REPORT OF SURVEY CONDUCTED AT

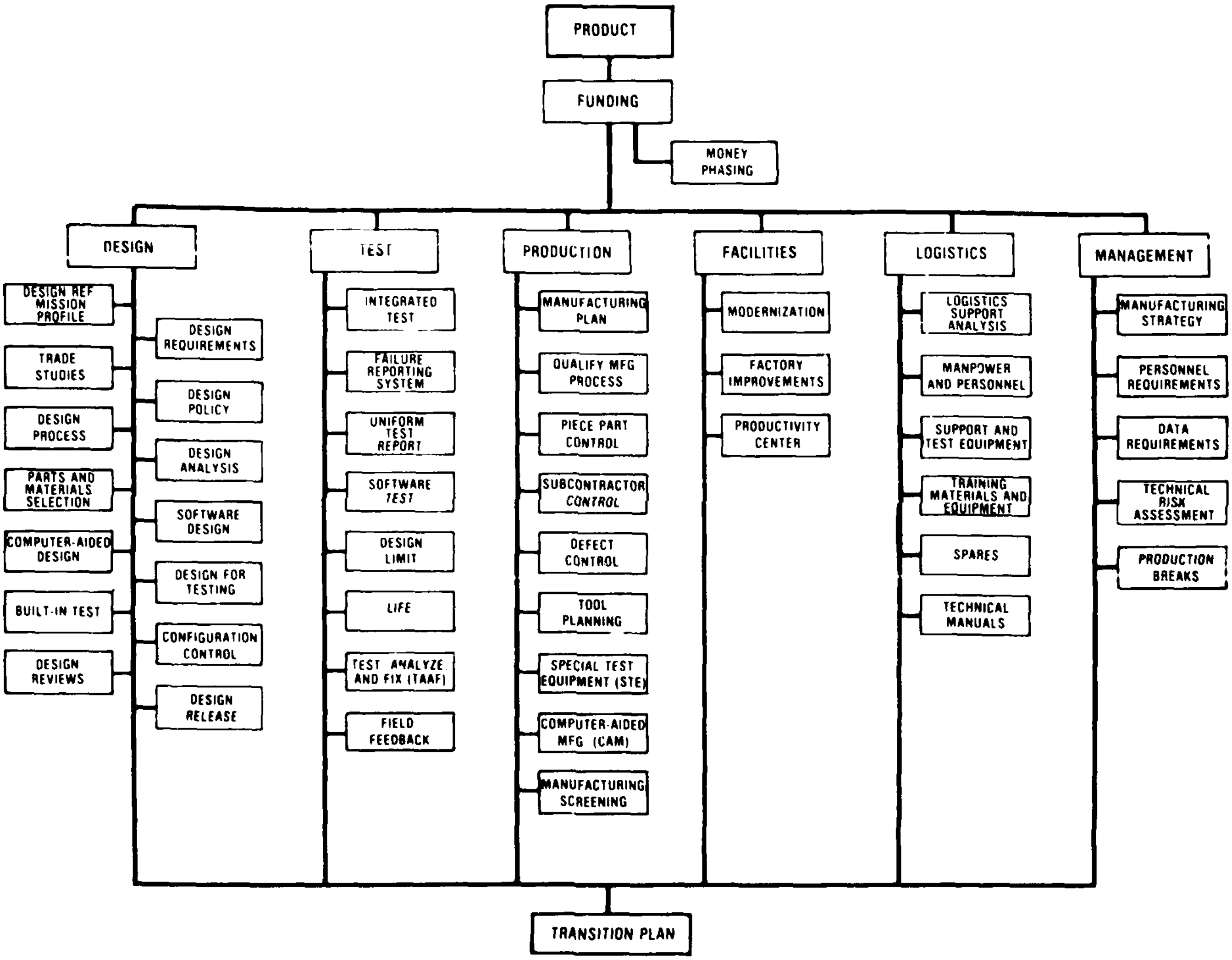
MOTOROLA INCORPORATED GOVERNMENT ELECTRONICS GROUP

SCOTTSDALE, ARIZONA

MARCH 1988

DoD 4245.7-M, "TRANSITION FROM DEVELOPMENT TO PRODUCTION"

CRITICAL PATH TEMPLATES



REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
March 88

3. REPORT TYPE AND DATES COVERED
BMP Report Mar 88

4. TITLE AND SUBTITLE
Best Manufacturing Practices Survey Conducted at
Motorola, Incorporated Government Electronics Group
Scottsdale, AZ

5. FUNDING NUMBERS

6. AUTHOR(S)
Office of the Assistant Secretary of the Navy (RDA)
Best Manufacturing Practices Program

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Office of the Assistant Secretary of the Navy
(Research, Development & Acquisition)
Product Integrity Directorate
Washington, D.C. 20360-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Same as Number 7.

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
~~No Foreign Distribution~~

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The purpose of the Best Manufacturing Practices (BMP) survey conducted at this facility was to identify their best practices, review manufacturing problems, and document the results. The intent is to extend the use of progressive management techniques as well as high technology equipment and processes throughout the U.S. industrial base. The actual exchange of detailed data will be between contractors at their discretion. ~~A company~~ point of contact is listed in the report

The intent of the BMP program is to use this documentation as the initial step in a voluntary technology sharing process among the industry.

14. SUBJECT TERMS

15. NUMBER OF PAGES
16

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	

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STATEMENT "A" per Adrienne Gould
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SECTION 1

INTRODUCTION

1.1 SCOPE

The purpose of the Best Manufacturing Practices (BMP) review conducted at Motorola Incorporated, Government Electronics Group (GEG) was to identify best practices, review manufacturing problems, and document the results. The intent is to extend the use of high technology equipment and processes throughout industry. The ultimate goal is to strengthen the U.S. industrial base, solve manufacturing problems, improve quality and reliability, and reduce the cost of defense systems.

To accomplish this, a team of DoD engineers reviewed Motorola GEG in Scottsdale, AZ to identify the most advanced manufacturing processes and techniques used in that facility. Manufacturing problems that had the potential of being industry wide problems were also reviewed and documented for further investigation in future BMP reviews. Demonstrated industry wide problems are submitted to the Navy's Electronics Manufacturing Productivity Facility (EMPF) for investigation and resolution.

The review was conducted on 21-25 March 1988 by a team of DoD personnel identified on page 2 of this report. Motorola GEG is primarily engaged in design, development, and production of communications systems and tactical components.

The results of BMP reviews are being entered into a data base to track best practices and manufacturing problems. The information gathered will be available for dissemination through an easily accessible central computer. The actual exchange of detailed data will be between contractors at their discretion.

The results of this review should not be used to rate Motorola GEG among other defense electronics contractors. A contractor's willingness to participate in the BMP program and the results of a survey have no bearing on one contractor's performance over another's. The documentation in this report and other BMP reports is not intended to be all inclusive of a contractor's best practices or problems. Only selected non-proprietary practices are reviewed and documented by the BMP survey team.

1.2 REVIEW PROCESS

This review was performed under the general survey guidelines established by the Department of the Navy. The review concentrated on the functional areas of design, test, production, facilities, logistics, management, and transition planning. The team evaluated Motorola GEG's policy, practices, and strategy in these areas. Furthermore, individual practices reviewed were categorized as they relate to the critical path templates of the DoD 4245.7-M, "Transition From Development To Production." Motorola GEG identified potential best practices and potential industry wide problems. These practices and problems and other areas of interest identified were discussed, reviewed, and documented for dissemination throughout the U.S. industrial base.

The format for this survey consisted of formal briefings and discussions on best practices and problems. Time was spent on the factory floor reviewing practices, processes, and equipment. In-depth discussions were conducted to better understand and document the practices and problems identified.

1.3 BMP REVIEW TEAM

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SECTION 2

BEST PRACTICES

The practices listed in this section are those identified by the BMP survey team as having the potential of being among the best in the electronics industry.

2.1 DESIGN

DESIGN PROCESS

Traceability of Systems Engineering Documentation

Implementation has begun of an automated system for submitting project peculiar design engineering documents. The system "makes public" all documentation required by company design standards. Design documentation requirements are not considered complete by management until the documents/reports have been entered into the automated project documentation file.

The automated system compels design personnel to concentrate on completing and documenting engineering tasks on schedule. This insures the timely flow of information to all project personnel early enough in the project so that many design errors can be avoided.

Traceability of documents in the system is provided by an assortment of means, including:

1. Correlation between functional and schematic diagrams, and the design specification,
2. Document delivery schedules,
3. Document hierarchy, and
4. Status of the product documentation package.

Technology Transfer Via Use of Chief Engineers

The positions of Chief Electrical Engineer and Chief Mechanical Engineer have been established in each of their operations/offices. They are staff to the engineering managers and carry equal status. They are the technical managers for GEG. Their duties typically include the following:

1. Chairing design reviews.
2. Relieving engineering managers of most technical responsibilities.
3. Responsibility for creating and maintaining design standards through participation in proceedings of the engineering councils.
4. Providing additional guidance to project engineers in their day-to-day work.
5. Directing special projects which enrich the technical capabilities of the company.

The chief engineers provide the means for insuring that corporate experience is shared, maintained, and incorporated in all of their designs.

Integration of Producibility into Product Design

Producibility is being successfully integrating into new product designs. Their methodology is based on a corporate directive that six sigma quality (3.4 defects per million parts) be designed into their products.

The manufacturing and quality departments have 1992 as a goal for characterizing all of their processes. The findings are being incorporated into GEG design standards. Among the benefits to product producibility are:

1. The design activities are being provided with the quantitative data necessary to design six sigma quality into the product.

2. Manufacturing is now being provided with more quantitative and definitative real time defect data, which they can use to identify, correct and improve their processes.

3. As manufacturing refines their processes (GEG manufacturing actively seeks to improve their technological capabilities), they have the ability to direct engineering design.

Design Disciplines and Organizational Structure

The existence of a chief engineer and a chief mechanical engineer within the reach of the group' s functional units is an excellent way of assuring technical compliance of the equipment designed. The chief engineers are jointly responsible with the Engineering Department Managers for technical matters within their divisions. These duties include the holding of design reviews, establishing design methodologies, and setting engineering standards. These individuals are also well positioned to provide the necessary drive for changing the corporate culture. These culture changes are necessary in making the transition from a traditional engineering environment to one dominated by computer integrated data. New standards, procedures, and a management commitment are necessary for this transition to be successful. The chief engineers, as technical managers with intimate knowledge of the programs within their divisions, are in an ideal position to influence the manner in which development work is performed by setting and enforcing new procedures.

COMPUTER-AIDED DESIGN (CAD)

Equipment Standardization

The decision has been made to standardize on one type of computing equipment for the CAE/CAM/CIM functions at the very early stages of the conversion process. This decision carries the short term penalty of not being able to use some software because of its unavailability on the computer chosen. This problem will most likely be solved in time as popular software becomes more hardware independent. The benefits of a single computer platform, however, will make achieving genuine data integration much more easily attainable and far out-weigh the short tenn costs.

CIM Data Integration

The broad scope of the data being addressed by the CIM architecture is very good. Integration of the Engineering Data Base with material management, financial management, and business management is an excellent means of improving overall efficiency. Goals for the implementation of Computer Integrated Manufacturing have been set very high. The data integration issues are being driven by the Six Sigma Program and the Total Cycle Time Management Program which have top level management support. Within these programs Motorola appears to have successfully segregated tactical short term requirements from strategic goals thereby improving their chances of seeing the maximum benefit from the completed data system.

PARTS AND MATERIALS SELECTION

Standard Parts Program

As part of efforts to improve quality and productivity, Motorola GEG has embarked on an innovative parts standardization program that defines a limited set of parts for use in engineering design and manufacturing. While part standardization programs are not new, they have created a parts data base that is category oriented, uses a menu-driven selection/review process, which highlights standard parts, displays parametric data, and identifies application restrictions. The component data is arranged in a hierarchical manner. Beginning with component category (i.e. capacitors, resistors, diodes, transistors, microcircuits, etc.) and component type (i.e. capacitor - fixed, capacitor - variable, etc.) the engineer/designer selects parts ɹor their design that provide unique part numbers for each component. Currently, there is no direct transfer of selected parts into the users own project component library. This feature is planned as a future enhancement. In addition to the graphical representations of the selected components, functional models (where applicable), and physical models are being developed. Characterization data is being gathered and will be available in the future to facilitate the Six Sigma design process. This characterization data will be statistical data collected from lots of components received.

The intent is to limit the number of parts in their components libraries. However, they recognize the fact that programs require program specific, non-standard, components as well. Consequently, their systems have the flexibility to add non-standard parts to their program specific component libraries. These additions require concurrence at a high management/technical level, the Chief Engineer.

2.2 PRODUCTION

MANUFACTURING PLAN

Focused Factory - Short Cycle Manufacturing

The concept of short cycle manufacturing (SCM) focuses on structured flow paths, people leverage, continuous flow, linear operations, and dependable sources of supply. Short cycle manufacturing is applicable to most of Motorola GEG projects. For example, the APACHE project has shown production improvements due to SCM. Since December 1985 through the projection for December 1988, the total cycle time has been reduced 73%. For the same time frame, material inventory has been reduced 67%. In fact, about 10% of the material as received is moved directly from the dock to the manufacturing line. The appropriate operator then accepts the material. The advantages of SCM include inventory reduction, reduced cost and waste, and forcing the timely correction of problem areas. However, smart preselection of components is necessary and changing the production schedule may be difficult.

A public address system is used frequently to communicate with those on the floor, thus avoiding the rumor mill. The KAN-BAN card system is a factory cell approach to request or pull just enough product up to the next process. This greatly reduces the continued production of defective product to only a few units because large quantities are not produced and then left to sit on a staging shelf, awaiting the next process. KAN-BAN is one of the essentials in the short cycle time of the just-in-time approach, which has increased throughput so drastically.

QUALIFY MANUFACTURING PROCESS

Process Characterization/Standardization

A comphrehensive effort to characterize, optimize and standardize existing and new manufacturing processes is being implemented at GEG. The purpose is to develop Group Standard processes and documentation using a statistical approach to qualifying best performance capabilities. This will result in developing a set of Producibility Guidelines for Engineering to insert into the Design Drafting Standards and enable process capabilities are maintained. It will also eliminate redundant and conflicting process documentation.

These documents will be broken into two types of documents. Process Requirements Documents (PRD's) are non-proprietary documents which will provide for the input/output requirements for a given process. Process instructions are proprietary documents which are "How to's," written to meet the needs of the PRD's. Many benefits can be obtained through the standardization of processes and process requirements. The key element is the commitment to acheiving this goal. This commitment was made by assuring that the standardization committee would include key technical people and by providing the necessary funding (13-20M for materials and labor). Conceptually, process characterization/standardization forms the basis for best manufacturing processes. The key elements of this concept involves complete understanding of the materials used and the process from pre-control through in-process control. Statistical process control is built into the operation. Pre-control establishes an acceptable zone of operation, but also includes shutdown limits with a zone of concern to take appropriate corrective actions between the acceptable and shutdown limits. Also included is a Failure Mode and Effects Analysis (FMEA). FMEA includes potential failure cause and effect, failure mode, and appropriate process functions.

Wire Bonding (Advanced Manufacturing)

The wire bond operation has achieved high sigma levels by focusing on materials, equipment, personnel, and process control. This practice is also established around the concept of process characterization/standardization. Materials are characterized and qualified on a pre-lot and lot-by-lot basis. Test chips with constant metallization are used in the wire evaluation. All materials must be compatible taking into consideration all process variables. Most wire bonding equipment has been redesigned to improve repeatability and yield through improving overall precision. The next step would be retrofitting the wire bonders with closed loop process control. Personnel undergo 180 hours of training per year. Skills are improved with personnel attitude a key ingredient. Process control is established about two gates, one statistical pre-control and a second, statistical in-process control. In 1987, 2,300 wire bonds were pulled. The mean pull strength was 10.5 grams with a range from 10 to 11 grams. This data is well above the MIL-STD-883 limit (2.5 grams). Present day wire pull data is in the 12.16 sigma range. Processes are being developed which use fine wire in the 0.0005 inch range, cold gold, and bonding for RF devices.

PIECE PART CONTROL

Incoming Inspection

Incoming inspection is treated in an exceptionally comprehensive and thorough manner. The laboratory performs full mechanical and electrical incoming inspection tests as required by the most stringent government and commercial standards. The printed wiring board testing area is a DESC certified laboratory employing the complete range of MIL-P-55110 tests. Automated optical inspection is also used. The electrical test area performs functional, PIND, and environmental stress screening. The entire electrical incoming inspection area is designed to eliminate ESD. The primary traffic area for personnel without ESD precautionary paraphernalia is designated as the "yellow brick road". This keeps non-test personnel away from ESDS areas. Of particular note is the component solderability test methodology. Emphasis is placed on tightly controlling the test conditions for repeatability and objective verification of component wetting. An innovative optical measurement of lead wetting has been designed and is in the proof of concept stage. If successful, this method will take the debate out of "wetting". The dipping system is microprocessor controlled for repeatability. The solder pot is blanketed in nitrogen and the solder pump loop has been redesigned in house for very fast dross removal, yielding a mirror solder pot surface in 20 seconds.

DEFECT CONTROL

Cycle Time Management

Operators suggest critical process improvements. Operator logs describe equipment and process status. POSITROL records are generated each shift to indicate the What, How, Who, and When of activity on a particular machine.

FMU-139 operators make heavy and effective employment of SPC throughout their processes. In addition to the four manufacturing engineering personnel, who are constantly on the factory floor, working with and listening to operators recommendations, certain select individuals are trained and used as SPC technicians. "POKA-YOKE" or mistake proofing from Shiegeo Shingo's "Zero Quality Control: Source Inspection and the POKA-YOKE System" has been locally applied to operators processes with great success.

This pre-control system employs very tight and fast quality checks based on process operating characterization. Thresholds, still within acceptable limits are established. When process performance meets or goes beyond the safe limits, a warning flag is activated. When the actual unacceptable limit is exceeded, the process shuts down.

Focused Factory - Statistical Process Control

A model Statistical Process Control (SPC) program has been implemented throughout Motorola GEG. The program, known as Six Sigma, has provided the capability to continuously analyze and control the performance of their manufacturing. The intended results of the program are being realized on a daily basis through a significant reduction in defects along with lower rework and scrap rates.

SPC is being successfully implemented throughout manufacturing with a team effort by both management and manufacturing personnel. This coordinated effort has produced some significant results from the standpoint of SPC by placing more responsibility for the monitoring and controlling of various process charts with those personnel who operate the process. Along with this is the SPC Process Technician Program, where a select group of manufacturing personnel trained in the use of SPC are assigned to implement and monitor the program in their respective areas.

GEG has aggressively moved one step beyond their own facility and implemented a voluntary vendor SPC program. Those vendors who agree to participate in the program must be willing to maintain an acceptable level of critical process controls within their own manufacturing facilities.

GEG has developed and implemented an exemplary training program, once again using the team approach stating that everyone from management to the operators will receive varying degrees of SPC training. Numerous programs and support areas have already received training in the SPC basics. Training is being reinforced through the implementation of various plans and control charts, constructed in a class room environment, along with identifying problem areas and new processes.

The development of new processes is being accomplished through an in depth four phase progression system. From defining the process to performing extensive process capability analysis, parameter optimization, and process control all of which enabled Motorola GEG to characterize their manufacturing processes.

Six Sigma Concept

Motorola GEG is implementing an aggressive and comprehensive program, called the Six Sigma Concept, to eliminate defects. A given product is considered to have achieved a six sigma level of quality when it exhibits a defect rate of less than 3.4 parts per million (ppm) at the part and process step levels. The goal is to achieve six sigma quality by 1992. This ambitious program significantly exceeds the Navy's goal of less than 100 PPM defects by 1992. To achieve six sigma quality, they are applying the following tools:

- Statistical Process Control (SPC)
- Designing for Producibility
- Short Cycle Manufacturing
- Participative Management Practices
- Parts Standardization
- Supplier Qualification
- Supplier SPC
- Computer Simulation
- Process Standardization

This program is a major initiative which involves cultural changes affecting GEG, its suppliers, and Motorola corporate. Defects are eliminated at each stage including design, part suppliers, and manufacturing. The program is well understood and is being enthusiastically implemented throughout GEG thanks to an excellent training program, highly effective internal communications, and the positive working environment that exists. Although this program is in its initial stages, there seems to be a total commitment at all levels in the corporation.

Defect Control (FMU-139 Manufacturing)

Significant productivity improvements have been realized on the FMU-139 fuze manufacturing line. These improvements are a composite result of effective local integration of several corporate wide initiatives. These initiatives include the Participative Management Program (PMP), Cycle Time Management, and the Six Sigma Program. As a consequence of these initiatives, over a two year period, units completed went from 125/day to 450/day, cycle time was reduced from 42 days to 4 days, and factory floor space was reduced by 25%. In addition, this increase in productivity is being accomplished with only two additional personnel.

Red, yellow, and blue caution lights are noticeably positioned at each major/critical process. Blue indicates that the team is ahead of their production requirement. Yellow means that the process is running the danger range, but still within limits or the team is not making rate. A red light means something is out of limits on the production floor and production will shut down the line.

The key to these huge productivity gains is working level people power. Motorola has been particularly successful in applying the team concept to all aspects of their operations. The FMU-139 manufacturing operation maximizes operator level ownership and participation in the decision making process. Operators are fully trained in the operation, maintenance, and troubleshooting of their particular piece of equipment. The equipment boasts a poster saying, "this machine operated and maintained by John/Jane Doe."

2.3 LOGISTICS

TRAINING MATERIALS AND EQUIPMENT

Training Program

Some elements of the training program played a key role in achieving major cultural changes in the company. Included are a course on Total Cycle Time Management and a series of courses on statistical process control (SPC). All of these courses are given to teams and are tailored to the actual job environment of each team. Also offered is a course on designing for manufacturability, which is required of all engineers. The courses are exceptionally well developed and effectively delivered.

2.4 MANAGEMENT

MANUFACTURING STRATEGY

Manufacturing 5 Year Plan/Cycle Time Management

The manufacturing strategy in-place is directed toward meeting the goals of customer satisfaction, total cycle time reduction, and achievement of six sigma. That strategy includes an innovative manufacturing 5 year plan and an effective cycle time management plan.

The manufacturing plan calls for "short cycle production", which is synonymous with "cycle time management". This plan implements short, quick, moves between work stations/operations and reduces/eliminates queues at those locations, thereby reducing cycle time.

Another positive factor is the practice of having the operator perform the inspection required for that operation, thereby reducing/eliminating inspection bottlenecks.

The plan also calls for a verified, producible design before design release, thereby reducing/eliminating WIP changes and rework.

An innovative gimmick that has helped to reduce cycle time is the placing of a 3-light status indicator at each work station. The indicator may be seen throughout the room and indicates the current status of the operation in-process by the color of the light that is illuminated.

PERSONNEL REQUIREMENTS

Best in Class People Program

Motorola GEG has undertaken an extremely innovative and unique approach in the selection of future employees in production operations. This program is currently titled "Best in Class People". This enhanced employment process consists of four distinct features: (1) introduction to a quality culture; (2) sense of accomplishment at being hired; (3) place responsibility for being hired on the applicant; (4) test for basic learning skills. GEG will be implementing changes ranging from selection techniques to a physical relocation of its personnel activity. It is anticipated that the enhanced selection process will ultimately result in productivity increases, cost benefits, product quality improvement, increase in learning speeds, a more flexible work force, greater employee pride, reduced training requirements, and reduced supervisory requirements. The Best in Class People Program also includes current employee assessment and supervisory assessment plans which will be implemented at later dates. These are very innovative and ambitious programs. GEG is very people oriented and feels that this Best in Class People Program by selective hiring and retention of quality, well-trained people, will ultimately be a positive factor toward increased productivity and lower costs.

SECTION 3

SUMMARY

Motorola GEG has initiated an major defect reduction program named the Six Sigma Concept which has as its goal the defect rate of less than 3.4 parts per million by the year 1992. This concept is supported with other integrated programs. The Six Sigma Concept is supported at all levels with resources and training of personnel.

Qualification of manufacturing processes is accomplished through process and material characterization to further support the defect reduction goals. This process optimization is seen in the wire bonding operation. Incoming inspection is performed extensively to provide quality material for manufacturing processes.

A standard parts program has been initiated to further improve quality and productivity through the design process. All of these programs provide the necessary components to support the overall Six Sigma Concept for defect reduction and process characterizations.

The point of contact for this BMP survey is:

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His cooperation, time, and quality of effort in preparation and hosting of this survey at Motorola GEG and participation in the Best Manufacturing Practices Program is greatly appreciated.