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"COST OF POOR QUALITY IN AIRCRAFT MAINTENANCE PAKISTAN AIR FORCE"

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GROUND MAJOR ACCIDENT

TWO C-130 AIRCRAFT

SEPT,1998

Brief Description

On 10 Sept 1998, Squadron Leader ABC, along with eight crewmembers was detailed to carryout a taxi test of a C-130 aircraft. The taxi test fell due after the **right brake assembly change**. The aircraft was started at 1522 hrs and taxied out to runway to check the brakes. Two high-speed aborts (up to 70 kts) at the runway were carried out. After the aircraft cleared the runway, fire was observed in main wheel well area by outside witnesses. When the aircraft entered the tarmac, Duty Air Traffic Controller gave call to inform the pilot, however the pilot did not acknowledge the calls. When the aircraft came close to the operation room, the crew chief informed the pilot about the fire and the pilot pulled the fire handles to shut down the engines. Consequently the aircraft became uncontrollable and collided with another parked aircraft. Both the aircraft caught fire and sustained major damage. Two pilots, two engineering officers and a flight engineer were fatally injured while Chief Warrant Officer sustained major burns and expired after two days.

Cause of Wheel Fire

The brakes heated up to significantly high temperature because of technical malfunction. Subsequently, the hydraulic mist formed by the leakage in wheel well area ignited which caused the fire.

Cause of Collision

Feathering of all four engines (propellers) by the pilot instead of stopping the aircraft with brakes or thrust reversal, resulted in loss of normal brakes, nose wheel steering and VHF radio. The aircraft had lost emergency pump operation as well as emergency wheel braking. The aircraft consequently rolled uncontrollably and collided with parked aircraft.

Human Factor- Supervisory Lapses (Flight Lines)

Failure to ensure the use of **Technical Orders** for M**aintenance** and ensure completion of **mandatory maintenance checks**.

THE COST OF POOR MAINTENANCE AND NEGLIGENCE, PAF PAID ON MINOR JOB OF BRAKES REPLACEMENT AND TAXI TEST AS

2 x C- 130 MIL Transport Air Craft

2 x Well Trained & Experienced Pilots

2 x Engineering Officers

2 x Non Commissioned Officers

2x Technicians

MILLIONS OF DOLLARS AND LOSS OF VALUABLE LIVES

EXECUTIVE SUMMARY

Maintenance of any kind performed on a system is a consequence of the fact that systems (or components) deteriorate and fail. Any product or system that has maintenance directions or procedures has an implicit statement that there is a non-zero probability that the system could at some point operate outside its specified parameters. Failure to perform maintenance to maintain the dependability of a system can have effects ranging from benign to catastrophic. Developing effective maintenance procedures can be at worst a circular process ---- procedures cannot be tested unless something deteriorates or fails. Accelerated stress testing can be used to induce failures, but there is no guarantee that all failures that should be covered in a maintenance plan will be exposed. Also, maintenance procedures are generally not extensively tested until a product has been deployed (and then, properly performed maintenance can be critical).

Maintenance has close ties to a variety of other topics relevant to dependable embedded systems design. Dependability is the most obvious tie, because without maintenance, dependability declines. System life cycle is closely related, because maintenance is an important part of the lifetime of a system. Human factors are also important because human error during maintenance can cause further problems. Additionally, diagnosis is used to tell what's wrong with a system, or what needs maintenance. Other factors that are related to these topics include project budget, time-to-market and quality.

We often hear about how much it costs to buy any particular model of plane, but people often underestimate just how expensive it is to operate and maintain aircraft. Not only do you have to consider the direct costs of flying the plane (pilot pay, fuel, and other consumables), but also the costs of pilot training, the costs of parts and labor to perform routine maintenance, the costs of training ground crew to perform that maintenance, the costs of obtaining and maintaining support equipment needed to service the planes, and the costs of the facilities needed to perform this service and maintenance. We often lump all these factors together into the "life-cycle cost" of an airplane.

As aircraft have become increasingly complex, the life-cycle costs associated with maintaining sophisticated equipment and training crew to operate and service that equipment have grown substantially. For this reason, we see a trend in militaries around the world to standardize on as few types of aircraft as possible. By operating only a couple of types of planes, a military can consolidate it’s training and servicing activities thereby minimizing the amount of money needed for aircraft operations and maintenance.

In the same context of maintenance of aircraft and quality of work, this paper emphasize upon the cost of poor quality in maintenance. The thesis includes the existing process of Quality Control system and Quality Assurance, followed by the shortcomings in the process, inspections and procedures of aircraft maintenance.

The scope of the thesis is to carryout an in-depth analysis of rejection rate in process, procedures, process of rework, inspections and also to highlight the effects in terms of cost of poor quality and failures. These failures may be due to material failure, human factor, training lapses, and experience levels or in implementation of the quality program, it enhances an additional cost in maintaining quality.

The thesis also highlights that the concept of Quality Control and Quality Assurance which need further enhancement towards Total Quality Management. The recommendations suggests for a gradual change in Quality Management style to TQM at all levels. To achieve this there is a need to educate the PAF personnel, update it processes, procedures and train its manpower to reduce the rework and cost.

ABBREVATIONS

A/C	-	Air Craft
AOR	-	Air Occurrence Report
BLA	-	Base Line Allowance
COG	-	Cost of Quality
CAT	-	Category
DR	-	Defect Report
DSVS	-	Detected Safety Violation
EO	-	Engineering Officer
EPE	-	Evaluator Proficiency Evaluation
FCF	-	Functional Check Flight
F/L	-	Flight Lines
Hyd	-	Hydraulic
Maint	-	Maintenance
MDR	-	Maintenance Defect Report
NCO	-	Non Commissioned Officer
OJT	-	On Job Training
OTI	-	One Time Inspection
PAF	-	Pakistan Air Force
PE	-	Personnel Evaluation
PMF	-	Primary Maintenance Flight
QA	-	Quality Assurance
QAP	-	Quality Assurance Program
QCS	-	Quality Control Services
QVI	-	Quality Verification Inspection
QVR	-	Quality Verification Report
Rs	-	Pakistani Rupees
SEO	-	Senior Engineering Officer
SI	-	Special Inspection
SQN	-	Squadron
SO	-	Special Observations

TDV - Technical Data Violation

TODO - Time Compliance Technical Order

TO - Technical Order

UR - Unsatisfactory Report

WPIP - Work Procedures Improvement Programme

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“A country without a strong air force is at the mercy of any aggressor. Pakistan must build up her air force as quickly as possible. It must be an efficient Air force, second to none.”

Quaid-e-Azam on his first ever visit to Risalpur in 1948

INTRODUCTION

PAF, despite known constraints, has constantly endeavoured to maintain itself at the highest possible state of operational readiness to face emerging challenges. To achieve this goal all branches of the PAF are engaged whole-heartedly in their respective areas of responsibility. It is most critical therefore, that in accomplishment of our common objective to keep highest levels of operational preparedness, these activities remains focussed and orchestrated in one direction. While the Air Staff under the central direction of the CAS enables and monitors all activities.

For accomplishing the targets for year 2003-2004, PAF was allotted a total of Rs 33 billion, which accounts for approx 23% of overall defense budget. Of this amount, Rs 12 billion are to be paid by the government to foreign vendors to fulfill obligations for contracts affected during the past years. Rs 10 billion are to be utilized for meeting obligatory and inescapable expenditure i.e. Rs 4 billion for pay and allowances, Rs 1.5 billion for MES works & utilities and Rs 2 billion for miscellaneous requirements, and Rs 15 billion for operations, maintenance and the down payment for new contracts.

In order to sustain its flying potential the Engineering Branch in the field of Aircraft Engineering, Electrical Engineering, Radars, Weapons and Support undertake a wide variety of activities that are considered noteworthy. Today PAF has a history that it had maintained and flown the oldest versions of a/c and threatened a much larger and latest equipped air force of India. This was just because of efficient and effective utilization of engineering branch.

Due to the current global situation, being a Muslim country no one is supporting Pakistan to acquire any latest equipment and on the other hand we are suffering losses on the remaining assets due to our own reasons. Despite all the hard work and extra efforts, PAF still bears some losses, which could be completely removed. These are the losses on daily operations. To remove all these problems PAF has established Quality Assurance and Flight Safety Departments, which emphasize on the safety of the valuable assets of PAF and maintenance of high quality of work standards.

Maintenance is a complex part of the lifetime of a dependable embedded system. Design and maintenance must be simultaneously planned in order to ensure an efficient and cost-effective outcome over the life of the product. There are a variety of approaches to maintenance, and different approaches are applicable based on the expected use and maintenance schedule of an item. Economic considerations are tightly related to maintenance and system lifecycle; it is clear that failure to consider design's effects on maintenance, and vice versa, can have adverse affects on operations of an organizations.

The maintenance of aircraft, in fact is the management of failures of aircraft systems/components. Like all other management costs, maintenance of aircraft also carries costs. These quality costs consist of: -

- All costs associated with failures of aircraft systems/ components resulting from improper maintenance or due to unpredictable situations (Failure Costs)

- All costs associated with the efforts to verify that quality is being maintained (Appraisal Costs)

- All costs associated with airline's efforts devoted to planning and implementing a quality system (Prevention Costs)

Visualizing the same from another perspective, the management of failures of aircraft systems/components can be done by adopting two strategies - managing the consequences of failures and preventing them to reoccur.

CHAPTER-1

LITERATURE REVIEW

Defining Quality

Quality can be defined as combination of various factors such as: -

- Perfection
- Consistency
- Elimination of waste
- Speed of delivery
- Compliance with policies and procedures
- Provision of a good, usable product
- Doing it right first time
- Total commitment to service and satisfaction

Levels of Quality[1]

An organization is committed to total quality must apply three levels: -

- Organization Level. At the organization level the quality centre on meeting external customer requirements. An organizational must seek inputs on regular basis. Question such as the following help to define the quality at organization level: -

    - Which services meet your expectations?
    - Which do not?
    - What services or product that you are not receiving?
    - Are you receiving products or services that you need?

- Process Level. Organization units are classified as functions or departments, such as marketing, product development, operations, finance, etc. at this level managers must ask questions such as: -

[1] The Management and Control of Quality, part 1, Introduction to Quality, chapter 1, page 28

- What product or services are most important?
- What processes produce those products and services?
- What are the key inputs to the process?
- Which processes have the most significant effect on the organization's customer driven performance standards?
- Who are the internal customers and their needs?

➢ Performance Level(Job / Task Design Level). Standards of output must be based on quality and customer service requirements that originate at the organizational and process levels. These standards includes requirements for such things as:
  - Accuracy
  - Completeness
  - Innovation
  - Timeliness
  - Costs

➢ For each output of an individual's job, one must ask
  - What is the requirement for both internal and external customers?
  - How can requirements be measured?
  - What is specific standard for each measure?

Viewing an organization from this perspective clarifies the role and responsibilities of all the employees in pursuing quality. Top managers must focus attention at the organizational level, middle managers and supervisors at process level, and all employees must understand quality at the performance level. Getting every one involved is the foundation of Total Quality Management.

Quality Assurance

Quality assurance refers to any action directed towards providing consumers with goods and services of appropriate quality. Every manager is responsible for studying and improving the quality of process for which he or she is responsible, thus every manager is a quality manager. Because some managers lack the technical expertise required for performing needed statistical tests or data analysis, technical specialist usually reside in the "Quality Assurance Department".

Quality assurance specialist performs special statistical studies and analysis and may be assigned to work with any manufacturing or business support functions. It must be remembered that quality assurance department cannot assure quality in the organization. Its proper role is to provide guidance and support for the firm's total effort towards this goal.

Cost Of Quality[2]

Historically organizations tend to treat strategic planning and quality improvement planning as two separate and isolated activities. Strategic planning is typically conducted on a regular basis, usually annually, using a formal structured approach. Quality improvement planning, on the other hand, tends to be very ad hoc. Most organizations do not schedule quality improvement planning at regular intervals. When they finish their current improvement projects they then identify new ones. In many cases improvement projects are added to the regular work of the individuals involved with the projects and tend to get worked on only when they have time. This approach results in projects not being completed in a timely fashion, if they are in fact ever completed.

[2] Morse, Roth, and Poston, Measuring, Planning and Controlling Quality Costs, National Association of Accountant, 1987.

While strategic planning is conducted on a regular and formal basis, many organizations do not communicate these plans throughout due to their confidential nature. However, the organization is expected to achieve these plans, even though they have not been communicated.

Improvement planning should likely be conducted as part of the strategic and business planning process. Improvement projects should focus on the needs of current and future customers and support the strategic and business goals of the organization. These improvement projects should be scheduled and resourced such that they can be completed before the next planning period.

The concept of cost of quality (coq) emerged in 1950's. Traditionally the reporting of quality related cost has been limited to inspection and testing, other cost were accumulated in overhead accounts. In defining and isolating the full range of quality related costs, following facts emerged: -

- Quality related costs were much higher
- Quality related costs were not only related to manufacturing operations but to services as well like departmental stores
- Most of the costs resulted from poor quality and were avoidable. While no clear responsibility for action to reduce them was assigned, nor any structured approach formulated

Cost of poor quality has numerous objectives, the most important objectives are:-

- Translate the quality problems into the "language " of upper management, the language of money
- Dollars figure can be added meaningfully across departments or products and compared to dollar measures
- Middle manages who must deal with both workers and supervisors, as well as top management must have ability to speak both the languages

- It helps management evaluate the relative importance of quality problems and identify major opportunities for cost reduction
- It can aid in budgeting and cost control activities
- It can serve as a scoreboard to evaluate the organization's success in achieving quality objectives

Cost of Quality, Quality Planning and The Bottom Line[3]

As organizations strive to increase their bottom line performance in this highly competitive environment they often forget to integrate two important planning activities, strategic and quality planning. This is likely due to a lack of understanding of the cause and effect relationship between strategy, quality, productivity, profitability and competitiveness. To maximize the profits of an organization it is necessary to align the objectives and priorities of the business and the quality improvement process.

Understanding Cause and Effect Relationship

Quality improvement projects should be selected that link to the strategic business objectives and goals. If the strategy is to increase market share, projects selected should focus on those areas that would have the greatest impact on future buying decisions of present customers and future customers. However, if the business strategy is to increase profit in a particular product, the projects selected should focus on reducing quality costs by reducing errors, eliminating non-value-added activities and waste. Another challenge to understanding this relationship is the definition of quality. Quality is meeting customer requirements, error free, at the lowest possible cost. There is still a perception that quality can be too good. Upon investigation, this is usually a case of exceeding the requirements.

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[3] Atkinson, Hawley. Al. Linking Quality to Profits: Quality-Based Cost Management. ASQ Quality Press: Milwaukee, Wisconsin, 1994. 405pp.

A byproduct of quality improvement is the improvement in productivity. By eliminating errors, non-value-added activities and waste, resource capacity becomes available. However this presents another challenge to management. If these resources are not deployed onto something else then there is no impact to the bottom line. Management has learned through bitter experience that if the resources are laid off or let go then the improvement process is destroyed. Increased quality also reduces the production cycle time. It also decreases the use of machinery and equipment due to less rework. This results in a reduction in asset investment. Less material are now required due to less scrap, rework and waste.

Improving quality and productivity increases the profitability of the organization. Margins are increased due to these lower costs. Increased sales result due to higher conformance to quality, better on time delivery and the opportunity to reduce selling price. White-collar operating costs are also reduced due to elimination of poor quality, waste and non-value added activities.

Competitiveness of the organization is increased. Customer satisfaction increases due to improvement conformance to requirements, better on time delivery and lower costs. Sales and market share will increase due to this improvement in customer satisfaction and increased perceived value. The organization will also be more competitive due to increased profitability.

Concept of Cost of Quality

The concept of Cost of Quality (COQ) has been around for many years. Dr. Joseph M. Juran in 1951 in his Quality Control Handbook included a section on COQ. The American Society of Quality (ASQ) established the Quality Cost Committee under the Quality Management Division for Quality in 1961. However it was Philip B. Crosby who popularized the use of COQ because of his book Quality is Free in 1979. Several current quality system standards, ISO 9000, QS-9000, AS-9000, reference the use of COQ for quality improvement.

The concept of Cost of Quality is confusing. What is being referenced are the costs due to the lack of quality or costs to ensure quality is produced. Adding to this confusion is the fact that some authors refer to these costs as "Cost of Poor Quality". Sometimes poor quality costs refer only to the "failure" costs. Crosby refers to the COQ costs as the "price of conformance" - the prevention and appraisal costs and the "price of nonconformance" - the failure costs.

Cost of Quality (COQ) is the sum of the costs incurred by a company in preventing poor quality, the costs incurred to ensure and evaluate that the quality requirements are being met, and any other costs incurred as a result of poor quality being produced. Poor quality is defined as non-value added activities, waste, errors or failure to meet customer needs and requirements. These COQ costs can be broken down into the three categories of prevention, appraisal and failure costs. The COQ model is often referred to as the PAF model after these three categories. See figure 1.

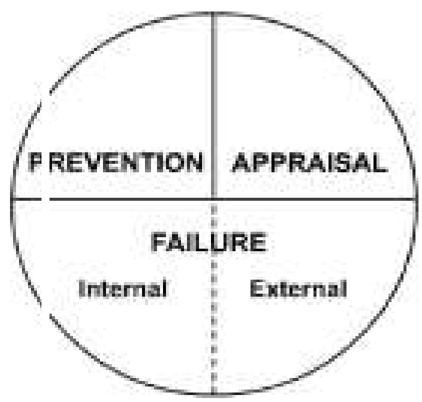

FIGURE 1: PAF MODEL

Prevention Costs**:** The planned costs incurred by an organization to ensure that errors are not made at any of the various stages during the delivery process of that product or service to a customer. The delivery process may include design, development, production and shipping. Examples of prevention costs include education and training, continuous improvement efforts, quality administration staff, process control, market research, field-testing and preventive maintenance.

Appraisal Costs**:** The costs of verifying, checking or evaluating a product or service at the various stages during the delivery process of that product or service to the customer. Examples of appraisal costs include receiving or incoming inspection, internal product audit, inspection activities, inventory counts, quality administration salaries, supplier evaluation and audit reports.

Failure Costs**:** The costs incurred by a company because the product or service did not meet the requirements and the product had to be fixed or replaced or the service had to be repeated. These failure costs can be further subdivided into two groups - internal or external failures.

Internal Failures include all the costs resulting from the failures that are found before the product or service reaches the customer. Examples include scrap, rework, extra inventory, repair stations, re-design, salvage, corrective action reports and overtime due to nonconforming product or service.

External Failures are all the costs incurred by the company resulting when the customer finds the failure. These external failure costs do not include any of the customer's personal costs. Examples of these costs include warranty, customer complaint administration, replacement product, recalls, shipping costs, analysis of warranty data, customer follow-up and field service departments.

Many of the COQ costs are hidden and very difficult to identify by formal COQ measurement systems. Many of these costs, if identified, would be considered as the cost of doing business. Three major groups of hidden costs that are not considered in most COQ systems include customer-incurred costs, lost reputation costs and customer dissatisfaction costs. While these costs are not captured by normal COQ systems they are most important. Future purchasing decisions by both current and future customers are very dependent on these costs. If external failures are eliminated all of these costs are also eliminated. This puts a higher priority on elimination of the external failure costs.

Experts estimate that 60-90 % of total quality costs are the result of internal and external failure and responsibility of management. Better prevention of poor quality clearly reduces internal and external as fewer items are made. In addition less appraisal is required, because the products are made correctly first time. However because the production is viewed in the short term, many managers fails to understand or implement these ideas.

Improvement Strategy Using COQ Data

COQ data is useful as a measurement tool. This data can be used very effectively to identify and prioritize improvement opportunities and then, once a change is made, track the impact of the change. The strategy for using COQ data for improvement is to attack the failure costs and drive them to zero. Implementing this strategy result in problem solving and improving or changing the processes that produce the product or service. The money spent to investigate and correct the problems that result in the failure costs are prevention dollars. By capturing these dollars the organization can determine the bottom line benefit of eliminating the failure cost.

Appraisal costs activities should be minimized, as they are non-valued added. They are defined as non-value added, as they do not change the quality of the product or service being evaluated. The more inspections or verifications conducted the less likely poor quality will be shipped to the customer, however these activities do not prevent the poor quality from being produced. By spending more money on prevention activities, appraisal activities can be reduced and this should also lead to lower failure costs.

Using COQ to Impact Bottom Line

Not all failures have the same financial impact on an organization. As stated earlier the external failures have a higher priority as they cause additional costs to your customers, which will impact their future buying decisions. Potential future customers will also be impacted because customers tell other companies about their problems and some of the companies they tell will not buy as a result of that problem. By determining a standard or average cost for each type of failure, it is possible to select and prioritize failures to best support the strategic business goals. The first step to establishing a standard cost is to list all the activities necessary as a result of the failure such as getting the defective product back from the customer, producing a replacement product and then getting it to the customer. There are many other activities required however they are too numerous to list but should be part of the cost calculation. Once all activities have been identified a cost of each activity is added and all the costs are then totaled. This cost multiplied by the frequency of the particular failure equals the total annual cost.

Capturing Quality Costs Through Activity Based Costing[4]. The importance of quality has had major impact on the role of accounting systems in business. Standard accounting systems are generally able to provide quality cost data for direct labor, overhead, scrap, warranty expenses, product liability costs, maintenance repair and calibration of test equipment. However most accounting systems are not structured to capture important cost of quality information. Costs such as service effort, product design, remedial engineering effort, rework, in process inspection and engineering change losses must be estimated or collected through special efforts.

Quality in Maintenance[5]

Maintenance of any kind performed on a system is a consequence of the fact that systems (or components) deteriorate and fail. Any product or system that has maintenance directions or procedures has an implicit statement that there is a non-zero probability that the system could at some point operate outside its

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[4] www.1000ventures_bussiness.org.com
[5] Harrington, H.J., Poor Quality Costs, Mercel Dekker, Inc., 1987

specified parameters. Failure to perform maintenance to maintain the dependability of a system can have effects ranging from benign to catastrophic. Developing effective maintenance procedures can be at worst a circular process -- procedures cannot be tested unless something deteriorates or fails. Accelerated stress testing can be used to induce failures, but there is no guarantee that all failures that should be covered in a maintenance plan will be exposed. Also, maintenance procedures are generally not extensively tested until a product has been deployed (and then, properly performed maintenance can be critical).

Dependability

Dependability is obviously a desirable system attribute. Even if a system is designed to be "dependable," it is likely that it will need maintenance at some point in its life. Generally, if a system is designed poorly, maintenance cannot improve its poor performance. Maintenance can simply restore or prolong a previous state of operation. Of course, a poorly designed system could be retrofitted during a maintenance procedure, but retrofitting goes further than maintenance.

Profits and Economics of Maintenance

Profits and business models are strongly related to maintenance, and affect design decisions made. These economic considerations cover a broad range of other topics, which will be discussed below. How is a business model affected if there is a low availability of working systems, which need to be repaired often? What are the economic benefits and design considerations of disposal versus repair at the system or component level? Who will perform maintenance when it is necessary, and how do the choices affect recommended types of maintenance? What aspects of system maintenance are safety-critical, and how does that affect the system design? Also, how do maintenance contracts affect design decisions?

Repair or Replace

Economic benefits of disposal and repair are often approached most easily from an accounting point of view. If the cost of designing for maintenance is much higher than the cost of not doing so, and the applications in which the product will be used are such that replacement is feasible, then disposal may be a viable option. Considerations about the expected lifetime of the system must be taken into account as well. It may in fact be cheaper, over the expected lifetime of a product, to design for maintenance, instead of having to maintain inventories of replacements, which may never be used. On a system level, mechanical systems are virtually always repaired rather than disposed and replaced, because of the cost associated. Electronic systems are sometimes repaired, but often that repair is done through the disposal and replacement of a subassembly or component. Electronic components are virtually impossible to repair in a cost-effective manner, while larger numbers of mechanical components are. On a related note, regulatory agencies may require replacement of failed or degraded components, instead of repair, because of the failure modes associated with the components, or their criticality in the system.

If there is a low availability of systems that need to be repaired often, it can make sense to simply swap known-good components or subassemblies for faulty ones and diagnose and repair the faulty pieces at a slower pace. For example, if there are a limited number of aircraft necessary for a particular mission, the time necessary to diagnose and repair a malfunctioning engine may make it worthwhile to have extra engines on hand and simply replace an entire engine, and later fix the faulty one.

Personnel

The issue of who performs maintenance when it is necessary is an important one from the point of view of profits. There are endless variations on who can perform what maintenance how and when, but three common situations will be covered.

The first approach is for the owner or user of the system to perform the maintenance himself or herself. In a safety-critical system, this may not be allowed unless the owner has special maintenance training or certification, or hires a suitably trained or certified third party to perform the maintenance. Commercial airplane maintenance is one example of this situation.

A second approach is for the producer of the system to have an in-house maintenance staff which performs all maintenance, either at the system's location or on the producer's premises. If the maintainers and the designers work closely together, this approach generally results in the highest quality maintenance. People knowledgeable about the design and functionality of the system are arguably best qualified to maintain it.

A third approach is for a third-party to provide maintenance. If the maintenance personnel are well trained, this approach can result in maintenance as good as would be provided by the system provider, and may result in quicker service, if the third-party happens to be located closer to the user's location.

Safety-critical portions of a system pose unique issues in maintenance. Safety-critical parts of a system may have requirements associated with them that virtually require (or exclude) certain types of maintenance. However, design decisions can be affected to the same degree by safety requirements as they can be for other profit or business models.

Diagnostics

Built-in system diagnostics can be an invaluable troubleshooting aid when performing maintenance. Their use needs to be weighed against a variety of factors. Economics play a large role again. Are built-in diagnostics worth the money? Should an external diagnostic tool be manufactured instead and provided only to service providers? If the system will never be repaired, but only replaced, built-in diagnostics are useless except for indicating system failure, and for testing during development. Even there, their use is questionable given the cost of incorporating them in the design in the first place. If built-in diagnostics are available for troubleshooting, the question of how much information will be made available about their function arises.

Types of Aircraft Maintenance

Maintenance operations have been categorized based on their frequency and their motivating factors. Four of the most common designations are described below - predictive, preventative, corrective and faultfinding.

Predictive Maintenance involves a series of steps prior to actually performing maintenance. It begins with sampling physical data over time, such as vibration or particulate matter in oil. Analysis is then performed on the collected data to create an appropriate maintenance schedule, and maintenance is performed according to the schedule. This type of maintenance analysis works well for mechanical systems because the failure modes are well understood. Additionally there is historical data useful for creating and validating performance and maintenance models for mechanical systems.

Preventative Maintenance refers to maintenance performed when a system is functioning properly to prevent a later failure. Generally, it is performed on a regular basis and the maintenance will be performed regardless of whether functionality or performance is degraded. The frequency of the maintenance is generally constant, and is usually based on the expected life of the components being maintained, but there is not necessarily any monitoring occurring at the same time (as there would be in predictive maintenance). One common example is lubrication of mechanical systems after a certain number of operating hours. Another is replacement of lightning arresters in jet engines after a certain number of lightning strikes.

Corrective Maintenance refers to maintenance done to correct a problem when something has failed, or is failing. The need for corrective maintenance can be beneficial or detrimental depending on the product and the profit model used during the design phase of the product. On the most obvious level, corrective maintenance is detrimental to operation because it means that something failed, and the system is (probably) not available during the time needed to perform the maintenance. On the other hand, it may be that the economics and planned functionality of a system are such that using a cheaper, replaceable device for which failure is anticipated, makes sense.

Failure-Finding Maintenance involves checking a (quiescent) part of a system to see if it is still working. This is most often performed on portions of a system dedicated to safety -- protective devices. This is an important type of maintenance check to perform because failures in safety systems can have more catastrophic effects, if other parts of the system fail.

Why Quality Management?

Quality improvement is integral to running a business the smart way. To drive responsibility for the quality process through the ranks of your organization, you should assess individual contributions to the quality process as part of every employee's periodic review.

The best organizations have a systemic and comprehensive focus on quality and performance improvement that applies to all areas of product and service, to all areas of the organization and to all people within the organization. This focus is not just a program, but also a way of life, a strategy requiring improvement by everybody in everything all the time and pursuing a vision of everyone doing the right things.

Total Quality Management (TQM)

TQM refers to an integrated approach by management to focus all functions and levels of an organization on quality and continuous improvement. TQM focuses on encouraging a continuous flow of incremental improvements from the bottom of the organization's hierarchy. TQM is not a complete solution formula as viewed by many - formulas cannot solve managerial problems, but a lasting commitment to the process of continuous improvement.

Seven Rules of Managing Quality[6]

1. Define what quality means to you and your customers, and how it can help to achieve your business goals and compete more effectively for market share.
2. Develop a strategy that defines a specific aspect of quality designed to provide a competitive advantage. Think outside the box; as you think about quality in your division, look at the bigger picture to address the strategy that will best guide your organization in the marketplace.
3. Focus all functions and levels of your organization on quality and continuous improvement. Build a company wide lasting commitment to the process of continuous improvement. Involve multiple departments in cross-functional quality improvements processes.
4. Use an integrated approach leverage your service-profit chain; stress attention to details, but incorporate also competitive benchmarking, evaluation and continuous improvement - all combined in an interactive process with your team members and customers
5. Build a measurement and benchmarking methodology that will rank you against the competition and provide a mechanism for tracking your progress both independently an in comparison to industry wide best practices. Measure quality improvements both in quality-specific terms and in terms of the impact it has on your short- and long-term business goals. Assess individual contributions to the quality process as part of every employee's periodic review.
6. Top management must be completely involved in the quality improvement process rather than simply supportive of it. Allow for independent

[6] www.1000 ventures.org.com

assessment of the company's quality management system, and its product and service quality, and act on the findings.

7. Give ownership for quality to your employees**,** encourage a continuous flow of incremental improvements from the bottom of the organization's hierarchy. Quality is not something that management can mandate or dictate. To gain employee commitment to the quality process, your company's management, control, and reward systems must be modified to give employees greater responsibility and opportunity to become quality and customer oriented and motivate them to strive for continuous improvement.

Five Main Advantages of TQM

1. Encourages a strategic approach to management at the operational level through involving multiple departments in cross-functional improvements and systemic innovation processes
2. Provides high return on investment through improving efficiency
3. Works equally well for service and manufacturing sectors
4. Allows organizations to take advantage of developments that enable managing operations as cross-functional processes
5. Fits an orientation toward inter-organizational collaboration and strategic alliances through establishing a culture of collaboration among different departments within organization

Barriers To Successful TQM

- Lack of long-term commitment and leadership for management
- Insufficient empowerment of workers
- Lack of cross-functional, cross-disciplinary efforts
- Misdirected focus - emphasis on the trivial many problems facing the company rather than a critical few

- Emphasis on internal processes to the neglect of external - customer-focused - results
- Lack of focus in training and coaching
- Lack of cost-of-quality measurement, performance reporting, and reward/formal recognition systems
- Emphasis on quick fixes and low-level reforms, short-term performance at the expense of long-term improvements

CHAPTER 2

PAF QUALITY ASURANCE PROGRAM[7] (QAP)

To promote effectiveness of air operations, the mandate of Quality Assurance Program is to provide an active feed back and insight to the Commanders about the maintenance activities and state of facilities directly affecting safety as well as the mission readiness of PAF. As such, to help prevent and correct problematic situations anywhere in the maintenance complex, almost all the activities and equipment/facilities including personnel proficiency are evaluated. The QA staff is required to identify the problems / observations as well the causes. The solutions are adopted in keeping with the available resources. The Commanders are required to implement solutions through educational redress rather than punitive measures. The QA staff provides feedback to Commanders / Supervisors about response of concerned agencies through follow up evaluations / observations. Additionally; it is identified that the Quality Control aims to attain quality of products (like A/C, radars, support equipment etc.) through certification whereas, QA help improve quality of products by bringing overall improvements in the working environment. The objective of QAP therefore is to attain better quality through systemic improvements.

QAP Coverage

To bring system improvements, QA's concept revolves around evaluation of all the main activities and state of facilities directly affecting the attainment of organizational objectives. In this regard, it may be pointed out that the higher management is also included in the evaluation activity but in case of PAF the senior supervisors / managers are not directly included in the subject process.

Conceptually, the QAP helps identify problems and their causes, offer solutions and provide feed back regarding adoption as well as effectiveness of the

[7] PAF Quality Assurance Manual

solutions. To bring improvement in the overall working environment, the QAP as such, carries out sample evaluations of all the activities / areas and does not certify the quality of equipment/products.

Implementation Methodology

To carry out sample evaluations, the methodology:-

(a) Takes into account all possible limitations faced by the work centres.

(b) And caters for the fact that it takes time to adopt corrective measures.

The limitations of work centres are quantified through the averaging process over a period of six months to one year. The consequent Base Line Allowance (BLA) is applied to Quality Verification Inspections (QVI) only. In case of Special Inspections (SIs) and Personnel Evaluations (PEs), the BLA is pre-calculated and in these cases the failure is given only for the Major discrepancies/observations. The BLAs are calculated bi-annually. The finalization of BLA must take into account inadequate sample sizes, low manning and wanting expertise of QA staff, lack of response / co-operation of the work centres etc. A higher BLA helps in identifying the problems and their resolution.

The sampling evaluation methodology of QAP demands direction of efforts to resolve the known problematic trends and detect the potential trouble areas. The indicators of problematic trends are to be taken from Air Occurrence Reports (AOR), Ground Occurrences, Defect Reports, and Activity Returns etc. The relatively stable activities or areas with lesser problems like Communication Squadrons could be covered only through "monitoring " sparing greater effort for intense activity periods / work centres.

Evaluations / Type of Activities

The continuous evaluation of concerned activities is carried out through: -

(a) Inspections

(b) Monitoring activity

The typical commonly identified inspections covering most of the activities are:-

(a) Quality Verification Inspections

(b) Special Inspections

(c) Personnel Evaluations

The reports arising out of the monitoring activities are termed as: -

(a) Tech Data Violations (TDVs)

(b) Detected Safety Violations (DSVs)

(c) Special Observations (SOs)

Management Aspects

The QA program involves active comments / criticism causing organizational frictions. As such, the mandate of QA demands that the managers must promote acceptance of the programme by the workers as well as the immediate supervisors. To promote acceptance of the programme, all the factors and limitations of the work centres must be kept in view while identifying the responsibilities. A lesser degree of programme acceptance may demand review of the BLAs as well as the attitude of QA evaluators. On the other hand, a very happy atmosphere between the QA staff and work centres in the presence of various events/un-serviceability in the air (as well as on the ground) depict compromises on part of QA evaluators.

To help promote the cause of safety and operational readiness of PAF, the application of QA effort needs to be prioritized. The effort should first be directed to resolve the known problem areas. Rest of the effort to be utilized to identify and provide feedback about the resolution of suspected / potential problems areas / activities.

Basically, the QA evaluations should be taken (and employed) as a data gathering activity providing pertinent indicators of various problems. The QA effort as such, should be directed to find out causes of the problems, offer solutions and provide feed back. To correct the situations and attain co-operation of the users in identifying the problems, educational redress rather than punitive action should be the basic technique. As such, the essence of QA's management is to promote learning and system through data gathering and analysis.

Inception of Quality In PAF

The concept of quality in the PAF is as old as the history of PAF itself. The activity was introduced to RPAF in 1948, in the form of Aeronautical Inspection Services (AIS). The headquarter of AIS was established at PAF base Drigh Road (Shahrai-e-Faisal) headed by the Chief Aeronautical Inspection Officers (CAIO). In 1949, AIS was moved to PAF base Masroor. In the initial days, the training of officers and airman was conducted in UK, however since 1985, PAF started training its personnel in Pakistan.

In 1960 the AIS organization was renamed as “Quality Control Services”. The QCS meant to ensure quality of end products through inspections and certification. By rejecting the un-serviceable items and provision of quality products is ensured.

The mandate of QCS does not allow active evaluation of maintenance or production processes. As such QCs was not aimed at identifying problems, finding causes and offering solutions to correct the situation.

Quality Assurance

Over 10 years experience with aircraft related quality assurance programme (QAP) has set the base for its expansion to Depot level activities as well as air defense assets, which significantly affects the mission effectiveness of PAF.

The quality assurance does not certify but aims to provide quality products by endeavoring to improve all the processes, methods, techniques, tools, testers, procedures, facilities and provisions as well as expertise of workers etc, directly or indirectly involved in maintenance or production.

Quality assurance in PAF is basically a data gathering activity to: -

(a) Identify problems in the form of trends existing at operation, inspection and depot level as well as Air Defense setup

(b) Find out causes of these problems

(c) Offer solutions and provide follow ups

From the foregoing, it is evident that quality assurance programme is a useful management tool to bring improvements in all the processes affecting quality of PAF's assets.

Quality Assurance Program (QAP) classically, aims to improve all the directly involved processes but in PAF the QA also seeks to improve organizational responses of supporting agencies like Administration, logistic etc.

Aim of Quality Assurance Program

"TO ENHANCE THE OVERALL MISSION EFFECTIVENESS OF PAF BY ENDEAVORING TO PROMOTE THE QUALITY OF ASSETS"

The Concept Of QAP

To attain the desired quality of work, the quality control services primarily inspect and certify the products. Stage by stage as well as end – products inspections are carried out to certify products, may those be a pre-flighted aircraft, a periodic inspected aircraft, an engine produce by maintenance unit, a radar inspected or an item provided by log depots as per user demand. In case of observation during the inspections, the QC personnel would just identify the discrepancies, which after necessary rectification would be re-inspected for certification. The quality organization is not primarily tasked to find out the causes of the discrepancies observed during an inspection. Consequently, the QCS cannot help improve the working environments, whereas, to improve the quality of products, the work centre needs outside to help identify the causes of their problems and offer solutions as well as provide feedback regarding adoption and effectiveness of the solutions. Realizing this requirement the concept of Quality Assurance came up according to which the quality of products is to be ensured by improving the working environments.

In order to do so, the QAC mandate of certification of product has been modified to sample inspections. The primary objective of the of sample inspections is to identify problems and their causes, offer solutions and provide feed back regarding the results of corrective measures. Each and every activity like end products, tools, testers, procedures / publications, facilities, state of expertise of technicians, etc are subjected to sample inspections.

As such though corrective measures in all the areas of maintenance / production and associated activities, an overall improvement in the quality of work is achieved.

The following comparison between QCS and QAP further amplifies the basics of QA: -

QCS	**QAP**
Certification of all the end products	No certification but sample inspections
Identification of the discrepancies for correction on the end products	Identification of the discrepancies in all the areas for trend formulations
No need to find out causes of problems and offers solutions	Find out causes, offer solutions as well as provide follow-ups
No concern with overall working	Aims to improve over all working

Basic Objectives Of Quality Assurance Program (QAP) PAF

The aim of Quality Assurance Program (QAP) is to help enhance "Mission Effectiveness" of PAF. To achieve this aim according to the concept, in conjunction with other organization checks and balances, QAP endeavors to promote quality of PAF's assets by attaining following objectives: -

(a) Identification of existing and potential problematic trends / areas in the work complex
(b) Identifying the causes of problems
(c) Offer solutions as well as provide on the spot assistance in correcting situations
(d) Provision of feed back / follow up regarding adopted solution

Implementation Methodology

To achieve the objectives, QA carries out sample evaluations of all the activities / processes of a work complex / unit. The implementation methodology works on the basis of two assumptions: -

(a) The work centre always has some limitations / short comings related to publications / work references, tools, testers, available manpower, expertise level, facilities, working habits etc. these limitations short comings creates certain problems in the achievements of the objectives of the work centers

(b) It takes time to adopt corrective measures

With aims to quantify the limitations faced by the centers, the expected minor mistakes / discrepancies are averaged over last six months this average is termed as BLA (Base line average). With an aim not to blame the work centers for their short comings, BLA, is a kind of allowance extended to work centers vis-à-vis the after mentioned tangible as well as intangibles limitations. The allowance to the work centers in the following ways: -

(a) In case of equipment involving technologies (like A/C, Radars, engines, powered support equipment etc) where margin of recovery / safety is lesser, only certain numbers of minor discrepancies (calculated through BLA) are allowed. Consequently, for evaluation of such equipment, the failure (or un-sat rating) is awarded in case of a major discrepancy or when minor discrepancies exceed 125%of the allowance.

(b) Where as, for non-powered equipment, facilities tools, and publications/work procedures as well as personnel evaluations primarily, any number of minor discrepancies works as the basic allowance. Consequently, no BLA is computed for evaluating non-powered support equipment, facilities, personnel etc and is awarded only in case of a major mistake.

The method for computation of BLA and rating criteria (in case of A/C, powered support equipment, radars, engines etc.) are shown below:-

(a) $\text{BLA} = \dfrac{\text{Last six months Cat1,II \& Minor Discrepancies}}{\text{Total No of Inspections}}$

$$\text{e.g. } BLA = \frac{100}{25} = 4$$

(b) Quality Verification inspections QVI Rating Criteria

Satisfactory - $\pm$ 25% of BLA (3-5 for a BLA of 4)
Excellent – less than 75% of BLA (2 or less for BLA of 4)
Unsatisfactory –more than 125% of BLA (6 or more for BLA of 4)

NOTE: A Red Cross discrepancy always results in an “unsatisfactory rating”.

According to the QA’s concept, the allowance extended to work centers as such, help in identifying discrepancies as well as problems faced by the work centers. The feed back to supervisors about the adoptions as well as effectiveness of solutions / corrective measures. Through corrective measures, the problems / shortcoming of work centers are gradually reduced. Organizations like the armed forces, according to QA’s concept, take about six months time to look after a problematic trend and bring about an appreciable change in the working environment. As such BLA are re- computed biannually in case of A/C, radars, powered support equipment etc. it is therefore evident that the methodology of QAP based upon sampling aims to promote quality of work by helping to reduce the limitations faced by the work centers.

Evaluation Concept and Plan

QAP provides a methodology to supervisors to evaluate the quality of work and improvement total quality through assessment of workers proficiency, equipment, state of facilities etc.

(a) Existing and problem areas
(b) Root cause of these problems
(c) Solution to the problems
(d) Follow up to provide feedback about improvements / effects

Direction / Prioritizations of QA Effort

Before elaborating the evaluation concept and plan, it is important to identify that the evaluations are carried out to detect the problems. It is therefore, necessary that QA effort be prioritized:-

(a) To solve the known problems

(b) Identify potential hazards

Evaluation Concept

The evaluation concept is based upon sampling. As per basic concept the evaluations are rated giving allowance for the limitations faced for the limitations faced by the work centers. The work centers are held responsible only in case the mistake committed is incompatible with their limitations. To identify the limitations of work centers, statistical methods are adopted to transform the limitations into tangible figures. This process is termed as base line averaging.

In case of A/C and powered support equipment where the margin of recovery / safety is lesser the base line allows only certain number of minor discrepancies. Where as, in case of non-powered support equipment and facilities (where the recovery allowance is greater) any number of minor mistakes allowed.
It is identified that conceptually, a discrepancy, which is on operation, could cause imminent danger to the equipment and operations is termed as major or red cross entry.

In case evaluation is rated “FAIL” is charged to the agency responsible for the problem. The evaluation concept of QA through sampling therefore, aims to address the causes and seek solutions to substandard processes thereby gradually reducing the limitations of work centres in providing quality products.

The quality control supervisors provide necessary guidelines for the employment of QA efforts to identify the problem areas, root causes, solution and follow up procedures.

Tasks of QAP

In keeping with the aim to enhance mission effectiveness of PAF and the objectives of identification and resolution of problems faced by work centers, the QAP as a data gathering agency is tasked with certain assignments:-

(a) Assess and report about the condition of working in the areas / activities namely "O" and "I" levels, depots and air defense network
(b) Make recommendations to the senior supervisors to improve the quality of work; enhance safety as well as training programs
(c) Provide on the spot and follow-up assistance in correcting problems
(d) In collaborations with supervisors, ensure that maximum training value is attained from all inspections / evaluations
(e) Serves as technical advisory agency in assisting the senior supervisors
(f) Ensure that the appropriate actions are taken through concerned commanders and to notify AHQ when deficiencies are detected in PAF's directives and technical orders / publications
(g) Mange works procedures improvement program
(h) Monitor the functional check flight program
(j) Attendance of aircraft occurrence
(k) Manage the aircraft weight and balance program where applicable
(l) Maintain standardized format of records
(m) QA is primarily, not an extension of work force but may augment the personnel as directed during contingencies and exercises

Features of QAP

The identification of deficiencies and problem areas are key functions of QA. By determining causes of problems, recommending corrective actions as well as through feedback to supervisors, QA endeavors to promote quality of work. Following features are identified for QAP: -

(a) Use of statistical methods to score evaluations

(b) Evaluation of personnel along with equipment

(c) Use of standard forms / reports which routed to concern supervisors

(d) Follow up actions

(e) Monthly summary providing feedback to commanders

CHAPTER – 3

QAP DATA COLLECTION AND EVALUATIONS

The QA program evaluates all the processes (directly / indirectly) involved in maintenance / production activities in the PAF. The maintenance / production and associated activities are evaluated by collecting data / inputs through inspections as well as monitoring rounds. The monitoring activity of QAP would be elaborated in the later part of this chapter whereas, the three types of inspections performed by QA are listed below: -

a) Quality Verification Inspection (QVI)

b) Special Inspection (SI)

c) Personnel Evaluation (PE)

Quality Verification Inspection (QVI)

QVI is an inspection of equipment following a maintenance inspection or repair action. The maintenance inspection could be a part of major depot level production or a simple activity of daily inspection performed on support equipment like generators, fork lifters, ladders etc. The purpose of a QVI is to verify that the inspection or repair action was properly done. QVIs with an aim to determine the condition of equipment are performed before its operation or use. For QVI, the same work reference or technical data is used required for the job.

QVIs are generally performed on end items like aircraft, engines, radars, vehicles, generators, test stations etc, which primarily, have moving parts / components. The QVI for required schedule / unscheduled inspection may also be accomplished by checking a portion of the required inspection items. This type of inspection is specifically identified by work card or area and has a baseline average. The QVI report may reflect deficiencies by work centre to identify specific weaknesses in the maintenance / production effort and point out where the improvements are required by managers.

Categories of Discrepancies. Categories of discrepancies are used to aid commanders and maintenance supervisors in identifying areas that are weak and require emphasis or additional training. Various categories are applied by QA. Identifying factors that have contributed to conditions discovered during equipment inspection. In case of QVIs, the discrepancies are identified in accordance with following categories: -

(a) Category-I. A discrepancy that was a required inspection item but was missed on the last inspection. This category must be a specific work card item for a specific condition. This type of discrepancy is generally termed as missed carded item.

(b) Category-II. TO / Work reference deviations. A defect related to an improperly installed equipment or component such as missing hardware, safety wired incorrectly and deviations from TO / work reference requirements. It is generally termed as incomplete or improper work / Inspection.

(c) Category-III. Readily detectable items. An obvious defect that should be readily detected by a worker or supervisor during normal accomplishment of routine maintenance, but is not part of the task or inspection.

(d) Category-IV. Generally, termed as other discrepancies. This category includes discrepancies which do not meet criteria of categories I, II or III, for example, bench check rejects, future inspection requirements, transient or en-route maintenance and not readily detectable discrepancies.

Base Line Average. As identified earlier, to quantify the limitations of work centres, QA locally computes an average of discrepancies / mistakes. It is called the baseline and is used by QA to determine QVI ratings. It also helps to compare the unit's present performance with its previous performance. To compute a baseline, the following applies: -

(a) A baseline average is developed at least semi-annually for each type of equipment inspection and maintenance action. To calculate the baseline, categories I, II and III are required. To compute the average, the number of inspections performed divides total number of discrepancies. If the average comes out in fractions, then it will be rounded off to the next whole number e.g. 2.1 to be rounded off to 3.

$$\textbf{BLA} = \frac{\text{No of Minor Cat-1. 11 \& 111 Discrepancies}}{\text{Total No of Inspections}} = \frac{30}{6} = 5$$

(b) While finalizing the BLA the sample sizes, low manning and wanting expertise of QA staff, lack of response/cooperation of the work centres etc. must be considered. Proper weightage to all these factors must be allotted while calculating the BLA instead of working out the figures merely on the bases of aforementioned formula.

(c) Newly identified problem areas may be added to the QAP at any time. The BLA for such areas should be re-computed monthly until 6 months historical data becomes available for computing the average. The BLA for a new inspection can also be determined in less than six months if, necessary data is already available.

QVI Procedure and Report Routing. The following procedure is to be followed: -

(a) Determine the type of inspections / actions to be evaluated

(b) Ensure that exact technical data / work reference of the inspection is available

(c) Carry out the inspection strictly following prescribed technical data / work reference

(d) Note down the discrepancies observed during inspection

(e) The routing sequence will be agreed locally in consultation with the supervisors with an aim to inform all concerned required to create the response. As an example, if comments on the report indicate that training was a problem, QA routes the report to training management also for review and action

(f) Evaluate the progress through sampling / monitoring of corrective actions at the respective work centres

Report Preparation and Writing

Before writing the report, the previous reports of same activity should be considered for historical background of the problem to identify any existing or appearance of a new trend. The report must identify the causes of problems and recommend suitable solutions.

Rating System of QVI

The rating system provides a method of applying objective rating to the inspections and evaluations performed by QA. Scoring is applied to those inspection and evaluation items / activities identified in the monthly plan and to the additional selected problem areas. The QVIs are rated by comparing the number of chargeable discrepancies (Category I, II & III) with the baseline allowance as follows: -

(a) Excellent - Less than 75 percent of BLA

(b) Satisfactory - Plus or minus 25 percent of BLA

(c) Unsatisfactory - More than 125 percent of BLA

(d) A red X (major) discrepancy always results in an unsatisfactory rating

Special Inspection (SI)

Special Inspections (SIs) are generally conditional or procedural compliance oriented. These inspections are of two types, which could cover all aspects of maintenance activities involving personnel, end items (like aircraft, radar, vehicles etc) facilities including support equipment. The first type of SI is ordered by higher authorities may it be Air Headquarters or senior supervisor of the Base and is termed as "Special Task". This type of special tasking is generally of one-time in nature and may be continued till the problem is resolved. In case of special tasking the evaluations are non-rated and a consolidated report is submitted to the concerned authorities.

The second type of SI evaluates areas of routine maintenance, which are not covered by QVIs and PEs. Some of the activities evaluated under special inspections are as follows: -

- Fire extinguisher
- Tool kit
- Bench stock
- Documentation
- Tech orders, publications, manuals, procedures etc
- Ground equipment (primarily non-powered)
- Foreign Object Damage (FOD) / operational area check
- General cleanliness and condition of installations / work areas

Procedure for Special Inspection. The following procedure is adopted for special inspection: -

(a) Determine the type of inspection (equipment / activity)

(b) Ensure that specified inspection criteria are available

(c) Carry out the evaluation as per laid down criteria

(d) List down the discrepancies

(e) Monitor the progress of corrective action at the respective work centre

Rating of SIs. SIs is rated as "Pass" or "Fail". The "Pass" or "Fail" criteria is locally developed against the given work reference / procedures. SIs are primarily performed in case of non-powered support equipment, TOs / publications, documentation / records, safety measures, facilities, storage conditions, etc. which are technically simple activities as such, a number of similar equipment pieces or activity areas / items are grouped in a single evaluation / inspection. SIs ordered as special tasks may not be rated and would only identify discrepancies as well as solutions.

Personnel Evaluation (PE)

This evaluation is performed to determine the proficiency of workers and supervisors. A personnel evaluation can be either after-the-fact (job completed) or over-the-shoulder (during the work). Before starting over-the-shoulder evaluations, QA evaluator is to brief the person about the evaluation and the rating criteria etc. The evaluation begins when individual starts the job or the portion of the task to be evaluated. The evaluation is concluded when the job is completed and documents filled / signed, or when in the judgment of evaluator, performance has been evaluated sufficiently to determine the rating. If the evaluation results in a "fail" rating, QA will provide on-the-spot assistance and remedial measures in the areas requiring improvement.

Types of PEs

Following are the types of personnel evaluations:-

(a) Task Evaluation (TE). An over-the-shoulder evaluation of personnel during the job performance. It is also termed as workers' evaluation (WE).

(b) Supervisor Evaluation (SE). An over-the-shoulder evaluation of a supervisor completing an inspection /job

(c) Completed Maintenance Action (CMA). An after-the-fact evaluation of a previously completed maintenance action

(d) Completed Maintenance Inspection (CMI). An after-the-fact evaluation of previously completed maintenance inspection

(e) Completed Supervisor Inspection (CSI). An after-the-fact evaluation of supervisor who has performed and documented an inspection of completed job (cleared a red "X" entry)

(f) Evaluator Proficiency Evaluation (EPE). An over-the-shoulder evaluation of a QA inspector performing a personnel evaluation (for initial qualification of QA personnel and also for initial / semi-annual qualification of QA augmenters)

Procedure for Personnel Evaluation. Following procedure is adopted for Personnel Evaluations: -

(a) Brief the person about evaluation

(b) Inform him about the rating criteria

(c) De-brief the individual being evaluated after the completion or termination of evaluation

(d) The individual's supervisor should also be briefed

(e) Every evaluation to be conducted using exact data / reference that the person uses in performing the task

(f) Reports of the personnel evaluation will be raised on specified form

Rating of PE. The rating of a PE is either "Pass" or "Fail". That means, in case of PEs also (just like SIs), there is no need to calculate the BLA and pre-calculated basic allowance is extended to the personnel. According to the pre-calculated allowance, "fail" rating is declared only in case of a major mistake. The evaluator therefore awards "fail" rating in case of any of the following conditions: -

(a) The worker fails to comply with a step (or steps) of prescribed data / procedure that could affect the performance of equipment / activity

(b) The worker or supervisor fails to detect a category I, II or III major (red "X") discrepancy / problem while complying with the work reference / procedural requirements

(c) The worker or supervisor demonstrates lack of proficiency about the job or system knowledge to such a degree that the job cannot be completed

(d) The worker or supervisor commits an act that could result in injury to personnel or damage to the equipment / facilities

(e) The person attempts to perform the job without data / work reference

(f) In case of a "UNSAT" QVI, the concerned worker as well as supervisors would be awarded "FAIL" rating in accordance with the PE's rating criteria stated above

Failed Rating. The fail rating of an individual's evaluation means that a specific task was not performed satisfactorily. The rating applies to that specific task and is not applied to other tasks an individual is qualified to perform. When an evaluation results in a fail rating, the QA evaluator immediately notifies the supervisor about failure and the circumstances involved. The supervisor must investigate the cause for each failure and determine the necessary corrective actions. He should also determine if the individual concerned is to be restricted in the performance of normal duties. If the supervisor determines that the individual should be restricted from unsupervised performance of the task, he should accordingly annotate the remarks in relevant records of the individual.

High PE Pass Rates. The experience has indicated that the pass rate of PEs is generally higher than the factual position. QA supervisors should in person periodically monitor the conduct of PEs. Work centre supervisors should be apprised that PE failures diagnosed by QA are useful indicators and these must not be taken as a reflection of work centre's efficiency. Similarly, the corrective actions on PE failures should have a bias towards "educational redress" rather than "punitive action". Matters involving carelessness, disregard to regulations, casual attitudes etc. however, should not be taken lightly.

In order to ensure that the PEs is objective and realistic, QA is to make the PE plan in accordance with the following considerations: -

(a) Expose all workers to PEs with a bias towards junior / inexperienced workers

(b) Newly posted personnel specially, who are new to the system should be exposed frequently

(c) Expose personnel to PE in the areas showing a weak / problematic trend

The Monitoring Rounds / Activity

Monitoring is a recognized QA activity other than declared evaluations / inspections. It is aimed at collecting data / inputs regarding adherence to instructions / requirements laid down by various work references (and solutions offered by QA) may it be related to any activity directly or indirectly affecting maintenance / management of PAF assets. It helps QA in observing / monitoring any activity at will / random without disturbing the routine work. It does not affect the routine work as such, QA could inspect / observe any activity / area of any work centre. The QA evaluators / inspectors would only interfere in case of a violation which could affect the working requiring immediate attention of the concerned supervisors. And for monitoring, the QA personnel are just required to inform about their presence in a work centre and no prior coordination is necessary.

Employment. Monitoring is an important feature of QAP, which attains special importance in case of following: -

(a) Armament exercises
(b) Major exercises etc
(c) Lack of QA effort to carry out QVIs / SIs / PEs due to diversion in a particular problem area, special tasking etc
(d) Diversion of QA effort to specially monitor certain activities to resolve identified or suspected problems. Regarding suspected problem areas, places like POL bulks generally located at distance from Bases where most of the DSGs, MES personnel like generator operators, valve-men, laborers etc. are not sufficiently trained / aware (especially about safety precautions), require greater visits of QA monitoring teams

Monitoring rounds help in observing work habits and in identifying violations as well as other special observations (to be elaborated separately) requiring attention of the supervisors / commanders. As such, monitoring activity needs to be meticulously planned and objectively executed by QA managers to serve the specific aims.

CHAPTER – 4

VIOLATIONS AND SPECIAL OBSERVATIONS

Inspections as well as monitoring rounds, form part of QA's evaluation activities. The QA's monitoring activity helps in: -

(a) Detection of non-adherence to procedures especially safety related matters

(b) Follow-up of QA evaluations

Detected Safety Violation (DSV)

Detected Safety Violation (DSV) is an observation by the QA staff of an unsafe act or condition, being performed / existing anywhere in the work complex.

Procedure for DSV. An unsafe act/condition, existing anywhere in the work complex is recorded as a DSV as per the following procedure: -

(a) In case of an unsafe act, it would be charged to the personnel involved in the activity. For example, a person working on an unearthed radar / aircraft or in POL store with missing fire extinguisher is committing an unsafe act as such, DSV is recorded against him.

(b) If an unsafe condition exists (where nobody is working or attending to the activity), it will be charged to the supervisor. For example, a missing fire extinguisher or chemicals stored without proper ventilation are unsafe conditions to be charged to supervisors.

Whenever an unsafe activity is observed, the job is to be stopped till the problem is resolved or the supervisor concerned clears the work to continue after adopting appropriate measures. For example, in case of fuel spillage during servicing of an A/C refueling is to be stopped. After cleaning the spillage under the A/C, refueling could be resumed. In the same manner, fire extinguisher is to be placed in POL storage to fulfill the requirements of safety.

If a person commits an unsafe act during a formal evaluation, it will not be recorded as a DSV but the individual's evaluation will be rated "fail". For example, a PE of a worker is to be conducted for an engine on the test bed. He starts the engine run while EGT gauge is not installed on the test bed. In this case the DSV will not be raised but PE of the worker will be rated fail.

The following procedure to be followed for documenting a DSV: -

(a) DSV will be recorded on specified Form and raised in two copies.

(b) The report should indicate the necessary details including names of the worker / supervisor who were informed about the observation / activity.

(c) Original copy of the Form will be handed over to the section for corrective actions and further routing to the concerned. A duplicate copy will be maintained in the suspense file for record till the original copy is received.

Tech Data Violation (TDV)

Whenever a job is accomplished without work procedures or the relevant data is held but not consulted, a TDV is recorded. The TDV is charged to individuals. The violation of procedures, if part of an evaluation, is not reported separately but the inspection is rated fail.

Like the DSV, the TDV is also documented on F-10962 in duplicate and routed according to local procedures. The report should contain all the details of event / violation.

Special Observation (SO)

Special observations are those, which are of significant nature and highlight trends or habits, which could affect the quality of work. DSVs and TDVs are not to be reported as SOs unless being depicted as trends supported by requisite data. For example, personnel working without ear plugs during ground run or carrying out job without requisite data / procedures are DSV and TDV respectively. If these violations are repeatedly observed, then making this data as a base, the trend can be formulated. As such based upon DSVs and TDVs, SO could be made to indicate a trend.

Occasions for Special Observations

Special Observations can be recorded on the following occasions: -

(a) To indicate trends

(b) Whenever any observation demands special attention of the authorities. For example, despite recurring documentation problems no refreshers are planned and conducted

(c) Whenever a problem observed has no solution, it will also end up as an SO with an aim to inform all concerned to seek solution. These are generally the kinds of observations, which have not had any precedence

(d) To identify a problem which does not form part of any evaluation or falls in the domain of violations

The SOs primarily, pinpoints a problem, which is not covered under any other type of QA observation. Generally, after initial observations, additional inspections (QVIs, SIs or PEs) need to be performed to collect requisite data for finalizing the trend. An additional SO is then made to depict the trend.

Procedure for SO

The following procedure is followed: -

(a) Each SO is documented on specified Form in duplicate

(b) The routing of Form is determined by the nature of discrepancy for Unsatisfactory condition

CHAPTER - 5

QA OBSERVATIONS AND TREND FORMULATION

To help enhance the quality of work, QA inspectors evaluate various activities through sample evaluations by implementing the monthly / quarterly inspection plan. The commanders and senior supervisors could best utilize the QA effort by employing it as data collection agency identifying trends and monitoring progress of adopted solutions as well as adherence to procedures/instructions.

QA Reports and Trends

The details about any evaluation, violation, special observation etc are recorded in the form of QA reports. As such for trend analyses, the QA reports must contain the following details: -

(a) Historical background

(b) Assigning of responsibilities

(c) Appropriate routing

Trend : Definition & Formulation

A trend is defined as set of acts or omissions. The commonality factor (of acts / omissions) is therefore identified to highlight a trend. A correctly formulated trend could therefore, greatly help improve the working environment. As such, the attention of QA managers should be on detecting and formulating a trend whereas, various inspections must be taken as a means to identify and provide the necessary database for the subject purpose. There are two stages of trend detection. First, the data collection from sources / inputs as given in the following:

(a) Data Collection Through QA Reports. Data could be collected through (Fail / Pass as well as Un-sat / Sat) reports scattered over a considerable period about a particular area/activity. As an example, during a month increased number of discrepancies on the ejection seat installation in a particular Sqn could lead to a trend. The reasons and solutions also need to be ascertained.

(b) Special Inspections. Discrepancies observed through SIs are gathered by grouping the same kind of equipment. Repeated SIs in the same area could be utilized to formulate the trend. Non-adherence to standard documentation could identify unawareness or attitude problems, which could lead to an adverse trend.

(c) Special Observations. As identified earlier, the inputs of SOs could help to formulate a trend. As an example, the drip trays being dragged in Sqns by technicians could highlight the trend related to design deficiencies as well as careless attitude of technicians.

(d) TDVs and DSVs. The reported cases of TDVs and DSVs could also help to formulate trends. As an example, people working without procedures in various work centres indicate a trend of attitudes or deteriorated condition of publications / manuals which can't be easily consulted.

(e) Effort Diversion into a Suspected Problem Area. A trend could also be detected and formulated by carrying out inspections in a suspected problem area.

(f) Meetings / Interviews with Personnel Concerned. Talks with the workers, meetings and interviews also expose many bottlenecks of the system and help to find out trends as well as their root causes. Meetings with Os I/C before finalization of QA summary could help in finalization of various trends especially, in identifying agencies responsible for problems related to logistics and administrative facilities.

After having collected the information through aforementioned sources, the data is reviewed for the characteristics identified below: -

(a) Relevancy

(b) Reliability

(c) Accuracy / completeness

(d) Coverage of total spectrum

Having judged the data for the aforementioned characteristics, the trend is formulated. For the purposefulness of activity, another interesting aspect of detection and formulation of trends through "Pass" rated QA reports needs identification. It is not necessary that a trend/problematic situation be identified only through failure cases, DSVs, TDVs, and SOs etc. Due to the peculiar QAP concept revolving around the allowance given to work centres for their limitations, detecting the commonality factor from the “Pass” reports also could identify potential problem. Visualize a case where, all the pre flight QVIs of a Sqn during a month are rated pass with a BLA of 4 discrepancies. Assume that most of the discrepancies identified in the reports are related to engine trade. These recurrent engine entries may be promoting an adverse trend. That is why SNCOs I / C trades of QA Sqn are to monitor the entries of on-going QA evaluations (irrespective of pass / fail ratings) to identify development of an adverse trend to the QA officer.

It is therefore pertinent to conclude, "That the attention of QA managers should be rather on detection and formulation of trends whereas, various inspections must be taken as a means to identify and provide the database for subject purpose. Additionally, the senior Base supervisors and evaluators at the Headquarters should also pay attention to trends and their resolution rather than the pass percentages of various QA evaluations."

Additionally, it needs to be re-identified that QAP is a data collection / gathering agency. The QA inspectors are there to collect data through sampling from various activities. The QA officers are required to formulate and depict trends through FAIL as well as PASS reports. The commanders and senior supervisors could best utilize QA effort by employing it as a data collection and agency monitoring progress of adopted solutions.

CHAPTER- 6

PROCESS OF AIRCRAFT MAINTENANCE

In order to understand the cost of poor quality in aircraft maintenance, we will examine the process of aircraft maintenance in PAF. PAF has establishment almost in every city of Pakistan, these establishments are called PAF Bases. At base level, two types of maintenance activities are performed during maintenance of an aircraft: -

a) First line maintenance or Flight line maintenance
b) Primary Maintenance Flight (PMF) or Second line maintenance.

At both levels scheduled and unscheduled maintenance activities are carried out.

First Line Maintenance

Five types of Scheduled inspections are performed. These are:-

i) Pre-flight inspection
ii) Through flight inspection
iii) Post flight inspection
iv) Weekly
v) 25 hours

Pre-Flight Inspection

This inspection is carried out before the aircraft is subjected to flight.

Through Flight Inspection

This inspection is carried out before the aircraft is subjected to second flight and so forth.

Post Flight Inspection

This inspection is carried out after the aircraft flying is ceased. (Flying call off)

Weekly

This inspection is carried out once in a week. In this, detailed maintenance inspection is carried out.

25 Hours

This inspection is carried out after the air craft has flown 25 hours.

Unscheduled Inspection

This inspection is carried out in case of any major component failure.

Primary Maintenance Flight (PMF) or Second Line Maintenance

Following three scheduled inspections are carried out in this:

i) 50 hours
ii) 100 hours
iii) 200 hours

50 Hours

It is carried out after the aircraft has flown 50 hours.

100 Hours

This inspection is carried out after aircraft's 100 hours flying. In this more detailed inspection is carried out than 50 hours.

200 Hours

Similarly this inspection is carried out after air craft has flown 200 hours flying. In this more detailed inspection is carried out than 100 hours.

Unscheduled Inspection

Any major unscheduled maintenance beyond the capability of squadron Flight Line or First Line maintenance is carried out under this inspection or any defect is rectified that is recorded after Functional Check Flight (FCF).

Maintenance Process of an Aircraft at Base Level

- Induction

  During this phase A/C from squadron is handed over to PMF for required schedule inspection

- Components removal

  Various components of different systems are removed

- Components cleaning

  Components are cleaned and checked for any defects

- Components bench testing

  In this phase components are dispatched to requisite back shop facilities for bench testing

- Installation

  Once the components are declared serviceable after bench test they are installed on the A/C

- Ground run

  Once all the components are installed the A/C is subjected to full power ground run to ascertain the performance of engines

- Aircraft Quality Verification Inspection (QVI)

  Once the A/C is cleared from ground run it is handed over to quality assurance for Quality Verification Inspection (QVI)

- Functional Check Flight (FCF)

  After Quality Assurance (QA) clears the A\C it is handed over for FCF to the concerned squadron pilot

Maintenance process of an aircraft at base level attached as “Appendix A”

CHAPTER – 7

ANALYSIS OF BENEFITS OF QAP IN PAF

Quality Control Services (1977—1987)

The concept of quality in PAF is as old as the history of PAF itself. In the year 1977 the Aeronautical Inspection Services was renamed as Quality Control Services (QCS). Quality Control Services are primarily meant to ensure quality of end products through inspections and certifications. By rejecting the unserviceable items (and in many cases re-routing them through the production lines) provisions of quality products is ensured. The mandate of QCS did not allow active evaluation of maintenance or production processes. As such QC was not aimed at identifying problems, finding causes and offering solutions to correct the situations.

An efficient Quality Control System is a fundamental requirement for any production activity. It is defined as the process through which it measure actual quality performance, compare it with standards or specifications given in relevant publications and act on difference. It becomes all the more important in aviation environment where acceptable error margins are narrow and consequences are serious.

Quality maintenance is the responsibility of individual technicians, shop supervisors and maintenance commanders. The role of Quality Control (QC) is to Monitor the repair of the unserviceable equipment and to evaluate its condition after the maintenance has been performed. The QC ensures that the maintenance carried out on the equipment meets the laid down repair and serviceability criteria. These evaluations are designed to inform maintenance commanders of the equipment condition and the repair proficiency. As different from Quality Assurance (QA), which checks and monitors the system or the process, Quality Control checks the quality of the products. The QC programme will be named as the internal QC programme.

Quality Assurance (1988—1998)

With the induction of F-16 in 1983 PAF moved from Quality Control Services (QCS) to Quality Assurance (QA). QA in PAF is basically a data gathering activity to: -

- Identify problems in the form of trends existing at "O", "I" and Depot Level as well as in Air Defence setup
- Find out causes of these problems
- Offer solutions and provide follow up

Task of Quality Assurance

Quality Assurance Program provides a methodology to evaluate the quality of work through assessment of workers proficiency, equipment, state of facilities etc. the senior supervisors provide necessary guidelines for employment of QA effort to identify: -

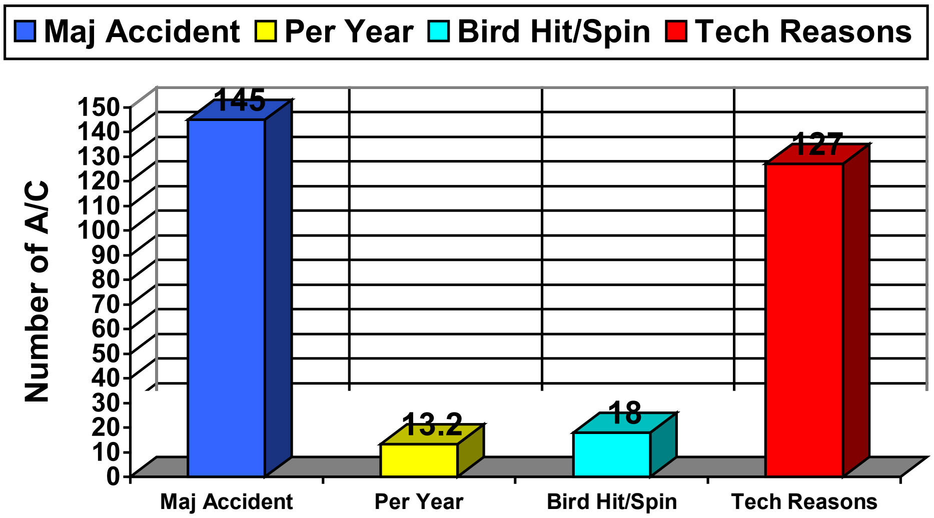
a) Existing and Potential problem area
b) Root causes of these problems
c) Solution to these problems
d) Follow-up to provide feed back about improvements / effects

Financial Resource / Benefits of Quality Assurance in Aircraft Maintenance

Quality Control (1977—1987)

a) No of A/C destroyed due to major accidents = 145 @ 2.01/10,000 hrs of flying. (No of A/C destroyed / year = 13.2)
b) No of A/C destroyed due to bird & spin cases = 18
c) No of A/C destroyed due to technical reasons (including material factor) = 145-18 =127

QUALITY CONTROL 1977 - 1987



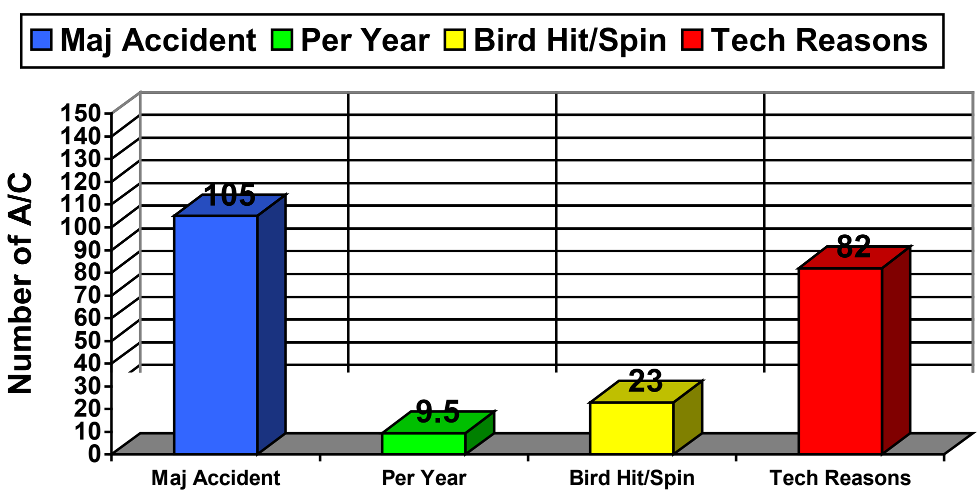
Quality Assurance (1988—1998)

a) No of A/C destroyed due to major accidents 105@1.33 / 10,000 Hrs of flying. (No of A/C destroyed / year = 9.5)

b) No of A/C destroyed due to bird & spin factor = 23

c) No of A/C destroyed due to technical reasons (including material factor) =82

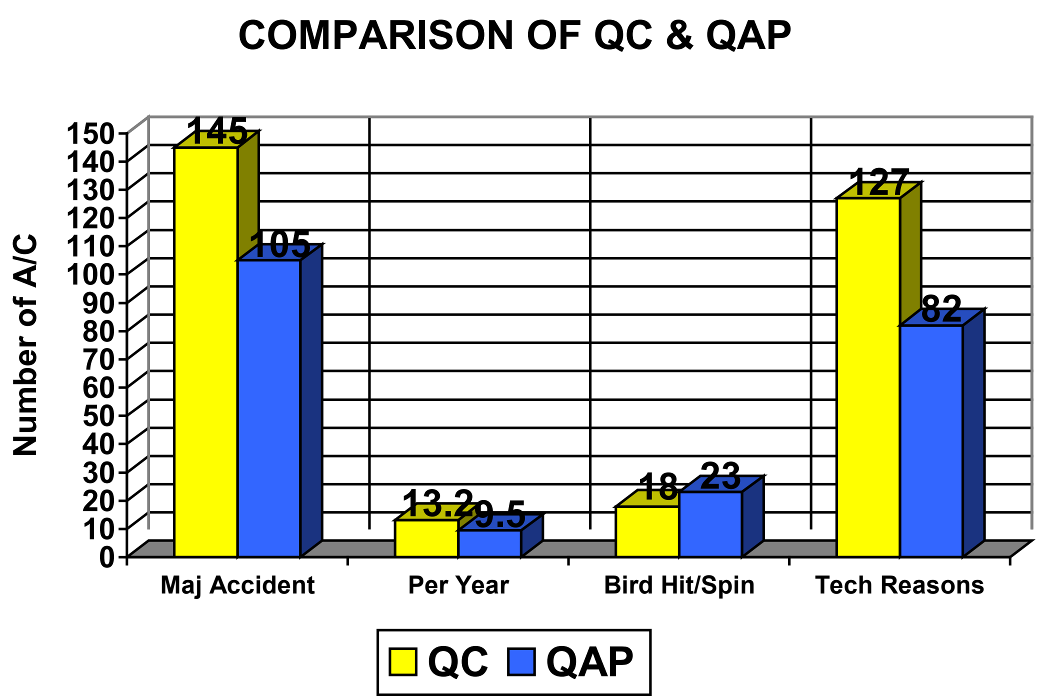
QUALITY ASSURANCE



Cost-Avoidance / Benefit Analysis of Quality Assurance Program

- No of Aircraft Saved in 10 years = 45 (127 – 82 =45)
- No of Aircraft Saved per year =45 / 10 = 4.5
- Average Price of PAF – Chinese Inventory Aircraft = Rs.160.82/- million
- Average Money Saved Per Year = 160.82 * 4.5 = Rs.723.69 /- million
- Expenditure Incurred on QAP = Rs.90.94 million
- Savings / Cost-Avoidance Analysis = 723.69 – 90.94 =

Rs. 632.75 million



CHAPTER - 8

SERVICEABILITY & RELIABILITY OF AIRCRAFT

What is Serviceability?

It means availability of serviceable aircraft ready for operations. To keep the force at readiness the serviceability is calculated for all the aircraft, radars and transport in all PAF squadrons. But the highest priority is being laid on the aircraft. The serviceability of all the squadrons are maintained on daily basis and the monthly average is calculated at the end of the month. All the fighter units are maintaining a base line of minimum 75% as PAF standard. In case of lower than this standard, Squadron Commander and the Base Commanders are answerable to AHQ.

What is Reliability?

Reliability is an integral part of the serviceability. It means that a minimum number aircraft must get air borne out of 75% serviceable a/c. The PAF standards of reliability are 90% of the 75 % serviceable aircraft.

Implication of Serviceability & Reliability on PAF Operations and Impact of TQM on PAF

The implication of serviceability and reliability on the PAF's operations can be seen in the following areas:-

- War Plans
    - Gulf War
    - Iraq War
    - 1965 /1971 Indo-Pak war

- Time based Competition
- Success Factor
- Support Equipment

War Plans

The war plans are prepared in accordance with the serviceability and reliability rate. PAF needs to maintain the minimum standards to meet the challenges from an enemy bigger in numbers. In case of emergency, the number of serviceable aircraft who could take off to deliver the goods in the enemy territory provides a major impact on the success of war. In today's scenario the airpower destroys the enemy's front line forces even without their ground troops movement. Here the efficiency and effectiveness are directly proportional to the serviceability and reliability of the equipment.

Gulf / Iraq War

The Operation Desert Storm and the recent Iraq war have shown the impact of serviceability & reliability of the coalition forces, which used to fly 3000 sorties per day. To achieve this, the US & UK were maintaining serviceability and reliability of 75% & 90% respectively.

1965 Pak-Indo War

In 1965 war, Pakistan planned to attack two Indian airfields at 1600 hrs on the first day with 16 aircraft (8 aircraft for each base). The strike package was scheduled to fly from different bases. But due to poor serviceability & reliability, 16 a/c were not ready by the time of mission. The time was rescheduled and the number of a/c was reduced to eight, but unfortunately only four a/c were ready for the mission. Both the impact and the surprise were lost.

1971 East Pakistan

By the time of 1971, PAF had put in lot of effort to enhance its serviceability and reliability. At Dhaka, PAF had only one fighter squadron with all the supply line cut off. But due to excellent serviceability and reliability PAF managed all its planned and unscheduled missions conducted without any problems.

Time Based Competition

In today's scenario, the organization is time compressed due to the competition. If you are late in taking the required actions, you might be out of the competition and would require generating double the efforts to catch-up. Similarly in the military organizations, if you are slow then you cannot match the enemy's forces. To maintain the competitive edge, the armed forces should be at the highest order of readiness to meet the surprises of the enemy. The serviceability and reliability provide the competitive edge to meet the time-based competition.

Success Factor

In case of organization such as air force the success factor depends largely upon the readiness of the fighting elements. The fighting forces comprises of a/c, radars, surface to surface, and surface to air missiles etc. If these forces are maintained the chances of failure are remote and the success factor may be beyond expectations. The serviceability and reliability is the key element for the success factor. If one maintains the desired standards then the success is expected to be very high.

Support Elements

The support element consists of air defense radars, surface to surface and air missiles, small weapons, laser guided bombs, munitions and other ammunitions.

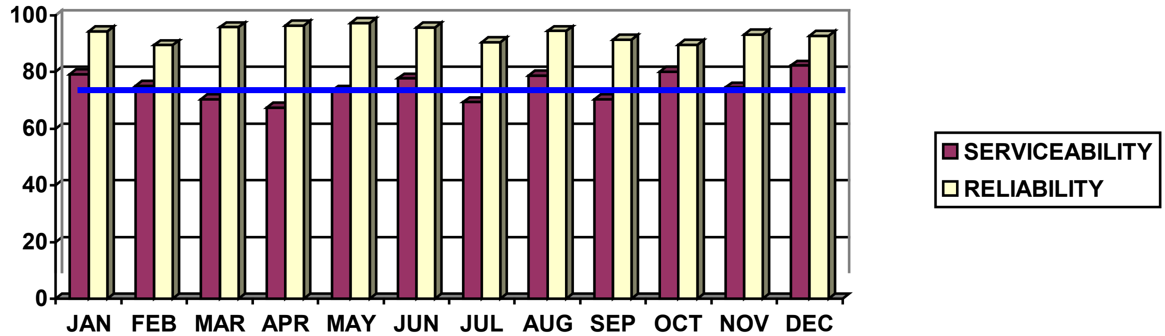
All the items have a service life and a periodically testing time limit. On their inspection high standards are maintained. Their reliability depends upon the schedule maintenance and inspections. If the standards are maintained the support elements become integral part of success factor.

To maintain the high standards of serviceability and reliability, PAF spends a handsome amount of budget on maintenance, inspections, processes and procedures. If the ground crew are not very well trained and are put on sensitive equipment to work, they may cause a heavy loss to the equipment and to the nation as a whole. To avoid the losses, the quality assurance department emphasis on the standards, procedures, processes and also emphasis on Total Quality Management and high quality of work. The teams in every field and the quality specialists ensure high standards of work. However at times it is difficult to arrest the negligence, casual and careless attitude. This lack of professionalism directly affects the serviceability & reliability of any squadron. Here are some serviceability and reliability record for years 2001-2003 for reference. You can well appreciate that how the declining trend of serviceability has been arrested gradually by the PAF.

SERVICEABILITY / RELIABILITY
X-Type A/C
(2001-2003)

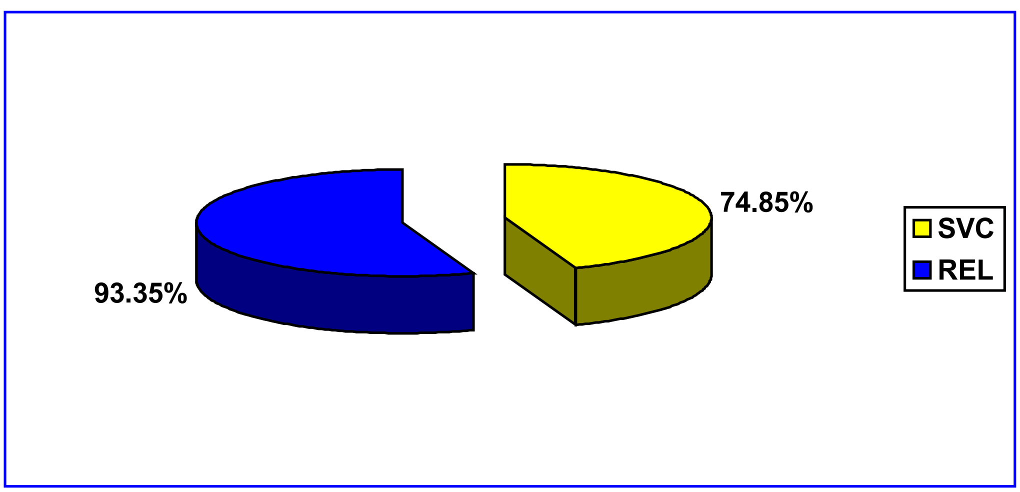
	2001		2002		2003	
	SER %	REL %	SER %	REL %	SER	REL
JANUARY	79.22	94.24	90.8	91.1	77.9	87.0
FEBRUARY	75.08	89.43	88.2	91.1	79.3	85.1
MARCH	70.34	96.34	87.8	96.5	78.6	84.4
APRIL	67.45	97.3	87.2	93.2	77.0	91.6
MAY	73.4	95.6	82.2	95.5	83.2	93.9
JUNE	77.7	90.4	89.5	98.9	83.4	94.2
JULY	69.36	94.44	89.5	93.7	79.2	91.3
AUGUST	78.69	91.30	79.8	94.0	74.4	98.0
SEPTEMBER	70.3	89.6	82.2	93.6	78.9	93.4
OCTOBER	80.06	93.16	**69.3**	96.6	78.6	93.5
NOVEMBER	74.5	92.7	83.3	91.5	82.3	95.5
DECEMBER	82.2	95.8	78.9	93.3	88.9	97.56

Serviceability / Reliability
X-Type A/C
2001

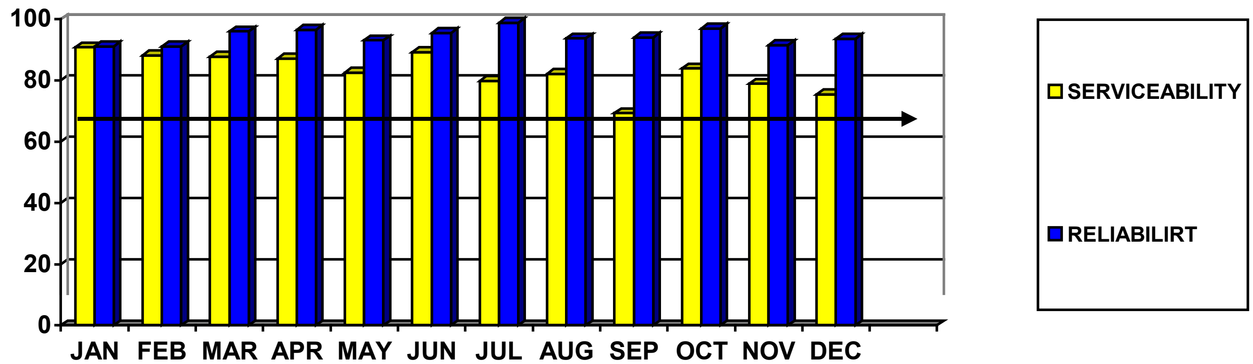


Base Line For Serviceability 75% & Reliability 90%

Serviceability / Reliability
2001

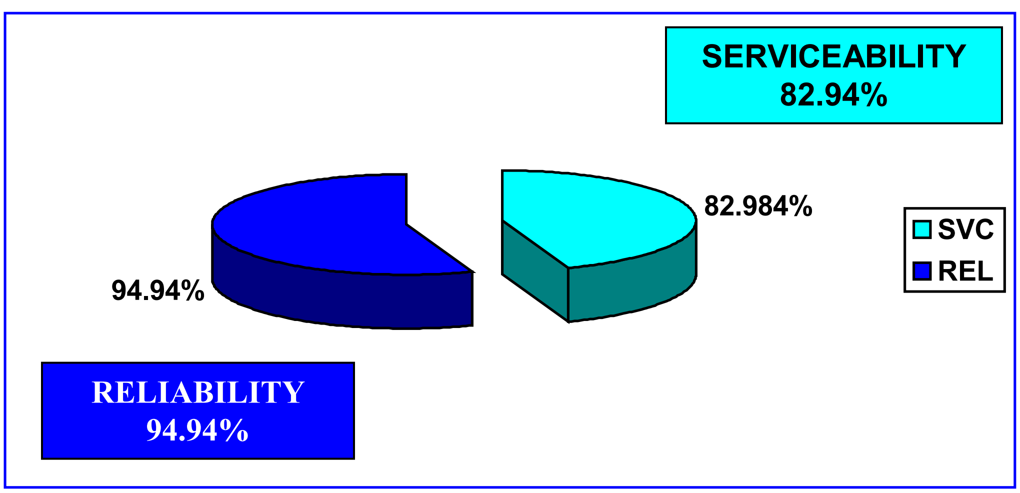


Serviceability / Reliability
X-Type A/C
2002

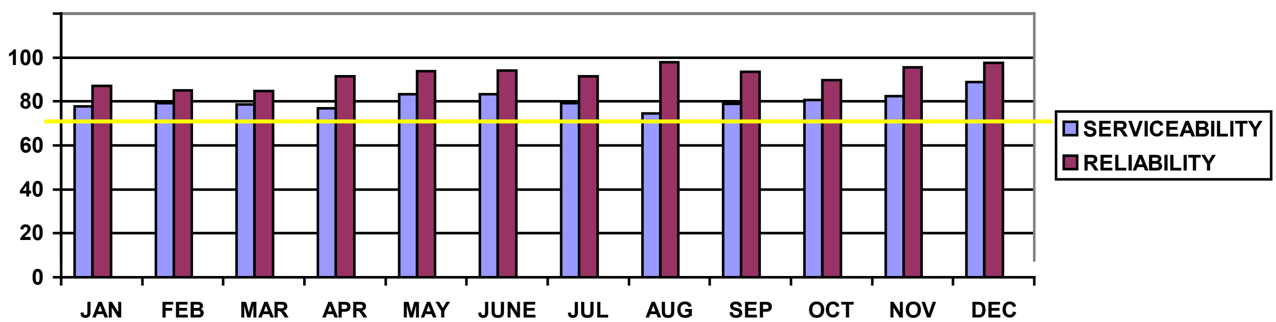


Base Line For Serviceability 75% & Reliability 90%

Serviceability / Reliability
2002

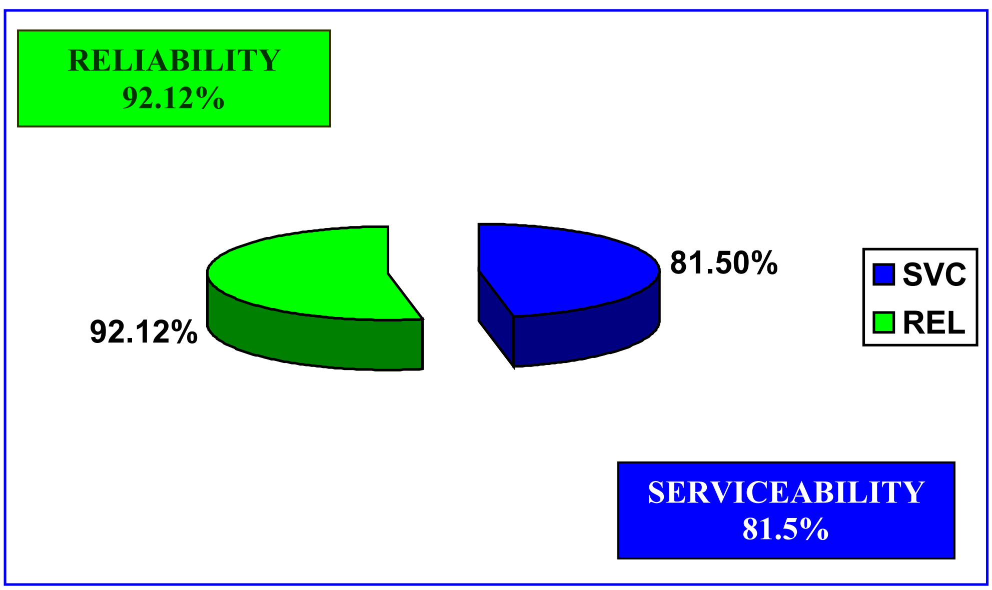


Serviceability / Reliability
X-Type A/C
2003



Base Line For Serviceability 75% & Reliability 90%

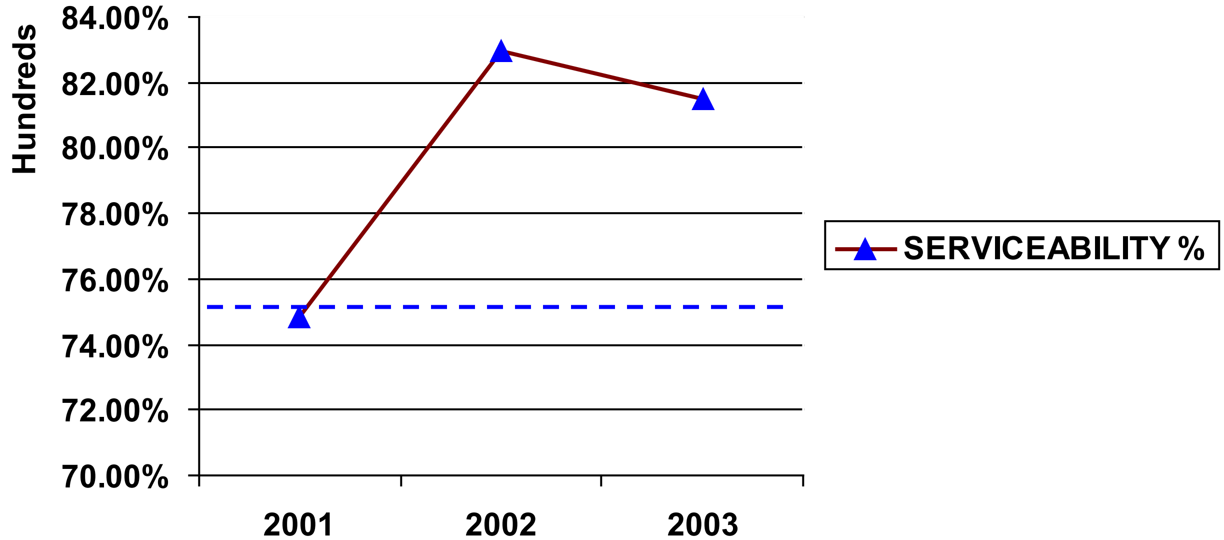
Serviceability / Reliability
2003



Serviceability Record

X-Type A/C

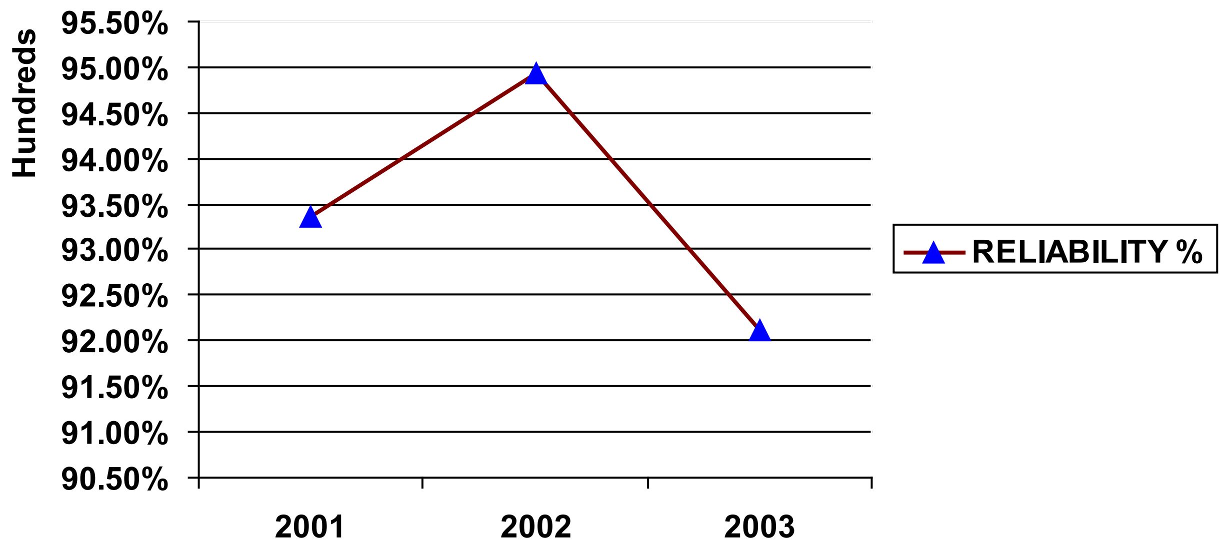
2001-2003



Reliability Record

2001-2003

X-Type A/C



From 2001 to 2003, PAF had initiated number of training programs / refresher courses for inspections & maintenance to achieve and maintain the serviceability / reliability above the desired standards. In doing so it has spent huge amount of foreign exchange. One major accident cost an aircraft, an experienced pilot, may be few lives on ground and loss of property that PAF has to pay. This cost is included in cost of poor quality of maintenance standards.

The AORs helps in formulating the trend of occurrences, rectification and preparing to arrest the trend for the future occurrences. A general concept of AOR reporting is, that it effects the overall grading for the Flight Safety Trophy. However, in actual it is not like that. PAF squadrons need to adhere to the AOR policy and must not try to avoid reporting of AORs.

CHAPTER-9

ANALYSIS ON
COST OF NON-CONFORMANCE IN AIRCRAFT MAINTENANCE

Types of Costs

Failure Cost

The costs incurred by a company because the product or service did not meet the requirements and the product had to be fixed or replaced or the service had to be repeated. These failure costs can be further subdivided into two groups - internal or external failures.

- Internal Failure Costs

  Internal failure costs include failure in any of the following inspections: -

  - Scheduled Inspections and Unscheduled Inspections
  - Flight Line Inspections
  - Quality Verification Inspections (QVI)
  - Rectification Quality Verification Inspections

- External Failure Costs

  These costs include: -

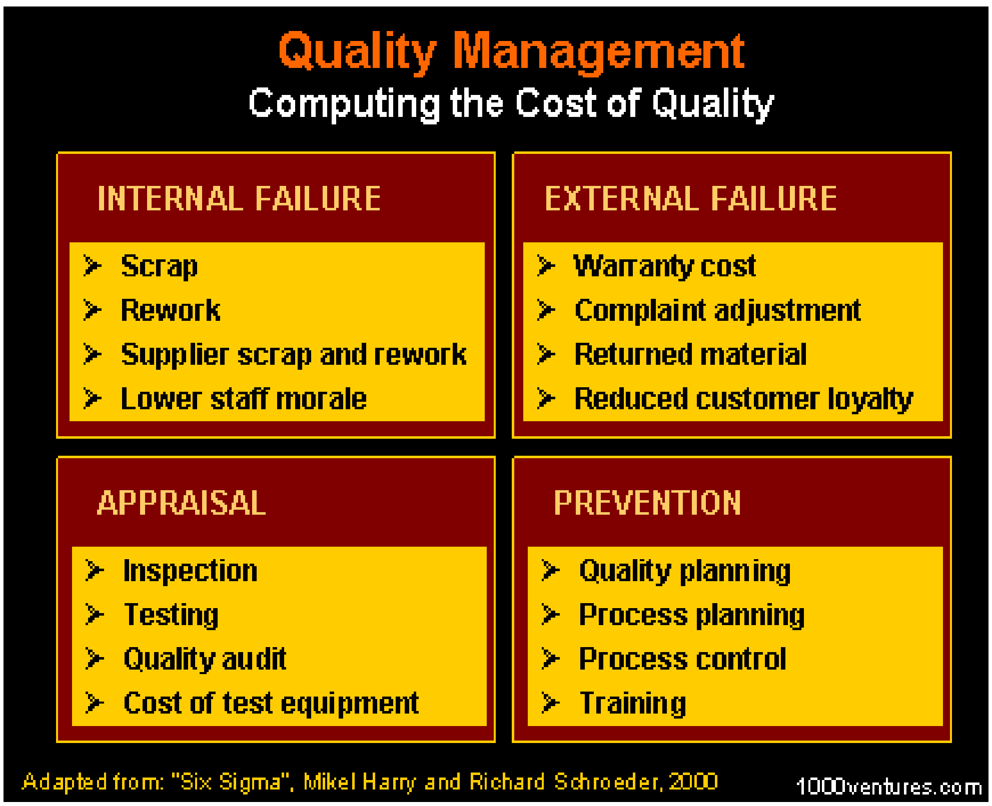
  - Unsatisfactory reports (URs)
  - Air Occurrence Reports (AORs)
  - Costs of Violations
  - Functional Check Flights (FCF)

- Appraisal Costs

  These include Special Inspection (SI) costs, cost of verification, checking, evaluating, internal product audit, inspection activities, inventory cost, quality administration, supplier evaluation and audit reports. These are mainly related to testing of tools, testers and non-powered support equipment.

- Prevention Costs

Prevention costs in Pakistan Air force are mainly concerned with training such as costs of Personnel Evaluation (PEs). It generally include education, continuous improvement, process control, quality control, market research, field-testing, and prevention measures.



Air Craft Quality Verification Inspection

Year 2002: Primary Maintenance Flight

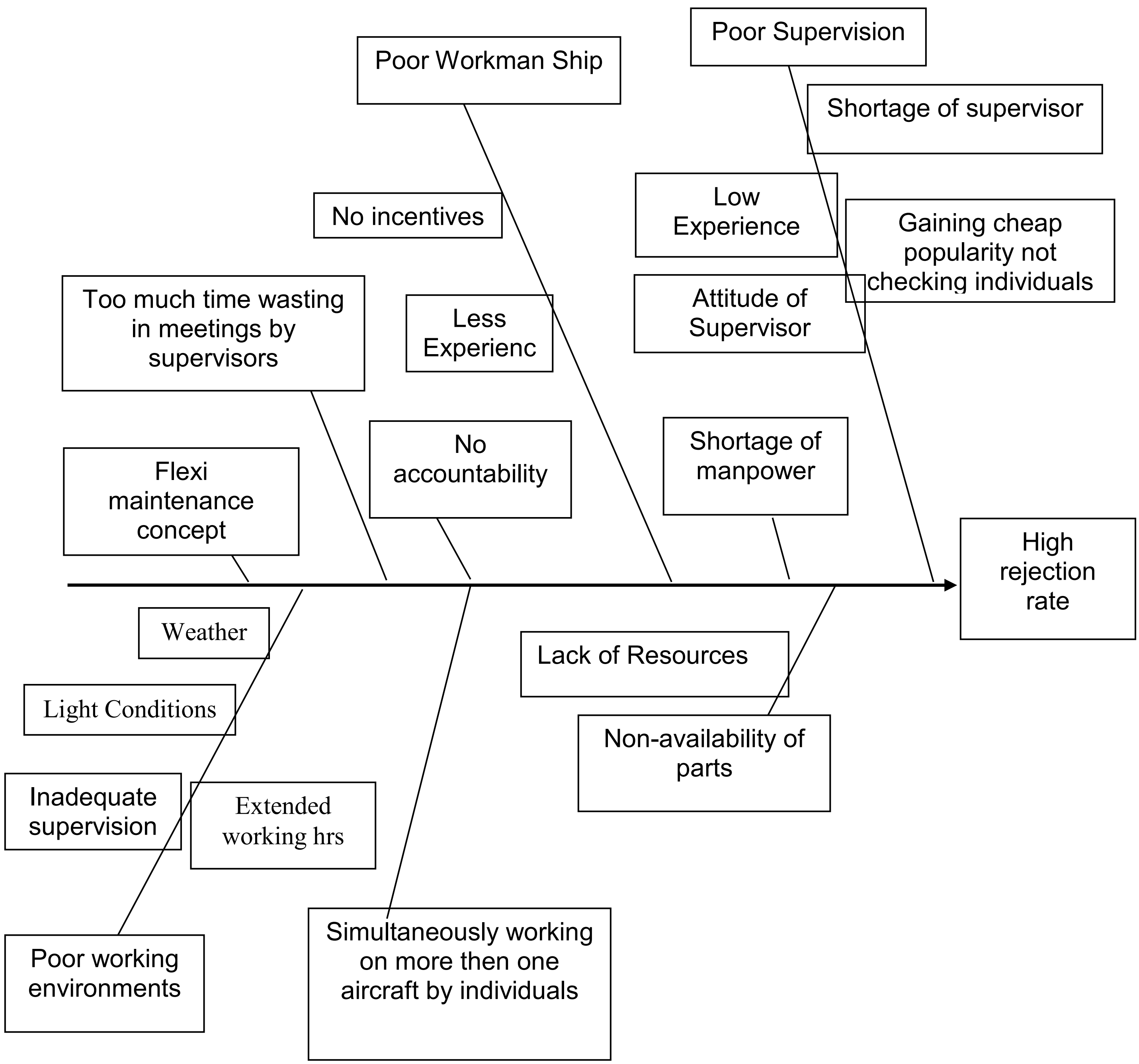
Internal Failure Costs

Hours	Performed	Pass	Fail	Rejection Rate %
50	43	26	16	39.4
100	17	6	11	64.71
200	19	9	10	52.64

In year 2002, Quality Verification Inspection of Primary Maintenance Flight, at 50 hours inspection the rejection rate was 39.4 %, in 100 hours the rejection rate was 64.71 % and in 200 hours the rejection rate was 52.64 %.

Analysis of High Rejection Rate

The reasons of high rejection rate are shown in the cause-effect diagram: -



Major Defects Reported in QVI

Following are the major defects found during the Quality Verification Inspection in year 2002: -

a) Electrical Short Circuiting
b) Landing Gear Malfunctioning
c) Control Problem
d) Hydraulic Leaks
e) Pneumatic System Defects
f) Foreign Object Damage in Engines and Cock Pit area
g) Fuel Leak

Quality Verification Inspection of 516 Tactical Attack Squadron (TAS)

Following table shows the data of Quality Verification Inspection of 516 Tactical Attack Squadron carried out in year 2002.

Air Craft Quality Verification Inspection

Year 2002: 516 TAS

	Performed	Fail	Rejection Rate %
Pre Flight	48	24	50
Through	23	10	44
Post	35	12	35
Weekly	43	18	42
25 Hrs	40	17	42.5

Quality Verification Inspection of 286 TAS

Following table shows the data of Quality Verification Inspection of 286 Tactical Attack Squadron carried out in year 2002.

	Performed	Fail	Rejection Rate %
Pre Flight	48	21	43.75
Through	23	9	39.14
Post	35	14	40
Weekly	43	19	41.31
25 Hrs	40	16	38.1

Rating of Special Inspections (SI)

Special Inspection is rated as "Pass" or "Fail". The "Pass" or "Fail" criteria is locally developed against the given work reference/ procedures.

Special Inspections – 2002

The data of special inspections in year 2002 is evaluated and is shown below in the table: -

Performed	Failed	Rejection Rate %
4494	726	16.15

Personnel Evaluation-2002

The data of Personnel Inspections in year 2002 is evaluated and is shown below in the table: -

Performed	Failed	Rejection Rate %
2,221	287	12.92

Causes of High Failure Rate of Personnel Evaluation

Following are the causes of high failure rate of personnel evaluation carried out in year 2002.

- Trainee-trainer shift mismatch
- Lack of supervision and management
- Low experience
- Poor working environments

Violations

Following are the violations monitored during the QA activities:-

Year 2002 – Violations

Technical Data Violation	Detected Safety Violation	Special Observation
97	300	83

CHAPTER- 10

ANALYSIS OF UNSATISFACTORY REPORTS

Unsatisfactory Reports (URs)

Work center raises an unsatisfactory Report whenever any component or equipment failure occurs before its life is expired. The following table shows URs raised during 2002 for various components.

Aero Engines	37
Main Hydraulic Pump	33
Main Fuel Pump	08
Miscellaneous	78
Total	156

Mean Time between Failures

The following table gives the description of the mean time between failures of the life components along with their total lives calculated on average only for the year 2002.

Description	Life	MTBF
Aero Engines	150 HRS	65.49
Hydraulic Pump	200 HRS	129.07
After Burner Fuel Pump	150 HRS	70.3

Unsatisfactory Reports: 2002
Aero Engine

Material Failure	08
Human Factor	10
Not Confirmed	11
Miscellaneous Factor	08
Total	37

The total number of rejections in the year 2002 were 37, the over hauling cost for one engine is Rs.2, 337,000.0, therefore the total cost of non-conformance comes out to be Rs. 86.469 Million.

For overhauling of an engine, it has to be transported from the Pukar base to Samundar. The cost for this transportation of engines for the overhauling is Rs 0.8 million. Average engines that can be transported per sortie are four. Therefore the total number of sorties required to airlift 37 engines is ten. Once the overhauling is done the engines are to be brought back from the Samundar Base to Pukar so an additional ten sorties will be required making 20 sorties in total. Therefore, the cost of 20 sorties calculated by simply multiplying 0.8 million by 20 we get Rs.16 million

Now, the total cost comes out to be Rs. 102.469 million by simply adding the overhauling Cost and the transportation cost.

Main Hydraulic Pump: 2002

Material failure	28
Human factor	01
Not confirmed	01
Miscellaneous factor	03
Total	33

The total number of rejection of pump in the year 2002 was 33 while the over hauling cost for one pump is Rs.17,100.0 therefore the total cost of non-conformance comes out to be Rs.0.56 million.

The Cost of one new is pump Rs.171, 000.0 and the number of average pumps written off during the year 2002 found out to be six, therefore the total cost of non-conformance calculated is 171,000.0x6 = RS.1.026 million.

Therefore the total rejection cost by adding overhauling cost and the cost of new pumps we get a total of Rs.1.59 million.

Functional Check Flight (FCF)

Functional Check Flight (FCF) performed on total of 161aircraft. Out of which 132 got cleared on first attempt while rest of them cleared in subsequent attempts. A total of 29 additional sorties were flown.

Unit	1ST CLR	2ND CLR	3RD CLR	4TH CLR	Total
516 TAS	49	7	1	0	57
286 TAS	46	3	0	3	52
PMF	37	10	2	3	52
TOTAL	132	20	3	6	161

Cost of Non-Conformance for FCF

The average cost of one sortie is Rs.0.256 million[8]. A total of 29 additional sorties were flown. The cost of cost of non-conformance for FCF sorties comes out to be to be Rs.7.42 Million.

Aircraft Quality Verification Inspections

In the following table there is a comparative analysis of QVI for two fighter squadrons located at one of the PAF operational base. The rejection rate in the year 2001 was 49.09% followed by a rejection rate of 44.33% in 2002, and a rejection rate of 47.73 in the year 2003.

	2001	2002	2003
Performed	418	467	528
Passed	213	260	276
Rejection Rate %	49.04	44.33	47.73

Rectification QVIs

The following table shows the comparative analysis of 3-years time period for any premature failure of the components. In 2001 the rejection rate for rectification QVI was 13.58%. In year 2002 the rejection rate was found to be 18.8% and lastly in 2003 it was 18.44%.

	2001	2002	2003
Performed	383	1129	1166
Passed	331	917	951
Rejection Rate %	13.58	18.8	18.44

[8] Directorate of Budget, PAF

Special Inspections(SI)

The table for the Special Inspections shows the following data. In the year 2001 the rejection rate was 17.63%. In 2002 it was around 16.15% and in 2003 there was a dramatic decline in the rejection rate and it was 9.02%.

	2001	2002	2003
Performed	4255	4494	4203
Passed	3505	3768	3824
Rejection Rate	17.63 %	16.15%	9.02%

Personnel Evaluation (PE)

The rejection rate for PE in 2001 was 46.23%, in 2002 it was 12.92% and in 2003 was 51.58%. The reduction in rejection rate in 2002 was due to extra coaching and additional training programs. However, the same could not be continued in true sprit because of operational commitment of PAF due to deploying of flying units at dispersed location against war against terrorism.

	2001	2002	2003
Performed	623	2221	1014
Passed	335	1934	491
Rejection Rate	46.23%	12.92%	51.58%

Unsatisfactory Reports

The rejection rate due to the premature failure of any component causes the Unsatisfactory Reports. In 2001 there were 144 URs followed by 156 in 2002 and 102 in 2003.

	2001	2002	2003
Aero Engine	40	37	42
Hydraulic Pump	38	33	46
Main Fuel Pump	10	08	09
Miscellaneous	56	78	05
Total	144	156	102

Violations

The violation like all other fields can lead to extremely dangerous situation. The total number of violations was 686 in 2001,480 and 445 in the year 2002 and 2003 respectively.

	2001	2002	2003
Tech data Violation	69	97	112
Detected Safety Violation	302	300	165
Special Observations	315	83	168
TOTAL	686	480	445

Aero Engines

External failure costs are due to the failure in the Aero Engine that can be because of material failure, human failure and some collective failures. The comparative analysis for the 3 years is as below.

	2001	2002	2003
Material Failure	07	08	10
Human Failure	12	08	05
Not Confirmed	15	14	11
Miscellaneous Factor	06	07	16
TOTAL	40	37	42

Main Hydraulic Pump

Main Hydraulic Pump is another part that can be a cause of external failure cost. The record of the non-conformance is shown in the following table.

	2001	2002	2003
Material Failure	33	28	40
Human Failure	--	01	--
Not Confirmed	--	01	03
Miscellaneous Factor	05	03	03
Total	38	33	46

The rise in rejection rate is an alarming condition for any organization. PAF had some trend of high rate of rejection in aircraft maintenance, which were due to many direct / indirect contributing factors. To arrest this trend PAF's quality assurance has devised procedures for checking the root causes and to eliminate them. The QA officer identifies the problems and informed the top management. The identification is being done through various quality inspections.

Unsatisfactory Reports

The unsatisfactory reports are raised whenever any equipment or component failure takes place before items life expires. Every component has a life. The record of items continuously remains under check. Generally the components failure takes place due to various reasons such as: -

- Material failure
- Human failure. Human error during installation or servicing any component
- Miscellaneous factors. It reflects any contributing factors, which makes the component failure
- The reasons for failure, which could not be established, justified or classified, come under undetermined, and not conformed

Material Failure

The material failures are generally occurs due to following reasons

- Expiry of life of any component
- Over or under torque application by the technician
- Temperature variation, over heat conditions
- Over stressed flight conditions
- Environmental changes like extreme hot and cold temperatures where the seals generally most affected
- Non-standard component installation

Human Factor

The rise in the rejection rate and the unsatisfactory reports are mainly caused by the human factor. The human failure directly affects the maintenance of an aircraft and raises the cost of quality working. Some of the main reasons are as follows: -

- Shortage of trade wise manpower
- Extended working hours
- Working simultaneously on two or more aircraft
- Poor working environments and weather effects
- Lack of professional knowledge
- Lack of interest
- Lack of motivation
- Lack of training
- Poor workmanship
- Lack of supervision
- Shortage of desired tool available at working place
- Working without consulting technical orders instruction
- Fear of being tested, inspection, being observed by the quality inspector
- Due to pressure from officer commanding, flight commander and engineering officer for early recovery of aircraft for subsequent flying
- Taking short cut in maintenance
- Changing of manpower / technicians working on aircraft due to pack up/ shift change
- No concept of team work on aircraft till completion of work
- Individual personal problems

Violations

The violations on technical, safety and special observations lead to the rise in rejection rate and thus increases the cost of quality in maintenance. These are basically due to: -

- Shortage of manpower
- Time compression during exercises
- Non availability of technical orders
- Not securing the aircraft systems which could results on some damage like: -
  - Parking aircraft without earthing
  - Working on ejection system without ensuring safety of seat cartridges
  - Working on aircraft weapon firing system without proper cautions, procedures etc
- Opening of oil / hydraulic cans with screw driver (normal practice) instead of using can opener
- Not using specialized tools while working on aircraft

CHAPTER-11

AIR OCCURENCE REPORT
(AOR)

The AOR is a general term used in aviation for any occurrence or accident. AOR is raised whenever an A/C experiences malfunctions that warrant it to land as soon as possible. It is a brief initial report prior to the final investigation on any occurrence. It reflects the date, aircraft number, type, time of occurrence, whether the occurrence took place on ground or air, the visible damage to the equipment, property, loss of life, causes, factors etc. For any occurrence that takes place on an aircraft with or without any damage, an AOR is raised to the air headquarters.

The AOR's can be classified as major in flight / ground, minor in flight / ground. The record of all the AOR are kept to track any specific trends or causes of accidents. All the squadrons of PAF have their own record maintained by flight safety officer at the base level and flight safety directorate at AHQ's level.

In case of an AOR after take off, pair recovery is mandatory and the mission of both the pilots is considered "abort" and it has to fly again. It means the cost of one mission of two aircraft is further added in the total expected flying budget. At times mission is of larger number of aircraft and all aircraft to recover without completion of mission, there fore the cost of all recovering aircraft and rescheduling of mission is added. Mostly such missions are aborted due to some technical problems, which can aggravate the situation if pressed on. However, if the mission is aborted on ground before take off and no damage to the aircraft, only the cost of fuel is added in the total. At present a sortie of a single fighter aircraft is costing approximately Rs. 256,000 per hr.

On a fighter base with two fighter squadrons, there were 110 and 175 AORs during 2002 and 2003 respectively. Out of these (110,175) AORs, 74 and 109 were due to pure maintenance problems. The additional cost of mission, cost of part replaced, man hrs, inspections, functional check flight etc can be calculated as:-

<u>2002</u>

- Rs. 256,000.0 = cost of one sortie
- 74 x 2 = 148 wasted sorties
- 74 x 256,000.0 = Rs. 18,944,000.0 (Problem Aircraft)
- 74 x 256,000.0 = Rs. 18,944,000.0 (Escorting Aircraft –Wasted Sortie)
- Cost of 148 sorties 37,888,000.0
- Maintenance + part + man hrs cost
- Functional Check Flight

Similarly the cost for year 2003 can also be calculated. During the year 2003 total Number of AOR were 175. The completed missions during the year were 66. Un accomplished missions were 109 and the sorties wasted were 218. Therefore, the cost of non-conformance is Rs. 55.808 million.

<u>2003</u>

- 109 x 2 = 218 wasted sorties
- 109 x 256,000.0 = Rs 27,904,000.0 (Problem Aircraft)
- 109x 256,000.0 = Rs 27,904,000.0 (Escorting Aircraft –Wasted Sortie)
- Cost of 218 sorties 55,808,000.0
- Maintenance + part + man hrs cost
- Functional Check Flight

Some of the maintenance related AOR for year 2002 & 2003 are shown for the reference of calculation of cost of poor quality in aircraft maintenance, PAF is paying every year.

TYPES OF AOR DUE POOR MAINTENANCE 2002-03

AORs ABC Type Aircraft

S/ NO	AOR NO DATE	BRIEF DESCRIPTION	CAUSE/ FACTOR	COST
01	12-2-2002	During post flight, no 2 tank fuel booster pump panel found missing	Human factor- ground crew-in adequate maintenance	Rs. 30,000.0
02	5-3-2002	Boost hydraulic pressure dropped to zero in air. On post flight heavy leak was observed	Human factor, ground crew- improper installation of pipe	2 x Rs. 256,000.0+ Rs 181800.0 + Maint cost + Rs 20,000.0 cost of ground run + 256,000.0 cost of FCF
03	8-3-2002	After take off left main gear did not go up	Adjustment of left gear actuator at the upper limits by ground crew	2 x 256,000.0 + cost of actuator + maintenance + inspection on hydraulic test bench
04	22-3-2002	Just after takeoff main hyd light came on and pressure dropped to zero	Human factor- ground crew- improper inspection & installation of main Hyd pump	2 x 256,000.0 + Rs 181800.0 cost of Hyd pump + actuator + inspection on hydraulic test bench + 256,000.0 cost of FCF
05	14-4-2002	During recovery main air pressure dropped to zero	Improper installation of canopy actuator	Cost of new Actuator +Rs. 256,000.0 cost of FCF
06	9-6-2002	Both drop tanks jettisoned in air	Electric short circuiting of No-5 switch	Rs. 80,000.0+ Rs. 256,000.0 +Rs. 256,000.0
07	19-6-2003	Fire warning light came on in air	China made bulb FJ-20 was installed in lieu of French made	Rs. 256,000.0 x 2+ cost of new Bulb.

			ASTRA-313	
08	19-7-2003	When power was retarded below 95000 RPM, left engine compressor stalled with roaring / pulsating noise with loss of thrust and EGT rise	Inadequate maintenance – ground crew. Misalignment of centrifugal valve during tuning of engine	Cost of engine Rs. 337000.0 + Maintenance + ground run + 256,000 cost of FCF
09	28-9-2003	During taxi rudder movement was restricted. A/C switched off on taxi track	Causes of occurrence is installation of masking tape on trailing edge of vertical edge	Could have gone out of control and hit any obstacle – loss of a/c, loss of life, major damage to a/c, property

During the year 2002-2003 the cost PAF paid due to the poor quality of work was Rs. 37.888 million & 55.808 million respectively.

Causes of Air Occurrence

Some of the AORs that, requires immediate recovery are as follows: -

- Landing Gears
- Radio Failure
- Pneumatic pressure failure
- Vibrations
- Compressor Stall
- Oil Failure
- Electrical Malfunction
- Hydraulic System Failure
- Fire warning light coming on in air
- Bird hit

CHAPTER – 12
Hidden Cost

Whenever any weapon system (aircraft) is purchased, the Original Engineering Manufacturer (OEM) defines maintenance / inspection schedule of various components. In case of Chinese system described here, the maintenance / inspection schedule define by the OEM[9] is as under: -

- 50 hrs inspection – 07 days for maintenance / inspection
- 100 hrs inspection – 12 days for maintenance / inspection
- 200 hrs inspection – 17 days for maintenance / inspection
- Weekend / Holidays – Not included

PMF Data for Aircraft 50 Hours Inspection (Jan to Dec, 03)

S.No	TYPE OF INSPECTION	DATE IN	TIME SCALE	DATE OUT	DELAY/HOLIDAY	ACTUAL DELAY
1	50 HRS	9/1/2003	7 DAYS	24/1/03	7 / 2	4
2	50 HRS	24/1/03	7 DAYS	12/2/03	10 / 3	-
3	50 HRS	24/1/03	7 DAYS	12/2/03	10 / 3	4
4	50 HRS	13/2/03	7 DAYS	28/2/03	7 / 2	6
5	50 HRS	26/2/03	7 DAYS	12/3/03	6 / 2	3
6	50 HRS	26/2/03	7 DAYS	14/3/03	8 / 2	-
7	50 HRS	26/2/03	7 DAYS	28/4/03	--	-
8	50 HRS	16/3/03	7 DAYS	28/3/03	4 / 2	-
9	50 HRS	22/3/03	7 DAYS	31/3/03	2 / 1	-
10	50 HRS	28/3/03	7 DAYS	23/4/03	15 / 5	4
11	50 HRS	11/4/2003	7 DAYS	28/4/03	10 / 1	-
12	50 HRS	24/4/03	7 DAYS	14/5/03	10 / 4	-
13	50 HRS	8/5/2003	7 DAYS	14/5/03	--	-
14	50 HRS	17/5/03	7 DAYS	24/5/03	--	-
15	50 HRS	26/5/03	7 DAYS	4/6/03	1 / 2	-
16	50 HRS	7/6/2003	7 DAYS	15/6/03	--	-
17	50 HRS	13/6/03	7 DAYS	28/7/03	--	-
18	50 HRS	19/6/03	7 DAYS	30/6/03	3 / 1	-
19	50 HRS	22/6/03	7 DAYS	17/7/03	14 / 5	14
20	50 HRS	2/7/2003	7 DAYS	21/7/03	9 / 3	4
21	50 HRS	18/7/03	7 DAYS	31/7/03	5 / 2	5
22	50 HRS	6/8/2003	7 DAYS	24/8/03	10 / 2	1
23	50 HRS	15/8/03	7 DAYS	25/8/03	3 / 1	2
24	50 HRS	16/8/03	7 DAYS	29/8/03	5 / 2	-
25	50 HRS	16/8/03	7 DAYS	25/8/03	2 / 1	2
26	50 HRS	23/8/03	7 DAYS	15/9/03	10 / 3	5
27	50 HRS	27/8/03	7 DAYS	15/9/03	10 / 3	4
28	50 HRS	4/9/2003	7 DAYS	19/9/03	6 / 3	3
29	50 HRS	11/9/2003	7 DAYS	20/9/03	2 / 1	2

[9] PAF Aircraft Maintenance Manual

30	50 HRS	25/9/03	7 DAYS	4/10/03	- / 1	-
31	50 HRS	26/9/03	7 DAYS	26/9/03	2 / 3	2
32	50 HRS	17/10/03	7 DAYS	26/10/03	1 / 1	1
33	50 HRS	2/11/203	7 DAYS	16/11/03	3 / 4	2
34	50 HRS	10/11/2003	7 DAYS	22/11/03	5 / 2	2
35	50 HRS	22/11/03	7 DAYS	30/11/03	- / 1	-
36	50 HRS	13/11/03	7 DAYS	20/11/03	- / 6	-
37	50 HRS	26/11/03	7 DAYS	5/12/03	1 / 1	1
38	50 HRS	22/12/03	7 DAYS	28/12/03	- / 1	-
						71

Total Delay in days = 71
Aircrafts less produced 71/ 7 = 10.14

PMF Data for Aircraft 100 Hours Inspection (Jan To Dec, 03)

S.No	TYPE OF INSPECTION	DATE IN	TIME SCALE	DATE OUT	DELAY/HOLIDAY	ACTUAL DELAY
1	100 HRS	1/1/2003	12 DAYS	23/1/03	7 / 4	8
2	100 HRS	1/1/2003	12 DAYS	22/1/03	6 / 4	6
3	100 HRS	23/1/03	12 DAYS	27/2/03	18 / 6	5
4	100 HRS	3/1/2003	12 DAYS	7/2/03	15 / 9	--
5	100 HRS	7/2/2003	12 DAYS	23/3/03	28 / 5	23
6	100 HRS	22/3/03	12 DAYS	16/4/03	8 / 5	--
7	100 HRS	9/4/2003	12 DAYS	4/5/03	11 / 3	6
8	100 HRS	25/4/03	12 DAYS	26/5/03	15 / 5	4
9	100 HRS	30/4/03	12 DAYS	29/6/03	39 / 10	22
10	100 HRS	14/5/03	12 DAYS	18/06/03	18 / 6	6
11	100 HRS	7/6/2003	12 DAYS	28/6/03	7 / 3	3
12	100 HRS	12/6/2003	12 DAYS	3/8/03	33 / 8	13
13	100 HRS	20/7/03	12 DAYS	11/8/03	7 / 4	5
14	100 HRS	20/07/03	12 DAYS	3/8/03	1 / 2	--
15	100 HRS	23/7/03	12 DAYS	3/9/03	24 / 7	12
16	100 HRS	13/8/03	12 DAYS	6/9/03	9 / 4	--
17	100 HRS	12/9/2003	12 DAYS	4/10/03	7 / 3	1
18	100 HRS	19/11/03	12 DAYS	10/12/03	7 / 3	--
19	100 HRS	26/11/03	12 DAYS	27/12/03	--	--
20	100 HRS	26/12/03	12 DAYS	30/12/03	--	--
						114

Total Delay in Days = 114
Aircrafts less produced 114 / 12 = 9.5

PMF Data for Aircraft 200 Hours Inspection (Jan To Dec, 03)

S.No	TYPE OF INSPECTION	DATE IN	TIME SCALE	DATE OUT	DELAY/HOLIDAY	ACTUAL DELAY
1	200 HRS	7/2/2003	17 DAYS	21/4/03	45 / 12	14
2	200 HRS	2/3/2003	17 DAYS	9/4/2003	13 / 8	13
3	200 HRS	16/4/03	17 DAYS	12/6/2003	31 / 10	4
4	200 HRS	19/4/03	17 DAYS	4/6/2003	28 / 10	14
5	200 HRS	4/7/2003	17 DAYS	13/8/03	16 / 8	--
6	200 HRS	14/7/03	17 DAYS	7/8/2003	3 / 5	--
7	200 HRS	31/803	17 DAYS	27/9/03	5 / 6	4
8	200 HRS	12/9/2003	17 DAYS	19/10/03	14 / 6	7
9	200 HRS	21/9/03	17 DAYS	20/10/03	7 / 5	--
10	200 HRS	4/10/2003	17 DAYS	8/11/2003	14 / 4	4
11	200 HRS	17/10/03	17 DAYS	13/11/03	7 / 3	2
12	200 HRS	19/11/03	17 DAYS	12/12/2003	3 / 3	3
13	200 HRS	10/12/2003	17 DAYS	4/1/2004	-- / 7	--
						65

Total Delay in Days = 65
Aircrafts less produced 65 / 17 = 3.8
"Total less A/C produced = 10.14+9.5+3.8 = 23.44
or 23 Aircraft

<u>Affects of Production delays.</u>

In any air force of the world, all the aircraft are planned to complete their life simultaneously, the production delays disturb the staggering of aircraft and create following problems: -

- Less number of aircraft available for flying
- Few aircraft made to fly more to complete the daily / monthly flying task
- Staggering of aircraft gets disturb
- Chances of canalization of aircraft components
- Less time available for maintenance for other aircraft due to extra flying

The analysis reveals that the maintenance is not according to the desired requirements. The less number of aircraft produced during 50,100 and 200 hrs inspection indicates that the squadrons are not at the desired level of serviceability and reliability. In case of any contingency the PAF would not have the desired aircraft ready to meet the challenges. To overcome the shortage of aircraft, at the time of emergency it would lead to incomplete and improper maintenance, subsequently raising the cost of maintenance. **The engineering wings must lay emphasis on timely delivery of aircraft. These aircraft are included in the serviceability (75%) and reliability (90%) calculations**. To fulfill the requirements, PAF needs to look after the causes for these delays. Some of the reasons are as follows: -

- Non availability of parts
- Shortage of man power
- Poor working environments
- Poor work man ship
- Poor supervision
- Lack of individuals motivation and sprit
- Flexi maintenance concept
- No accountability
- Too much time wasting in meeting by supervisors
- Simultaneously working on more then one aircraft by individuals

CHAPTER-13

COST OF NON-CONFORMANCE

Cost Of Aircraft Components[10]

For the analysis purpose, the cost of some components is given below. The cost keeps on varying in accordance with the changes of foreign currency exchange rates.

COMPONENT	COST IN $ US	COST IN PK Rs. @60.60 29-10-04	OVERHAULLING COST
PNEUMATIC SOLENOID VALVE	480.0	29,088.0	-
HYDRAULIC PUMP	3,000.0	181,800.0	17,100.0
AERO ENGINES	726,000.0	43,995,600.0	2,337,000.0
MAIN FUEL PUMP	4,640.0	281,184.0	20,000.0
AFTER BURNER FUEL PUMP	4640	281184	20,000
BOOSTSTABLIZER PUMP	12,320.0	746,592.0	-
ARU-ARM RAGULATOR UNIT	12,750.0	772,650.0	-

The unsatisfactory reports (UR) of Aero Engines for the year are shown in the table below.

Unsatisfactory Report For The Year 2002-2003

	2002	2003
AERO-ENGINE	37	42
HYDRAULIC PUMP	33	46
MAIN FUEL PUMP	08	09
MISCELLANEOUS	78	05
TOTAL	156	102

[10] Directorate of Budget, PAF

Aero-Engines

The cost of nonconformance for the aero engines can be calculated as below: -

- Cost of new engine $ 726,000.0 = Rs. 43,995,600.0 (@ $ 1= Rs. 60.60)
- Total rejection 37
- Cost of overhauling Rs. 2,337,000.0
- Cost of nonconformance for 37 engines which was overhaul during 2002

  37 x 2,337,000.0 = 86.469 Million
- Cost of 1 C-130 Sortie Rs. 800,000.0
- Total # of engines can be air lift in one sortie 4
- Total sorties required lifting 37 engines 10
- Total sorties for replacement of engines 10+10= 20
- Cost of sorties 20 x 800,000 = 16,000,000.0 = 16 M
- Rejection cost of 37 engines = 86,469,000.0+16,000,000.0 = 102 Million

Hydraulic Pumps

The cost of nonconformance for the Hydraulic pumps can be calculated as below: -

- Cost of new Hydraulic Pump $ 3000.0 = Rs 181,800.0 (@ $ 1= Rs. 60.60)
- Total rejection 33
- Cost of overhauling Rs. 17100.0
- Cost of nonconformance for 33 pumps which was overhaul during 2002

  33 x 17,100.0 = Rs. 564,300.0
- Cost of 6 new hydraulic pumps 6 x 181,800.0 = Rs 1,090,800.0
- Total cost of pumps during 2002 = 1,090,800.0 + 564,300.0 = Rs. 1,655,100.00
- Cost of non conformance for Hydraulic Pumps 1.6 Million

Functional Check Flight (FCF)

The cost of nonconformance for the functional checks flights during 2002 can be reviewed by calculating the cost of rework. There were 161 FCF sorties flown out of which 132 were cleared in fist sortie, 20 were cleared after second sortie, three were cleared after third sortie and six were cleared after fourth attempts.

- Cost of one sortie — Rs. 256, 000.0
- Additional sorties flown — 29
- Cost of nonconformance — 29 x 256,000.0 = 7.42 Million

AORs

The total number of AORs during 2002 and 2003 are listed below system wise. There were 110 and 175 AORs during 2002 and 2003 respectively. Out of these (110,175) AORs, 74 and 109 were due to pure maintenance problems.

AOR	2002	2003
Engine	08	12
Electric	02	06
Pneumatic System	04	06
Boost Hydraulic	07	06
Retract Hydraulic	06	09
Main Fuel Pump	02	05
After Burner	03	06
Break Assembly	03	04
Oil System	05	04
Air Frame	04	06
Armament	10	16
Radio	05	06
Instrument	05	04
ARU	10	15
Radar	-	04

Cost of AORs during 2002

Total number 110

Accompanied sorties 36

Unaccompanied sorties 74

Sorties wasted 148 (2 x 74)

Cost of one sortie   Rs. 256,000.0

Cost of nonconformance for AORs

256,000.0 x 148 = Rs. 37.888 Million

Cost of AORs during 2003

Total number 175

Accompanied sorties 66

Unaccompanied sorties 109

Sorties wasted 218 (2 x 109)

Cost of one sortie   Rs. 256,000.0

Cost of nonconformance for AORs

256,000.0 x 218 = Rs. 55.808 Million

Cost of Non-Conformance

- Aero engines = Rs.102.469 M
- Hydraulic Pumps = Rs.1.6 M
- Functional Check Flight = Rs.7.42 M
- Air Occurrence Reports = Rs.37.888 M
- Total = Rs.149.377 M
- Total PAF Bases = 8
- Cost for 8 Bases = 149.367*8

  Rs. 1194.936 M
- Cost of 1 Aircraft = Rs.160.82 M
- Aircraft Per Year = 1194.936 / 160.82

  = 7.43 A/C

In this total cost PAF can buy seven more aircraft of Chinese inventory.

CHAPTER – 14

ANALYSIS ON WHY PAF IS PAYING HIGH COST IN POOR QUALITY OF AIRCRAFT MAINTENANCE

After analyzing the various processes of quality assurance practiced in PAF now there is a need to analyze the overall system to identify the reasons why PAF is paying high cost of quality in aircraft maintenance. In this regard I will analyze all the possible areas for identification of cause.

Is the system of maintenance faulty or inadequate?

PAF follows a very comprehensive and systematic maintenance system. Similar aircraft maintenance system is being used by majority of air forces like USA, UK, China, and Australia. The system is based on the principle of staggering the aircraft in such a way that all the similar weapon systems reach their service life simultaneously, so that, subsequently, if the weapon system is to be changed, then a new and complete system should be brought in. To maintain the weapon systems, all the flight lines and engineering wings at the bases maintains a staggering record of aircraft and follows a comprehensive maintenance program. This schedule includes daily, weekly, monthly, 50 hours, 100 hours and 200 hours maintenance. This follow up schedule helps to maintain the systems readiness and provides any specific trend with any aircraft. The system of maintenance as well as the process of inspection is very well streamed lined, which ensure the serviceability, and reliability of aircraft. There is no flaw or inadequacy in the maintenance system.

Is there any deficiency lies with the training of the technicians / workforce?

Training is one of the largest initial costs in quality initiative. Not surprisingly it is one in which many organizations are reluctant to invest. Even if they invest they often take great pains to measure the benefits against the cost. The leadership in quality—Deming, Juran, and others actively promoted training and education. Training generally includes quality awareness, leadership, project management, communication, teamwork, problem solving, meeting the requirements, process analysis, waste reduction, cycle time reduction error proofing and other issues that effect effectiveness, efficiency and safety.

In total quality environments workforce needs to understand the goals of training, which should include: -

- Training plans should be based upon the job skills requirements
- Organization should have formal training departments
- Training contents should be customized to work requirements
- Continual reinforcement of lessons learned in training program is essential
- Reinforcement of new knowledge at all level of training

In PAF, after induction of the airman, a very robust, comprehensive initial training is provided. These airmen are divided into specialized trades based on their aptitude. These trades include airframe, engine, avionics, radio, radar, instruments, and armament.

After completion of initial training, the airmen are provided a training program of two years at Korangi in specialized field. On completion of training these specialized airmen are posted to different flight lines of squadrons, where they remain under supervision of experienced personnel. During the stay at the new units they are provided different refresher courses, examinations and inspections to enhance their working capabilities. If airmen fail in exam and inspection they are provided extra coaching and training to match the abilities of the batch. The refreshers courses are being organized and implemented by the Quality Assurance Departments under the supervision of quality officers and inspectors. Same technicians, after gaining enough experience and training, are posted to Quality Department as well.

The technicians selected for quality department are known as quality assurance evaluators, who are technically sound and current on the system. They are familiar with the assigned systems, support equipment, maintenance / management procedural requirements and possess interpersonal skills. These qualifications for personnel selected as evaluator are necessary to ensure effectiveness of the Quality Assurance Programme.

Proper training assists evaluators in detection of malpractices and deficiencies. Newly assigned QA evaluators are therefore, initially evaluated to determine their capabilities as well as training requirements. The QA supervisor is to ensure that initial evaluation is performed to determine the ability of newly inducted QA person to perform inspections and evaluations, knowledge of management procedures, effective writing skills and ability to analyze various findings. QA inspector must be initially certified and maintain certification in that activity (for example, refueling, engine run, etc).

Individuals assigned to QA must be thoroughly familiar with their areas of responsibility and other aspects like QA management procedures. To ensure this, the QA officers arrange training programs for QA evaluators who are trained about their responsibilities for maintaining proficiency in concerned spheres. The QA sections also under take set of lectures for the purpose of their staff training.

Training of Quality Assurance Inspectors. The Quality Assurance Program can achieve its objectives if the QA inspectors are able to build up and maintain a good reputation as well as win the confidence of workers (and their supervisors) deployed in various work centers. To establish the credibility of QA evaluators, it is important that they are well trained, professionally sound, temperamentally mature in the discharge of their duties and possess good oral / written communication skills. Continuous training is therefore, essential to build up the aforementioned qualities in the QA evaluators.

Is the process of Quality Assurance Standardized or faulty?

PAF's Quality Management & Quality Control Services have already been looking after production oriented and procurement quality. Various specialist teams and categorization elements from AHQ are also aimed at improving the quality of work. QAP is also trying to help improve the processes and attain the response of management as well as logistic elements directly affecting maintenance/production activities in the PAF.

The ISO-9000 primarily deals with the system of management of an organization. The aim is to bring improvement attaining better results by streamlining all the processes (directly or indirectly) responsible for output. To promote quality of an organization, ISO-9000 provides a set of standards, the scope of which covers almost every type of organization may they be manufacturing/production units, educational institutes, banks, hospitals, airlines, air forces etc.

ISO-9000 being a management tool aims to document every activity performed with reference as well as points out deviations for correction through an organizational quality evaluation system. Consequently, it helps in providing consistent quality work/production.

Advantages of Adopting ISO-9000 – PAF

Following are the advantages of adopting ISO-9000: -

(a) Due to written procedures, not only the responsibility of management is defined but also everybody starts working according to system / procedures

(b) One man show is controlled through efficient system of design, purchasing and contract review

(c) Easier understanding of the system by a new inductee, due to designated responsibilities

(d) Decision making becomes easier, due to identification of problem at every stage coupled with use of statistical tools and techniques

(d) Calibration of instruments/gauges, results in better process control

(e) Communication and co-operation between the staff

(f) Testing of raw material, improve the standards of manufactured products

(g) Internal quality auditing checks help in overcoming flaws of the system

Co-relation of QAP and ISO-9000

While ISO-9000 aims to bring quality system improvements in an organization, QA (being an essential part of ISO-9000) acts as data gathering agency to evaluate and highlight problematic trends and their causes, provide on the spot solutions as well as feed back to the managers about results. Thus QA aims to improve all the processes through sample evaluations in all the organizational activities related to maintenance / production.

The ISO-9000 of Quality Assurance Program ensures that the process of maintenance and documentation is according to the desired international standards and failing which means that the status of ISO certification is lost. PAF lays emphasis on the maintenance of desired standards.

Is there any problem with implementation of the system?

Common Implementation Problems

While analyzing the PAF, the question arises, why there is a problem in implementation of the quality management program? As the armed forces bear bureaucratic culture, which empowers an individual to think, that he is exempted from being questioned and whatever he wants can be done, there are few other reasons, which lead to the poor implementation of any program such as: -

(a) I am the Boss / I am Right. The approach of being the boss is the biggest hindrance in implementation of any program. At times the squadron commander is hard pressed due to incomplete flying task, he desires to violate or take some shortcuts and go for short-term achievements. This short cut or over looking in maintenance leads to cumulative problems, which require more repeated work thus losing in terms of cost.

(b) Time compression. The process of implementation gets disturbed because of time factor. Many times during exercises where the time available is less and squadron has to complete flying task, shortcuts in procedures and processes takes place. This time compression leads to high rate of rejections, rework and higher cost in maintenance.

(c) Workforce Attitude. The attitude of work force is directly proportional to the rate of rejection. If the worker has some mental, family or other problem at the back of his mind, he would take a wrong action, which leads to rework, or rejection. Despite having all the process steps available he might look for an opportunity to complete his task earlier so that he can look after his personal worries. Thus with the wrong attitude of an individual in implementation of the laid down instructions, it could cause a great loss to PAF in terms of money and asset.

(d) Motivation. Motivation is also a big factor in implementation of any instructions. If the workforce is motivated and skilled, happy to perform well, they would like to work according to the laid down instruction. On the contrary if an individual is depressed, angry, de motivated, he would not hesitate to disregard the rules and regulations, and to choose an undesirable method to complete the task.

(e) Reward and punishment / incentives. In PAF majority of works on the flight lines are done well and are therefore appreciated. Although rewards and recognition create a sense of competition among the workforce and keep them motivated. However, actual problem starts when an individual is penalized for something, which he thinks, is not his fault. Such individuals are the biggest source of depression and de-motivation. They don't hesitate to bypass laid down procedures and disturb the entire sequence of maintenance. Once an individual is under such condition, he should be kept away from the sensitive work areas so that no damage is inflicted to the weapon and the management system.

(f) Inadequate Manpower. All the flying squadrons in PAF have their own establishment of manpower and the technicians are allotted to them accordingly. However, at time, there is shortage on any specific system but the overall total of manpower is managed by providing people from other trades. This ad hoc filling of vacancies create problems when the specific trade man is required to work on any system. Similarly, when an individual is working on more than one weapon systems simultaneously, his shuffling between two weapon systems distracts his attention to concentrate on job and also frustrates him. This causes lot of fatigue, lack of interest, anger, annoyance, de-motivation and all reasons to take short cut, avoid the lengthy procedures, consultation of work orders etc.

Similarly same situation occurs at engineering wing where at a time many aircraft are opened up for 50, 100, and 200 hrs inspections. The shortage of manpower at such a place where lot of pressure is to roll the aircraft at earliest can lead to the implementation failure. This failure can be either by the technician, supervisor or may be by the engineering officer.

(g) Posting Tenure. Generally in PAF, an officer is placed for a period of three years at maximum, however many times the posting tenure of individual extends due to various official or domestic reasons. The extension in the posting period has its advantages and disadvantages. The disadvantage appears in the form of attitude of the individual. He assumes that he is master of every thing, based on his experience he tends to take short cuts, avoids consulting the technical data for rectification and verification, disregard standard operating procedures, and take the advice of new superior officer as insult. Similarly the same is true for the technician. If the technician is a quality inspector, then the nuisance value would increase automatically.

CHAPTER -15

CONCLUSION

As organizations strive to increase their line performance in the highly competitive environment they often forget to integrate two important planning activities, strategic and quality planning. This is likely due to a lack of understanding of the cause and effect relationship between strategy, quality, productivity, profitability and competitiveness. To maximize the profits of an organization it is necessary to align the objectives and priorities of the business and the quality improvement process.

A byproduct of quality improvement is the improvement in productivity. By eliminating errors, non-value-added activities and waste, resource capacity becomes available. However this presents another challenge to management. If these resources are not deployed onto something else then there is no impact to the bottom line. Management has learned through bitter experience that if the resources are laid off or let go then the improvement process is destroyed. Increased quality also reduces the production cycle time. It also decreases the use of machinery and equipment due to less rework. This results in a reduction in asset investment. Less material are now required due to less scrap, rework and waste subsequently the cost of maintenance is reduced.

Cost of Quality (COQ) is the sum of the costs incurred by a company in preventing poor quality, the costs incurred to ensure and evaluate that the quality requirements are being met, and any other costs incurred as a result of poor quality being produced. Poor quality is defined as non-value added activities, waste, errors or failure to meet customer needs and requirements. These COQ costs can be broken down into the three categories of prevention, appraisal and failure costs. The COQ model is often referred to as the PAF model after these three categories.

According to Dr. Deming philosophy, there is no such thing, as quality problem, Quality originates in functional area, not in quality department, and therefore the burden of responsibility for such problems falls on these functional departments. The quality department should measure conformance, report results and lead the drive to develop a positive attitude towards quality improvement.

At an average PAF is paying Rs. 1194.936 Million in maintenance. If the cost of other systems also calculated then it becomes a huge amount. PAF must cut down this cost and emphasis on the reasons, which are supplementing the increase in maintenance cost.

In PAF, the concept of quality needs to be changed. The process of quality assurance should be gradually changed into Total Quality Management at all levels. For this purpose there is a need to educate the officers and technicians to enhance their skill levels and lay responsibilities on them as a quality manager in their working areas.

PAF needs to update its processes, procedures and train their manpower to reduce the unnecessary cost of poor maintenance. This requires adapting the policy of continuous improvement and to remain current with the latest Quality philosophies.

RECOMMENDATIONS

Experts estimate that 60-90 % of total quality costs are the result of internal and external failure and responsibility of management. Better prevention of poor quality clearly reduces internal and external as fewer defective items are made. In addition less appraisal is required, because the products are made correctly first time. However, because the production is viewed in the short term, many managers fail to understand or implement these ideas.

As Dr. Deming said that the process of continuous improvement must never be stopped, the same also holds good for the processes of maintenance in PAF. During the analysis for cost of poor quality in aircraft maintenance, some areas were observed which need improvement in line with total quality management.

- Training and implementation

  Technicians and junior officers, who are the core of major workforce of PAF, think that quality is solely the responsibility of Quality Assurance Department, whereas upholding quality is the duty of every individual. Although the vision and concept is present, but there is a lag of its implementation in true sprit, therefore: -

  - Awareness in quality management should be provided at the grass root level. For Flying, Engineering and other branch cadets be educated on the total quality management at PAF Academy Risalpur. It should be made a compulsory subject of the syllabus
  - Aircrew be provided short courses (2 weeks) on process of maintenance and inspections at PAF workshops to have better understanding of the system
  - An introduction to total quality management principles should be included in the entire training institute for the other ranks as well

- The course must highlight the importance of quality management in their field and should be drilled through motivational techniques
- Workshops should be arranged with practical problems for better education on the subject for officers and technicians
- Seminar should be arranged, chaired by the specialist from civil to enhance the vision on the subject
- Quality magazine should be published, highlighting the importance of Total Quality Management, Cost Management and Quality Planning at least biannually
- Top management should take interest in quality management and emphasize its implementation
- Process of Rework should be reduced as far as possible and a culture of "Doing the job right first time" should be incorporated
- Refresher courses should be arranged at the workplace
- Every individual should be made responsible for quality

➢ Evaluation of Rejection Rate Data

- To arrest the high rejection rate, the data should be evaluated on quarterly basis at Air Headquarter Level during System Safety Review.

➢ Analysis of Mean Time Between Failures (MTBF) of Life Components

We have seen that Unsatisfactory Reports, material failures takes the lion's share, where the life components are rejected prematurely due to MTBF. Either the life of the components needs to be revised with consultation with the manufacturer or the assignable causes should be evaluated and remedial actions taken.

- Study of Air Occurrence Reports (AOR)
    - The core objectives of raising AORs are finding root cause of malfunction so that in future such incidents are not repeated

    - It is recommended that a group of specialized individual should investigate AORs data of last ten years of every flying squadron, along with the cost incurred and suggest remedial measures to avoid reoccurrence in future

    - Trends should be highlighted in relation to the AORs for all the weapon systems and a manual to be prepared by all units for the brief of new commander

- Test Equipment
    - The Test equipment (tools, testers etc.) has considerably high rejection rates that can lead to erroneous results, which is detrimental to aircraft
    - Technicians must emphasize the importance of maintaining the higher quality of test equipment and tool
    - Refresher training on the maintenance of equipment quality should be conducted

- Production Delays
    - Every engineering wing must submit quarterly return in which the total number of aircrafts produced and delays are mentioned. Subsequently remedial measures must be taken in order to keep the production as per plan and to keep the serviceability at optimum level

- Engineering and Operations branch should coordinate for the flying task and availability of aircraft according to their maintenance schedules
- At the base level, OC Eng. should emphasize on quality work on maintenance.
- Officer Commanding Engineering Wings should highlight the importance and implication of production delays to all the officers and the technicians at the bases
- All the work force should be aware of losses due to the production delays through quarterly meeting
- The engineering wings must lay emphasis on timely delivery of aircraft

➢ Training of Quality Teams in Foreign Country. The quality teams should be given chance to undergo training abroad specially Japan, Korea and USA. Along with the best quality officer of the year, some non commissioned officers should also be given opportunity to visit abroad for Quality Courses. This would not only increase the motivation but also enhance a healthy competition among them to perform better. It would bring better results for PAF.

➢ Monthly Quality Meetings. To understand the impact of Quality issues, the top management should be provided with the dollar value of all the failures occurred due to poor maintenance, rework, careless attitude etc. so that a careful analysis and strict decisions can be taken. The reasons should be highlighted such as lack of training, lack of motivations, poor implementation, shortage of manpower, attitude of Quality Inspectors etc so that corrective actions can be suggested and implemented.

➢ Analysis of Root Causes. The Quality Assurance Program of PAF is basically a process of data gathering for establishing a trend of the occurrences and its remedial actions. However, it is evident that the trend formulation is achieved for the short duration but there is a lack of in depth analysis of the problems. PAF needs to train its officers to establish the root cause through in-depth analysis. Finding a result of an investigation for timely submission of the occurrence report is one of the reasons for not having in-depth analysis of the problem. The Flight Safety Directorate must assist the investigating officers and provide some leverage for submission of investigation so that an in-depth analysis could be done.

- Documentation and Publications. Though the Quality Department provides enough publications and documentation but they are rarely utilized. It is basically just to take short cuts and save time. All the flight lines are provided the technical orders but while working, many times the technicians avoid the instructions due to their own knowledge and experience. The supervisors also compromise due to shortage of time. Strict disciplinary action should be taken against the engineering officer and the technician, when technicians are found working on aircraft without job cards and technical instructions. PAF should also revise its documentation according to the ISO- standards and should include latest philosophies of Total Quality Management in their publications.

- Team Work. The concept of flexi maintenance is also one of the reasons for having maintenance failure. During the maintenance work if the time for the shift changeover comes, the technicians leave the job and hand it over to the next team without proper briefing for the rectification. The change of team at mid of work causes lot of problems due to lack of interest of departing shift, incomplete briefing to new team, frustration of the new team to complete the job, unavailability of skilled technician etc. To over come the problem, PAF must introduce the team concept. A team should be responsible to complete the task so that they are responsible of reoccurrence of the problem.

- Quality Teams Generally the Quality Teams of Quality Assurance Department visits the flight lines to conduct various inspections. Their attitude remains as of police inspector rather than to assist in maintenance. This culture of Quality Inspectors needs to be changed. Additionally all the squadrons should have their own quality teams with the aim to assist and help the workers in following the requisite work instructions. This would enhance the confidence of the workforce and provide better results.

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MAINTENANCE PROCESS OF AN

Appendix "A"