, contamination, and moisture. More details are listed in the Appendix. The frequency of the testing is dependent upon the grade level of the PCR. Grade 1 will require more frequent testing than grade 2 and grade 3. Grades 4 though 5 do not require testing of the incoming plastic materials. Visual inspection is required for all grade levels.

Once the recycled plastic is remove from the bale, the plastic is sorted and the debris is removed from the bale. The debris, including, metal, other plastic, paper, and other debris, can be removed by automated or manual methods. Weighing the bale and then subtracting from it the weight of the packaging materials and the debris that is removed from the bale determines the amount of post-consumer plastic. The post-consumer weight is recorded by lot number on the inspection sheet for incoming materials. The sorted plastic is then sent to the shredder where the recycled plastic particle size is reduced to a flake or small granule. The particles can be washed and dried in a wash line. Then, a conveyer, typically, sends the shredded plastic to an extruder. The process flow of extruded material should be recorded by pounds of PCM per minute and related to the line speed of the transfer device. Thus, if any other plastic material, i.e., post-industrial material (PIM), is added to the PCM mix then the total pounds of PCM can be recalculated and recorded per lot number. This will ensure PCR certification for all of the grades of PCR.

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The process conditions of the extruder are recorded at a frequency dictated to the grade level specification. The process control is recorded by lot number and kept with the building portfolio of the PCM. The process parameters include screw RPM, temperatures in the extruder, the temperature of the extrusion die, the back pressure at the screen packs, frequency of screen pack changes, and the back pressure at the die. The screen packs retain the contaminants in the plastics stream. The inspection sheet for process control is listed in the Appendix. The frequency of the screen pack changes is an indication of quality of PCR and an item that is recorded to establish the grade level of the PCR. This does not include degradation of the polymer due to repeated heat histories. Different grade levels of PCR will have different level of requirements for documentation of the process control. For PCR grade level 1, the information on the back pressure, temperature, and screw speed must be recorded every 2 hours and displayed with a quality control chart during the manufacturing process. For PCR grade 5, no documentation is required. The documentation requirements for the remaining grades are listed in the Appendix. The PCR grade level is established with an intended product use. After the extrusion operation, the PCR is evaluated for product specifications. Testing of the incoming recycled plastic material is limited to the Grade levels 1 and 2. The plastic is tested for melt index, density, contamination, and moisture. More details are listed in the Appendix.

The third phase of the PCR Quality Assurance program occurs during the packaging of the plastic pellet or flake into containers. Production of a prototype film with the PCR plastic is required for grade levels 1, 2, and 3. In that, the plastic material is sent from the dryer to a separate line that has a small extruder making a film. The film is produced and samples are taken from it and tested for quality. The rate of production is recorded during packaging per lot. The final PCR product is tested for quality parameters. The types of tests depend upon the grade level of the PCR. More details are provided in the Appendix.

The quality assurance program is based upon proper documentation and testing throughout the manufacturing operation. The implementation can occur in several different ways with varying degrees of automation and technology. The process control charts and inspection sheets can be automated and be a part of an on-line quality control process. Training of personnel is an essential component of an effective quality control program with the inclusion of quality control manuals. Each company should add these PCR guidelines to the company's quality control manuals. The manuals are highly dependent upon the manufacturing company's operation and should be developed individually at each facility. Correction actions should also be included with the company's quality control procedures. Finally, quality audits should be held periodically at each facility to assess the implementation of the quality assurance protocol. An example quality manual for PCR manufacturer is provided in the Appendix.

The elements of the proposed quality assurance system encompass all of the aspects that were listed in the statement of work of the research proposal. The quality protocol will be implemented with a quality control manual that documents the quality system. The guidelines for quality control will be given to each manufacturing company at the end of the research project. Draft guidelines are provided in the Appendix. Each company can then incorporate the quality manual into the quality system for their respective operations. The quality manual will include many items that are part of an effective quality management system, including, quality policy, quality objectives, responsibility for quality control in the manufacturing operation, training procedures, process control on respective equipment, inspection with material specification documents, testing with reliable sampling plans, lot traceability, control of nonconforming materials with the use of corrective actions, documentation of quality records, and internal quality audits. The quality system will encompass five categories, or grades, of PCR. The first three grades are the highest quality and will require a detailed process control plan, including use of quality control charts, documented process control, and detailed quality audits. Grade levels 4 and 5 require less documentation and process control, but still require documenting the receipt of incoming materials and PCR certification. Grade 4 requires additional testing for environmental stress cracking resistance.

## **Future Work**

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The next phase in the research project is to test the quality standards and protocol in a small lab type environment at CSU, Chico. The purpose of the testing phase is to evaluate the elements of the quality system with PCR materials from several suppliers. Post-consumer materials will be sent through a small extruder and the quality of the PCM will be monitored and then tested based upon the new quality system. The effectiveness and efficiency of the quality system will be evaluated and the PCR materials will be evaluated with material characterization test equipment, e.g., FTIR, DSC, and melt index. The testing will measure the quality of the incoming post consumer plastics, PCR from several manufactures and the effectiveness of the quality assurance procedure. The quality management system will be modified and improved based upon the results of the testing phase and recommendations from the California Integrated Waste Management Board (CIWMB).

The fifth phase will test the protocol in three existing PCR manufacturing facilities. The business will be selected based upon recommendations from the CIWMB. The protocol will be evaluated for efficiency and effectiveness according to the factors listed in the statement of work from the CIWMB. The quality management system will be modified and improved based upon the results of the testing phase and recommendations from the CIWMB.

The last phase will document the results in reports and submit the final report to California Integrated Waste Management Board's Contract Manager. Additional papers can be presented to national plastics organizations. Each of the commercial plastics organizations that participated in the survey can receive a compact disk with the testing protocol or they can download the protocol from my CSU, Chico website, <http://www.csuchico.edu/~jpgreene/>. The final testing protocol can, also, be published and disseminated through the Society of Plastics Engineers at the annual technical conference, ANTEC, as well as through other plastics journals.

# Appendix

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**Post Consumer Rating Standards**  
for LLDPE, HDPE, LDPE, PP, and PET

**PCR Certification:** Certifies that the plastic used in the creation of PCR is from Post Consumer Materials (PCM) per standards provided in the CIWMB Recycled Content Trash Bag Program<sup>18</sup> and the Rigid Plastic Packaging Container Program.<sup>19</sup>

**PCR Grades:** Certifies that PCR material has a particular quality level.

**Grade 5.** Uses current *Minimum Recycled Plastic Post-consumer Material (RPPCM)* quality standards from the CIWMB. It cannot be used for trash bag blown film. It can be used for low quality applications and other plastic products. The film has poor quality and features a film that has lensing, gels over 0.032 inches, and visible flow disturbances around the gel.

**Products:** Plastic lumber - OK

: Some Rigid packaging containers that are not used for oil based materials– OK

: Trash bags – Not OK

**Quality Assurance Standards**

- a. Incoming Material Specifications: per Incoming Specification 2
- b. Process Control: Process control sheets on incoming recycled plastic sources and additional plastic materials and additives added to the recycled plastic during processing
- c. Testing: No additional testing certification beyond PCR certification.

**Grade 4:** Uses current PCR specifications from the CIWMB with a few additional process control sheets to monitor quality of PCR during production and quality testing for environmental stress cracking.

**Products:** Plastic lumber - OK

: Rigid packaging containers - OK with testing for environmental stress cracking.

: Trash bags – Not OK. It cannot be used for trash bag blown film because it has fair film quality that features a film that has no lensing and a high number of gels making the appearance unacceptable. The film has no hard gels over 0.00.015 inches and no soft gels over 0.032 inches. Gels have slight visible flow disturbances.

**Quality Assurance Standards**

- a. Incoming Material Specifications: per Incoming Spec 2
- b. Process Control: Process control sheets required:
  - i. On incoming recycled plastic sources,
  - ii. On additional plastic materials and additives added to the recycled plastic during processing.
  - iii. After change of material.
- c. Testing: Testing required for environmental stress cracking plus PCR certification

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**Grade 3:** Is acceptable film quality that features a film that can be readily made into blown film, does not have lensing and has gels that are visible, though at a moderate level. The film features no lensing, no hard gels over 0.00.015 inches, no soft gels over 0.032 inches, and no visible flow disturbances.

**Products:** Trash bags –OK.

**Quality Assurance Standards**

- a. Incoming Material Specifications: per Incoming Spec 1
- b. Process Control: Process control sheets required:
  - i. On incoming recycled plastic sources,
  - ii. On additional plastic materials and additives added to the recycled plastic during processing. After change every 10<sup>th</sup> box.
- c. Testing: Some additional testing certification beyond PCR certification.
  - i. Melt Index
  - ii. Density
  - iii. Melt Flow
  - iv. Moisture
  - v. Odor
  - vi. Color
  - vii. Inspection and evaluation of hard and soft gels from extruded 1 mil film strip from 100% PCR.

**Grade 2:** Is good film quality that features a film that can be readily made into blown film, does not have lensing and does not have hard gels that are visible. Also, no soft gels over 0.020 inches. No visible flow disturbances. Less than 65 visible gels per square inch.

**Products:** Trash bags –OK.

**Quality Assurance Standards**

- a. Incoming Material Specifications: per Incoming Spec 1
- b. Process Control: Process control sheets required:
  - i. On incoming recycled plastic sources;
  - ii. On additional plastic materials and additives added to the recycled plastic during processing;
  - iii. After change every 5<sup>th</sup> box.
- c. Testing: In addition to testing certification beyond PCR certification.
  - i. Melt Index
  - ii. Density
  - iii. Melt Flow

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- iv. Moisture
- v. Odor
- vi. Color
- vii.** Inspection and evaluation of hard and soft gels from extruded 1 mil film strip from 100% PCR

**Grade 1.** Is near virgin resin quality that features a film with no lensing and no gels over 0.010 inches and less than 15 visible gels per square inch.

**Products:** Trash bags –OK.

**Quality Assurance Standards**

- a. Incoming Material Specifications: per Incoming Spec 1
- b. Process Control: Process control sheets required:
  - i. On incoming recycled plastic sources,
  - ii. On additional plastic materials and additives added to the recycled plastic during processing.
  - iii. After change every box.
- d. Testing: In addition to testing certification beyond PCR certification.
  - i. Melt Index
  - ii. Density
  - iii. Melt Flow
  - iv. Moisture
  - v. Odor
  - vi. Color
  - vii. Inspection and evaluation of hard and soft gels from extruded 1 mil film strip from 100% PCR

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**Quality Control Sheets for Incoming Post-consumer Recycled Material**

**Incoming Material Specifications- Level 1**

The incoming recycled plastic materials must meet the following specifications:

Source: Stretch Film from industrial or commercial collection programs.

Resin: Film Grade LLDPE

Product: Stretch Polyethylene Natural Film

Type: Industrial or Commercial stretch films and stretch bags

Bale Properties:

Dimensions: 2'x3'x3' minimum to 3'x 4'x 5' maximum

Bale Weight: 1200 lbs maximum

Strapping: Non-rusting wire or polypropylene

Bale integrity: Must be maintained through shipping, unloading, and storage

Melt Index: Between 0.5 – 2.5

Film Density: Between 0.917 and 0.922

Storage Conditions: Bales must be stackable

Contamination:

- a. No hazardous materials
- b. No medical wastes or sharp objects
- c. No animal parts
- d. No biodegradable materials
- e. No PVC or PVDC
- f. No excessive trash, loose paper, or corrugated inside of bale
- g. No wood or broken pallets
- h. No polystyrene or polyurethane foam
- i. No foam plastics
- j. No oil or grease
- k. Less than 3% HDPE film
- l. Limited amount of moisture

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**Incoming Material Specifications- Level 2**

The incoming recycled plastic materials must meet the following specifications:

Source: Plastic from industrial or commercial collection programs.

Resin: PET, HDPE, Film Grade LLDPE, LDPE, PP, or PS

Product: Various

Type: Industrial or Commercial plastic

Bale Properties:

Dimensions: 2'x3'x3' minimum to 3'x 4'x 5' maximum

Bale Weight: 1200 lbs maximum

Strapping: Non-rusting wire or polypropylene

Bale integrity: Must be maintained through shipping, unloading, and storage

Melt Index: Measured

Film Density: Measured

Storage Conditions: Bales must be stackable

Contamination:

- a. No hazardous materials
- b. No medical wastes or sharp objects
- c. No animal parts
- d. No biodegradable materials
- e. No PVC or PVDC
- f. No excessive trash, loose paper, or corrugated inside of bale
- g. No wood or broken pallets
- h. No polystyrene or polyurethane foam
- i. No oil or grease

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**Post Consumer Pellet Specifications: Grades 1, 2, and 3**

Test	Method and Conditions	Acceptable Targets	Typical Test Frequency	Property Range
Melt Index, I <sub>2</sub>	ASTM D1238-88	HDPE base resin – 0.25-0.85 LDPE base resin – 0.25 – 2.5 LLDPE base resin – 0.5 – 2.5	Every 5 <sup>th</sup> Box or as agreed	+/- 15% within shipment +/- 30% across shipments
Melt Flow Ratio I <sub>21</sub> / I <sub>2</sub>	ASTM D1238 Condition E	12 – 32	Once per campaign	MFR change pre-extrusion to post-extrusion <10%
Resin Specific gravity	ASTM D792-91 or ASTM 1505-90	HDPE, LDPE, or LLDPE agreed to by trash bag manufacturer and resin manufacturer	Every 5 <sup>th</sup> Box or as agreed	+/- 1%
Bulk density		> 31.5 lbs/ft <sup>3</sup>	Every Hour at Extruder	32-40 lbs/ ft <sup>3</sup>
Moisture level	ASTM D-4019-88	<750 ppm	Every 5 <sup>th</sup> box or as agreed	< 750 ppm
Pellet Uniformity		Number of pellets in 1 gram sample. 5 reps per test	Every 5 <sup>th</sup> Box or as agreed	+/- 10%
Contamination Gels and Debris		Extrude a film strip from 100% PCM at 1.0 mils & at least 4" wide. Compare visually against control standards and/or gel size ratings	Every 5 <sup>th</sup> Box or as agreed	Grade 1, 2, 3 are acceptable
Melt Temperature		Measured at repro extruder	Every hour by lot number	
Color	Color Scale L a (absolute) b (absolute)	As mutually agreed > 60 <  4  <  7  in clear glass sample cup	Average 5 readings Every 5 <sup>th</sup> box or as agreed	
Antioxidant level	TBD	As requested per application		
Wood contaminant	TGA	< 2% by weight	Every 5 <sup>th</sup> box or as agreed	

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**Post Consumer Pellet Specifications: Grade 4**

Test	Method and Conditions	Acceptable Targets	Typical Test Frequency	Property Range
Melt Index, I <sub>2</sub>	ASTM D1238-88	HDPE base resin – 0.25-0.85 LDPE base resin – 0.25 – 2.5 LLDPE base resin – 0.5 – 2.5	Every 5 <sup>th</sup> Box or as agreed	+/- 15% within shipment +/- 30% across shipments
Resin Specific gravity	ASTM D792-91 or ASTM 1505-90	HDPE, LDPE, or LLDPE agreed to by trash bag manufacturer and resin manufacturer	Every 5 <sup>th</sup> Box or as agreed	+/- 1%
Environmental Stress Cracking	TBD	TBD	Every 5 <sup>th</sup> box or as agreed	
Moisture level	ASTM D-4019-88	<750 ppm	Every 5 <sup>th</sup> box or as agreed	< 750 ppm
Pellet Uniformity		Number of pellets in 1 gram sample. 5 reps per test	Every 5 <sup>th</sup> Box or as agreed	+/- 10%

**Post Consumer Pellet Specifications: Grade 5**

Test	Method and Conditions	Acceptable Targets	Typical Test Frequency	Property Range
Melt Index, I <sub>2</sub>	ASTM D1238-88	HDPE base resin – 0.25-0.85 LDPE base resin – 0.25 – 2.5 LLDPE base resin – 0.5 – 2.5	Every 5 <sup>th</sup> Box or as agreed	+/- 15% within shipment +/- 30% across shipments
Resin Specific gravity	ASTM D792-91 or ASTM 1505-90	HDPE, LDPE, or LLDPE agreed to by trash bag manufacturer and resin manufacturer	Every 5 <sup>th</sup> Box or as agreed	+/- 1%
Moisture level	ASTM D-4019-88	<750 ppm	Every 5 <sup>th</sup> box or as agreed	< 750 ppm
Pellet Uniformity		Number of pellets in 1 gram sample. 5 reps per test	Every 5 <sup>th</sup> Box or as agreed	+/- 10%

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**Inspection Sheet for Incoming Materials**

Plastic Lot No: \_\_\_\_\_

Plastic Type: \_\_\_\_\_

Date: \_\_\_\_\_ Time: \_\_\_\_\_

Shipping Company: \_\_\_\_\_

Material: \_\_\_\_\_

Source: \_\_\_\_\_

Purity: Non-plastic amount: \_\_\_\_\_ Other Plastic amount: \_\_\_\_\_

Weight of Pallet: \_\_\_\_\_

Quality of Plastic: Check all that apply:

1 Hazardous materials                      No    Yes

2 Medical Wastes                              No    Yes

3 Animal Parts                                 No    Yes

4 Biodegradable Materials                  No    Yes

5 PVC or PVDC                                 No    Yes

6 Excess trash or debris                      No    Yes

7 Broken wood                                 No    Yes

8 Polystyrene or Polyurethane                  No    Yes

Quality Grade Level of PCR:

Plastic Color or Clear?

Operator: \_\_\_\_\_

Phone: \_\_\_\_\_

Weight of plastic minus packaging materials and debris: \_\_\_\_\_

Explain: \_\_\_\_\_

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9	Foam products	No	Yes	Explain: _____
10	Oil or grease	No	Yes	Explain: _____
11	HDPE film	No	Yes	Explain: (Approx. %) _____
12	Moisture	No	Yes	Explain: (Approx. %) _____
13	Stapes or Glue	No	Yes	Explain:
14	Food residue	No	Yes	Explain:
15	Oil bottles	No	Yes	Explain:
16	Colored bottle	No	Yes	Explain:
17	Stones, rocks, or pebbles	No	Yes	Explain:

**Comments:**

**Inspection Sheet for Process Conditions**

Plastic Lot No: \_\_\_\_\_

Quality Grade Level of PCR: \_\_\_\_\_

Date: \_\_\_\_\_ Time: \_\_\_\_\_ Operator: \_\_\_\_\_

Pounds of PCR: \_\_\_\_\_

Pounds of PIM: \_\_\_\_\_

Pounds of Virgin: \_\_\_\_\_

Pounds of Additives: \_\_\_\_\_

% PCR: \_\_\_\_\_

Extrusion rate: \_\_\_\_\_

Rear Temperature: \_\_\_\_\_

Middle Temperature: \_\_\_\_\_

Front Temperature: \_\_\_\_\_

Die Temperature: \_\_\_\_\_

Back Pressure: \_\_\_\_\_

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Screw Speed: \_\_\_\_\_

Number of Screen Pack Changes per hour: \_\_\_\_\_

Maintenance Problems:

Appearance quality of extrudate: Poor      Fair      Good      Excellent

Quality of small test film:

Number of hard gels per 4 inch film:

Number of soft gels per 4 inch film:

Lensing: No    Yes    Explain: \_\_\_\_\_

Visible flow disturbance: No    Yes    Explain: \_\_\_\_\_

**Comments:**

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**Inspection Sheet for Outgoing PCR Materials**

Plastic Lot No: \_\_\_\_\_

Date: \_\_\_\_\_ Time: \_\_\_\_\_

Pounds of PCR: \_\_\_\_\_ Pounds of PIM: \_\_\_\_\_

Pounds of Virgin: \_\_\_\_\_ Pounds of Additives: \_\_\_\_\_

% PCR: \_\_\_\_\_

Material Testing (Average of 5 samples)

*Grades 4 and 5 Specifications*

Melt index: \_\_\_\_\_ Standard Deviation: \_\_\_\_\_

Resin Density: \_\_\_\_\_ Standard Deviation: \_\_\_\_\_

ESCR (Grade 4 only): \_\_\_\_\_

*Grades 1, 2, and 3 Specifications*

Melt Flow ratio: \_\_\_\_\_ Standard Deviation: \_\_\_\_\_

Bulk Density: \_\_\_\_\_ Standard Deviation: \_\_\_\_\_

Moisture Level: \_\_\_\_\_ Standard Deviation: \_\_\_\_\_

Pellet Uniformity: \_\_\_\_\_ Standard Deviation: \_\_\_\_\_

Contamination (TGA): \_\_\_\_\_ Standard Deviation: \_\_\_\_\_

Gels: \_\_\_\_\_ Standard Deviation: \_\_\_\_\_

Color: \_\_\_\_\_ Standard Deviation: \_\_\_\_\_

Antioxidant level \_\_\_\_\_ Standard Deviation: \_\_\_\_\_

<i>Resin Properties</i>	<i>Value</i>	<i>ASTM Test</i>	<i>US units</i>
Melt Index		ASTM D1238 Condition E	Grams/10 minutes
Density		ASTM D792 plaque	g/cc
Color		Color Scale L	

**Key Elements of ISO 9001 Certification**<sup>20</sup>

**QP1000 - DOCUMENT CONTROL**

- 1.0 Document Distribution
- 2.0 Document Revision
- 3.0 Procedure and Work Instruction Format
- 4.0 Temporary Changes

**QP1010 - QUALITY RECORDS**

- 1.0 Identification of Quality Records
- 2.0 Record Generation
- 3.0 Record Maintenance
- QP1010-1 Quality Records

**QP1020 - MANAGEMENT RESPONSIBILITY**

- 1.0 Planning
- 2.0 Management Representative
- 3.0 Responsibilities and Authorities
- 4.0 Management Review

**QP1030 - JOB DESCRIPTIONS**

- 1.0 Preparation
- 2.0 Format and Content
- QP1030-1 Job Description Format

**QP1040 - COMPETENCE, AWARENESS AND TRAINING**

- 1.0 New employee selection
- 2.0 New Employee Orientation

**QP1050 - QUOTATION PROCESS**

**QP1060 - SALES ORDERS**

**QP1070 - CUSTOMER COMPLAINTS**

- 1.0 General
- 2.0 Receiving a Contact/ customer Complaint
- 3.0 Trouble Shooting/Problem Diagnosis
- 4.0 Repairs and/or Replacements:
- 5.0 Trend Analysis

**QP1080 - RETURNED GOODS AUTHORIZATION**

- 1.0 Origination
- 2.0 Receiving Goods and Processing
- QP1080-1 Returned Goods Authorization

**QP1090 - WARRANTY AND SERVICE POLICIES**

- 1.0 Warranty Coverage
- 2.0 Service Programs
- 3.0 Parts Pricing
- QP1090-1 Limited Warranty

**QP1100 - DESIGN AND DEVELOPMENT**

- 1.0 New Product Initiation
- 2.0 Design and Development Inputs
- 3.0 Design Planning
- 4.0 Product Development
- 5.0 Design and Development Output
- 6.0 Design Review and Verification
- 7.0 Design Validation

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QP1100-1 Design Completion Checklist For Electromechanical Devices  
QP1100-2 Design Completion Checklist For Non-Electromechanical Devices  
QP1100-3 Request For Engineering Action (REA)

**QP1110 - DESIGN CHANGE**

1.0 Request for Design and/or Process Changes  
2.0 Engineering Change Notice  
QP1110-1 Engineering Change Notice (ECN)

**QP1120 - PRE-PRODUCTION QUALITY AND PLANNING**

1.0 Design Completion  
2.0 Design Transfer and Documentation  
3.0 Production Plan

**QP1130 - SUPPLIER EVALUATION**

1.0 Vendor classification  
2.0 Vendor evaluation  
4.0 Vendor Files  
QP1130-1 New Vendor Notification  
QP1130-2 Vendor Survey Form

**QP1140 - PURCHASING**

1.0 Order Determination and Requisition  
2.0 Order Placement  
4.0 Record keeping and Matching  
QP1140-1 Purchase Requisition  
QP1140-2 Purchase Order  
QP1140-3 Purchase Order Log  
QP1140-4 Purchase Order Follow-Up

**QP1150 - RECEIVING AND INSPECTION**

1.0 Receiving  
2.0 Inspection  
3.0 Stocking  
5.0 Rejection, Discrepancies and Disposition  
QP1150-1 Receiving Log  
QP1150-2 Receiving And Inspection Report

**QP1160 - SCHEDULING**

1.0 Production Planning  
2.0 Work Order Packets

**QP1170 - MANUFACTURING**

1.0 Kitting Work Orders  
2.0 Production  
3.0 Final Inspection.  
4.0 Packaging and Labeling  
5.0 Final Release

**QP1180 - PART NUMBER ASSIGNMENT**

1.0 Number Designation  
2.0 Part Number Assignment/Record Keeping  
3.0 Classification System

**QP1190 - SERIAL NUMBER DESIGNATION**

**QP1200 - PRODUCT LABELING**

1.0 Label Control

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- 2.0 Identification Labels
- 3.0 Safety Hazard Labels

**QP1210 - CUSTOMER PROPERTY**

- 1.0 Receipt, Inspection and Stocking of Customer Supplied Items
- 2.0 Unsuitable or Missing Items
- 3.0 Customer Supplied Tooling and Fixtures
- 4.0 Intellectual Property
- QP1210-1 Material Return Notice

**QP1220 - CONTROL OF MONITORING AND MEASURING DEVICES**

- 1.0 General requirements
- 2.0 Storage, Handling and Maintenance
- 3.0 Calibration System
- 4.0 Inspection of Special Tooling
- 5.0 Out-of-tolerance Conditions
- 6.0 Control of Subcontractor Calibration
- 7.0 Test Software
- QP1220-1 Calibration Record

**QP1230 - CUSTOMER SATISFACTION**

- 1.0 General
- 2.0 Post-Sale Follow-Up
- 3.0 Customer Survey
- 4.0 Post-Service Follow-Up
- QP1230-1 Post Sale Satisfaction Report
- QP1230-2 Customer Satisfaction Survey
- QP1230-3 Customer Satisfaction Report

**QP1240 - INTERNAL QUALITY AUDITS**

- 1.0 Audit Guide
- 2.0 Audit Process
- 3.0 Corrective Action
- 4.0 Audit Records
- QP1240-1 Quality Assurance Audit Checklist

**QP1250 - MONITORING AND MEASUREMENT OF PROCESSES**

- 1.0 Effectiveness Criteria
- 2.0 Reporting
- 3.0 Improvement
- 4.0 Review

**QP1260- CONTROL OF NONCONFORMING PRODUCT**

- 1.0 Identification and Segregation
- 2.0 Nonconformance Report
- 3.0 Returned Goods
- 4.0 Disposition
- 5.0 Corrective Action
- QP1260-1 Nonconformance Report

**QP1270 - DATA ANALYSIS AND CONTINUAL IMPROVEMENT**

- 1.0 Data collection
- 2.0 Data analysis
- 3.0 Continual Improvement

**QP1280 - CORRECTIVE ACTION**

- 1.0 Initiating a Corrective Action
- 2.0 Investigating the Cause

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- 3.0 Taking Corrective Action
- 4.0 Preventing Recurrence
- 5.0 Verification and Closure
- QP1280-1 Corrective Action Request

**QP1290 - PREVENTIVE ACTION**

- 1.0 Product Design
- 2.0 Process Design
- 3.0 Preventive Actions from Data Analysis

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## **Quality Control Manual Guidelines**

Each company should take the following guidelines and supplement their existing quality control system with these documents. The purpose of the manual is to provide a framework for each company to implement the quality procedures in the manufacturing operation.

### 1. Purpose and Scope

The purpose of the quality management system is to reduce the amount of variability in the PCR product and to establish performance characteristics of the PCR product in terms of defined testing procedures. The scope of the quality system is all materials and machinery that are used to produce a PCR product.

### 2. References

The references used to establish a quality system include references 14, 15, and 17.

### 3. Terms and Definitions<sup>21</sup>

3.1 Quality Control: Set of operational, managerial, and processing activities that a company uses to ensure that the quality characteristics of a product are at acceptable levels.

3.2 Control Charts: Primary techniques of statistical process control that plots averages of measurements of a quality characteristic taken from a processing operation over time.

3.3 Quality characteristics: Parameters of a product that define its intended use in terms of form, fit, and function.

3.4 Nonconformity: A specific type of failure of a product that does not meet one or more of its specifications.

3.5 Upper control limit: The maximum acceptable value of the control parameter that is monitored.

3.6 Lower control limit: The minimum acceptable value of the control parameter that is monitored.

### 4. Management Responsibilities

Management for each organization must be committed to provide an environment for high quality by providing training opportunities for their employees, adequate testing, inspection, and monitoring equipment, and resolve to make improvements in the manufacturing process to reduce the causes of quality problems.

### 5. Quality Management System- Standard Operating Procedure (SOP)

5.1 General Requirements – The general requirements of the quality system applies to all materials and procedures used to produce PCR materials that are certified by the CIWMB.

5.2 Documentation Requirements – All of the materials and procedures used to produce certified PCR must be have documentation that describes the quality characteristics of the material. Different levels of documentation are required for different grades of PCR. The quality manager or production manager must approve the documents.

5.3 Procedure Writing – The quality and operation procedures must be written and made part of employee training. The operation procedures include work place instructions for each job classification. Any changes to the procedures must be captured and added to the procedures.

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- 5.4 Control of Quality Records – The quality records are to be available to the operator during the processing stage and controlled by the quality engineer or production manager. Every lot of material should have an identifiable and verifiable quality tracking number.
- 5.5 Management Responsibility – The quality engineer or production manager is responsible for ensuring the quality procedures are followed per the quality management system. The production manager or plant manager will be required to verify all of the information on the quality documentation is accurate with a signature.
- 5.6 Customer Focus – The PCR product should be based upon a customer focus where customer requirements are implemented in the quality systems with appropriate product tests.
- 5.7 Management Review – The quality system should be evaluated on a regular basis by the management team and improvements made to increase the effectiveness of the quality procedures.
- 5.8 Resource Management – Training is required at least once a year for employees on quality practices and procedures.
- 5.9 Quality System Implementation
- a. Operations in Quality – The sequence of the processing operations is defined for all elements of the PCR production; from receipt of incoming recycled plastics through washing, drying, extrusion, and packaging stages. An example of implementing the quality system is given below.
    - i. Receipt of recycled materials- The incoming bale is inspected per the Quality Control Sheets for Incoming Plastic Material.
      1. Complete the check-list for Quality Control of Incoming Materials.
      2. If it does not meet Incoming Materials Specifications for Level 2 the reject bale.
      3. If it does meet Incoming Materials Specifications for Level 2 then inspect the bale for Level 1 specifications.
      4. Record the level that it passes inspections on the Quality Control of Process Conditions
    - ii. Decide which grade specifications of PCR that the recycled plastic can meet.
      1. Follow the documentation and testing protocols for the grade that is selected.
        - a. Grade 5 –Documentation per Quality Control of Incoming Materials is required for PCR certification from the CIWMB.
        - b. Grade 4 – Same as Grade 5 plus documentation for Environmental Stress Cracking per specifications.
        - c. Grade 3 – Same as Grade 5.
        - d. Grade 2 – Same as Grade 5.
        - e. Grade 1 – Same as Grade 5.
      2. Follow the testing requirements for the grade that is selected.
        - a. Grade 5 –Testing is required for PCR certification from the CIWMB. Testing includes melt index and density.

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- b. Grade 4 – Same as Grade 5.
  - c. Grade 3 – Same as Grade 5 plus testing for moisture and odor
  - d. Grade 2 – Same as Grade 3.
  - e. Grade 1 – Same as Grade 3.
- iii. Processing of recycled materials- Process conditions and materials are monitored.
- 1. Follow the documentation and testing protocols for the grade that is selected.
    - a. Grade 5 –Documentation is required for PCR certification from the CIWMB.
    - b. Grade 4 – Same as Grade 5 plus documentation for Environmental Stress Cracking per specifications.
    - c. Grade 3 – Document the processing conditions per Quality Control of Process Conditions document.
    - d. Grade 2 – Same as Grade 3.
    - e. Grade 1 – Same as Grade 3.
  - 2. Follow the testing requirements for the grade that is selected.
    - a. Grade 5 –Testing is required for PCR certification from the CIWMB. Testing includes melt index and density.
    - b. Grade 4 – Same as Grade 5 plus testing for Environmental Stress Cracking per specifications.
    - c. Grade 3 – Same as Grade 5 plus testing for melt flow, moisture, odor, color. Plus extrusion of 1” strip or equivalent.
    - d. Grade 2 – Same as Grade 3.
    - e. Grade 1 – Same as Grade 3.
- iv. Testing of PCR Product-
- 1. Follow the documentation and testing protocols for the grade that is selected.
    - a. Grade 5 –Documentation is required for PCR certification from the CIWMB.
    - b. Grade 4 – Same as Grade 5 plus documentation for Environmental Stress Cracking per specifications.
    - c. Document the processing conditions per Quality Control of Outgoing PCR Product document.
    - d. Grade 2 – Same as Grade 3.
    - e. Grade 1 – Same as Grade 3.
  - 2. Follow the testing requirements for the grade that is selected.

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- a. Grade 5 –Testing is required for PCR certification from the CIWMB. Testing includes melt index and density.
  - b. Grade 4 – Same as Grade 5 plus testing for Environmental Stress Cracking per specifications.
  - c. Grade 3 – Same as Grade 5 plus testing for melt flow, moisture, odor, color.
  - d. Grade 2 – Same as Grade 3.
  - e. Grade 1 – Same as Grade 3.
- b. Identification and Traceability – Each lot of PCR material will have a *Plastic Lot Number* that will track the material as it is process through the manufacturing operation, including, receipt of recycled materials, compounding processing, and testing of final product. The PCR product will have a grade level based upon the specifications that include the *Plastic Lot Number*. Nonconforming material can be traced to the processing operation parameters and the incoming plastic quality.
  - c. Control of Monitoring and Measuring Devices – The monitoring and measuring devices are a set of test equipment that are periodically calibrated so that they can be used at the required intervals described in the specifications for grade level of PCR.
  - d. Internal Audits – Internal audits are required to held several times a year to ensure that the documentation and testing procedures are following the quality management system.
  - e. Inspection and Testing – The inspection of materials and testing of the PCR product are described in the specifications for each grade level of PCR.
  - f. Control of Nonconforming Product – Nonconforming product is to be identified on the quality control sheets for inspection, processing, and outgoing product. Nonconforming products are either discarded or blended with other PCR product.
  - g. Analysis of Data – The data from the process control charts are analyzed with statistics to generate an upper control limit and a lower control limit for the processing parameters that are measured, including, quality rating and moisture of PCM at the entrance toe the conveyer stage, melt temperature and back pressure at the extruder stage, and moisture, density, and color at the PCR packaging stage.
  - h. Improvement – Corrective Action – If the process control charts have a recordable event that is higher than the upper control limit or lower than the lower control limit, then the operator will notify the production manager who will make adjustments to the process to bring the measurable parameter to be within the upper and lower control limits. The appropriate process adjustments can be determined from experience or from knowledge gained from conducting design of experiments. The correction action should be recorded and added to the quality control system for the company.
  - i. Improvement – Preventative Action – If a corrective action is repeated for a recurring problem than the production manager should initiate a project to provide a long-term solution that prevents the occurrence in the future.
  - j. Best Practices Checklists – At the startup of the production machine, the operator should complete a checklist that has best practices for each of the machines so that the equipment will operate at peak performance. The best practice checklist should be developed from experience or from customer feedback.

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