ADVANCED PRODUCT QUALITY PLANNING

THE ROAD TO SUCCESS

D.H. STAMATIS

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Advanced Product Quality Planning

PRACTICAL QUALITY OF THE FUTURE

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List of acronyms

1PP	first production prove-outs
AAR	appearance approval report
AIAG	auto industry action group
a.k.a	also known as
ANFIA	Associazione Nazionale Filiera Industria Automobilistica/Italy
APPC	average purchased part capacity
APQP	advanced product quality planning
APW	average production weekly
AQP	advanced quality planning
ARL	attribute requirements list
ARL	average run length
AWM	automotive warranty management
BIQS	built in quality supply base
CA	capacity analysis
CA	corrective action
CC	critical characteristic
CFT	cross-functional team
CIR	customer input requirements
CNs	change notices
COA	certificate of analysis
CP	control plan
CPCP	chrysler product creation process
C_{pk}	capability index of a stable process—short term
CPR	cost per repair
DFM/A	design for manufacturing and assembly
DFR	decreasing failure rate—a downward bending curve on an AWS hazard plot for TIS or mileage
DRIVe	delivery rating improvement verification
DV&R	design verification and reporting
DVP&R	design verification plan and report
DVP	design verification plan

E-108	branding directive. Ford global automotive parts trademarks
EBSC	external balanced scorecard
ELV	end of life of vehicle
EPV	error proofing verification
ES	engineering specifications
EWT	early warranty tracking
FECDS	Ford engineering CAD and drafting standards
FEU	field evaluation units—a fleet of saleable evaluation units built on the assembly line at 12 weeks before Job #1
FIEV	Fédération des Industries des Équipements pour Véhicules/France
FMEA	failure mode and effect analysis
FPDS	Ford product development system
FPSC	first production shipment certificate
FSP	Ford supplier portal
FTA	fault tree analysis
FTT	first time through
Gauge R&R	gauge repeatability and reproducibility
GCS	global claims system
GD&T	geometric dimensioning and tolerancing
GIM	global issue management
GME	general motors Europe
GPDS	global product development system
GYR	green, yellow, red
HTIS	part per vehicle issues—high time in service
IAOB	International Automotive Oversight Bureau/US
IATF	International Automotive Task Force/France
IFR	increasing failure rate—an upward bending curve on a AWS hazard plot for TIS or mileage
IPD	in plant date
IRE	initial risk evaluation
KIP	key input processes
KO	kick off date (for a particular program)
KPI	key process indicators
KPI	key process input
KPO	key process output
LPA	layered process audit
MAQMSR	automotive quality management system document
MAQMSR	minimum automotive quality management system requirements
ME	manufacturing engineering
MMOG/LE	material management operations guideline/logistics evaluation

MP&L	material planning and logistics
MPPC	maximum purchased part capacity
MPW	maximum production weekly
MR	model responsible
MRD	material review date
MSA	manufacturing site assessment
MSA	measurement system analysis
NBH	new business hold
NCT	non-conformance tracking
NIST	National Institute of Standards and Technology
NTEIs	new tooled end items
OEE	overall equipment effectiveness
OEM	original equipment manufacturer
ASQ	American society of quality
PA	process audit
PA	program approval (For a particular program. Usually the funds for the program are approved)
PBCP	process-based business collaboration platform
PBCP	prototype build control plan
PCA	permanent corrective action
PCA	process control audits
PCP	product creation process
PD	product development
PDC	product design complete
PDCA	plan, do, check, act (known as the Shewhart cycle)
PDR	production demonstration run
PDSA	plan, do, study, act (known as the Deming cycle)
PFC	process flow chart
PND	program need date
PPAP	production part approval process
PPC	purchased part capacity
P_{pk}	performance index—long term. (P_{pk} is the preferred index for it accounts for the true standard deviation as opposed to the C_{pk} which uses the approximate value of (R-bar/d_2) can only be used for stable and normally distributed processes)!
PPQI	prototype process potential and quality indexes
PQOS	plant quality operating system
PPR	process planning review
PRAS	parts return analysis system
PSO	process sign-off
PSW	part submission warrant
PTC	production tooling complete
PV	process validation

PVP	process validation plan
PVT	plant vehicle team
QFD	quality function deployment
QMS	quality management system
QNA	quality narrative analyzer
QNBH	quality new business hold
RAT	recycling action team—a cross functional team working to increase the use of recycled material
RFQ	request for quote
RSMS	restricted substance management standard
SAWRP	supplier associated warranty reduction program
SC	significant characteristic
SC	strategic confirmation (for a particular program)
SCA	supplier change request
SCCAF	special characteristic communication approval form (A Ford Motor Company document that summarizes all critical and significant characteristics)
SI	strategic intent (for a particular program)
SIM	supplier improvement matrix
SMMT	Society of Motor Manufacturers and Traders/UK
SPC	statistical process control
SPDP	supplier preliminary data profile
SQE	supplier quality engineer
SQRA	supplier quality risk assessment
SRE	supplier readiness evaluation
SREA	supplier request engineering approval
STA	supplier technical assistant (Ford customer representative)
TACT	estimated cycle time
TAKT	actual cycle time
TAP issues	tooling aid process
TCD	target completion date
TGR	things gone right
TGW	things gone wrong
TKO	tooling kick-off
TPSL	top problem supplier location
VDA 6.3	a German approach that defines "a process-based audit standard" for evaluating and improving controls in a manufacturing organization's processes.
VDA	Verband Der Automobilindustrie E.V. (German Automobile Industry Association)
VDA-QMC	Verband der Automobilindustrie—Qualitäts Management Center/Germany

VFG	vehicle function group—code for component classification used in quality testing
VO	vehicle operations
VOC	voice of the customer
webCN	change notice system
WERS	worldwide engineering release ystem (Ford System)
WIS	warranty information system

Preface

Advanced product quality planning is a process developed in the late 1980s by a commission of experts gathered around the "Big Three" US automobile industry: Ford, GM, and Chrysler. Representatives from the three automotive original equipment manufacturers (OEMs) and the Automotive Division of American Society for Quality Control (ASQC, now called ASQ for American Society for Quality) created the Supplier Quality Requirement Task Force to develop a common understanding on topics of mutual interest within the automotive industry.

This commission invested five years in analyzing the then-current automotive development and production status in the US, Europe, and especially in Japan. At the time, the success of the Japanese automotive companies was starting to be remarkable in the US market.

APQP is utilized today by these three companies and some affiliates. Tier 1 suppliers are typically required to follow APQP procedures and techniques and are also typically required to be audited and registered to IATF 16949 by September of 2018. The success of this methodology has been met with enthusiasm in other industries and in European markets with appropriate and applicable adjustments to reflect the specific industries and requirements for the product and industry.

As important as APQP is, there are unfortunately no full-length books about it, perhaps because each OEM has so many individual requirements other than the AIAG's requirements. To be sure, there are many APQP training manuals even today, but hardly any books. In 1998, I published the first book on APQP with an intent to introduce the reader to the methodology and the management techniques necessary to fulfill the quality planning strategy. In this book, I continue the discussion of the core methodology but I also include detailed discussions about the key tools, a lengthy discussion on PPAP and an overview of the specific requirement of FCA, Ford and GM. Furthermore, I have addressed the requirements of the AIAG, VDA, IATF 16949 and ISO 9001 as they relate to APQP i.e. risk, warranty and GD&T.

The basis for the make-up of a process control plan is included in the APQP manual (AIAG: APQP). The APQP process is defined in the AIAG's

APQP manual, which is part of a series of interrelated documents that the AIAG controls and publishes. These manuals include:

- The failure mode and effects analysis (AIAG: FMEA) manual
- The statistical process control (AIAG: SPC) manual
- The measurement systems analysis (AIAG: MSA) manual
- The production part approval process (AIAG: PPAP 4th ed.) manual

The Automotive Industry Action Group (AIAG) is a non-profit association of automotive companies founded in 1982.

In our modern world we demand quality in everything that we do or receive. However, in demanding quality we are faced with a serious problem, as we do not have a standardized definition of quality. Generally, most of us will settle with a simple definition that states: *quality is defined by the customer.*

As simple as this definition is, it presents major problems because it is not standardized, and each customer may indeed have a different perspective of what quality is. To neutralize this vagueness most industries have come to recognize that fundamentally a "quality product or service" needs at least five elements for success in satisfying the customer, and these are:

1. Leadership commitment and engagement
2. Workers that are involved with their representatives
3. Business ethics and legality
4. Use of a systematic, comprehensive process to ensure effectiveness and continual improvement
5. Sustainability and integration

These five elements, if applied correctly and on a timely basis, will indeed provide some stability, accountability, sustainability, low risk of dissatisfaction, and satisfaction for a good product or service produced.

It turns out that these elements provide the basis for the Advance Product Quality Planning (APQP) process. To be sure, the process is pretty much standardized through the AIAG requirements, but there are still areas where specific organizations have their own.

The typical process of APQP is defined in five areas and each area has inputs and outputs. In a cursory form they are:

- Establishing the project
- Identifying legal and other requirements
- Defining scope, management commitments, and responsibilities
- Conducting internal audits against the predetermined milestones
- Certification procedure

In the automotive industry, the APQP is meant to cover all automotive OEM requirements for planning activities into one process. Suppliers apply APQP to ensure the quality of their new products and to drive continual improvement. It also provides a framework for a structured approach to product and process design. It represents a standardized set of quality requirements that enable suppliers to design a product that satisfies the customer. The primary goal of product quality planning is to facilitate communication and collaboration between engineering activities. As such, it requires the engagement of a cross-functional team (CFT) that includes marketing, product design, procurement, manufacturing, and distribution. The objective is to ensure a clear understanding of the voice of the customer (VOC), and to translate it into requirements, technical specifications, and special characteristics.

Obviously, one can see that in the final analysis, APQP provides a standardized way of sharing results between suppliers and customers (including, automotive companies), as well as guidelines for an effective development process, which for most organizations are the following "core" phases: development, industrialization, and product launch.

So, APQP's main content is to serve as a guide in the development process and also a standard way to share results between suppliers and customers (whoever they are). In these three core phases there are imbedded 23 generic topics that are monitored continually. These 23 topics are expected to be entirely completed before production is started. They cover such aspects as: design robustness, design testing and specification compliance, production process design, quality inspection standards, process capability, production capacity, product packaging, product testing and operator training plan, among other items. (It is important to realize that some organizations have more than 23. For example, Ford Motor Co. has 30 elements, 23 of which deal with quality and the last 7 deal with capacity and capability). A generic cursory overview of APQP shows that APQP focuses on:

- Up-front quality planning
- Determining if customers are satisfied by evaluating the output and supporting continual improvement

APQP consists of five phases:

- Plan and Define Program
- Product Design and Development Verification
- Process Design and Development Verification
- Product and Process Validation and Production Feedback
- Launch, Assessment and Corrective Action

These phases for practical purposes are translated into five major activities:

1. Planning
2. Product Development
3. Process Development
4. Product and Process Validation
5. Production

Finally, these major activities are subdivided into manageable elements. So, in the big picture of the APQP process we evaluate at least seven major elements. They are:

1. Understanding the needs of the customer
2. Proactive feedback and corrective action
3. Designing within the process capabilities
4. Analyzing and mitigating failure modes
5. Verification and validation
6. Design reviews
7. Control special/critical characteristics

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Dr. Stamatis has written more than 70 articles, presented many speeches, and has participated in both national and international conferences on quality. He is a contributing author on several books and the sole author of 59 books.

Introduction

Sometimes there is confusion about the terminology used for APQP. The terms advanced quality planning (AQP) and advanced product quality planning (APQP) are used. So, let us examine each.

AQP is the generic methodology that focuses on the design/development of the supplier's manufacturing process to ensure that it is capable of producing parts that meet design requirements at the quoted tooling capacity. APQP, meanwhile, is a structured method for *defining* and *executing* the actions necessary to ensure that a product satisfies the customer. To be successful in AQP and APQP a team approach is necessary and open communication is mandatory—see Figure I.1.

Therefore, the goal of the APQP process is to facilitate communication between all persons and activities involved in a program and ensure that all required steps are completed on time, with a high quality-of-event, at

Figure I.1 The integration of communication and team effort in the APQP process.

acceptable cost and quality levels. In addition, the following characteristics must be accounted for:

- *Time*: Milestones for deliverables must be appropriate, applicable and doable.
- *Transparency*: No hidden agendas and cutting corners at the expense of quality initiatives.
- *Thoughtfulness*: Appropriate, applicable and a holistic approach must be given to particular situations within the set milestones for deliverables.
- *Tolerance*: Customers and suppliers must understand the value of correct tolerances and variability. Both must use appropriate and applicable measurement system analysis, to identify, correct and validate all measurements.
- *Capability and capacity*: Both must be understood by the customer and supplier. If not, both will have consequences down the road of delivery. Remember that capability identifies whether or not the *process* can produce what the customer wants. Capacity on the other hand, identifies whether or not the *product* can be delivered at the amount (quantity) level required within all specifications.
- *Trust*: Customers and suppliers must operate at all times with an attitude of win–win. If not, they will fall short of their quality goals. Trust is the result of determination to do an excellent job on everything that is required to complete the milestone. With this determination, it is also required to have the appropriate discipline and dedication for the specific completion of tasks required to complete the milestone. Finally, with trust, the responsibility of decisiveness is also of paramount importance as decisions must be appropriate, applicable to the task, and made within the confines of the set timing.

Special note: Although the terms AQP and APQP are very similar (with minor differences), in practice, they are used interchangeably.

So, the purpose of the APQP process is to establish:

- Common expectations for internal and external suppliers. Typical items of concern are:
  - Minimize/reduce late changes to the part and process
    - Reduce/eliminate quality spills at all stages of production
    - Reduce/eliminate warranty
    - Increase customer satisfaction
    - *In short, minimize risk, eliminate waste, and save money!*
- Common process metrics. These aid the facilitation and early identification of required changes. They also help uncover hidden issues

that may develop into potential problems. In essence, they help avoid late changes.
- A common (standardized) program status reporting format. Standardizing the reporting format adds a discipline to the process of APQP that facilitates the concept and practicality of continual improvement. It does that by focusing on: (a) providing a quality product on time, at acceptable cost, to satisfy customers; (b) providing definite roles and responsibilities for the APQP elements; and (c) a better understanding of how the APQP elements relate to organization's timing.

So, what do we need before we can begin AQP? The answer is very simple—but very difficult to implement consistently in any given organization due to constant changes within the organization and or outside the organization (changes in requirements of timing, specifications, material, and change in process are typical). In any case, the themes that define a good beginning of any APQP program are: (a) teamwork (must be cross-functional and multidisciplinary); (b) communication (must always be open and two ways); (c) timing and planning (must be appropriate, applicable and realistic); and (d) all activities must be identified—no hidden agendas.

The roles may vary depending on the customer, supplier, and or product. Typical roles may be from the following list: (a) program management, (b) quality and reliability, (c) team leaders, (d) engineers, (e) suppliers, and (f) program team. Specific content may be in the areas of: (a) sourced part or module (supplier must be known); (b) source package; (c) official program timing; (d) design model (as appropriate); (e) engineering specifications; (f) engineering change notices (CNs), if applicable; and (g) lessons learned from previous programs.

Benefits of APQP

APQP supports the never-ending pursuit of continual improvement. The first three sections of APQP focus on planning and prevention and make up 80% of the APQP process. The fourth and fifth sections support the remaining 20% of APQP and focus on validation and evidence. The fifth section specifically allows an organization to communicate its findings and provide feedback to further develop the standard and processes. A list of some of the benefits of APQP include:

- Direct resources by defining the vital few items from the trivial many
- Promote early identification of change
- Enable intentional change (what is being changed on purpose to bring value to the customer)

- Evaluate incidental change (in the environment, customer usage, degradation, and interfaces)
- Avoid late changes (post-release) by anticipating failure and preventing it
- Reduce design and process changes later in the product development process
- Produce on-time, quality product at the lowest cost
- Provide multiple options for mitigating the risk when found earlier
- Enable greater capability of verification and validation of a change
- Improve collaboration between design of the product and processes
- Improve the design for manufacturing and assembly (DFM/A)
- Provide selection of lower-cost solutions earlier in the process
- Enable legacy capture and reuse, advancement of tribal knowledge, and standard work creation and utilization
- Include best-practice APQP evaluation process, process metrics, and status reporting
- Link the APQP process to product development and manufacturing processes
- Define roles and responsibilities for the APQP process
- Develop a common APQP process for both internal and external manufacturing and assembly suppliers

Besides the requirements of ISO 9001 and IATF 16949, all these benefits make APQP appealing to organizations that are not part of the automotive industry but want to improve their design and development process (for more detailed information see Stamatis, 1998; Advisera, 2017).

How do we do it? A typical model for implementing APQP in any organization is shown in Figure I.2.

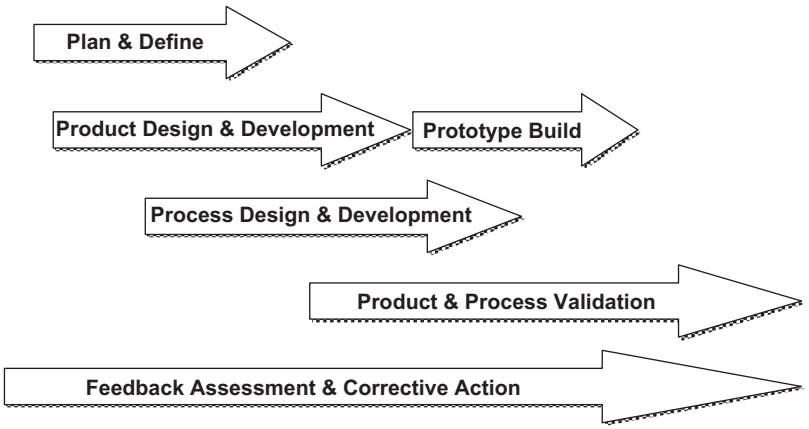

Figure I.2 A typical model for implementing APQP.

Table I.1 Key performance indicators

Concept Phase	Definition Phase	Target Setting Phase	Technical Design and Development Phase	Tooling Phase	Product Validation Phase
Start concept definition	Approve concept direction	Feasibility briefing/ pre spending approval; theme selection	Program and style approval; style freeze and tooling kickoff	Production design complete	Verification of process build
SOURCING (Purchasing Lead) ⟶					
PRODUCT DESIGN (Engineering Lead) ⟶					

The essence of the APQP process depends on certain foundations for the creation, identification and execution of all important milestones of key process variables (KPV). A typical definition of preset KPV milestones and timing may be in the form of Table I.1.

Key process indicators (KPIs) are standard quantifiable measurements that reflect the critical success factors of a program and designed so that they are measured consistently from program to program (repeatability). They are monitored throughout the development process within the program. It is very important to recognize that all KPIs are specific to each of the following timeframes:

- Approve concept direction to product design complete (PDC)
- Post-PDC to verification of process build
- Launch execution

To make sure that all KPIs are accounted for, a master list of KPIs should be generated with responsible areas identified appropriately. A typical master list may look something like Table I.2.

It must be noted here that in order to have successful KPIs a specific individual (or a team) must be responsible for each one. For example: (a) a designated lead is responsible for the execution of each KPI, (b) model responsible (MR) synthesizes all program KPIs, and (c) A designated product creation process (PCP) must be defined. The idea for this responsible party is to make sure that the defined process with its appropriate and applicable milestones will ensure that all requirements are delivered to the customer on time.

So, when one discusses APQP the fundamental essence is to make sure that the supplier's manufacturing is able to ensure capability of the producing parts. Of course, the ultimate insurance is depended on (a) process

Table I.2 A typical KPI master list

Program Plan	KPI Summary
KPIs	Timing of KPIs Based on process milestone (Gant Chart)

Milestones are key decision points to validate program execution. Generally, there are two levels of milestones: (1) Major milestones—Area Level Cross-Functional Checkpoints (2) Secondary milestones—Area level Cross-Functional checkpoints (Exception: Theme select both senior and area level checkpoint).

sign-off (PSO) and or process validation (PV) testing, (b) Completion of PPAP and issuance of product submission warrant (PSW), and (c) PVP Build. Therefore, the results of an excellent APQP are:

- Minimize, reduce, or eliminate late changes by including the best practices of the APQP evaluation process, process metrics, and status reporting of past experiences.
- Reduce and/or eliminate quality issues at all stages of production by linking the APQP process to product development and manufacturing processes and by making sure that the milestones are doable and can be accomplished on time.
- Reduce and/or eliminate risk and warranty by defining the roles and responsibilities for the APQP process, especially in the areas of FMEA, PPAP, and prevention methodologies.
- Increase customer satisfaction by developing a common (standardized) APQP process for both internal and external manufacturing and assembly suppliers.
- In short, eliminate or reduce waste (however defined).

Obviously, the APQP not only depends on the specific program for specific milestones (gates of progress), but also on the scalability of the program. For example in the automotive industry that includes: (a) vehicle, (b) manufacturing, and (c) power train scalability. The reason why scalability is important is because there is a profound need of program review for the process used to monitor the status of the deliverables and the overall health of the program. This is accomplished by (a) uniform (standardized) reporting formats to communicate program status within the team structure and (b) two-way communications on all levels. Specifically, each of the five categories mentioned have generic inputs and outputs.