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NH90: INSTALLATION OF T700/T6E ENGINE ON BASIC HELICOPTER AND PRELIMINARY FLIGHT TEST ACTIVITY

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ABSTRACT:

NH90 is a twin engine, four blades H/C in development phase to get the qualification for two different variants: TTH (Tactical Transport Helicopter) and NFH (Nato Frigate Helicopter). It is based on jointly requirements expressed by the Armed Forces of France, Germany, Italy and The Netherland.
The program is managed on Customer side by NAHEMA (NATO HElicopter Management Agency) representing the Armed Forces of the four Participating Nations, and on Industry side by NHI Industries, representing Agusta, Eurocopter, Eurocopter Deutchland and Fokker.

In the D&D contract signed September 1st 1992 all the development was foreseen with the RTM322 engine, manufactured by a Consortium which includes Rolls Royce and Turbomeca companies.
To tailor the NH90 to all specific operational needs, a dual engine possibility was considered with an Additional Work contract signed on October 6th 1995: the T700/T6E engine (manufactured by a Consortium which includes Alfa Romeo Avio, Fiat Avio, and General Electric companies) was chosen to be installed on the first prototype to replace the RTM 322 after 160 flight testing hours.

Testing activity with the new configuration is split in two sessions separated by a three months lay-up to allow for the installation of IPS on the engine. Final performance will be assessed with this configuration.
T700/T6E installation is influenced by choices made for the RTM 322 engine and an high level of commonality between the two installation has been achieved.

PT1 flew from Marignane to C.Costa on 29.07.97, with a direct flight of 1 hour and 50 minutes. First flight took place at C. Costa on 13 of March '98, after a 9 months lay-up;

Globally the evaluation of 2nd engine installation is obtained with 150 flight hours considered to be performed in one and an half year; in this period also a preliminary ship trials activity has been performed to evaluate the H/C handling qualities in naval operation; details of this trials are reported in the presentation.

ACRONIMS

AC	Alternate Current
AG	Agusta
CG	Centre of Gravity
DC	Direct Current
D&D	Design and Development
FADEC	Full Authority Digital Engine Computer
FTI	Flight Test Instrumentation
H/C	Helicopter
EBST	Early Basic Ship Trials
EC	Eurocopter
ECB	Engine Control Box
EDB	Engine Development Box
EIB	Engine Interface Box
ILS	Integrated Logistic Support
IPS	Inlet Particle Separator
LH	Left Hand
NFH	NATO Frigate Helicopter
OEI	One Engine Inoperative
PMC	Plant Management Computer
PT1	NH90 1st prototype
RH	Right Hand
TTH	Tactical Transport Helicopter

<u>GENERAL NH90 CHARACTERISTICS</u>

Requirements from european navies and armies lead, in the eighties, to define a common basis for a helicopter of 8/9 tons; among these the following (most important) may be extracted:

Survivability: low detectability
reduced vulnerability
NBC protection
crashworthiness

Advanced ILS philosophy:
enhanced reliability availability
maintainability testability
supportability characteristics

Max. commonality between Tactical (TTH) and Naval (NFH) variants

Agreement on these requirements resulted in the signature of the D&D contract, whose subject is the Design and Development up to the qualification of the two common weapon systems: TTH and NFH.
The activity, started in '92 after the signature of the contract, will be completed within 2003 when both variants will be qualified.
Currently the process to define the contract for the industrialisation phase is in progress.

NH90 is a helicopter with the following main characteristics:

* All composite, aerodynamically optimised fuselage with constant cross-section centre fuselage for small radar signature
* Fail-safe design of structure, rotating parts and systems for high safety levels
* Conventional configuration for main and tail rotor, 4 bladed rotors,
* Twin engine
* Electrical flight controls
* Avionic suite offering all-weather flight capability and integrated highly-automated cockpit to reduce pilot workload
* High degree of survivability, reliability and ease of maintenance due to the use of automatic health and usage monitoring devices

The above characteristics will be developed and tested in the frame of D&D contract where 5 prototypes are considered to be built and flown with the following time schedule:

PT1 first flight	performed	18.12.95
PT2 first flight	performed	19.03.97
PT3 first flight	planned	4th quarter 98
PT4 first flight	planned	2nd quarter 99
PT5 first flight	planned	2nd quarter 99

PT1, PT2 and PT3 are dedicated to the development of the Common Basic configuration while PT4 and PT5 are dedicated respectively to the qualification of TTH and NFH mission systems.

In the D&D framework all prototypes were considered to be powered by RTM 322 engine but to achieve the possibility to offer a dual engine choice a dedicated contract was signed to test an alternative engine: the T700/T6E.

Aim of this additional contract is to evaluate the T700/T6E installation(in the two versions with and without IPS) and related performance at H/C level, in relative terms with respect to the RTM322 installation and for this purpose the first flying prototype was defined as that to be used for the installation of the new engine.

To achieve the goal the global activity is split into three phases, and will be completed with the delivery of PT1 back to EC for RTM 322 re-installation:

Phase 1)
Includes the definition, design, tooling and hardware manufacturing or procurement, initial laboratory test, PT1 delivery from EC to AG, and AG acceptance.

Phase 2 a)
Includes the laboratory test as required, PT1 lay-up, PT1 initial ground tests and about 90 hours of flight up to a key point where the first appraisal of the T700/T6E installation on PT1 will be achieved. The

target is to have tested all the key characteristics of the new engine installation such as to give sufficient confidence to launch the productionisation phase.

Phase 2 b)

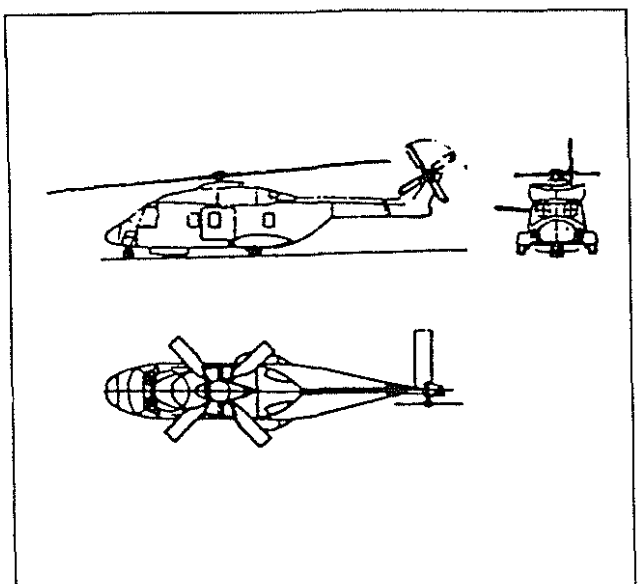
Includes the laboratory tests, lay-up to remove the engines and reinstall them after a modification performed to install the IPS, and PT1 flights (about 60 hours) devoted to engine/aircraft performance and integration, PT1 delivery from AG to EC and acceptance by EC

Qualification of T700/T6E installation on TTH and NFH is not included in the above phases and will be achieved in the production aircraft.

After completion of phase 1 with the acceptance of PT1 at AG, occurred after the roughly 2 hours direct transfer flight from Marignane to Cascina Costa on 29 July '97, a 9 months lay-up period started and led to the first flight of PT1 with the new engine on the 13 March '98.

At the time of PT1 arrival at AG, roughly 160 flight hours had been performed with RTM322 engine.

Since this period a flight testing activity dedicated to the optimisation of the installation was performed and currently approx. 50 flight hours have been logged by PT1 with the new engine.



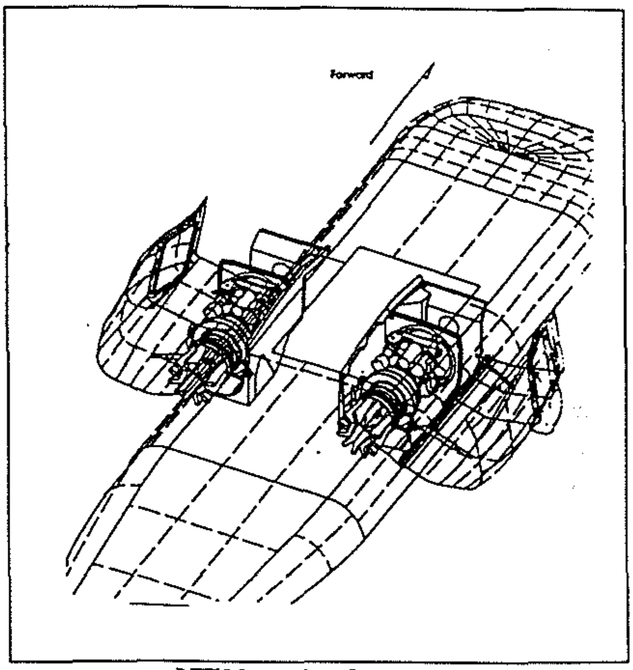
NH90

DESIGN COSTRAINTS

The engine bay of NH90 is made by two zones (one for each engine) in the helicopter upper deck, aft the gear-box bay.

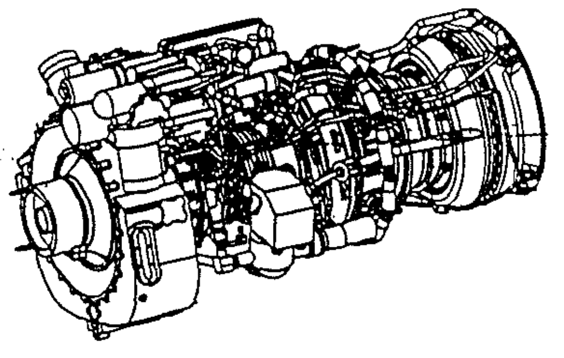
The air intake is made by a static plenum chamber (former tested configuration) that may be equipped with a upper scoop that transform it in a semi-dynamic intake (present configuration). The servicing cowlings can be opened laterally, while the front and the rear cowlings can slide forward and rearward respectively. The cowlings are all composite, while the internal firewalls are all in titanium.

The FADEC bay (for PT1) is in the cabin, below and rearward the engine bay.



NH90 engine bay zone

The T700/T6E engine is a front drive, turboshaft engine featuring a single-spool gas generator section consisting of a five-stage axial, single-stage centrifugal flow compressor, a through annular combustion chamber, a two-stage axial flow gas generator turbine, and a free or independent two-stage axial flow power turbine. The power turbine shaft is co-axial and extends to the front end of the engine. The engine has a top mounted accessory package and a dual channel FADEC system. The engine is provided with an inlet bellmouth (version /T6E) or with an integral IPS (/T6E1).



T700/T6E

The contract for the prototypical installation of T700/T6E engine on NH90 was placed after the original engine installation (with RTM322 engine) was already developed.
The contract specified that a precise goal of this installation was the maximisation of the commonality with the existing installation.
In addition it was decided that the selected prototype (PT1) at the end of the test campaign had to be retrofitted again with the RTM322, in order to proceed with the tests.

These constraints forced to focus the design on the following targets:

- on the engine side, to modify as much as possible the interfaces to make them similar to the RTM322 ones, to reduce the helicopter parts to be modified.
- on the helicopter side, to perform the modifications just inside the engine bay, maintaining as much as possible also the same interfaces between the bay and the rest of the helicopter, to reduce to the minimum the items to be changed.
- on the helicopter side, to develop installation solutions guaranteeing the future "return as it was" of the helicopter, thus avoiding permanent modifications of the prototype.

The result is an installation that in some items has compromise solutions, the only possible to match the above constraints.

DESIGN SOLUTIONS

The T700/T6E engine was modified to match NH90 interfaces as follows:
- the front flange and the spline for the power shaft were modified to allow the use of the existing helicopter power shaft and torque tube with gimbal.
- the inlet frame was modified to allow the installation of the bellmouth alternatively to IPS.
- a clutch was inserted at the starter interface (NH90 starter does not have it)
- various interfaces were modified to make them metric (NH90 is metric, T700 is designed in imperial dimensions)

The T700/T6E installation on NH90 PT1 has been designed maintaining exactly the same configuration of RTM322 installation for the following items:

- all helicopter parts outside the engine bays
- the external aerodynamic shape of the engine cowlings
- all the firewalls, except the air intake firewall, isolating the air intake from the engine bay
- the engine power shaft
- the torque tube with gimbal
- the fire detection system
- the fire extinguishing system
- the rear rails for rest legs

The following items were modified or changed

- the air intake firewall was changed
- the servicing cowling was modified in the zone of the holes for bay cooling
- the engine rear mounts were changed but they maintained the same interfaces with the upper deck.
- the engine rest legs were changed and the forward rail for rest leg was changed
- the bellmouth was changed
- the fuel, drains and bleed lines inside the bay were changed
- the primary exhaust duct was changed
- the FADEC installation was changed maintaining the same interfaces with the helicopter structure
- the EDB, EIB, ECB electronic boxes were changed

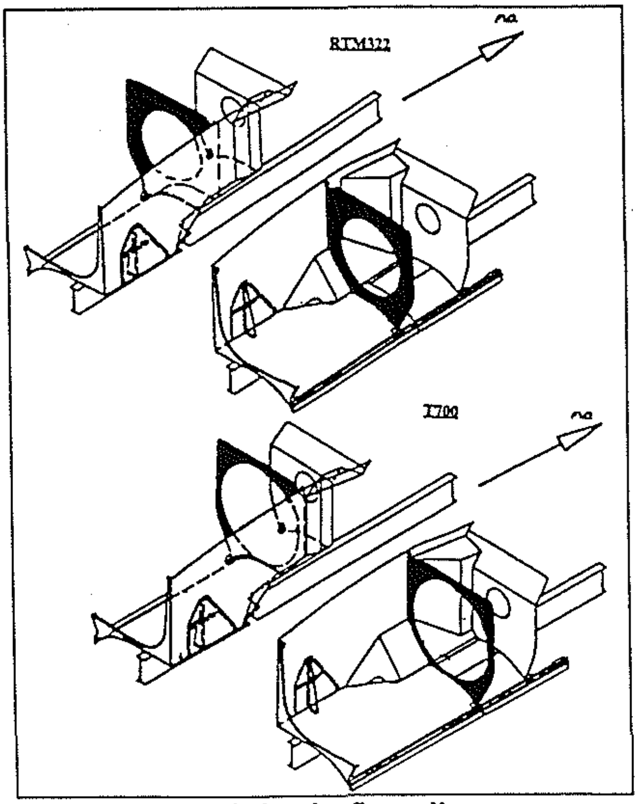
- the engine indicators in the cockpit were changed
- the wiring connecting the above boxes and indicators were changed
- the AC starter was modified in a model dedicated to T700

The T700/T6E1 installation on NH90 PT1 will be performed with the following modifications with respect to the T700/T6E one:

- the addition of a discharge duct for the IPS blower
- the modification of the servicing cowling with the hole for the above discharge duct.

1) Air intake firewall

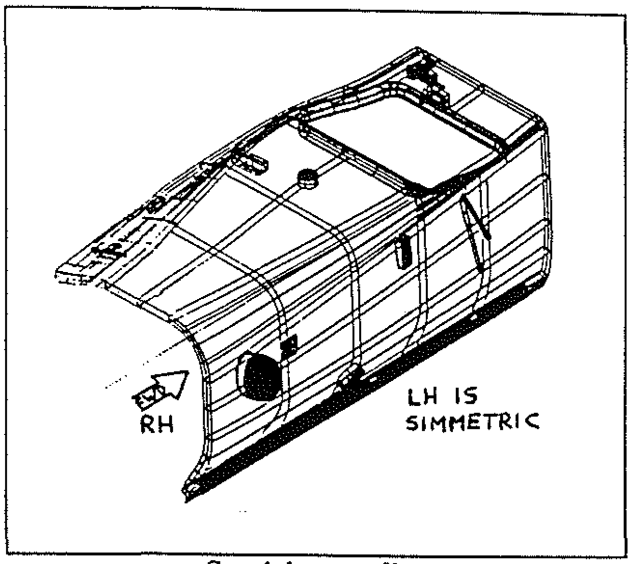
The new engine is longer than the previous one, and this causes the axial change forward of firewall position. It was necessary to strength the upper deck structure in the zone to support the loads. Internally the firewall has a larger hole where the bellmouth is connected, because the bellmouth diameter for T700 is greater, due to bigger engine front frame dimensions.
The forward movement of the firewall caused the reduction of the air intake plenum chamber volume, but this was balanced by the different aerodynamic shape of the bellmouth



Air intake firewall

2) Servicing cowling

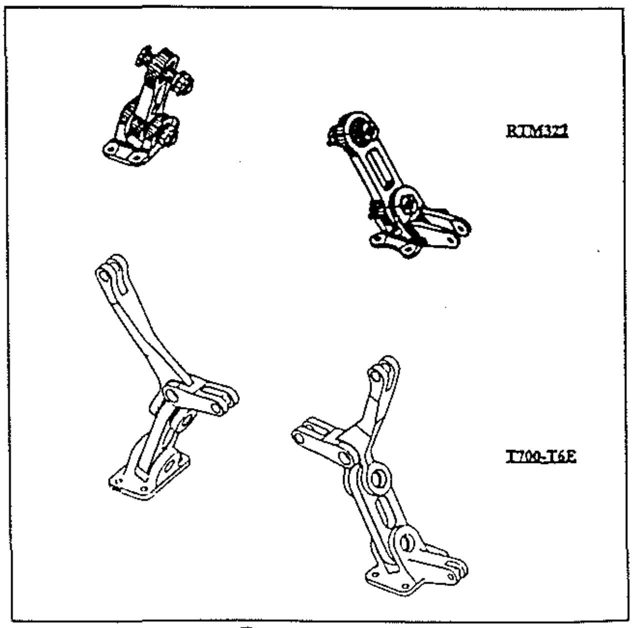
At the beginning the only scheduled modification was the hole in the rear zone for the IPS blower discharge duct (for /T6E1 engine).
During flight test it was necessary to modify the existing holes and to add a further hole in the RH cowling for bay cooling.



Servicing cowling

3) Rear mounts

Maintaining the same interface points on the supporting structure on upper deck, it was necessary to design mounts that in the lower part (near the upper deck) reproduced the RTM322 configuration, but in the upper part (near the engine) had new "fork" parts. This was due to the fact that the RTM322 has a 2-points system for mounts, while T700 has a 4-points system.



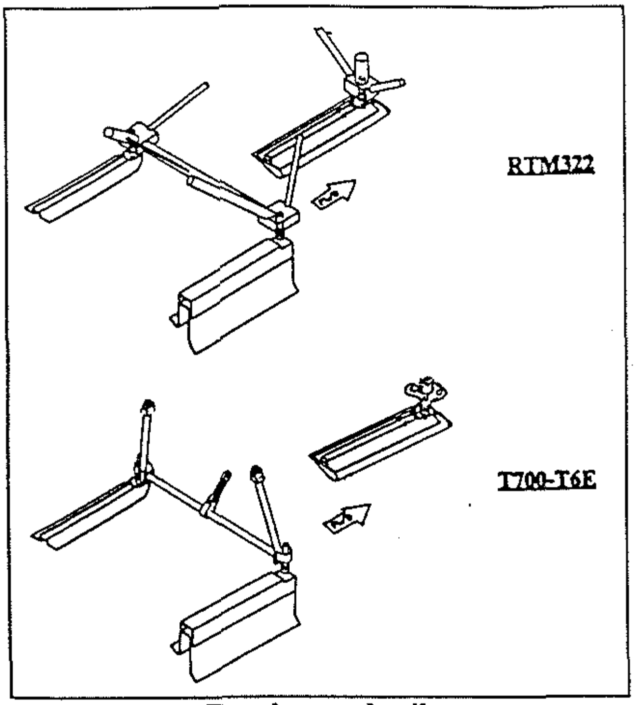
Rear mounts

4) Rest legs and rails

The legs are normally hanged up to the engine and not in contact with the rails. They are used only when the engine is slid back for quick removal, sustained and guided by the dedicated rails.

It was necessary to change the legs geometry because the linking points on the two engines are different.

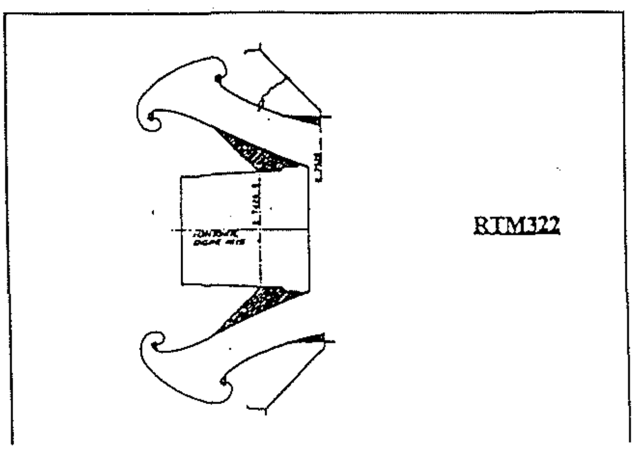
The rails for the rear legs were maintained the same, while it was not possible for the forward one due to the relevant leg position.

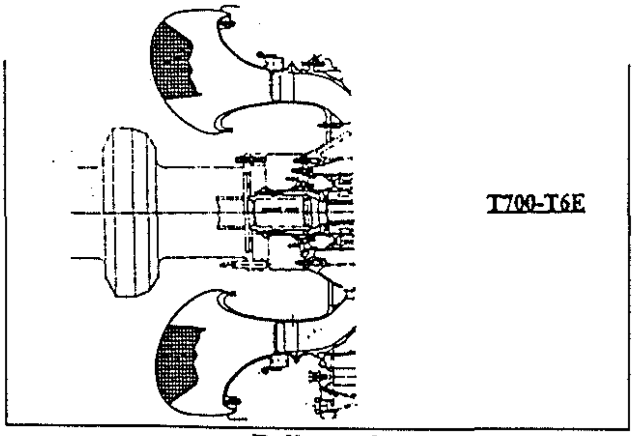


Rest legs and rails

5) Bellmouth

The different engine inlet configuration (especially in diameter) caused the modification of bellmouth shape. It was also designed shorter, to balance the reduced plenum chamber volume.





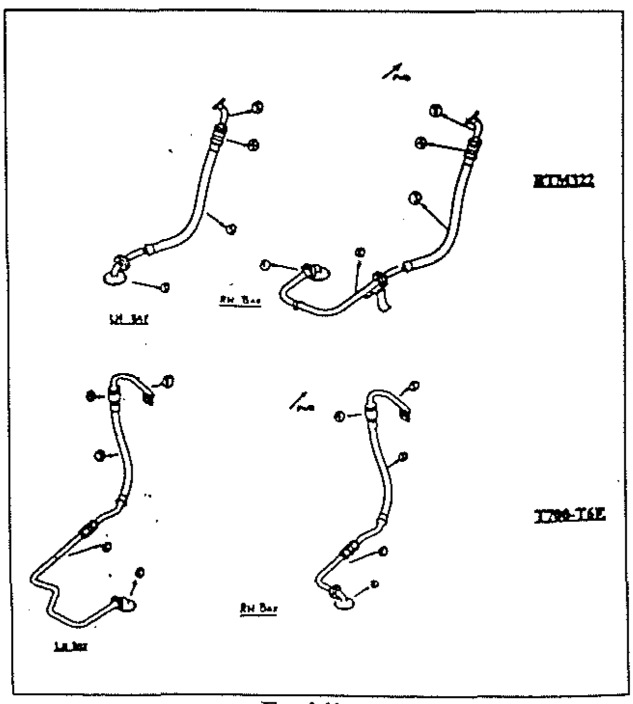
Bellmouth

6) Fuel, drain and bleed lines

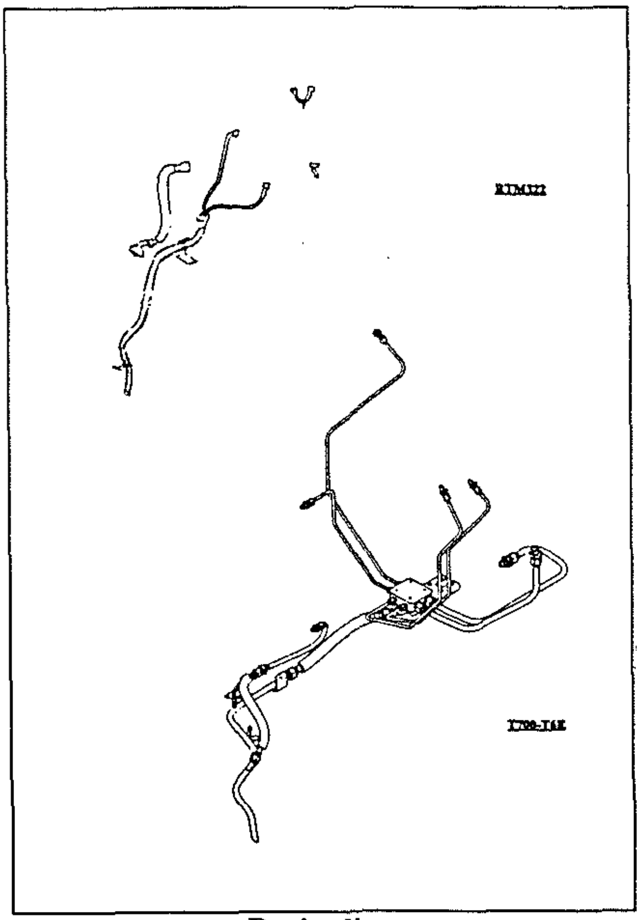
Maintaining the same interface ports on the upper deck, the different positions of engine ports forced to modify the routing of the pipes.

The fuel and bleed lines are conceptually very similar to the previous ones (logic and position of the quick-disconnection systems and of the flexible parts).

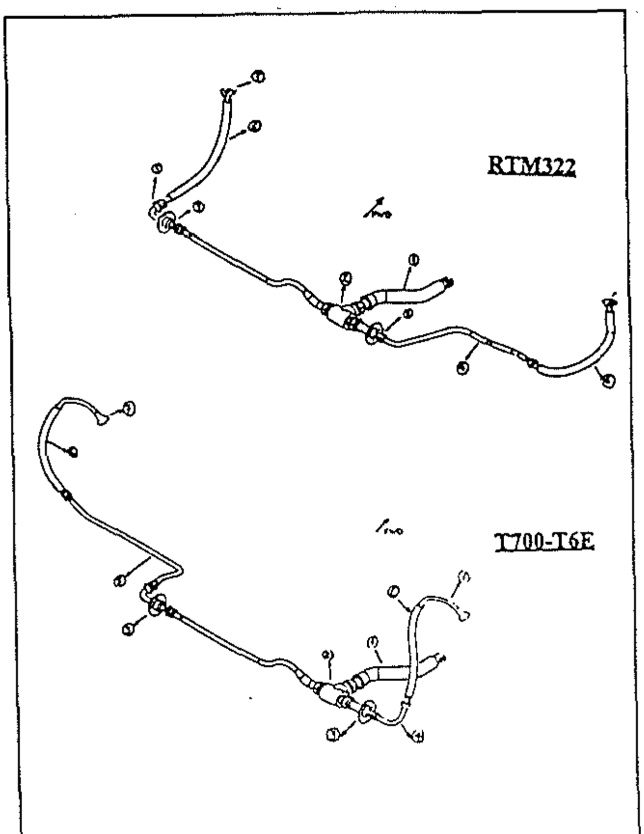
The drain line is greatly different from the previous one, because it is more focused on complete ducting of the drains to the drain points on deck, while before different drain lines discharged free on deck (this means more weight but less risk of flammable fluids in the bay). The drain line is an example of "compromise" installation due to contract constraints (the possibility of a different position of drain ports on upper deck and dedicated lines outside the bay should be considered for a production configuration).



Fuel lines



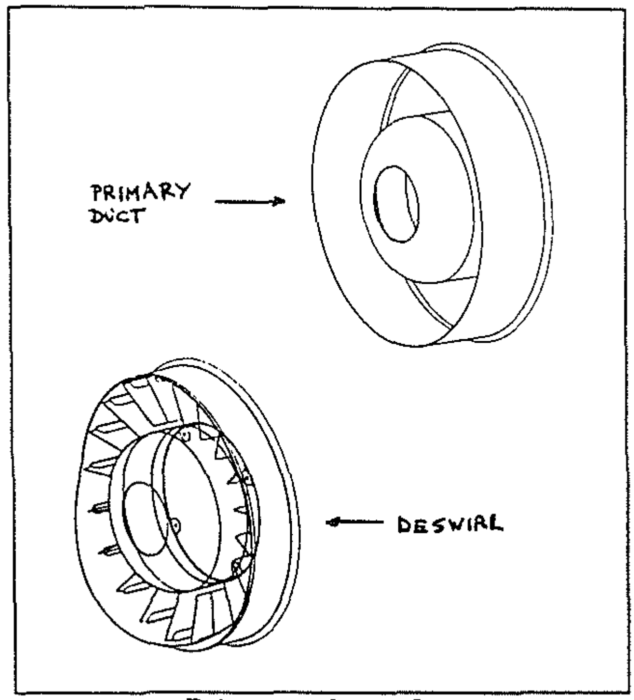
Drains lines



Bleed lines

7) <u>Primary exhaust duct</u>

The secondary duct was maintained the same, but, due to the major length of the T700, it was necessary to short the primary exhaust duct to maintain the same ejector length/diameter ratio. During flight test it was necessary to remove the simple primary duct and to install a more complex deswirl, to avoid bay cooling problems at ground idle.



Primary exhaust duct

8) <u>FADEC installation</u>

The FADECs for the two engines are quite different in dimensions and weight, but thanks to the large space available in the dedicated bay it was possible to maintain the same installation configuration and interfaces with structure, just designing a new support plate.

9) <u>EDB, EIB, ECB</u>

These 3 electronic boxes manage the data exchange between FADEC and helicopter.
The heavy differences between the two FADECs electrical/electronic interfaces forced to redesign the above boxes (EDB was quite heavily modified, because for RTM322 was a simple FTI box, while for T700 it manages also engine warning signals; the other two boxes where less affected)
It is to be noted that this configuration is peculiar to PT1, because for production information coming from the engines will be managed by PMC. In this reduced avionic configuration for example it is not possible (except via FTI) to

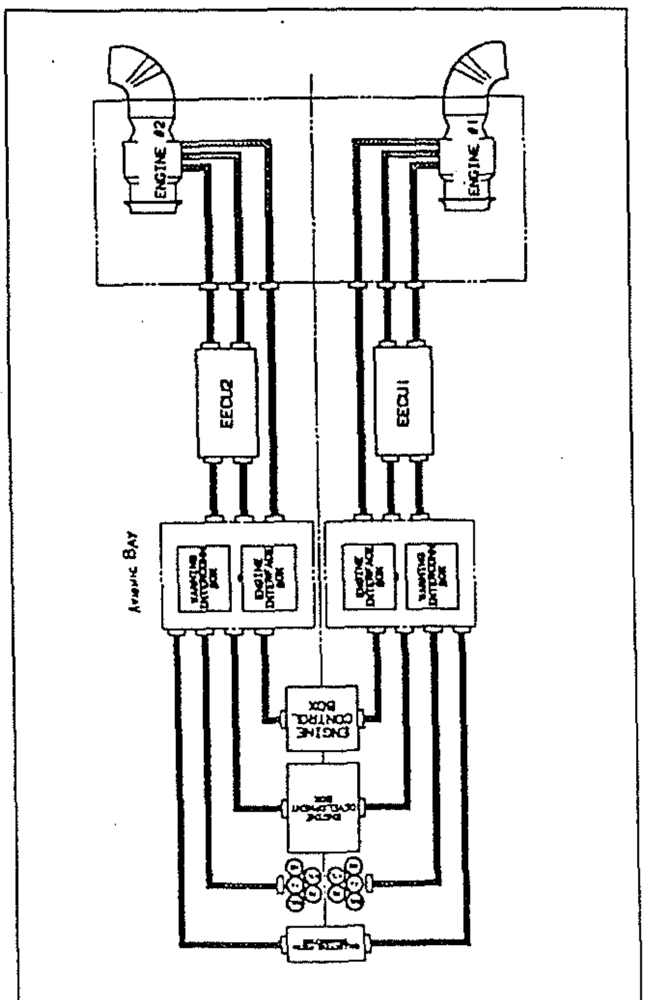
check the monitoring and diagnostic system of the engine.

10) Engine indicators

The PT1 configuration was maintained (serial configuration informations shall be merged in multifunction displays).
The indicators were changed in the scales (some limits are different for the two engines) and in the electrical parts inside (different FADEC supply requirements), but their functionality is the same.

11) Wiring

The wiring connecting all the electrical parts of the system were maintained equal in configuration and number.
When modifications were necessary, the existing wiring was never modified, but either it was removed and a new dedicated one was installed, or the new one was placed in parallel to the existing one that remained stowed. This was made to ease the "return as it was" work at the end of the campaign.



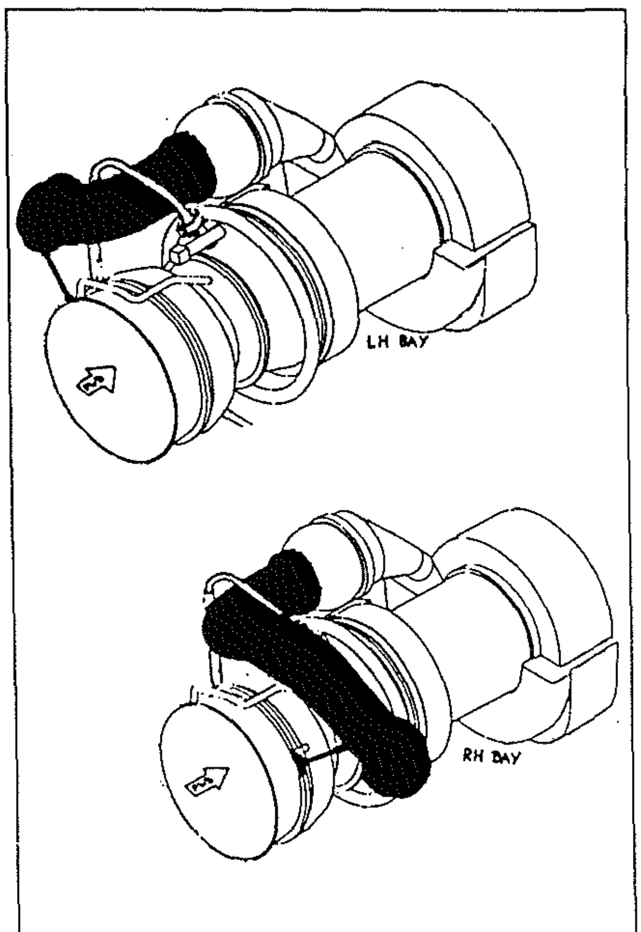
Engine installation electrical scheme

12) Starter

T700 needs a starting torque different from RTM322.
At the beginning a modification of the DC-starter previously installed on PT1 was planned.
Following the availability of a flyable model of the AC-starter previously planned only for production, the modification of the helicopter electrical configuration to allow its installation was decided.
After the first unsuccessful start attempt on helicopter, the B-model (planned identical to RTM322 one) had to be modified into a model specific for T700 prototype installation.

13) IPS blower discharge duct

The IPS need a fan to discharge the accumulated sand/dust, therefore it is necessary to define a duct to allow the removal outboard of the particles.



IPS blower discharge duct

FLIGHT TEST RESULTS

From first flight (performed on March 13th) to today, the following points were reached in approx. 50 FH:

- H/C envelope was progressively extended; now PT1 has reached 10000 ft altitude and ambient temperatures between +10 °C and +35°C. The max. speed of 167 kts has been reached.
  Flight conditions as OEI, autorotation, lateral and rear flight have been tested
- H/C handling qualities have been positively checked, even if no aggressive manoeuvres have been presently performed.
- Engines behaviour have been positively checked at different power conditions, from idle to max. continuous power.
- FADEC S/W, initially installed in a preliminary release with various limitations, is now loaded in an updated release having full capabilities.S/W performance in the conditions tested at today are considered very positive.
- Vibration levels have been positively checked (even if the complete vibration survey has not been completed).
- Bay cooling performance, after initial problems, have been optimised and positively tested even at high ambient temperature.
- Ship trials have been positively performed (see hereafter).

The next points to be tested up to December 98 are:

- Full performance evaluation (considering also aggressive manoeuvres)
- Completion of vibration tests
- Air inlet distorsion measurement
- Verification of s/w performance in all extreme conditions (OEI, failure simulation....)

During lay up starting in December 98, the installation of the IPS version of the engine (T700/T6E1) is scheduled, with the following aims:

- to evaluate performance modification with respect to the /T6E version.
- to complete the assessment on engine installation behaviour.
- to define engine performance (both versions) with respect to RTM322.

The end of this last part of test campaign is scheduled by mid 99.

TECHNICAL PROBLEMS DURING FLIGHT TEST

STARTER - CLUTCH COMPATIBILITY

The helicopter in the T700 configuration was ready to run on December 30th 1997.
The first start attempts on December 30th and 31st aborted on both engines, and one of the two starters had the shaft connecting it to the engine broken.
The reason was an engine clutch disengagement and following sudden re-engagement at high speed during the start acceleration phase, leading to an over-torque on the shaft.
The quickest solution was identified in the modification of the starter torque delivery.
The first start with one modified starter was performed on January 23rd 1998; the first start with both modified starters was performed on February 24th 1998.

BAY COOLING

The initial installation task was to maintain for T700 the same engine bay cooling configuration designed for RTM322 (in order to satisfy the requirement of commonality maximisation).
The original engine bay cooling configuration was as follows:

air entry (for each cowling):
-two holes in the forward zone of the cowling, one upper and one lateral, with external scoop on the lateral one.
-one slot along the cowling edge, in the rear zone

air exit (for each cowling):
- annular venturi ejector at the exhaust with primary duct

The first ground runs and flights shown that the task to maintain the RTM322 configuration also for T700 was not reachable, due to the differences in the engine configurations and heat emission.

In the period between first twin engine ground run (February 24th), first flight (March 13th) and final freeze (June 28th), the configuration was optimised passing through different steps.

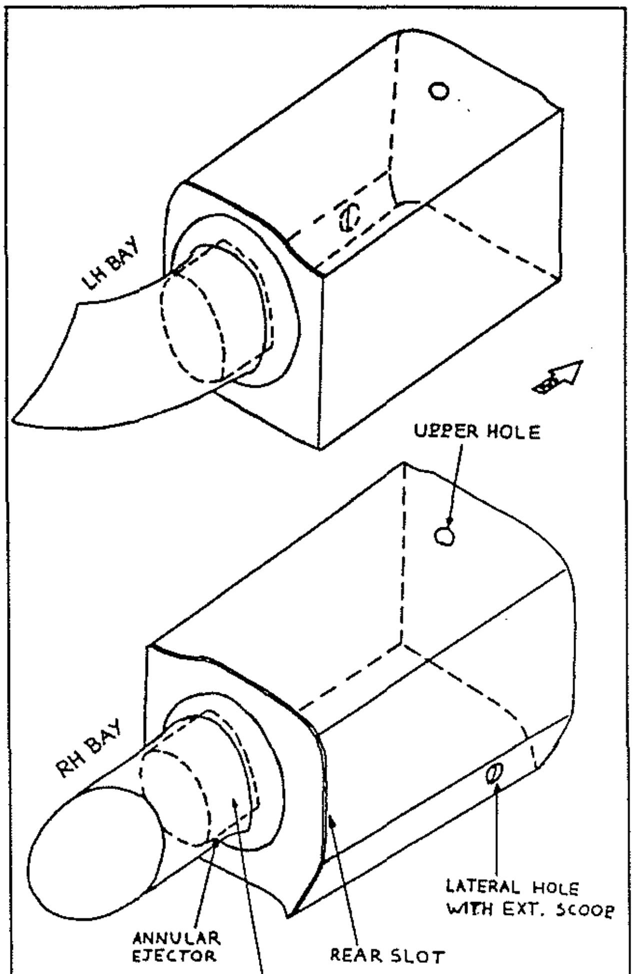
The present configuration is as follows:

air entry (for each cowling):
- two enlarged holes in the forward zone of the cowling, one upper and one lateral, with external scoops on both holes.
  The lateral hole has an additional internal scoop to properly route the air flow.
- one slot along the cowling edge, in the rear zone
- one hole only on RH bay, in the forward zone

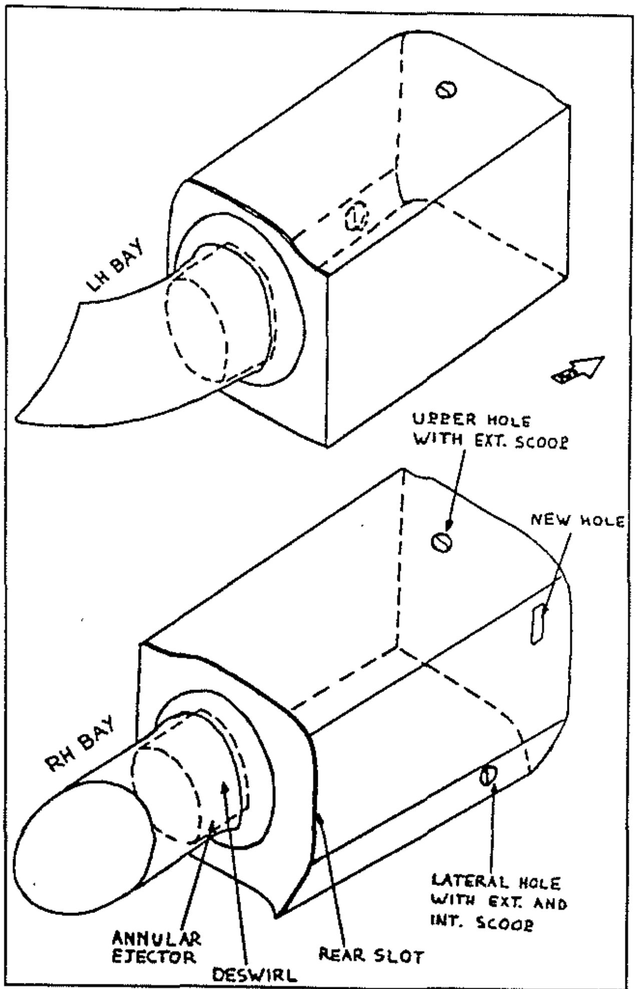
air exit (for each cowling):
- annular venturi ejector at the exhaust with deswirl

The present configuration has successfully passed the test of high ambient temperatures (+35°C) reached during ship trials.

During these tests also a dedicated 30-minutes long hovering was performed without problems (hovering in such bay configuration is the most critical condition).



Bay cooling original configuration



Bay cooling present configuration

For the bay cooling, the only items presently not yet evaluated are:

- IPS installation (effects due to the blower duct in the bay) - test scheduled in phase 2B.
- Infrared suppressor installation (effects on ejector performance) - test scheduled in certification phase.

SHIP TRIALS

A demonstration of the maturity level of NH90 including the new engine installation is the fact that PT1 has been used to perform a preliminary ship trials activity named Early Basic Ship Trials (EBST).

Aim of this preliminary activity was the confirmation during real flight tests of the results of piloted simulations for the following aspects:

1) Pilot field of view during manoeuvres (external visibility during approach, deck landing and take-off)
2) Pilot perception of clearance to deck
3) Handling Qualities
4) Helicopter attitudes during landings

Being the PT1 not equipped with normal devices to allow for a safe ship landings, some specific procedures or attention had to be used during this testing activity:

1) because this prototype had no specific tool (deck-lock) to retain PT1 on the ship after landing, a complete landing with rotor off was allowed only in emergency case when also normal lashing activity was allowed.
2) having the PT1 no floatation devices installed, to allow pilot to perform with enough confidence these trials a dedicated SAR helicopter followed all the testing activity performed on the ship.
3) because of the preliminary aspect of the trials, a period when usually sea and wind conditions are not extreme has been chosen for the testing; further to this a limitation to wind condition no higher than 30 Kts. has been defined.
4) weight was limited to 9000 Kg. to guarantee PT1 OEI capability
5) last limitation is provided by the pitch and roll motion of the ship because of the loads on a landing gear not in the final naval configuration and not fully qualified.

To assess PT1 characteristics in the worst operational condition from the attitude point of view, the maximum rearward CG configuration was chosen for the test.

EBST was performed on 20th and 21st of July; the ship dedicated to these trials was a Frigate provided by French Navy (Le Courbet) and the activity was performed in Mediterranean Sea (Base at Luni Sarzana -Italy).

The first testing phase was dedicated to the evaluation of the landing attitudes in the most favourable condition, that is with the ship anchored; in this condition ship roll and pitch motion were limited.

After this activity, some landings with ship moving at different speed (from 0 to max. 30 Kts. in step of 10 or 15 Kts.) have been performed approaching the ship from different position and performing different procedures to approach the deck:

- Straight-in
- Fore/Aft (left and right)
- Oblique and Cross deck (perpendicular).

Navies pilots of the 4 nations involved in the programme (France, Germany, Italy and Netherland) had the possibility to pilot the H/C during these trials.

The total activity resulted in:

- two days of flights
- roughly 8 flight hours
- 62 deck landings
- relative calm wind condition, the worst being of max. 12 Kts which resulted in a relative wind conditions of 32 Kts.

Here below the final assessment from the pilot point of view and following the 4 main tasks as listed above:

1) <u>Field of view</u>: the H/C attitude is considered good and does not limit the field of view during all the phases of deck landings.
2) <u>Deck Clearance</u>: final evaluation is left to the completion of the analysis of flight test data, but no problem occurred during landings.
3) <u>Handling Qualities</u>: in current H/C configuration, with a limited stabilisation system, the handling qualities were sufficient to perform the deck landings.
4) <u>Helicopter attitudes</u>: under the experienced conditions pilots were able to manage gentle landings (of course a final assessment has to be provided in adverse conditions).

In conclusion EBST gave confidence in the design of NH90 being capable of future shipborne operations, thus confirming the positive impressions received before in piloted simulations.

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