ANALYSIS OF AN AIRCRAFT PRODUCTION INSPECTION PROGRAM FOR OPERATORS AND OWNERS

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Abstract. *The purpose of this article is to present a case study of aircraft production customer inspection process and analyze the needs and benefits for such market practice. Enabling operators and owners to closely follow certain production process milestones contributes to a more reliable operation, compliance with customer expectations and proper detection, documentation and rectification of production discrepancies. Nevertheless, although often required by customers, few airframe manufacturers dispose of a formal production inspection program to guide operators and owners through the process. The production inspection program implemented by a large commercial aircraft manufacturer is thoroughly analysed, discussed and benchmarked for future references. The scope of such work includes observations of intermediate inspection activities throughout the aircraft final assembly line up to the end of the aircraft delivery process and consequent technical acceptance. Airframe and systems assembly processes are subject to either visual, operational or functional checks. As a result, production concessions are assessed and dealt with in such a manner to avoid future negative impacts on the aircraft operation, maintenance and airworthiness. Best practices and key tasks are discussed. A customer-oriented, flexible and thorough schedule of activities is perceived as a positive industry practice in the aviation business.*

Keywords*: aircraft inspection, assembly line, aircraft delivery process*

1. INTRODUCTION

It is common practice among general, executive and commercial aviation businesses to provide customer operators and owners with the opportunity to visit and inspect the purchased aircraft in the production line. Such opportunities are often taken over a few specific production milestones, when the customer-designated inspector has the chance to observe critical processes, systems or structures which, on a later date, would be rather difficult or impractical to inspect.

Although operators and owners may choose to limit themselves to inspect the aircraft upon its delivery, it is advised to comply with a more thorough inspection program, which would involve not only the delivery process, but also other significant milestones of the aircraft final assembly. Benefits include the timely detection, documentation and rectification of eventual discrepancies found during inspection, what results in a smoother start-up process, more reliable and cost-effective operation and maintenance, reduced aircraft downtime, awareness of the aircraft's critical spots, enhanced safety and higher aircraft resale value. To this contributes also a detailed concessions assessment, which, along with partial production reports optionally provided, shall support maintenance and operation procedures throughout the aircraft life-cycle.

Furthermore, a detailed production inspection avoids aircraft delivery delays, to the extent that early fault findings reduce the impacts of eventual product discrepancies.

2. METHODOLOGY

This paper shall analyze a large commercial aircraft manufacturer production inspection program. It has been chosen as reference due to its broadness and customization levels if compared to other airframe manufacturers. Such program focuses on meeting customer expectations, offering options and tailoring the process to operators and owners needs and available resources. The figure of a Customer Inspection Manager is assigned in order to better support the customer and plan the inspection program activities. One extra service provided by this manufacturer is the "customer's eyes" inspection. In this case, the customer does not have available time or means to take part in the process, so the manufacturer points out a team of the quality department to perform the inspections on the customer's behalf.

The basic work scope is to inspect aircraft assembly and sections and to manage the final aircraft acceptance and delivery.

2.1. Organisation

The production inspection program is modular and divided into 4 basic groups of activities or "modules", being:

- Module 1: General Inspections at the Airframe Manufacturer and Suppliers Facilities;
- Module 2: Inspections During Final Assembly Line;
- Module 3: Functional Inspections During Final Assembly Line;
- Module 4: Inspections Performed During Final Delivery Phase.

Within each module there are several inspection activities, each one independent and performed separately. The production inspection program can be customized according to the customer option between 3 different levels. Level 1 being the standard, the customer is able to perform additional checks and have access to a broader inspection by selecting levels 2 or 3.

Before presenting each set of activities, general guidelines are presented in order to establish rules that enable the customer to timely and properly prepare for the inspection and also to avoid any impact in the production schedule. These are:

- Inspection activities shall respect the daytime working hour limits of 08:30 and 17:30;
- An advance notice shall be sent to customer 10 days prior to Aircraft Section Inspections as predicted in Module 1;
- An advance notice shall be sent to customer two hours prior to final assembly line inspections as predicted in Modules 2 and 3. In this case, activities shall take place in the end of the respective production phase and at a location already familiar to the customer;
- Notification for final delivery phase inspections shall be as per the aircraft purchase agreement;
- The inspection timeframe shall be allocated in minutes for each inspection activity, not to compromise production schedule and final delivery date adherence;
- In case of non-attendance by the customer, within a period of 30 minutes from the notification time the production zone shall be closed for work continuation.

2.2. Module 1: General Inspections at the Aiframe Manufacturer and Suppliers Facilities

Table 1 contains the scope of inspection activities in Module 1. As well as in the following tables throughout this article, the level of customization marked for each activity corresponds to the number of options provided by the program. If level 1 is marked, then it is the only activity available. Levels 2 and 3 indicate that the customer may choose more detailed inspection activities.

Table 1. List of Inspections in the Airframe Manufacturer and Suppliers Facilities

Item	Description	Section(1)	Level			Remarks
			1	2	3	
1	Fuselage Sections Inspection (structures and equipment)(2)	01 to 10	X			Reports included
2	Vertical Stabilizer inspection	11 to 15	X			
3	Wing Inspection	21 to 25	X			
4	Engine Pylon Inspection	31 to 35		X		
5	Horizontal Stabilizer Inspection	41 to 45		X		
6	Power Plant and Nacelles Inspection	51 to 55	X			Supplier Facility

(1) : the presented aircraft section numbers are fictional, not corresponding to any real aircraft.
(2) : some special fuselage inspections are considered as Level 2 inspections within the program.

2.3. Module 2: Inspections During Final assembly Line

Before the beginning of the final assembly line, the Customer Inspection Manager schedules a meeting with the customer representatives in order to explain the general procedures and have the level of inspection chosen, as well as which Level 2 and 3 activities shall be performed. The inspection timeframe is also presented to the customer representatives.

Table 2 contains the scope of inspection activities in Module 2.

Table 2. List of Inspections During Final Assembly Line

Item	Description	Duration (min)	Level			Remarks
			1	2	3	
1	Final mating of Fuselage Sections	60		X		
2	Wing-to-fuselage Final Mating – outside	70		X		
3	Wing-to-fuselage Final Mating – inside	40		X		
4	Nose Gear Doors – steps and gaps	Report only			X	
5	Vertical Stabilizer to Fuselage	20		X		
6	Passenger Service Units and Oxygen Containers	60		X		
7	Installation of Cover Light Panels under Overhead Stowage Compartment	60		X		
8	FWD/AFT Passenger/Crew Doors – functional check	20		X		

Item	Description	Duration (min)	Level			Remarks
			1	2	3	
9	AFT Cargo Door – steps and gaps	Report only		X		
10	Main Gear Doors – steps and gaps	Report only		X		
11	Wing Tanks Ribs – before installation of access panels	30		X		
12	Installation of Cabin Carpet	30		X		
13	FWD Cargo Door – steps and gaps	Report only		X		
14	Center Tank Installation	15		X		Optional
15	Center Wing Box – before closing	30		X		
16	APU Compartment with APU installed	20		X		
17	Wing front Spar Area Ribs and Slats Attachments	20		X		Slat extended
18	Pylon-to-wing Interface Connection	40		X		
19	Belly Fairing Area – air conditioning packs	30		X		
20	FWD Cargo Compartment	65		X		
21	Engine Installation	40		X		
22	Main Landing Gear Bay, including RAT and Landing Gear	30		X		
23	Tracks of Inboard Flap False Rear Spar – ribs	40		X		
24	Engine Pylon – before closing of visiting doors	15		X		
25	Radome – steps and gaps	Report only		X		
26	Nose Gear Wheel Well, including Gear	15		X		
27	AFT and Bulk Cargo Compartment	30		X		
28	Cabin Emergency Equipment	60		X		
29	Installation of Seats, Floor Covering, Galleys, Lavatories and Equipment	240		X		
30	Exterior Painting – including inscriptions and markings	180 + Report		X		
31	Additional Inspections – special requests			X		Optional

2.4. Module 3: Functional Inspections During Final assembly Line

The third module of the production inspection program is considered separately from the second module as it is oriented to additional functional checks to be carried also during the aircraft assembly line.

Table 3 contains the scope of inspection activities in Module 3.

Table 3. List of Functional Inspections During Final Assembly Line

Item	Description	Duration (min)	Level			Remarks
			1	2	3	
1	Cabin Strength and Tightness – delta P test	Report only			X	
2	Landing Gear	Report only			X	
3	FWD Cargo Loading System	30		X		
4	AFT Cargo Loading System	30		X		
5	Cabin Functional Inspection 1[(1)]	60	X			
6	Cabin Functional Inspection 2[(2)]	60	X			
7	Cabin Functional inspection – emergency systems[(3)]	60	X			
8	Refuel/Defuel Fuel Gauging	Report only			X	
9	Additional Functional Inspections – special requests				X	

[(1)] : C/B in service configuration of passenger lighted signs, passenger call systems, lavatory lighting, cabin lighting, reading and work lights, cabin interphone, passenger address system and loudspeakers.
[(2)] : C/B in service configuration of passenger entertainment system and video system.
[(3)] : C/B in service configuration of cabin emergency evacuation signaling system, escape slide lighting and emergency lighting.

2.5. Module 4: Inspections Performed During Final Delivery Phase

Once the aircraft final assembly line reaches its final stages, the customer is requested to inform the manufacturer the level of the inspection to be performed during the final delivery phase. This information has to be sent to the manufacturer prior to the notification of the scheduled delivery date and consists of choosing between a shortened ground check, standard ground check and extended ground check. In case of customer omission, the standard ground check is considered as the customer's choice. Regardless of the selected ground check, the inspector is limited to a

General Visual Inspection of the aircraft exterior and main interiors. As a result of this activity, the customer's quality findings list is analyzed and the necessary rectifications performed.

The cockpit is separately inspected in the presence of a Ground Test Engineer or pilot (Loong, 2005). During the acceptance flight, the cockpit is reevaluated. Finally, the engines and Auxiliary power Unit are inspected after the acceptance flight.

2.5.1. Shortened Ground Check

It consists of a walk-around inspection not exceeding 1 hour.
Table 4 contains the scope of activities.

Table 4. Shortened Ground Check Scope

Item	Description	Remarks
1	Walk-around	Flaps and Slats extended Nose & Main landing Gear Bay open
2	APU Compartment	After flight
3	Cabin	
4	L/H Engine	After flight
5	R/H Engine	After flight
6	FWD Cargo Compartment	
7	AFT Cargo Compartment	

2.5.2. Standard Ground Check

It consists of a walk-around inspection with platforms and stairs available for access to certain areas. It shall not exceed 3 hours.
Table 5 contains the scope of activities.

Table 5. Standard Ground Check Scope

Item	Description	Remarks
1	Walk-around	Flaps and Slats extended
2	Aircraft top view from cherry picker	Flaps and Slats extended
3	APU Compartment	After flight
4	Cabin	
5	L/H Engine	After flight
6	R/H Engine	After flight
7	Main Landing Gear and Compartment	
8	Nose Landing Gear Bay	
9	FWD Cargo Compartment	
10	AFT Cargo Compartment	
11	Electronic Bay	

2.5.3. Extended Ground Check

It consists of a walk-around inspection with platforms and stairs available for access to certain areas. It shall not exceed 5 hours.
Table 6 contains the scope of activities.

Table 6. Extended Ground Check Scope

Item	Description	Remarks
1	Walk-around	Flaps and Slats extended
2	Aircraft top view from cherry picker	Flaps and Slats extended
3	APU Compartment	After flight
4	Cabin	
5	L/H Engine	After flight
6	R/H Engine	After flight

Item	Description	Remarks
7	Hydraulic Bay	
8	Main Landing Gear and Compartment	
9	Nose Landing Gear Compartment	
10	FWD Cargo Compartment	
11	AFT Cargo Compartment	
12	Electronic Bay	
13	Radome	

3. ANALYSIS

The production inspection program presented in the previous section is a good example of a structured process that provides customers with the chance to inspect aircraft in production. More than that, this program suggests a logical sequence of activities, focusing on the main production milestones and related inspection opportunities.

The inclusion of optional checks and special customer requests give the desired customization level that is well-appreciated in the aviation business. Specific reports are also included in the scope of the program, contributing with crucial information for later operation and maintenance, as well as serving as basis for eventual concessions assessments. In addition, operators and owners are aware of the aircraft production history, maximizing technical knowledge and maintenance efficiency.

The suggested inspection activities, each corresponding to a certain production stage, are planned in a manner to suit the customer's needs and resources, culminating in 4 comprehensive inspection modules.

3.1. Module 1

Module 1 is basically composed of a set of visual inspection activities dedicated to inspect the aircraft's primary structures for their overall integrity and also for details such as minor mechanical discrepancies. Scratches, misalignments and unsatisfactory structure characteristics may be brought to the manufacturer's attention. Faults or concerns raised by the inspector may originate a report of conformity or concession agreement, generally issued respectively by quality control and contracts personnel. This same process is valid for the following inspection program modules.

3.2. Module 2

Module 2 has a more process-oriented guideline, as structures mating and critical systems installation begin to proceed. This is a thorough, detailed set of activities during which operators and owners are granted the chance to better understand the aircraft manufacturing philosophy, its ups and downs as an aeronautical product and also to foresee operation and maintenance requirements it shall face in the future.

The importance of these tasks comes also from the impracticability to perform such inspections during operation, once regular access to the referred structures is limited or complex. Examples are the wing-to-fuselage final mating interior inspection, forward and rear spars inspection, final mating of fuselage sections inspection, center wing box interior inspection and so on.

One of many benefits included in the program worth mentioning are the landing gear and cargo doors "steps and gaps" reports. A known source of increased downtime and unscheduled maintenance is door operation (Firoozmand, 2008); therefore a fault-free statement from the manufacturer is certainly beneficial to customers.

3.3. Module 3

The functional inspections offered in Module 3 have been tailored to the customer's needs as the activities scope contemplates critical cabin systems such as emergency, lighting, passenger address and entertainment subsystems. These are all well-known sources of frequent maintenance stops, what suggests actions to proof system reliability and quality. Furthermore, cabin tightness and fuel gauging are critical to an efficient operation.

These functional checks have many advantages for customers. They prevent the incidence of "burn-in" characteristics, which mean unexpected low dispatchability and completion rates at early stages of the aircraft life-cycle; they contribute to getting mechanics and engineers acquainted to the aircraft, especially in case of business start-up; they avoid delivery delays once faults are detected timely and may be repaired using the manufacturer's know-how; they minimize the chances to take delivery of an aircraft with any inoperative systems, specially interiors, which are particularly prone to failures and defects.

3.4. Module 4

Having performed the first three Modules in detail, the final delivery phase workload is diminished, thus avoiding delays. It comprises visual checks and specific activities such as cockpit, engines and APU inspections. There is little difference between the Shortened, Standard and Extended Ground Checks. Nevertheless, aircraft top view from cherry picker has benefits regarding painting quality and antennas integrity, whereas landing gears, hydraulic and electronic bays inspections serve the purpose of general conditions assurance (including cleanness, lubrication and fixation points' conditions).

3.5. Final Comments

It is also of great benefit to the operator/owner to have critical spots identified and closely observed during inspection (Dhillon, 1999). In this sense, one shall pay attention to the most common discrepancies or deviations historically found in new aircraft. These include (Firoozmand, 2008 and FAA, 2001):

- Minor corrosion points due to sealant poorly applied;
- Minor deviations and quality escapes in the aircraft interior;
- Cables and wires rubbing on other structures;
- Cable isolation and other plastic components with burning signs;
- Stiff or damaged door rubber seals;
- Doors with poor adjustment;
- Water infiltration;
- Control cables positioning;
- Loose equipment fixation points;
- Risks, bubbles or imperfections in the exterior paint;
- Accumulated dirt (mud, ice, dust, etc) in difficult access areas, surfaces or moving parts prone to dirt retention;
- Systems and structures poorly aligned, positioned or calibrated;
- Jammed screws and nuts;
- Minor assembly defects;
- Forced adjustments and fittings;
- Contamination of lubrication points;
- Non-operational test points.

Such historical observations may be used as reference for either establishing a new production inspection program or improving an existing one, always considering the specificities of the aircraft model in question.

4. CONCLUSIONS

This article has discussed the advantages of implementing a production inspection program. The benefits to operators and owners are to be seen during operation and maintenance, minimizing costs associated to aircraft unscheduled downtime and retaining resale value.

An example of production inspection program has been brought to analysis, and its concepts and modular characteristics presented. Although inspections are structure- and system-specific, establishing a formal inspection program has shown itself to be worth as an industry practice. Other production inspection programs are yet to be evaluated and compared, what is suggested by the author as subject of future studies.

5. REFERENCES

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6. RESPONSIBILITY NOTICE

The author is the only responsible for the material included in this paper.