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AIR CONDITIONING SYSTEMS

FOR HELICOPTERS

- Authors :

Francis COUGNENC
Chef du Service Conditionnement d'Air
Centre d'Essais Aéronautique de Toulouse
23 Avenue Henri Guillaumet 31056 TOULOUSE Cedex- FRANCE

Marcel LESCAUDRON
Ingénieur Service Equipements Fréon
Chez ABG-SEMCA
408 Avenue des Etats Unis 31016 TOULOUSE Cedex- FRANCE

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ABSTRACT

MODERN HELICOPTERS ARE TO BE EQUIPPED WITH AIR CONDITIONING SYSTEMS, IN ORDER TO HAVE ELECTRONICS AND AVIONICS PROPERLY COOLED AND A BETTER COMFORT FOR CREW AND PASSENGERS.

THE PAPER WILL COVER

1) THE CHOICE OF A BASIC PRINCIPLE : AIR OR VAPOR CYCLE, WITH THE TECHNICAL AND ECONOMICAL RELATED ASPECTS AND COMPARISON WITH AIRCRAFT PROBLEMS.

2) THE CERTIFICATION TESTS TO BE DONE FOR SUCH SYSTEMS WITH A PRESENTATION OF THE FACILITIES THE CEAT PRESENTLY OPERATES AND THOSE UNDER DEVELOPMENT.

3) SOME EXAMPLES OF RECENT OR CURRENT STUDIES AND REALIZATIONS.

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1 - INTRODUCTION

Regarded up to now as an optional equipment for hot countries operation, the air conditioning system used on helicopter is becoming increasingly widespread today. It enables :

- to improve crew comfort and hence to have missions done more efficiently,
- to improve passenger comfort,
- to operate high power equipment on board (detection radar for instance),
- to improve the avionics reliability (MTBF multiplied by 2 or 3 when the environmental temperature is reduced from 60°C to 30°C).

Owing to the helicopter flight altitudes, the only function of the air conditioning system will be to condition cabin air, to control cabin air temperature with no need to control pressure. This specific characteristic, compared with the problem currently met on aircraft where cabin pressure control is required, gives us the opportunity to envisage new solutions that will be analysed technically and economically.

2 - CHOICE OF THE AIR CONDITIONING SYSTEM FOR HELICOPTER

2.1 - Presentation and assumptions

In order to compare the various technical solutions to cool helicopter cabins, a comparative assessment has been established for a given type of helicopter - in this case the SA 365N - to emphasize weight penalty due to the installation of :

- a turbo-fan air-cycle system,
- a "bootstrap" air-cycle system,
- a vapor cycle system (791A01 or 789A01).

This assessment has been established with data based on specialized literature or test results. It defines the additional weight to be installed and the additional fuel mass required to cope both with flying at the total weight penalty and operating refrigeration unit. This assessment only applies to an aircraft for which air conditioning is required and used during most flights.

We do not take into account penalties brought about by the reduction in engine extracted power due to the turbine inlet temperature limitation. However this power penalty is essential, since air conditioning must be used when outside temperature is high and unfortunately power limitation, due to turbine inlet temperature, takes place at the same time.

The formula used for calculating extra-consumption is as follows :

$$\Delta m = (\Delta M + r \Delta W + r \Delta \mathcal{T}) (e^{\frac{c}{r} t} - 1)$$

where :

Δm is the additional fuel consumption compared with that of an unequipped helicopter.

ΔM is the additional weight due to the installation of the system on helicopter.

ΔW is the air conditioning system power consumption of the equipped helicopter in operation.

$\Delta \mathcal{T}$ is the additional drag induced by coolant air.

r is the weight/power of the helicopter in cruise.

c is the specific fuel consumption.

t is the cruise duration

r and c are the helicopter characteristics, t equals 2 hours.

<u>Dauphin 2N powered with Arriel 1C engine</u>

- Thermal load in cabin : around 6 kW
- Engine power : 984 kW upon take-off,
720 kW in cruise.
- Average weight : 3500 kg in cruise,
3800 kg at take-off.
- Weight/power ratio : 4.86 kg/kW.
- Engine specific fuel consumption : 0.354 kg/kW x h.

2-2 ENERGETIC COMPARATIVE TABLE

	AIR CYCLE		VAPOR CYCLE
	TURBOFAN TYPE	BOOTSTRAP TYPE	791A01 or 789A01
Net cooling power in cabin (KW)	6	6	6
Cycle coefficient of performance	0.04	0.14	1.5
Cycle power consumption (KW)	150	42.85	4
Factor to convert cycle power into energy extracted from engine	1	1	1.11
Ventilation power consumption (KW)	*Already taken into account*	*Already taken into account*	3.0 (Electrical power)
Factor to convert ventilation power into energy extracted from engine	–	–	1.25
ΔW : Engine power penalty (KW)	150	42.85	8.25
$\Delta \mathcal{T}$: (1/2 qV2) (KW)	3 . (1 kg/s)	4.45 . (1.5 kg/s)	1.5 . (0.5 kg/s)
ΔM : Installed weight (Kg)	35	52	62
Δm : Fuel/2h mission (Kg)	122	42	17
$\Delta M + \Delta m$ (Kg) : Additional weight to condition cabin air for 2 hours.	157	94	**79**

2.3 - Check

Test campaigns conducted on the SA 366 G helicopter by the Marignane Flight Test Department as well as the U.S. CG in Eglin Field did prove the validity of the previous assumptions.

The air cycle system tested on the SA 366 G has a cooling capacity lower by 30% than that of a vapor cycle system. The former air cycle system is of an intermediate technology, a comprise between the turbofan and "bootstrap" concepts. Additional fuel consumption solely due to its operation needs is 5.5 %, whereas that of vapor cycle system can not be measured (< 1%). The additional installed weight involved by changing the system is 21,5 kg,(25.5 kg with the incorporation of the heating system).

Moreover, these results an related to two systems having a different cooling capacity. The use of a vapor cycle system leads to an improvement of cabin comfort (lower temperature) and electronic racks environmental temperature conditions for a lessen penalty.

2.4 - Choice

The previous energetic comparative table emphasizes the gain in weight and fuel consumption achieved with a vapor cycle system.

It would be possible, knowing the sales prices of the various systems given by the aircraft manufacturer, to calculate for the operator the operational cost of each system. Though sales prices are not accurately known and keeping in mind that maintenance costs are practically equal for conventional cycle systems (turbofan, vapor cycle) and 30% higher for an advanced air cycle system (of the bootstrap type) the following statement can be established : the operational cost of a vapor cycle system in the aeronautical field must be at least 30% lower than that of the most suitable air cycle system.

If this asset is added to the vapor-cycle qualitative advantages, i.e. :

- possibility of using the air-conditioning system during take-off,

- little effect on turbine inlet temperature, hence little effect on engine life,

- ease of installation (All-electric unit),

we quite understand why helicopter manufacturers opt for vapor cycle system rather than for air cycles.

Furthermore, these conclusions link up with those published by John Madin and Robert Buckingham.*

3 - DEVELOPMENT AND CERTIFICATION OF THE AIR CONDITIONING SYSTEM

As a first step, the performance characteristics of the air conditioning system shall be checked with regard to such influential parameters as temperature, humidity and pressure.

As a second step, the correct adaptation of the air conditioning pack to the helicopter shall be checked.

3.1 - Test of the air conditioning system alone

Test bench shall be capable of supplying the air conditioning system with air controlled in :

- Temperature : its influence is obvious. Temperature shall be controlled at each inlet, taking cabin recirculation into account.

- Humidity : its influence is particularly important upon the generation in cabin air. The evolution of performance characteristics against humidity level shall be checked as well as the quantity of water discharged into cabin and possible evaporator freezing.

The control of dew point shall only be achieved by injecting water in the vapor form.

- Pressure : taking the tightness of the system into account, pressure fluctuations shall only be important at the level of the airflows induced by fans on each heat exchanger. Altitude chamber test will therefore not be required, provided the law of the airflow versus pressure is known.

3.2 - Test of the air conditioning system on helicopter

The appropriate adaptation of the air conditioning pack to the helicopter shall be checked in particular to establish that :

- the power of the air conditioning system is sufficient under all flight conditions.

- the air distribution is such as to provide even temperatures in cabin and on components with no draft effect,

- temperature control operates correctly.

* Study published in the "HELICOPTER WORLD" review

These performance characteristics shall be checked on board of a real helicopter or on a sufficiently accurate mock-up placed in a climatic chamber capable of simulating temperature, humidity, sun radiation and altitude if necessary.

The altitude parameter can be of interest to assess thermal exchanges at location of components in various flight configurations.

In the end, the air conditioning system shall be checked to establish it is capable of operating with a suitable reliability in the helicopter disturbed environment (in particular vibrations, electric and radio electromagnetic).

4 - TEST FACILITIES FOR AIR CONDITIONING SYSTEMS AT CEAT

The Centre d'Essais Aéronautique de Toulouse (Aeronautical Test Center in Toulouse) has the task of performing qualification testing for components and systems installed on board of aircraft. The test plant for air conditioning systems provides a wide range of facilities for testing systems installed on helicopters and most sophisticated aircraft.

These test facilities include :

- vacuum chambers of various sizes which reproduce environmental conditions in flight (pressure, temperature) around components and systems under test. If necessary the capacity of the chambers can be adapted to that of aircraft cabin

	LENGTH (M)	DIAMETER (M)	VOLUME (M3)
C1	14	8	700
C2	8,5	4	106
C3	12	6	340
C4	8	3	56
C5	9	3	63
C6	3.2	2.7	18
C7	6	2.5	30
C8	4	2	12.5
C9	4	3	28
C10	4	1.3	5

MAXI ALTITUDE : 60 000 Ft

It is worth noting that a 700 m3 chamber can enclose a whole helicopter.

- climatic chambers with sun radiation and controlled humidity

- pressure-temperature and humidity controlled air networks simulate engine air bleed and other cooling airflows (max. 40 bar, 700°C,

	AIR SYSTEM 1	AIR SYSTEM 2	AIR SYSTEM 3	AIR SYSTEM 4	AIR SYSTEM 5
PRESSURE bar	40	30	8	1,5	1,5
AIR FLOW lb/sec	2,2	4,4	5,5	6,6	12
TEMPERATURE MAX	700°C (1360°F)	650°C (1270°F)	350°C (700°F)	200°C (410°F)	150°C (320°F)
DEW POINT	-70°C (-100°F)	-70°C (-100°F)	-70°C (-100°F)	Ambient	Ambient

- advanced measuring means particularly adapted to the specific test requirements of air conditioning systems. They allow to acquire and process simultaneously more than 500 parameters on a real time basis and, in addition, to cover the automatic control and safety functions during endurance tests,

- mechanical test equipment such as, vibration test rig, centrifugal machine supplied with hot and cold air to conduct environmental tests on components under real operating conditions.

At last, the Centre d'Essais Aéronautique de Toulouse has launched the design and développement of a new test laboratory for air conditioning systems. In a first stage this facility will be operational by the end of 87. That will be followed by various extension phases over the next decade.

Then, the range of facilities and performance characteristics will be sufficiently wide to allow, in this new laboratory, tests on all types of air conditioning systems for future ground vehicles, aircraft and spacecraft to be conducted.