9-693-047
REV: JANUARY 31, 2002

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Process Control at Polaroid (A)

"Quality was not supposed to go down when we introduced Project Greenlight," noted Bud Rolfs, the manager heading Polaroid's first attempt at operator-based statistical process control (SPC). Although the project's plan was based on sound statistical theories, the data told a different story and people throughout the organization were increasingly concerned. Project Greenlight had recently been implemented at the R2 plant which manufactured instant film, and was intended to cut costs while maintaining and even improving product quality. Selling the idea of operator-based control had been difficult, requiring education of both upper management and hourly staff. Now it appeared that all the work might have been for naught.

By August 1985, with Project Greenlight nearing completion of its implementation phase, audits conducted by quality control (QC) of R2's film showed defect rates 10 times higher than their historical level. At the same time, defect rates measured by production operators had declined to half of their historical level. This information passed quickly through the ranks at R2, where many people already felt that the Greenlight project team had sacrificed quality in order to save money. Rolfs believed that these results were not indicative of lower quality, but verifying that position and convincing plant personnel and upper management of it would be a challenge. Moreover, the Greenlight team still had to convince all R2 personnel that quality products came from processes that were "in control and capable," not from "tweaking" machines to produce an acceptable product. Almost everyone in the plant was accustomed to a volume philosophy wherein machine utilization was top priority. Changing that mindset was proving to be especially difficult.

Polaroid Background

In 1985, as throughout its history, Polaroid's main line of business was instant photography. The Consumer Photography Division and the Technical and Industrial Division each accounted for approximately 40% of Polaroid revenues in 1984. Both divisions' sales of instant cameras and film were down in 1984, mostly due to the impact of a strong U.S. dollar on overseas sales and earnings. (International sales accounted for 40% of Polaroid's $1.3 billion in revenues and 60% of its profits.) **Exhibit 1** shows selected financial data.

Edwin H. Land, Polaroid's founder, revolutionized the photographic industry in 1948 with the development of the Polaroid camera. Since that time, Polaroid had led the instant photography market. By the mid-1970s, it offered two basic types of instant film: peel-apart and integral (see

This case was prepared by Professors Steven Wheelwright and H. Kent Bowen. HBS cases are developed solely as the basis for class discussion. Cases are not intended to serve as endorsements, sources of primary data, or illustrations of effective or ineffective management.

Exhibit 2). Both film types used similar technologies: opening the camera's shutter produced an image on a film negative; then, as the film was removed from the camera, a chemical reagent was activated which developed the image onto the photographic paper (the "positive"). With peel-apart film, the older of the two types, the user physically pulled the film from the camera (which activated the reagent) and then, after a brief period, peeled apart the two sides of the film envelope to obtain the finished photograph.

Integral film, introduced with Polaroid's SX-70 camera in 1972, came out of the camera in one piece and was self-developing and self-timing. Consumers inserted into the camera's base a plastic cartridge containing 10 frames (pieces of film) and a top cover sheet that was automatically ejected from the cartridge. The user aimed the camera at the subject and pressed a button which opened the camera shutter, thereby exposing the first frame. The camera then automatically ejected that frame, starting the development process, and the finished picture would be ready in less than a minute. The plastic cartridge also contained a battery providing power to the camera's flash, shutter assembly, and the film pack's frame ejection system. By the mid-1980s most consumer instant film was integral; peel-apart film was used mainly by professional photographers and industrial or technical users.

The Waltham, Massachusetts, site, which produced most of Polaroid's integral film, consisted of four main buildings: R1 manufactured 4" x 5" (102 mm x 127 mm) peel-apart film; R2 manufactured integral film; R3 contained administrative offices, and R4 produced batteries that were assembled into the integral film packs. The integral film manufacturing operations in R2 ran three shifts, five days a week, employing approximately 900 people (about 700 were hourly production workers).

Integral Film Production at R2

R2 was primarily an assembly operation. Starting with negative film, reagent, batteries, and plastic receiving sheets brought from other Polaroid plants, R2 produced sheet metal springs, pods, plastic cartridges, and plastic end caps internally, and then assembled everything into film cartridges. R2 had three floors: spring production, pod production, and packaging were on the first floor, while cartridge production and assembly were on both the second and third floors. Materials (reagent, negative film and other raw materials) arrived at a fully automated warehouse, which delivered materials as needed to different areas.

In the first production step, metal springs (used to keep the film frames pressed to the top of the cartridge) were stamped out of sheet metal in a ten-stage metal pressing operation. Elsewhere on the first floor, pod machines produced the reagent pods by folding foil material into a V, laminating one side, injecting the reagent under high pressure, laminating the open edges and center of the pod, and cutting off the individual pods. Pods were so designed that when the film frame was ejected from the camera, the reagent would be released through the front seal of the pod. The reagent then flowed between the negative and positive, developing the image. The correct amount of reagent in the pod was critical: too much would result in leaks and too little would result in incomplete development of the image.

The cartridge's outer shell (the plastic box) was created on R2's second and third floors. Each of several plastic injection molding machines fed half a dozen film assembly machines. Plastic box manufacture was nearly just-in-time: plastic boxes from each injection molding machine were produced and collected in an accumulator, which held up to four hours' supply for the downstream assembly machines. These plastic boxes were automatically sent from the accumulator to the assembly machines on an as-needed basis.

The film assembly machines were the most complex equipment in the plant. Film frames (the "picture") were manufactured from continuous streams of materials, then cut and placed in the plastic box along with a battery, spring, and cover sheet (which kept the top frame from being exposed to light while the consumer loaded the cartridge into a camera). Most of the assembly process, from the addition of the negative until final packaging, was done in the dark. Before entering the dark room, the positive material was fed into the front of the machine, along with the mask (the front and back cover of an individual frame). In the dark room, the negative was added and a pod attached. Thick long strips of material called rails were then placed on both sides of the positive (to create the gap between the positive and negative through which the reagent would flow), and a special "craft" material was attached to the top end (to absorb excess reagent). After all the materials had been applied to the front and back of the mask, it was folded over, cut, and the top and sides laminated to create individual frames. Next, a battery was inserted into the plastic box, then a spring, and finally a stack of 10 frames, with a cover sheet on top, was inserted on top of the spring. End caps were ultrasonically welded onto the plastic boxes (creating a light-proof container for the film). At this point, Polaroid began referring to the completed assembly—containing 10 frames—as a cartridge. This cartridge was placed into a moisture-proof individual cardboard container.

Packaged cartridges were inventoried and delivered to the first floor and packed singly or in multi-packs of two or three, to fill a large shipping carton. Shipping cartons, each containing 60 cartridges, were then stacked and wrapped (palletized), ready for shipment. Overall, materials represented about two-thirds of the cost of manufacturing at R2. The remaining third consisted of direct labor, indirect labor, administrative overhead, and allocated fixed costs.

Quality and Process Control Procedures at R2

The quality control department (QC) at Polaroid had final responsibility for the disposition (release to market) of all film. QC auditors randomly sampled 15 finished cartridges (each containing 10 frames) out of every lot (a lot contained approximately 5,000 cartridges—the amount produced by one assembly machine during an 8-hour shift). If sampled cartridges contained defects in excess of allowable limits, the lot was held and further testing done. Additional sampling and testing of more cartridges led to some portion or all of that lot being rejected or reworked, depending on the defect. Further, if excessive defects were found in one lot, the number of units sampled in the next lot was increased. (Since overall defect levels were very low, the amount of sampling done could affect dramatically how much of a lot was rejected.) QC auditors rejected just over 1% (50 cartridges of each 5,000) of the product produced in 1984, and sampled an average of just over 20 cartridges per lot of 5,000.

Prior to QC's audit of the completed lot production, operators at each stage of the process were to sample 32 random cartridges out of each lot, taking specific measurements of different characteristics of the cartridge and its contents, including the individual frames. Typical characteristics measured included the placement of the positive on the mask (done in the assembly area), the amount of reagent in the pods (done in the pod production area), and the tension of the springs (done in the spring production area). This information was supposed to be combined with operator knowledge of how the equipment had been running, to determine if a lot, or a portion of it, should be rejected. Production operators (and auditors) could reject as little as one cartridge out of a lot. Operator rejects had been running at just about 1% of production in 1984. However, operators frequently did not record the data they collected because they didn't "have time to take all the samples called for by the procedure." It was estimated that operators sampled one cartridge approximately 3 or 4 times per hour throughout their shift. In practice, if operators were uncertain about the quality of a particular lot, they would send it on, believing that quality control was better equipped to make final determinations.

Process control at R2 was initiated in the late 1970s with the tracking of injection molding equipment temperature and pressure variations. Process engineering technicians (assistants to the process engineers) were made responsible for gathering data and performing rough analyses. In the early 1980s, they also began measuring and analyzing other equipment and key product characteristics over time to test for adherence to design specifications. Bob Cook, a former process engineer who had supervised the second floor during the early 1980s, was a chief proponent of process control. Historically, process engineers at Polaroid had been responsible for materials, while mechanical engineers were responsible for equipment. Because no one was responsible for the overall process of production, when defects were discovered, much time was spent alternately blaming the materials or the machines.

In moving from process engineering to management in late 1981, Cook became responsible for the cost of materials used in his area, including scrap. Given the high cost of materials, Cook concentrated on increasing the yield of his machines instead of their utilization, and this meant reducing machine variability. The several assembly machines on Cook's floor all ran differently: each reacted uniquely to new parts, each ran at a slightly different speed, and each put products together with different levels of variation. Cook proposed a process called “baselining,” whereby the mechanical engineers and maintenance people were challenged to bring each machine back to the target specification, instead of "fixing" it to run as fast as possible. He received some management support for Baselining, which was essential given the cost of returning all the machines to specification. Fortunately, following this effort the yield on the second floor quickly rose above that on the third floor, reinforcing Cook's arguments.

After undergoing hip replacement surgery in 1982, Cook was unable to resume his line position when he returned to work in 1983, and was named process control manager. He discovered, however, that as a staff person with no direct authority it was difficult to get all the different groups (production, process engineering, mechanical engineering, maintenance, and quality control) to try his new ideas. Meanwhile, the traditional process control measures and analyses continued to be done by the process engineering technicians, mainly because it was their "specialty."

Quality and Process Control Issues in 1984

By the end of 1984, R2 quality control had grown to 125 inspectors, who primarily sampled film cartridges as fast as possible, all day long. Sampling meant exposing film and creating scrap, and the cost of that sampled scrap in QC alone was $540,000 in 1984. Operator-sampled scrap added another $740,000, and finished product (entire shipping cartons) rejected when sampling identified excessive defects resulted in an additional $2 million in scrap. Meanwhile, pressure to limit and reduce costs was mounting. Throughout the middle and late 1970s, R2 had run at full speed in order to keep up with demand, and plans were laid to expand the facility significantly. When the market flattened unexpectedly in the mid-1980s, management recognized the need to cut costs at R2. In addition, Polaroid planned to introduce a major new film to begin production in late 1985. A new product would require Polaroid to hire even more quality control auditors unless the number needed for current products could be reduced. If there were a way to decrease sampling without adversely affecting quality, R2 could free up resources for the new product and lower costs on current products.

In early 1984, George Murray, R2's quality manager, and Joe O'Leary, the assembly production manager, asked John Glaser, a QC engineer with a background in statistics, to conduct a study of current sampling patterns and to determine whether the amount of sampling could be reduced.

Glaser discovered that, due to the low defect rates, decreased sampling would have little impact on the number of defective cartridges actually reaching customers. Specifically, he found that halving production sampling would result in the release of defectives equal to 0.03% of production, and similar results held for cutting down on quality control sampling. Because the percentage of defectives was so low, and the population of cartridges produced so large, it would be prohibitively expensive for Polaroid to increase sampling to achieve a significantly greater level of confidence that only good product was getting shipped: hundreds of cartridges would have to be tested (and therefore scrapped) from each lot to do so. Additionally, sampling, in and of itself, did nothing to improve product quality. Therefore, if sampling were not accurate enough to find all the defectives, Glaser (like Cook) argued that it made sense to work on improving the quality of the production process itself.

In addition to Glaser's numerical analysis, management knew that the sampling process itself was imprecise and often inaccurate. When QC auditors found a defective sample in a lot, they tested a larger sample from both that lot and the next lot. Unfortunately, the act of testing itself could increase the defective rate. To check large quantities, auditors took cartridges out of their packaging and inspected them. The inspected cartridges that passed were then sent back to production to be repackaged. In the process of handling, unpacking, and repacking, some cartridges were damaged, increasing the likelihood that the auditors would find more defects, which in turn increased the sampling rate. This resulted in a vicious spiral—as the number of samples increased, auditors found more problems and rejected greater portions of each lot.

Operators had been aware of this for some time. Therefore, to avoid losing more production, some operators "salted" boxes: if they felt one series of cartridges might be marginally defective, they would intersperse them among several other cartridges. Although each cartridge was coded, operators knew that the codes were seldom checked. Operators often did not record defective samples, resulting in fewer recorded samples than requested. Management knew, however, that they were performing most of their required sampling because lost production could be tracked through the plant's accounting system, which showed an average loss of 25 to 30 sampled cartridges per shift.

There also were problems with the way QC tested the products it sampled. One test involved using an instant camera to check for film/camera interaction problems. For example, did the cartridge fit into the camera easily? Did the frames come out easily? Was the image centered on the frame? Was it properly exposed? QC used only "perfect" cameras (which operated to precise specifications) to test film. Many consumers' cameras, however, did not function precisely to specification. Thus quality control could easily miss problems related to the interaction of the film with imperfect cameras. Also, some people argued that QC was not testing for the types of defects that consumers noticed. For instance, the most stringent auditors would flip the film over right after exposing it and check to see if any excess reagent was leaking out of the top of the frame (small holes in the top of the frame allowed air to flow from between the positive and negative when reagent flowed through the gap). These stringent auditors averaged about 10% defectives. This type of "excess reagent" defect, however, was one that customers would likely never see, since during the time the image was developing, capillary action pulled the excess reagent back into the "craft" material. Looking for excess reagent first thus increased rejection rates of non-defective product.

Finally, Polaroid was receiving complaints from Japanese customers about defects never noted in other markets. One example was a visual defect on the outside of the cardboard box containing the cartridge that occurred 0.2% of the time but had been noted in many complaints. Polaroid managers were surprised that any complaints regarding this problem were received, until one manager demonstrated it visually. He stacked 2,000 units of film against the wall, indicating that these represented the 0.2% defectives of the one million units Polaroid had shipped to Japan in the previous month.

Project Greenlight

In mid-1984, O'Leary and Murray asked Bud Rolfs, the process engineering section leader for R2 assembly, to head up a team to investigate ways to reduce quality monitoring costs while maintaining or improving product quality. O'Leary and Murray wanted this group to investigate whether it was possible to make the quality control process more effective, beyond merely reducing the number of samples taken. The subsequent project's name, Greenlight, came from Murray's original idea of having a light over the machines that would be green when they were running on target.

As process engineering leader, Rolfs oversaw the monitoring and analysis of process control measurements (temperature, pressure, dwell time, etc.), and the use of statistical tools in production. Thus, he knew that R2 had all the process control tools it needed to implement operator-based statistical process control. All his team had to do was come up with a plan and convince management of its viability. As Rolfs stated, "Three hundred years ago, if we'd tried to sell an idea this radical from traditional quality inspection thinking, we'd have been burned at the stake."

In addition to Rolfs, the team included Glaser and salaried representatives from quality control audit, assembly, and mechanical engineering. The team took about five months to create its final plan, which consisted of three key elements. First, statistical process control principles would be adopted: processes in control and capable of producing within specifications would produce more consistent quality. Second, production operators would be given the process control tools that the process engineering technicians had been using and, in conjunction with sampling, would be expected to make disposition decisions themselves. Third, quality control auditors would concentrate on training operators and operationalizing specifications on new products.

Operators also were to become responsible for taking measurements and recording them on control charts. For a particular process characteristic, they would randomly take six measurements during the course of their shift and then plot the mean of the measured value. Early on, the QC auditors helped operators calculate the upper and lower control limits and add them to the chart for running two week periods. If an operator determined a machine was operating outside the upper or lower control limits, the protocol was to immediately shut down the machine and call for maintenance. Maintenance technicians would clean, recalibrate, and restart the machine. Similarly, if eight consecutive mean values fell into the upper or lower zones near the control limits, or if there was a consistent and continuing trend upward or downward on the chart, then maintenance also was to be called to investigate. Following maintenance and recalibration of the machine, new control limits would be calculated.

Once the Greenlight team agreed on the plan, members spent another two months making "about 500 presentations" to sell it to upper management. Selling management on the cost savings that could be achieved through reduced sampling was fairly easy; convincing them that quality would not suffer was harder. Some managers suggested that the plan would remove the guard dogs (the quality control auditors) and leave the foxes (the operators) in charge of the hen house. Eventually, when upper management agreed to the plan, the team began training operators and executing the implementation phase.

Implementation

R2 assembly machine operators had traditionally been free to change the speed, temperature, pressure, and other settings on their equipment. Under Greenlight, standard settings would be determined and operators would be required to shut down their equipment as outlined above, rather than "tweaking" it as they deemed appropriate. Maintenance procedures were also changed. In the past, each maintenance person had an almost unique set of solutions to problems with each piece of machinery. Project Greenlight required that maintenance personnel collectively determine and adhere to standardized "best practice" procedures in correcting all problems.

Project Greenlight was rolled out through R2 over the first six months of 1985. One of the first problems encountered was determining the proper centerline and range of values for the process control measurements to be taken. The centerline and ranges were initially set using base-line data collected at the beginning of the project using sampling techniques that became the recommended procedures for operators. The centerline was set at the mean of the mean values and was the initial target, and the initial control limits were set at three standard deviations. **Exhibit 3** shows base-line data for pod weight and finger height. Further, he hoped to do more extensive research on customers' needs and their relationship to various process parameters, in order to determine the specification target values and then the capability of each process. While the initial machine settings were being established, all operators were trained in basic statistics, theories and principles of process control, and construction and use of statistical process control charts.

Reactions to Project Greenlight

The initial reaction from production, quality control, and others at R2 was that the project team was "giving away the store." Machine operators believed that they themselves would act responsibly, but they did not trust their neighbors. Quality control personnel did not trust the operators: they knew the "games" that some operators played to avoid rejecting production, and thought that eliminating QC's policing role would increase the number of defectives passed on to customers. Also, most process engineering technicians felt they were better trained to do the sampling and process control tasks now being transferred to the operators.

In addition to getting people to trust the operators, the team also had to change the mindset of everyone at R2. Like most large manufacturing facilities, R2 was grounded in the concept of volume manufacturing, trying to minimize costs by keeping machine utilization as high as possible. Furthermore, operators and maintenance personnel already were very concerned with quality. However, they understood quality in a different way than that embodied in Project Greenlight, which necessitated replacing the old concept with a new one, not simply getting the new quality concept adopted. For example, based on the old concept, operators believed that shutting down equipment when process variation was high, but before defectives were actually produced (as Greenlight rules required), would be more expensive than waiting until defects actually occurred. For operators to adopt the new quality concept, that belief had to be replaced by one that held that such shutting down would be *cheaper*, not more expensive, in the long run.

For their part, maintenance personnel previously made adjustments to equipment that they individually believed would improve the quality of the product produced. Under the new concept, which required standardized procedures, maintenance personnel felt that their tasks were being depersonalized: what had once been an art was now being bureaucratized. Similarly, operators would need to believe that a more stable process could more effectively produce consistent quality than "tweaking" based on their own experience.

Results (April—August 1985)

The general dissatisfaction came to a head when the first few months of results from the auditors and operators were released (**Exhibit 4**). While the reported defective rate from the operators had dropped from just under 1% to 0.5%, the defective rate from the central process auditors had climbed from just over 1% to levels averaging 10%. **Exhibit 5** lists the sample types of defects assembly operators and auditors identified. It was quickly noted that auditors and assembly operators were finding different types and proportions of defects. Part of Rolfs' task was to assess which of these lists was a more accurate representation of the true defects in the process. To do this, he felt he needed to tie the key defects back to actual process measurements.

Two process measurements in particular (Pod Weight and Finger Height) had a direct impact on the customer's experience of the product. Operator's measurements for one machine are shown in **Exhibit 6**. Pod weight provided a measure of the pod coming off the pod machines, and could be related to excess or insufficient reagent. If the pod weight were too low there would be insufficient reagent to develop the photo. If the pod weight were too high, there would be excess reagent and it would leak out the back. Finger height provided a measure of the height of the small plastic tab that controlled the advance and ejection of the frames in the cartridge: the finger was designed so that only one frame at a time would be ejected from the camera after each exposure (see **Exhibit 7**). The injection molded box endcap with finger was ultrasonically welded to the box during the assembly operation. If the finger height were too high the frame would not eject, causing a frame feed failure. If the finger height were too low, two frames would eject at the same time, causing a double feed.

Challenges Going Forward

Rolfs and the other Greenlight team members did not believe that finished film quality in R2 had actually slipped. They had expected the defect rate the auditors identified to increase, but not to 10%. They also knew that the operators were not recording all of the defects they found: the project team had observed on several occasions that operators were sampling and testing more units than they were recording and were adjusting machines based on those unrecorded defects.

Defects the assembly operators did record showed few related to assembly, but Rolfs knew that operators were testing and discarding more film than they were recording, so they probably were not recording defects related to assembly. When pressed on the issue, operators said that they did sample and find assembly defects, but they discarded the defective products (thus protecting consumers) and then cleaned and adjusted their machines to correct the problem. As summarized by one operator, "If you are writing a report and you find a mistake, you correct it before you send it on to your boss. If your boss compliments you on the report, you don't point out where the mistakes used to be."

Rolfs thought that it might be possible to develop more systematic and automated methods for collecting operator data in the near future. For instance, many of the measurements currently were taken with a Microline, a device with which an operator could measure dimensions very exactly. Attaching this device to a personal computer seemed rather straightforward. The Microline would then send the measurement directly to the computer, which could record it immediately, and display it so that the operator could respond appropriately. Polaroid could purchase other, more complex data capturing devices as well. One was a gauge that could automatically measure 40 of the 450 potential characteristics on a sampled cartridge. That setup would cost $100,000 and require one full-time operator. Rolfs wondered to what degree Polaroid should automate information gathering, how much data they needed to collect, and what impact systems that forced compliance would have on morale and cooperation.

In the short term, Rolfs knew that other people would need convincing that there was not a quality problem (external customer complaint information would take another six months or more to gather, plus a couple of months beyond that to analyze). Furthermore, not only were SPC and Project Greenlight's future in R2 at stake, but if not successful at this site, the rest of Polaroid would be unlikely to adopt such concepts either. Over the longer term, the team faced other challenges. For example, how should they incorporate consumer research regarding customer specifications into the process control system? What could they do to ease the transition for maintenance, engineering, and quality control from the old concept to the new? Finally, what could they do in the future to keep people focused on improving quality once defect rates dropped significantly below 1%?

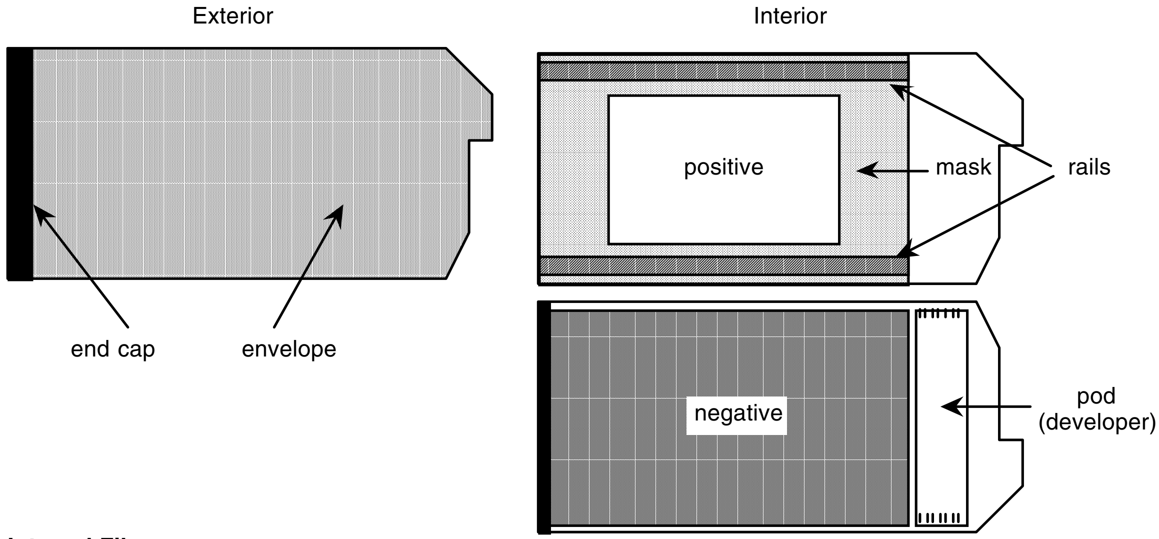
Exhibit 1 Polaroid Recent Financial Results ($ millions)

Income Statement	1980	1981	1982	1983	1984
Sales					
United States	791.8	817.8	752.5	730.1	743.5
International	659.0	601.8	541.4	524.4	528.0
Net Sales	1450.8	1419.6	1293.9	1254.5	1271.5
Cost of Goods Sold	831.1	855.4	769.6	698.3	735.2
S, G & A	483.9	520.8	472.6	462.1	492.6
Income from Operations	135.8	43.4	51.7	94.1	43.7
Interest Income	24.0	46.1	43.8	32.4	37.3
Other Income	1.4	3.1	1.7	0.1	2.2
Interest Expense	17.0	29.9	35.5	26.5	20.9
Pre-tax Earnings	144.2	62.7	61.7	100.1	62.3
Taxes	58.8	31.6	38.2	50.4	36.6
Net Earnings	85.4	31.1	23.5	49.7	25.7
Earnings per Share	$1.30	$0.47	$0.37	$0.80	$0.42

Balance Sheet	1980	1981	1982	1983	1984
Current Assets	1041.8	1101.8	1041.8	1042.1	1039.4
Net Property, Plant, & Equip.	362.2	332.9	281.8	277.0	306.6
Total Assets	1404.0	1434.7	1323.6	1319.1	1346.0
Current Liabilities	319.9	352.3	296.4	273.1	305.2
Long Term Debt	124.1	124.2	124.3	124.4	124.5
Shareholder's Equity	960.0	958.2	902.9	921.6	916.3
Total Liability & Equity	1404.0	1434.7	1323.6	1319.1	1346.0

Exhibit 2 Film Types

Peel-Apart Film



Integral Film

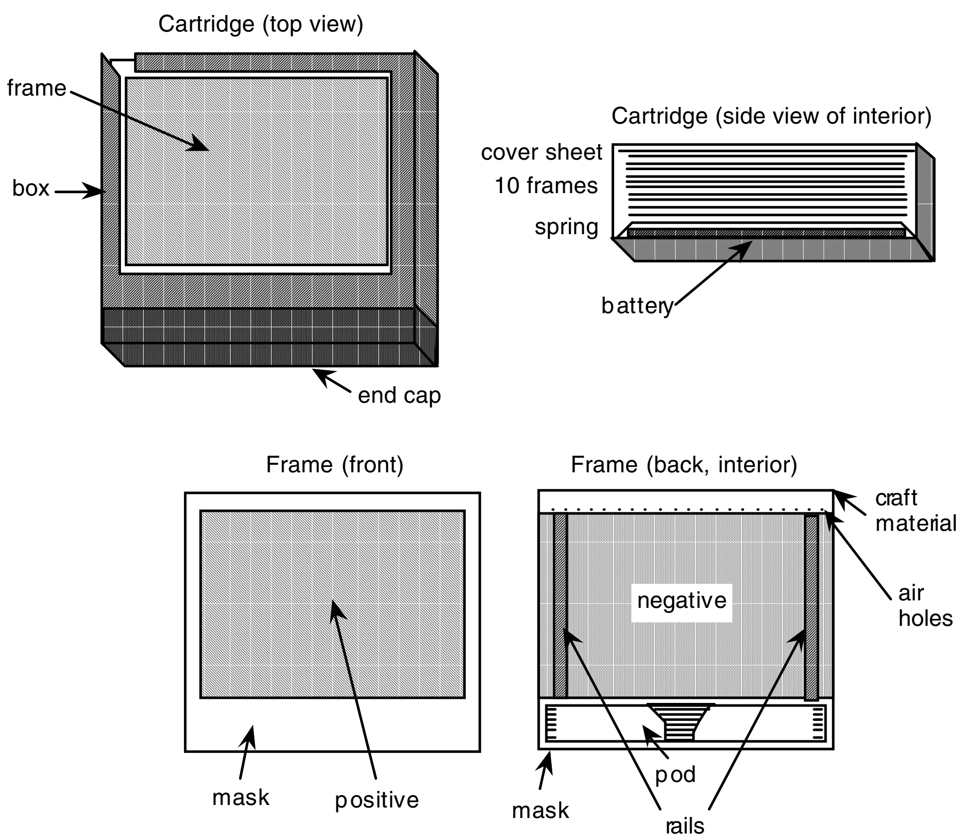


Exhibit 3 Base-line Data for Pod Weight and Finger Height

Pod Weight (grams)

	Sample Number:					
Day	1	2	3	4	5	6
20 July	2.792	2.810	2.777	2.799	2.803	2.788
21 July	2.774	2.783	2.799	2.820	2.812	2.807
22 July	2.797	2.790	2.785	2.795	2.866	2.826
23 July	2.819	2.787	2.809	2.862	2.823	2.816
24 July	2.754	2.793	2.820	2.846	2.823	2.807
27 July	2.784	2.781	2.733	2.801	2.823	2.844
28 July	2.844	2.799	2.781	2.802	2.820	2.813
29 July	2.806	2.786	2.836	2.815	2.836	2.808
30 July	2.843	2.766	2.795	2.778	2.835	2.783
31 July	2.816	2.790	2.823	2.802	2.780	2.804

Finger Height (mm)

	Sample Number:					
Day	1	2	3	4	5	6
20 July	2.021	2.158	2.049	1.959	2.107	1.875
21 July	1.836	2.256	2.099	2.269	2.193	2.193
22 July	2.004	2.166	1.955	2.125	1.988	2.009
23 July	2.177	2.171	2.068	2.143	1.979	2.278
24 July	2.167	2.032	2.032	1.955	2.018	2.007
27 July	2.016	2.108	2.105	2.037	1.957	1.881
28 July	1.939	2.302	2.019	2.154	2.104	1.830
29 July	2.179	2.189	1.970	2.067	2.088	1.903
30 July	1.962	2.128	1.976	2.228	2.036	1.949
31 July	2.260	1.990	1.863	2.183	2.020	1.889

Exhibit 4 Reported Defect Rates

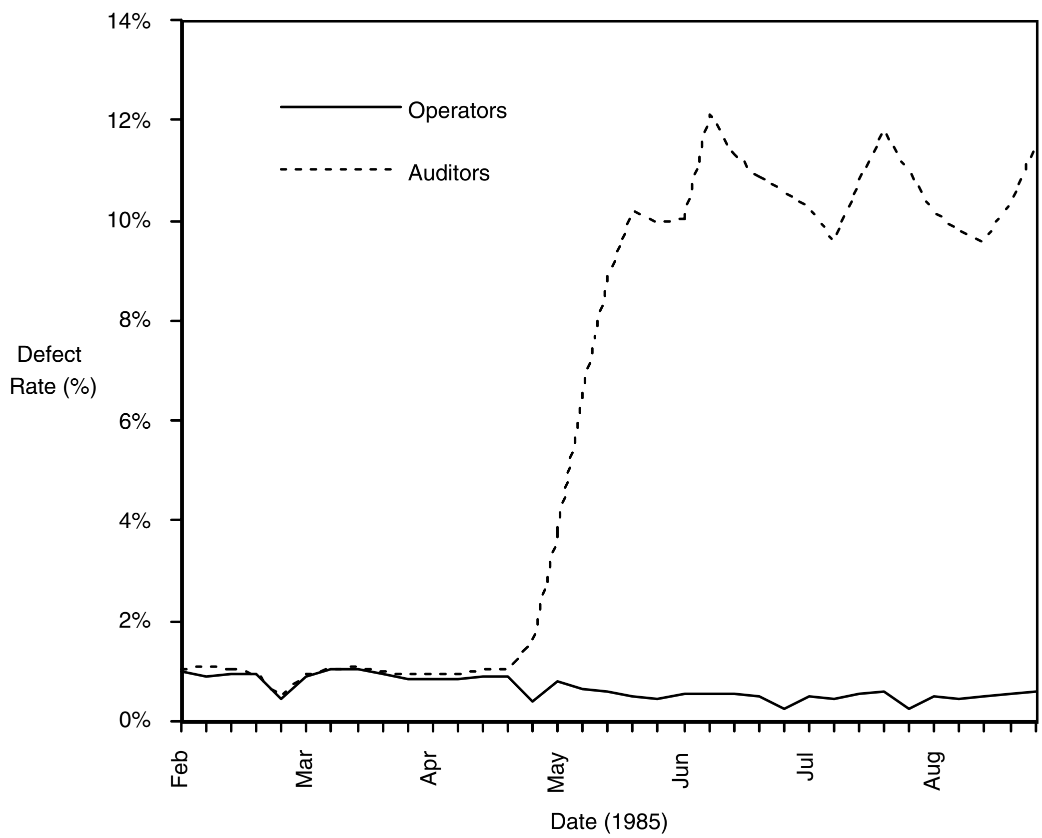


Exhibit 5 Types of Defects

Random sample of defects listed on August 6th and 7th, 1985

Assembly Operator Defects
excess flash on box
negative sheet defect
double feed
excess reagent
frame feed failure
damaged spring
malformed box
excess reagent
positive sheet defect
excess reagent
damaged spring
positive sheet defect
double feed
negative sheet defect
positive sheet defect
frame feed failure
insufficient reagent
damaged spring
negative sheet defect
double feed
excess flash on box
misalignment on assembly
excess reagent
marginal lamination

Auditor Defects
excess reagent
malformed box
frame feed failure
excess reagent
excess reagent
misalignment on assembly
insufficient reagent
frame feed failure
excess reagent
frame feed failure
negative sheet defect
dirt from assembly
excess flash on box
excess flash on box
insufficient reagent
positive sheet defect
excess reagent
misalignment on assembly
excess reagent
negative sheet defect
excess reagent
marginal lamination
positive sheet defect
frame feed failure
damaged spring
frame feed failure
damaged spring
dirt from assembly
malformed box
frame feed failure
dirt from assembly
frame feed failure
damaged spring
dirt from assembly
insufficient reagent
double feed
frame feed failure
excess reagent
dirt from assembly
double feed
malformed box
excess reagent
excess reagent
insufficient reagent
marginal lamination
frame feed failure
positive sheet defect
excess reagent
double feed
misalignment on assembly

Exhibit 6 Sample Statistical Process Control Measurements

Pod Weight (grams)

		Sample Number:					
Day	Shift	1	2	3	4	5	6
3 August	A	2.800	2.799	2.760	2.802	2.805	2.803
	B	2.750	2.820	2.850	2.740	2.850	2.790
	C	2.768	2.807	2.807	2.804	2.804	2.803
4 August	A	2.841	2.802	2.802	2.806	2.807	2.807
	B	2.801	2.770	2.833	2.770	2.840	2.741
	C	2.778	2.807	2.804	2.804	2.803	2.804
5 August	A	2.760	2.804	2.804	2.806	2.805	2.806
	B	2.829	2.804	2.805	2.806	2.807	2.807
	C	2.741	2.850	2.744	2.766	2.767	2.808
6 August	A	2.814	2.804	2.803	2.805	2.807	2.804
	B	2.787	2.802	2.805	2.804	2.805	2.804
	C	2.766	2.805	2.804	2.802	2.804	2.806
7 August	A	2.774	2.801	2.805	2.805	2.805	2.804
	B	2.770	2.801	2.833	2.770	2.840	2.741
	C	2.832	2.836	2.794	2.843	2.813	2.743
10 August	A	2.829	2.846	2.760	2.854	2.817	2.805
	B	2.850	2.804	2.805	2.806	2.807	2.807
	C	2.803	2.803	2.773	2.837	2.808	2.808
11 August	A	2.815	2.804	2.803	2.804	2.803	2.802
	B	2.782	2.806	2.806	2.804	2.803	2.802
	C	2.779	2.807	2.808	2.803	2.803	2.803
12 August	A	2.815	2.815	2.803	2.864	2.834	2.803
	B	2.846	2.854	2.760	2.829	2.817	2.805
	C	2.767	2.804	2.834	2.803	2.803	2.803
13 August	A	2.850	2.804	2.804	2.804	2.804	2.804
	B	2.810	2.820	2.814	2.794	2.798	2.787
	C	2.850	2.820	2.750	2.740	2.850	2.790
14 August	A	2.750	2.765	2.850	2.760	2.790	2.840
	B	2.830	2.770	2.848	2.760	2.750	2.830
	C	2.740	2.770	2.833	2.770	2.840	2.800
17 August	A	2.753	2.807	2.805	2.804	2.802	2.804
	B	2.851	2.751	2.752	2.773	2.849	2.806
	C	2.845	2.804	2.803	2.806	2.805	2.806
18 August	A	2.844	2.777	2.754	2.791	2.833	2.811
	B	2.806	2.839	2.805	2.804	2.850	2.740
	C	2.849	2.801	2.804	2.762	2.814	2.791
19 August	A	2.820	2.793	2.812	2.833	2.853	2.812
	B	2.790	2.780	2.764	2.843	2.843	2.818
	C	2.850	2.806	2.805	2.814	2.807	2.807
20 August	A	2.767	2.831	2.808	2.793	2.836	2.811
	B	2.833	2.825	2.793	2.813	2.823	2.766
	C	2.824	2.799	2.790	2.764	2.817	2.805
21 August	A	2.778	2.775	2.799	2.805	2.833	2.772
	B	2.801	2.832	2.758	2.759	2.773	2.814
	C	2.770	2.787	2.744	2.766	2.807	2.803

Exhibit 6 (continued) Sample Statistical Control Measurements

Finger Height (mm)

		Sample Number:					
Day	Shift	1	2	3	4	5	6
3 August	A	1.90	1.95	1.94	2.00	2.05	2.16
	B	2.15	2.17	2.11	2.13	2.02	2.03
	C	1.73	1.90	2.07	1.89	1.76	1.88
4 August	A	2.30	2.41	2.54	2.37	2.32	2.16
	B	2.28	2.16	2.19	2.08	2.25	2.24
	C	1.92	2.24	2.11	1.89	1.88	2.17
5 August	A	2.39	2.28	2.10	2.36	2.54	2.25
	B	2.11	2.21	2.24	2.21	2.17	2.24
	C	1.89	1.90	1.73	2.07	1.89	1.76
6 August	A	2.51	2.25	2.08	2.35	2.29	2.32
	B	2.22	2.19	2.22	2.24	2.01	2.23
	C	1.89	1.90	1.78	2.07	1.89	1.76
7 August	A	1.95	2.07	2.25	1.95	2.11	2.16
	B	2.08	2.03	2.27	2.23	2.24	2.13
	C	2.31	1.90	1.86	1.91	1.89	1.87
10 August	A	2.23	2.25	2.21	1.89	2.15	2.11
	B	2.23	2.21	2.05	2.19	2.07	2.16
	C	1.73	2.00	1.79	1.75	1.84	1.74
11 August	A	2.21	2.11	2.21	2.44	2.17	2.30
	B	2.17	2.19	2.15	2.04	2.07	2.22
	C	2.01	1.90	1.90	1.81	2.06	1.89
12 August	A	2.08	2.19	2.28	2.29	2.21	2.45
	B	1.93	2.09	1.90	1.95	2.04	2.09
	C	1.84	2.12	1.90	1.89	2.01	1.75
13 August	A	2.23	2.01	2.25	2.11	2.39	2.15
	B	2.19	2.22	2.18	2.15	2.23	2.04
	C	1.96	2.05	2.16	1.87	2.13	1.90
14 August	A	2.27	2.00	2.06	1.97	2.13	2.05
	B	1.92	1.78	1.76	1.77	1.78	1.87
	C	1.78	1.65	2.04	1.63	1.75	1.83
17 August	A	2.31	2.35	2.25	1.99	2.27	2.11
	B	2.02	1.97	1.81	1.73	1.77	1.82
	C	1.76	1.91	2.01	1.85	1.78	1.64
18 August	A	2.06	2.14	1.91	2.06	2.08	2.09
	B	1.76	1.83	1.79	1.79	1.77	1.94
	C	2.25	1.88	2.11	2.18	2.02	1.86
19 August	A	2.28	2.15	2.17	2.18	2.44	2.00
	B	2.31	2.27	2.16	2.10	2.24	2.28
	C	1.87	1.89	2.03	1.69	1.75	2.04
20 August	A	2.16	2.38	2.20	2.25	1.98	2.23
	B	2.06	2.08	2.14	2.24	2.26	2.18
	C	1.80	1.71	1.65	1.68	1.96	2.05
21 August	A	1.75	2.00	2.04	2.00	2.15	2.06
	B	1.90	1.90	1.81	1.86	1.98	1.81
	C	1.80	2.01	1.73	1.89	2.01	1.91

Exhibit 7 Schematic of the Endcap of the Plastic Film Cartridge