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RELIABILITY AND QUALITY COST

IN HELICOPTER MAINTENANCE AND OVERHAUL

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ABSTRACT

This paper describes the implementation of the quality information program now in use within MATA IAI Jerusalem Helicopters. The author believes that similar activities could and should be of great benefit to helicopter operators, manufactures and maintenance/overhaul activities. The highlights of the paper are: The spiral of progress and the art of vertical flight, reliability - manufacture's versus operator's point of view; the human factor; the helicopter as a system; the problem of dealing with a variety of equipment; data collection and the procles-sed data output; summary - results of the efforts.

INTRODUCTION

In the production of vertical flying machines, as with most modern manufacturing operations, a quiet revolution is taking place: quality control policy is changing from inspection to quality assurance.

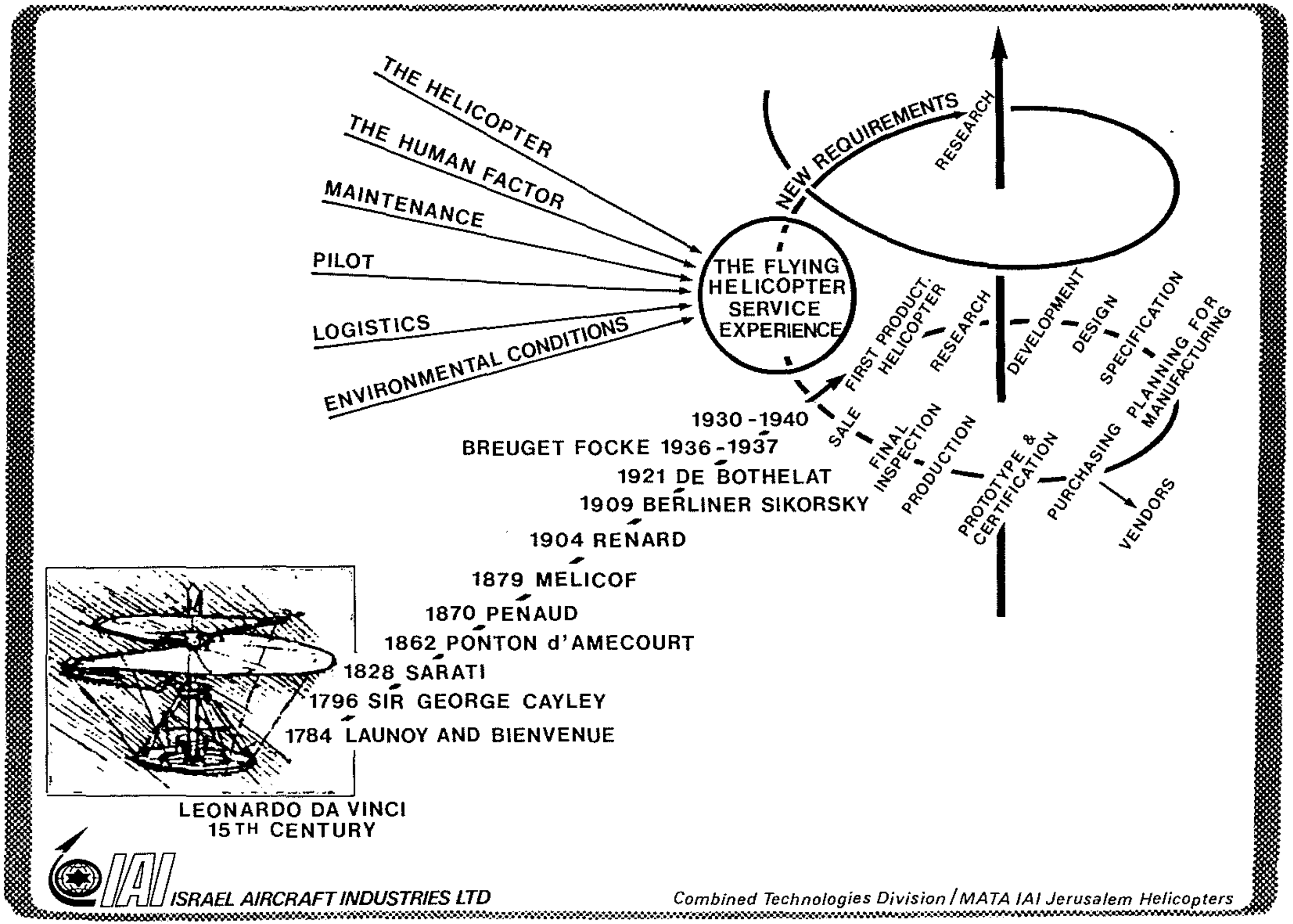
The spirit of this revolution affects helicopter maintenance, whether by an operator or a maintenance facility.However, most this activity still involves old fashioned inspection, and we have a long way to go until the gap is closed between such inspection and quality assurance.

In this presentation I would like to add a little stone or two to the big mosaic picture of the helicopter's "fitness-for-use". At the present state-of-the-art, the expression "fitness-for-use" is synonymous with quality. The first figure shows how we reached this state: this is the spiral of progress of rotary wing flight. Looking far into the past, we know that the great Italian genius Leonardo Da Vinci defined for the first time the requirements for vertical flight, as an idea and as a crude sketch. From that time until the development of the internal combustion engine, the helicopter remained simply as an idea on paper and in the dreams of frustrated inventors. During this long period, the helicopter did take to the air, but only in the form of ingenious toys.

The success of powered flight by the Wright brothers was a milestone which encouraged inventors by giving them the hope of applying power to a rotary wing. Only after a few decades did we see helicopters in production, marking the beginning of the helicopter industry, at the first turn of the progress spiral. After the rotary wing machine was sold to the user, it brought on the need for product support. Then new requirements began to come from consumers and service experience served as an input to research and development, affecting new helicopter designs.

In this presentation. I will try to share some of our experience of failure analysis and quality cost, considering the helicopter as flying system, taking into account the machine, the pilot, maintenance, logistics, and operational environmental conditions.

The reliability of the helicopter and its major components is a major issue of the development phase:it is a flying machine well defined by the manufacturer, and if each operator would only act in accordance with the manufacturer's directions, there would be a very high probability that the predetermined TBF would be achieved. Looking at the problem from the user's point of view, we find that results are poorer than the manufacturer expects.


THE HELICOPTER
THE HUMAN FACTOR
MAINTENANCE
PILOT
LOGISTICS
ENVIRONMENTAL CONDITIONS
THE FLYING HELICOPTER SERVICE EXPERIENCE
NEW REQUIREMENTS
RESEARCH
FIRST PRODUCT: HELICOPTER
RESEARCH
DEVELOPMENT
DESIGN
SPECIFICATION
PLANNING FOR MANUFACTURING
PURCHASING
VENDORS
PROTOTYPE & CERTIFICATION
PRODUCTION
FINAL INSPECTION
SALE
1930 - 1940
BREUGET FOCKE 1936 - 1937
1921 DE BOTHELAT
1909 BERLINER SIKORSKY
1904 RENARD
1879 MELICOF
1870 PENAUD
1862 PONTON d'AMECOURT
1828 SARATI
1796 SIR GEORGE CAYLEY
1784 LAUNOY AND BIENVENUE
LEONARDO DA VINCI
15TH CENTURY
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Combined Technologies Division / MATA IAI Jerusalem Helicopters

FIG.1

SLIDE 1

Problems arise in every day operations, and seemingly demand solutions generally: urgent actions ...in fact, these are often non-problems, and many actions are simply not necessary; many situations classified as problems are identifiable as due to lack of knowledge or experience. This may give rise to non-performance of vitally necessary actions through ignorance or lack of understanding of operational requirements.

The interaction between human beings and the flying machine may be called the "human factor". This may be composed of decisions involving people at various levels of responsibility and knowledge: management, pilots, machanics and inspectors This "human factor" is one of the variables that greatly influence the performance of the helicopter as a system.

At this point, I believe that some background information about MATA activities is in order: the name is an acronym for "Masokim Tasia Avirit", which is Hebrew for "Helicopters Israel Aircraft Industries Ltd (IAI).
IAI is divided into five divisions. MATA belongs to the Combined Technologies Division. The plant originated in another division called Bedek Aviation, with which it still maintains some connections, including quality control. All rotary wing activities at Israel Aircraft Industries are concentrated at MATA/Jerusalem Helicopters which overhauls, repairs and tests helicopter power train components and rotor blades. Here one of the major requirements is the ability to maintain a high level of competence while carrying out such work on various types and makes of helicopters and their accessories. The engineering group of MATA is engaged in R&D to improve reliability and T.B.F.

The purpose of the reliability and quality cost program within MATA is to improve the fitness-for-use of the helicopter and components... In order to do so we have to manage, control, measure and quantify... to generate data to enable both management and the customer to arrive at intelligent decisions.

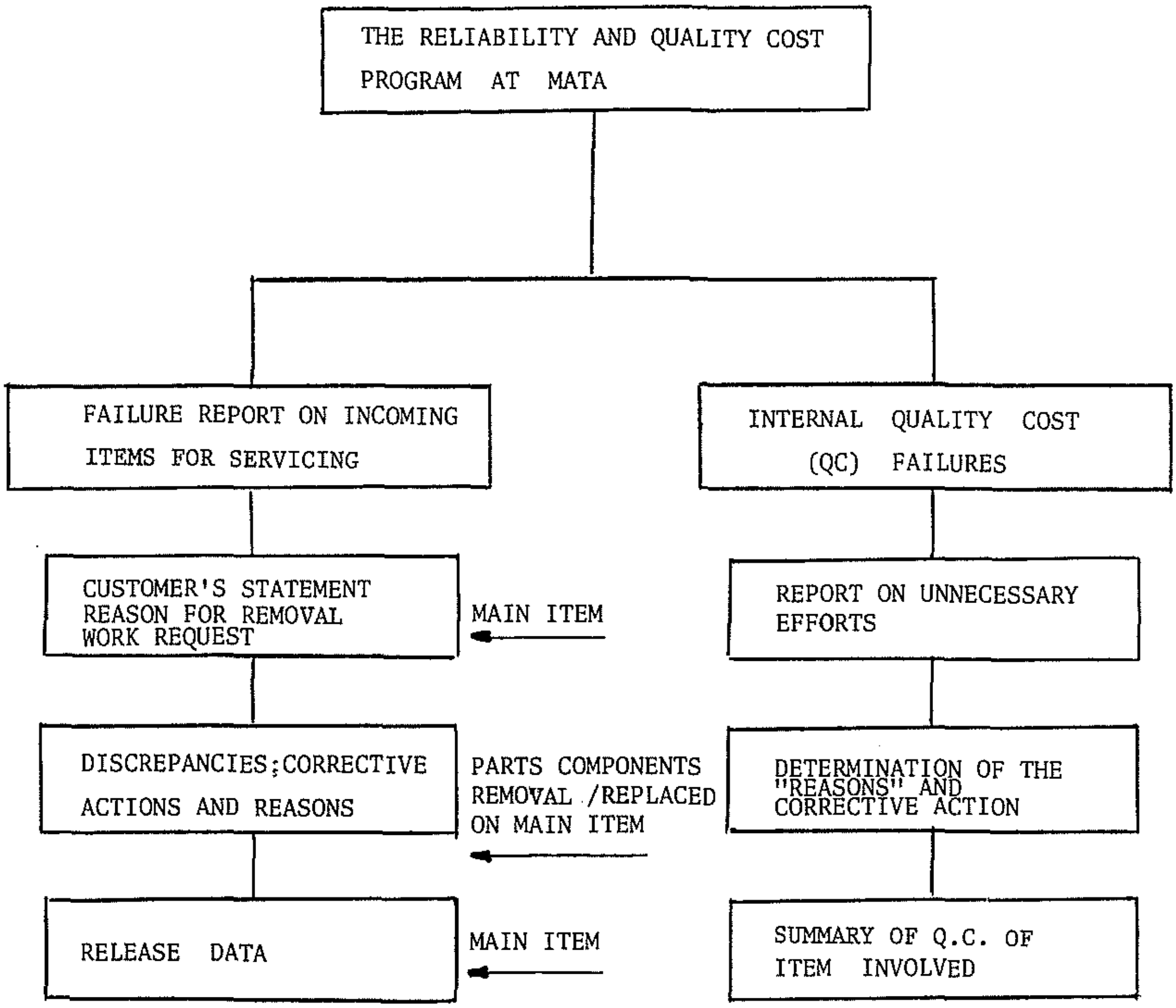
THE RELIABILITY AND QUALITY COST PROGRAM AT MATA
FAILURE REPORT ON INCOMING ITEMS FOR SERVICING
INTERNAL QUALITY COST (QC) FAILURES
CUSTOMER'S STATEMENT REASON FOR REMOVAL WORK REQUEST
MAIN ITEM
REPORT ON UNNECESSARY EFFORTS
DISCREPANCIES;CORRECTIVE ACTIONS AND REASONS
PARTS COMPONENTS REMOVAL /REPLACED ON MAIN ITEM
DETERMINATION OF THE "REASONS" AND CORRECTIVE ACTION
RELEASE DATA
MAIN ITEM
SUMMARY OF Q.C. OF ITEM INVOLVED

FIGURE 2

THE RELIABILITY AND QUALITY COST PROGRAM AT MATA (Fig. 2)

The program is divided into two sub-programs:

- Failure report on incoming items for servicing
- Internal quality cost - failures

The internal quality cost - failure - monitors the activity connected with unnecessary efforts, reasons and corrective actions within MATA.

I have no intention, in this presentation, to go into details and I will concentrate on "Reliability", failure reports on incoming items for servicing

R E Q U I R E M E N T S :

1. To be suitable for all activities in the unit.
2. Simple input (at workshop floor level).
3. To provide data for reliability assessment.
4. To provide data for quality costing, internal and external.

O B J E C T I V E S :

1. To increase MTBF, decrease downtime, and eliminate unjustified component removal.
2. To advise MATA management and the customer on reliability decision-making.
3. To establish causes of failure.
4. To initiate and monitor corrective actions.
5. To measure quality cost relative to cost center levels.

DATA INPUT:

It is obvious that the program must involve recording, handling and manipulation of large amounts of data... to say "manipulation" is really a misnomer, since the task could not possibly be done by hand within any practical time frame... only the computer can satisfy that requirement. In computer circles the acronym GIGO means "Garbage In, Garbage Out". In my experience similar programs failed due to human fallibility, for it is often extremely difficult for workshop floor level personnel (mechanics or inspectors) to describe a failure in terms suitable for computer input.

In this program an effort was made was made to avoid changing the routing of documentation covering non-routine work on flight-dependent elements. Thus the same copy is made to serve for approval of work and also as the input for key-punching.
The input data is inserted by the departmental inspector who records his observations as the basic data, and after completion by him the form is routed to the responsible Quality Engineer for coding and remarks (if any). The form is then checked by the Quality Assurance Technical Office for completeness, before it gets key-punched. (Fig. 3)

It was mentioned before that one of the prime requirements was to maintain a high level of reliable identification while mastering the technical difficulties arising from work on helicopters from different manufacturers and the almost endless variety of design solutions embodied in their components and systems. The key to overcoming this problem was found in the documentation furnished for each type: the Illustrated Parts Catalog (I.P.C.). In the I.P.C. there is a sort of common denominator which we can use for our input data: this is the Figure and Index Number used to identify a part in an illustration.
This allows the analyst to make a firm part identification and thus insure correctness of our data bank.

We codify helicopter make and model with a two character code, and use two digits for the principal components and systems. For example: FS = Super Frelon, and 02 = Main Rotor Blade. Our failure code was derived from the American T.O. 1H-53(H)B-06.
The input is designed so that the Quality Engineer can amplify the failure description with 32 additional characters. Corrective action and reasons for defect are codified alphanumerically.

DATA INPUT FLOW CHART

Work Shop Mechnic/ Inspector	Quality Engineer	Quality Assurance Technical Office	Computer Terminal Data Input-Output
Collection of Basic Data. - Department - Date - Model - Syst/Acces. - W.O. - Fig.2 Index No. - S/N - MRS - Verbal Description of the defect and corrective action	Codifies: - Defect - Corrective Action - Reason Remarks (if any)	Inspection For Completeness	Key Punch and store Data

Fig. 3

THE SOFTWARE

A single computer program is used to process all the quality information. Reliability and Quality cost records are distinguished by unique codes; thus they can be stored intermixed in a single disk file. A second file is used to store the following tables which translate data codes to human understandable messages in the output:

Malfunction description list
Aircraft subassembly configuration tree
Aircraft type table
Corrective action table
Cause-of-defect table.

The program, written in Fortran, performs three basic functions:

a) Selects records of interest on the basic of user input criteria (date, type of record, atc.).

b) Sorts the selected records also according to user request.

c) Produces reports with appropriate totals for analysis by Quality Assurance.

THE HARDWARE

The program is capable of being run on any small computer with enough disk storage space to accomodate the number of records which will undergo analysis at one time. Our local equipment consists of a Nova-3 minicomputer (manufactured by Data General), a dual 5 megabyte disk drive, a card reader, and a line printer. This equipment is connected, via dedicated phone lines, to a central facility at Lod, where access to a large Control Data computer is available. For the scope of processing needed at the current stage of development, our local minicomputer is more than adequate.

INFORMATION OUTPUT:

The data bank may be tapped in various ways to produce meaningful reports. In carrying out my responsibilities at MATA I have found three types of reports to be most useful:

a) Component MTBF report
b) Defective item report
c) Reasons-for-defect report.

Note: Since this program is relatively new, we have not accumulated enough data regarding the helicopter as a whole. However, every time it is necessary to remove an item it is also counted as an aircraft failure, this influencing and directly affecting the helicopter TBF.

These reports will be discussed in greater detail, together with examples from our experience. The reports are produced periodically and the results are compared to evaluate differences and measure improvements.

COMPONENT MTBF REPORT

The data is sorted by:

a) Manufacturer and model code
b) Component code
c) Serial number
d) Flight hours

THE DATA USED IS BASED ON:

- Customer statement
- Reason for removal
- Release data
- Primary cause of defect.
- Corrective action
- Reason for the defect.

All the reports are hard copies, as shown in Fig. 4.
Report contents are carefully analyzed by the responsible Quality Engineer, who prepares written recommendations based upon statistics from the report. For example: see Fig. 4

S-65 (CH-53) Sikorsky - APP Clutch

MTBF obtained: XXX
MTBF specified (by Mfr.): YYY
Primary failures responsible for premature removal:
- Excessive wear of clutch friction shoes
- Cracks in attachment flange.

Recommendation(s):
(1) Excessive clutch shoe wear is an old problem. The failure rate is unchanged. An engineered modification of the drum and clutch shoe assembly is likely to improve performance and result in acceptable MTBF.

(2) Flange cracking appears to be implicated in unbalanced drum and shoe assemblies, with failures occurring on unmodified clutches only. Service experience with modified assemblies determine if the problem has been solved.

DEFECTIVE ITEM REPORT

The data is sorted by:

a) Manufacturer and model codes
b) Fig. and Index no. in I.P.C.
c) Serial number
d) Flight hours

THE DATA USED IS BASED ON:

- All the data collected except release data.

(REPORTING PERIOD FROM 1 JAN 1981 TO 31 MARCH 1981)

MATA I.A.I. JERUSALEM HELICOPTERS QUALITY ASSURANCE MANAGEMENT :DATE:13 APR 1981

REPORT NO. DE:PT	REPORT NO. DATE	S/N	I.D.C. FIG.	I.D.C. IND.	SER NO	TSN HRS	DESCRIPTION	REMARKS: ***PART.NO***	W.L. STA / ** B.L. / ** HRS.	EA	CORRECTIVE ACTION / REASON	W.O.	CODE
42	800729	39			2523	1144	206 BELL-JET RANGER HEAD M.R.	206-011-10013 NO DEFECT-REMOVED FOR TIME CHANG			OVERHAUL SCHEDULED MAINTENA	96119003	
42	800730	41			2526	1339	206 BELL-JET RANGER HEAD M.R.	NO DEFECT-REMOVED FOR TIME CHANG			OVERHAUL SCHEDULED MAINTENA	96118476	
42	800806	50	11	000	56001	1009	206 BELL-JET RANGER HEAD M.R.	206-011-10013 NO DEFECT-REMOVED FOR TIME CHANG		1	OVERHAUL SCHEDULED MAINTENA	96157326	00
42	800806	50	11	079	56001	1009	206 BELL-JET RANGER HEAD M.R.	206-010-111-1 LOOSE OR DAMGED BOLTS, NUTS, SCR	SCREW	2	REPLACED UNCODIFIED	96157326	01
42	800806	50	11	003	56001	1009	206 BELL-JET RANGER HEAD M.R.	206-011-119-1 LOOSE OR DAMGED BOLTS, NUTS, SCR	NUT	2	REPLACED UNCODIFIED	96157326	02
42	800806	50	11	A79	56001	1009	206 BELL-JET RANGER HEAD M.R.	206-011-111-1 BEARING FAILURE OR FAULTY		2	REPLACED UNCODIFIED	96157326	03
42	800806	50	11	74	56001	1009	206 BELL-JET RANGER HEAD M.R.	206-011-128-1 BUSHING WORN OR DAMGED		4	REPLACED UNCODIFIED	96157326	04
42	800806	50	11	78	56001	1009	206 BELL-JET RANGER HEAD M.R.	206-010-110-3 IMPROPER FIT	WASHERTHR	2	REPLACED UNCODIFIED	96157326	05
42	800806	50	11	51	56001	1009	206 BELL-JET RANGER HEAD M.R.	206-011-147-1 NO DEFECT-TECHNICAL ORDER COMPLI	STRAP	2	REPLACED UNCODIFIED	96157326	06
42	800806	50	11	52	56001	1009	206 BELL-JET RANGER HEAD M.R.	206-011-140-1 NO DEFECT-TECHNICAL ORDER COMPLI	FITTING	2	REPLACED UNCODIFIED	96157326	07
42	800806	50	11	50	56001	1009	206 BELL-JET RANGER HEAD M.R.	206-010-123-3 NO DEFECT-REMOVED FOR TIME CHANG	PIN	2	REPLACED UNCODIFIED	96157326	08
42	800825	80			7582	122	206 BELL-JET RANGER HEAD M.R.	206-011-810-5 STATIC BALANCE VIBRATION EXCESSIVE			INSP.AND FOUND O.K SCHEDULED MAINTENA	96164983	

REMARKS

FIG. 4

Another example that I am bringing to the attention of this forum is quite dramatic:
The problem concerns the failure of main blade inspection method (BIM) tip seals.

You all probably recall the unsuccessful mission for the rescue of the American hostages in Iran. That operation was aborted when the number of helicopters available fell below the minimum deemed necessary for success. One of the helicopters had to land in the desert before arriving at the refueling point, and was abandoned due to cockpit indication of loss of spar pressure. Such indication can occur if there is actually a crack in the spar extrusion, it can alternatively show that pressure has been lost for some other reason.

Let us look at our defective item report on this subject and analyze together the relevant data collected in Israel. Since 1971 we recorded hundreds of XXX BIM tip seal failures. Out of this number, two cracked spars were actually found. The percentage of real problems to false alarms is less than 1%. In other words, I can safely state that a 99% likelihood exists that the aborted helicopter out in the Iranian desertexperienced a false alarm and that there was no crack in a Main Rotor Blade.

The loss of spar pressure due to a defective out board BIM seal was a cause known a long time ago, but only recently by the use of this program (and the sas experience in Iran)was it possible to quantity the problem. A new type of seal was developed at MATA back in 1971; since then it was retrofitted on nearly [redacted] blades and failed in only 3 cases.
Replacement of the original seals (when blades arrive at fourth echelon) with the new type has been a MATA recommendation adopted by the customer. The reliability of the cockpit BIM system. with the adoption of the MATA type seal, has been brought up to a crack detection probability of 66% which is quite impressive.

<u>"REASON OF THE DEFECT" REPORT</u>

The data is sorted by:
a) Manufacturer and model codes
b) Reason for defect code
c) Component/system code

<u>THE DATA USED IS BASED ON RELEASE DATA ONLY</u>

Human factor-caused problems can result in recommendations for changes by developing suitable instructions for the personnel concerned in flight and/or ground operations.

Problems arising from severe environmental conditions, such as sand erosion, can be treated in the same way as any other deficiency in design.

A good example of a problem associated with the human factor was the unnecessary removal of both Main Rotor Blades on Bell 212 Helicopters when vibrations developed. The problem was found to be the result of insufficient training and experience in installation of the blades, and went away after proper instruction of personnel.

Time does not permit presentation of additional examples, such as pilot error, sand erosion of stainless steel and cobalt main rotor leading edges, and many others.

Summaries of recommendations are submitted to MATA management and the customer as a basis for decisions relative to improvement changes. The effectiveness of any adopted improvement is subsequently monitored by the program itself.

In summary I believe that the reliability of the helicopter in the user's inventory can be improved dramatically by following similar programs.

It is to the mutual interest of manufacturers and operators to improve the fitness for use of the present flying helicopters and those in the future. Common efforts and exchange of information will benefit all the parties concerned.

R E R E R E N C E S

1. QUALITY PLANNING AND ANALYSIS FROM PRODUCT DEVELOPMENT THROUGH USE.
J. M. Juran, Frank M. Gryna Jr.
McGraw-Hill Inc. 1981

2. QUALITY CONTROL HANDBOOK - Third Edition
J. M. Juran
McGraw-Hill Inc.

3. HELICOPTERS AND AUTOGYROS OF THE WORLD
Paul Lambermont, Anthony Pirie
Cassell - London 1958

4. HELICOPTER GUIDE
C Charles Lester
Helicopter Utilities Inc., White Plans, N. Y. 1951

5. IRANIAN RESCUE MISSION - DEFENCE DEPT.
Issues Detailed Analysis
Aviation Week & Space Technology
May 19, 1980

6. A CRITICAL VIEW OF THE U.S. MILITARY ESTABLISHMENT
Esward N. Luttwak
Forbes, May 26, 1980

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