FOURTH EUROPEAN ROTORCRAFT AND POWERED LIFT AIRCRAFT FORUM

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AN OPERATORS VIEWPOINT ON FUTURE ROTORCRAFT R & D CRITERIA

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ABSTRACT

The present boom in civil helicopter operations is closely related to the large increase in off-shore oil- and gasexploration and exploitation in the past 10 years. The fact remains however that these activities represent a finitive market in the, not too distant, future. This in turn implies that the civil helicopter operators will have to develop other markets, which in the long run, will ensure the continuity of their companies.
Present new technology helicopters are already penetrating the fixed wing executive market, because of their largely improved economy, reliability, all weather capability and passenger comfort. This indicates that a further breakthrough in operating economy may not be ruled out when further developments of long-range rotorcraft, as dictated by the fact that oil- and gasexplorations already tend to move further and further off-shore, are realised.
These rotorcraft, either pure helicopters or developments of hybrid rotorcraft such as the Bell XV-15 and Sikorsky ABC, might become sufficiently economical to be considered for short and medium haul passenger services and thus penetrate a promising but as yet unattainable market for the pure helicopter, due to its still relatively high seat-mile cost, which cannot be off-set by a convenience factor, as acceptable in the executive market.
With the present civil helicopter R+D activities at Nasa, the FAA and, hopefully, in the future also in the EEC, as well as with the increasing interest through Agard in civil military helicopter R+D cooperations, it is felt that the operators have to present their future requirements today, to influence the designs of tomorrow and thus to improve their future chance of survival.
This paper therefore presents an effort to identify future civil rotorcraft requirements and proposes certain criteria for present and future civil helicopter programs.

INTRODUCTION

The future is one of many things that defies control by human beings. It will proceed with an implicable disregard for whether it meets our wishes or not. Yet it is not entirely unmanageable; it will, after all, be nothing more than a set of conditions. We can always try to influence those conditions in advance (ref. 1). When an assesment is made of the set of conditions the following negative and positive fact emerge:

A. Negative

1. The present boom in civil helciopter operations is mainly caused by the rapid growth of off-shore oil and gasexploration and exploitations. The use of helicopters for this market will probably further increase over the next 2 to 3 decades, then stabilise and decrease when other sources of energy become available and the remaining natural resources have to be conserved or become too uneconomical for exploitation (ref. 2-3-4).

2. Other uses of helicopters, such as heavy lift, logging and executive transport will probably not increase sufficiently to provide an adeguate replacement of the off-shore activities in the long term.

3. Present helicopters are still too uneconomical and unsophisticated in design to compete with fixed wing aircraft in general, which otherwise might open new large markets in the field of passenger and freight transportation.

4. Present rotorcraft availability depends heavily on military R+D. Military requirements, however important for the continued growth of the helicopter industry, do not produce the aircraft anymore which can be easily converted for economical civil uses.

B. Positive

1. Off-shore oil and gasexploration and exploitation is already moving further and further off-shore requiring medium and large long-range rotorcraft.
   It may not be ruled out that this may lead to rotorcraft, either pure helicopters or developments of promising new designs such as the Bell XV-15 Tilt Rotor and Sikorsky ABC, which may be sufficiently economical to compete succesfully in the general fixed wing market.

2. The new technology helicopters which are presently coming on the market are competing succesfully with fixed wing aircraft for executive transportation purposes. Even if, in this case, the convenience factor is important to off-set the still higher operating cost, the fact remains that a significant step has been taken to provide largely improved economy, made possible by new technology insights.
   It may therefore not be ruled out that further R+D, concentrated on improving the economy of rotorcraft, may provide operating cost decreases, which are beyond the present thinking.
   This viewpoint seems to be supported by a recent study of British Airways Helicopters Ltd. with Boeing Vertol regarding the possibilities for a large new technology civil cargo/transport helicopter as a competitor for short and medium haul airline use (fig 1).
   This study actually showed a significant lower seat - mile cost (fig. 2), which, according to BAH is already low enough to be competitive with comparable fixed wing aircraft when the unique operational flexibility, all-weather capability and environmental acceptability are taken into consideration.
   Another possible effective first generation civil transport helicopter could be produced from the basic Sikorsky CH-53E by stretching the fuselage (fig. 3).

3. The present involvement of NASA, the FAA and in the future the EEO in helicopter R+D programs, as well as the increasing interest of the AGARD in military-civil R+D cooperations and standardisation, may provide a sound basis for further civil rotorcraft developments to produce economic rotorcraft in the future.

To influence these conditions in advance, it must be realised that the next 10 years will probably be crucial to ensure the continuity of the growth of civil rotorcraft operations in the long term. The civil helicopter operators are aware of the fact, that the outcome will, for a large part, depend on long term goals to be presented by them to the military and civil R+D and aviation agencies, the manufacturers and designers. This situation closely resembles the developments in the 1930's in the airline industry, where the airlines were beginning to provide specifications for the aircraft they required for the future. These long term goals may be generally defined as follows:

- improve the over-all economy
- improve the all weather capability
- improve passenger and environmental acceptance
- improve engine fuel economy and one-engine-out performance.

ECONOMY

When taking into consideration that helicopter operations in the long term will have to compete with fixed wing aircraft, the following R+D criteria to improve the economy of those operations may be suggested:

1. Decrease aquisition costs of aircraft and spares by design for production.
2. Reduce maintenance manhours and groundtimes required to achieve a high utilisation capability, through designing for realistic on-condition maintenance, accessability of components and high T.B.O.'s.
3. Reduce unscheuduled maintenance and overhaul costs by significant reductions in vibration levels.
4. Increase performance and fuel economy and thus range-payload, resulting in lower seat-mile cost and also increase the economic cruise speed to further reduce the seat-mile cost.
5. Design the fuselage to accomodate a full passenger load over the desired range.

With regard to the above design criteria some further suggestions may be presented.

<u>sub 1.</u> The basic automated production line such as developped for the UTTAS and S-76 at Sikorsky, the use of advanced materials and constructions to reduce labour costs, as well as the introduction of large production series, used as a basic design criteriom, seems to be the right answer to reduce aquisition costs.

<u>sub 2.</u> Main gearboxes are a good example for pointing out possibilities for significant improvements. a) with the present technology, triple redundancy could be built in to cope with lubrication problems, when the military requirements for dry-run capability should be combined with dual <u>independent</u> oilsystems.

b) rotorshaft moments and vibrations could be separated from the gearbox if the rotormast should be attached to the fuselage like in the Hughes 500. This would provide higher reliability of the main gearbox. The rotorshaft could be designed to failsafe standards, replacement of the gearbox would not require removal of the rotorhead and control re-rigging, and vibrations could be reduced by limited tilting of the shaft in forward flight to achieve minimum cyclic induced flapping of the rotorblades.

sub 3. Vibration reduction through changing the tilt of the rotorshaft in forward flight may be one answer to the problem. However vibration absorbers, nodal systems and vibration isolators will have to be utilised to decrease vibrations further, in particular when high vibration levels are incurred with hingeless rotorsystems, which cannot be completely removed by tilting the rotorshaft in flight.

sub 4. Reference 5 and 6 offer some interesting thoughts on this subject. Improved engines, aerodynamic cleanlines of fuselages and increased rotor efficiency on new technology helicopters already has paid a big dividend producing a significant increase in miles flown per gallon of fuel. This in turn increases the payload-range capability and thus decreases mission cost. A further improvement might be possible with a further decrease in specific fuel consumption od new technology, possibly regenerative engines, using fan thrust of the engines in forward flight (fig 5), tilting the rotorshaft to control fuselage attitude for minimum drag conditions and last but not least further improvements in rotor performance. When we changed our cabin plans in the S-61N to provide a c.g. position for minimum flapping in normal cruise, the airspeed increased with 4-6 Kts at the same engine torque setting as used before.

An increase in economic cruise speed for the pure helicopter above 150 Kts does not yet seem to be feasable (ref 7). To compete with fixed wing aircraft over a 200-300 n.m. route distance, economic cruise speeds should be at least 225 Kts. This in turn implies, that increased R+D efforts may be required to ascertain the possibilities of hybrid rotorcraft, such as the Bell XV-15 Tilt Rotor and Sikorsky ABC, to be developped into economic medium and short haul passenger/cargo transports (fig 4-5).

sub 5. In general, fuselage size of present helicopters and some of the new technology helicopters is designes around military requirements with regard to hot day, high altitude performance crash worthiness requirements and utility transportation (ref 8). As the succes of the S-61N over other designs has shown, the economics of the helicopter are improved if the full load capability can be used for passengers transportation over the mean distance for the average mission.
Fig 2 shows how this can influence the seatmile cost. In general it may be stated that fuselage seize should be dictated by the performance requirements of FAR29 CAT-A for a 200-300 n.m. range, fully IFR equipped, with all required passenger convenience and safety equipment included in the empty weight.

ALL WEATHER CAPABILITY

The unique capabilities of the helicopter to conduct IFR operations to very low weather minima with relatively unsophisticated equipment (ref 9-10) has been well proven in the past 10 years. However, this capability cannot be fully utilised until adequate icing protection has been developped to safely accept low freezing levels like fixed wing aircraft, including not only the main and tail rotorblades but also fuselage ice collecting points. The pure helicopter, because of its significant decrease in rotor performance with altitude, even then will still be severly hampered by the fact that it cannot overfly the weather. In the case of the Tilt-Rotor and ABC concepts, this problem would be solved as these aircraft could overfly the weather like fixed wing aircraft and thus would not be forced to prolonged flights in icing. Another problem which is becoming more apparent with the increase in IFR flying is attitude control in heavy turbulence. In gusts the control sensitivity changes with the change in g-loading (fig 6). In helicopters with a small flapping hinge offset this is felt by the pilots as an attitude control-degradation, which is mostly corrected by decreasing the indicated airspeed, resulting in a reduction of g-load changes and thus control sensitivity-changes. If the hinge offset becomes large however, the helicopter becomes more gust sensitive in roll and pitch, requiring a fixed-wing type of control reaction from the pilot unless adequate automatic stabilisation is installed. From recent developments it seems that 6% hinge offset is about the best compromise. More research is however required to ascertain the optimum value which is also dictated by the increase in vibrations occuring with a large flapping hinge offset.

PASSENGER AND ENVIRONMENTAL ACCEPTANCE

The following two factors may be instrumental to the succes of rotorcraft when competing with fixed wing aircraft:

1. Passenger comfort

   Passenger comfort in present jet aircraft is rated high because of the low high frequency noise and vibration levels. The present wide-body wircraft have further increased passenger acceptance of airtravel.
   In present helicopters internal noise and vibration levels are still far too high. This is mainly caused by medium to high frequency noise, which, when at the same level (70 to 80 PNdB) of low frequency noise in present jet aircraft, has proven to be objectionable. An R+D program to analyse causes and effects is therefore required to provide an adequate solution to this problem, which is mainly caused by main gearbox and engine whine. The problem cannot be simply solved by sound - proofing, but could possibly require a major change in gearbox design and engine location. Cabin pressurisation, which is considered mandatory for larger passenger rotorcraft, may also reduce internal noise.
   Vibration levels are also a source of complaints. From vibration tests with the S-61N, using lead-lag tracking procedures as developped at our company, we found that one-per-rev. levels could be reduced to below 0.006 g in both the lateral and vertical mode, which is below the normal detection treshold.
   At the n- (blade) per rev. frequency, it was found that normal g-levels did not exceed 0.05 g. If this vibration level was exceeded pilots and passengers complained. For specification purposes a modified U.S. Army formula coul be used which, for the normal cruise only, could read:

   acceptable acceleration (g) = 0.002F + 0.01 (n-per rev.)

   = 0.002 F (one per rev. only).

2. <u>Environmental acceptance</u>

To retain its flexibility and thus its major advantage over present fixed wing aircraft, because it can use relatively small and easy to construct heliports at any suburban location, rotorcraft have to be good neighbours. Even with relatively low noise levels and the small noise footprints, possible through adequate approach and take-off procedures, heliports have been put out of business because of noise complaints and environmental action committees.

To provide heliports, near to built up area's therefore requires serious R+D efforts not only for noise reduction in the approach and landing, but also en-route, because of the normally low flight levels of these aircraft. Blade slap and tail rotor noise must be reduced drastically to fully utilise the unique flexibility possible with civil rotorcraft operations.

ENGINE FUEL ECONOMY AND ONE-ENGINE-OUT PERFORMANCE

To obtain the best fuel economy from any engine, even regenerative engines (ref 5-6), it is necessary to run these engines in normal cruise at a power setting for, basically, the lowest specific fuel consumption (sfc.). Both from the investment side and with regard to fuel consumption, a twin engined configuration seems preferable. However, power requirements for twin engined helicopters are also dictated by the following requirements:

1. FAR29 CAT A single engine performance requiring lower power loadings than optimal.
2. One-engine-out performance, to obtain an acceptable reject-take-off distance when an engine failure occurs just before the critical decision point (CDP), which in turn defines heliport size and presently causes major problems in the use of smaller heliports.

The first requirement introduces the need for engine development to reduce the sfc at lower power settings. This could be accomplished by a R+D program on regenerative engines, which, incidentally, also produce less noise.
The second requirement may be even tougher to solve as the ideal solution would be to retain full hover performance at maximum gross-weight when one engine fails, but without installing this excess power (through a third engine) permanently to prevent high fuel consumption under normal flight conditions. Research should therefore be conducred for the development of engines with super 200 percent emergency power ratings (ref6) to prevent the costly requirement for 3 engines.

FINAL REMARKS

This paper has tried to present a philosophy for the development of future civil rotorcraft, which may introduce selected criteria for R+D programs with the aim to ensure the continuing succes of civil helicopters operations in the long run. To quote Dr. A.W.R. Carrothers, former President of Canada's Institute for Research on Public Policy (ref 1) this paper's function is to say:

> "These are the things we should all think about, and these are the kinds of decisions which will confront us. It is the role of the political processes to say: "These are the actions we must take".

This paper can, from necessity, not cover all details. However, I sincerely hope that it will serve its purpose in pointing out not only some of the problems but also the possibilities for civil rotorcraft operations in the future, which, however, can only be realised if the right action is taken now by all who are involved, both in the helicopter industry and at Governamental levels.

ACKNOWLEDGEMENT

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REFERENCES

1. The Royal Bank of Canada - Discovering the Future -Montly letter- Vol 59, No.2-February/78

2. Petroleum Economist - How much Oil in the Wordl? Page 86/87 - March/78

3. Newsweek - North Sea Spoils Page 39 - April 3/78

4. Kahn, Herman Brown, William and Martel, Leon - The Next 200 Years William Morron and Company Inc. - New York/76

5. Stepniewsky, W.Z. - Energy Aspects of Helicopters with other Air and Ground Vehicles - Journal of the American Helicopter Society, Vol 23, No.1-January/78

6. Wiesner, Wayne and Snyder, William J. - Efficient Civil Helicopters: The Payoff of Directed Research - Journal of the American Helicopter Society, Vol 23, No.1-January/78

7. Lynn, Robert R. - The Rotary Wing Industry 2001 A.D. - ICAO Bulletin, February/78

8. Harding, David G. and Walsh, John P. - Civil and Military Design Requirements and their Influence on the Product, AGARD CP. 233, May/77

9. Van der Harten, R.J. and Cooper, P.G. - An Electronic Integrated Pilot Dispaly is Evaluated in North Sea Operations - AHS preprint No. 1021, May/76 - Vertica, 77 Vol 1.

10. Van der Harten, R.J. - Some Aspects of Offshore Operations in the Netherlands - AGARD CP. 233, May/77

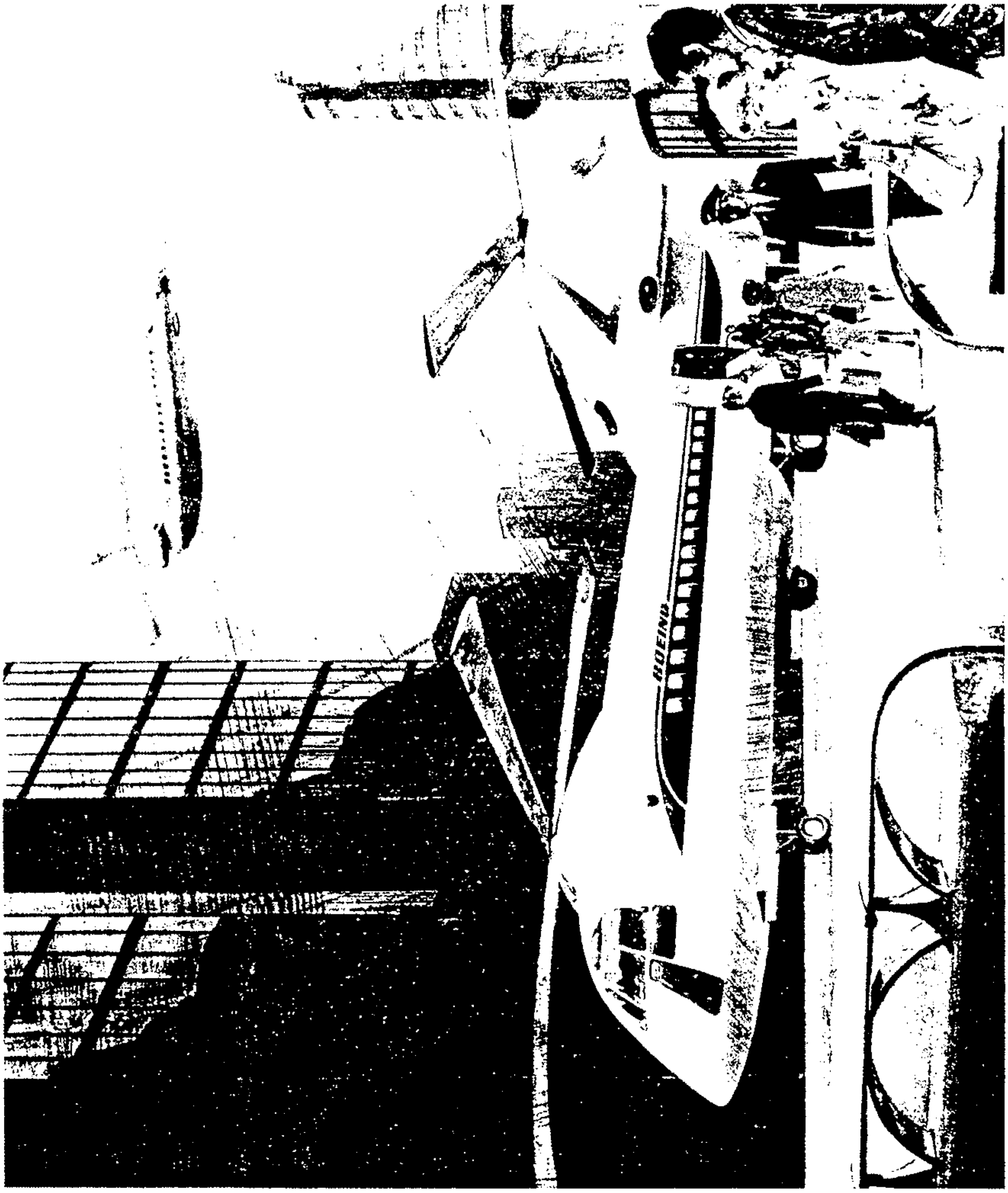


Figure 1.

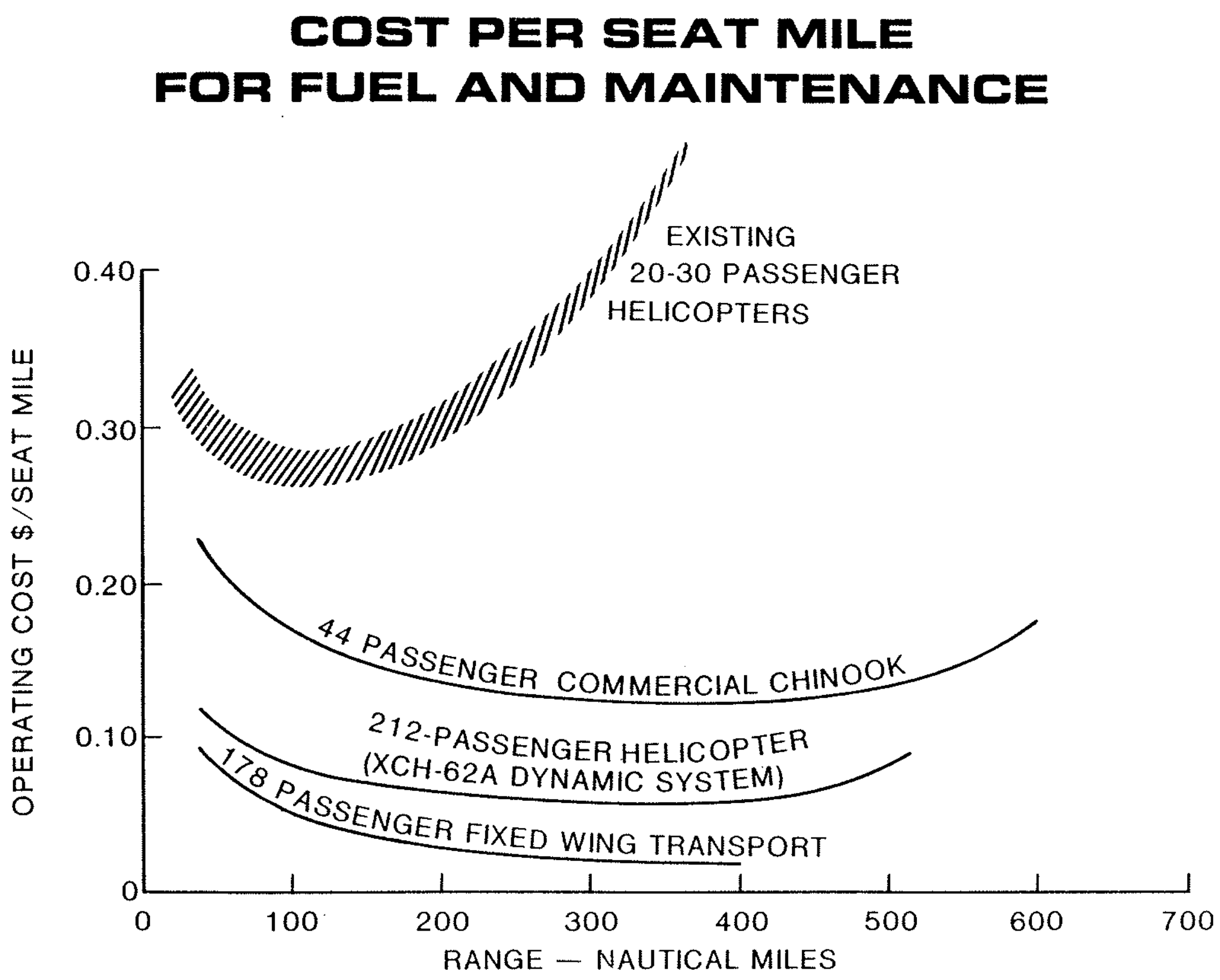

COST PER SEAT MILE
FOR FUEL AND MAINTENANCE
EXISTING
20-30 PASSENGER
HELICOPTERS
44 PASSENGER COMMERCIAL CHINOOK
212-PASSENGER HELICOPTER
(XCH-62A DYNAMIC SYSTEM)
178 PASSENGER FIXED WING TRANSPORT
OPERATING COST $/SEAT MILE
0.40
0.30
0.20
0.10
0
0
100
200
300
400
500
600
700
RANGE — NAUTICAL MILES

Figure 2.

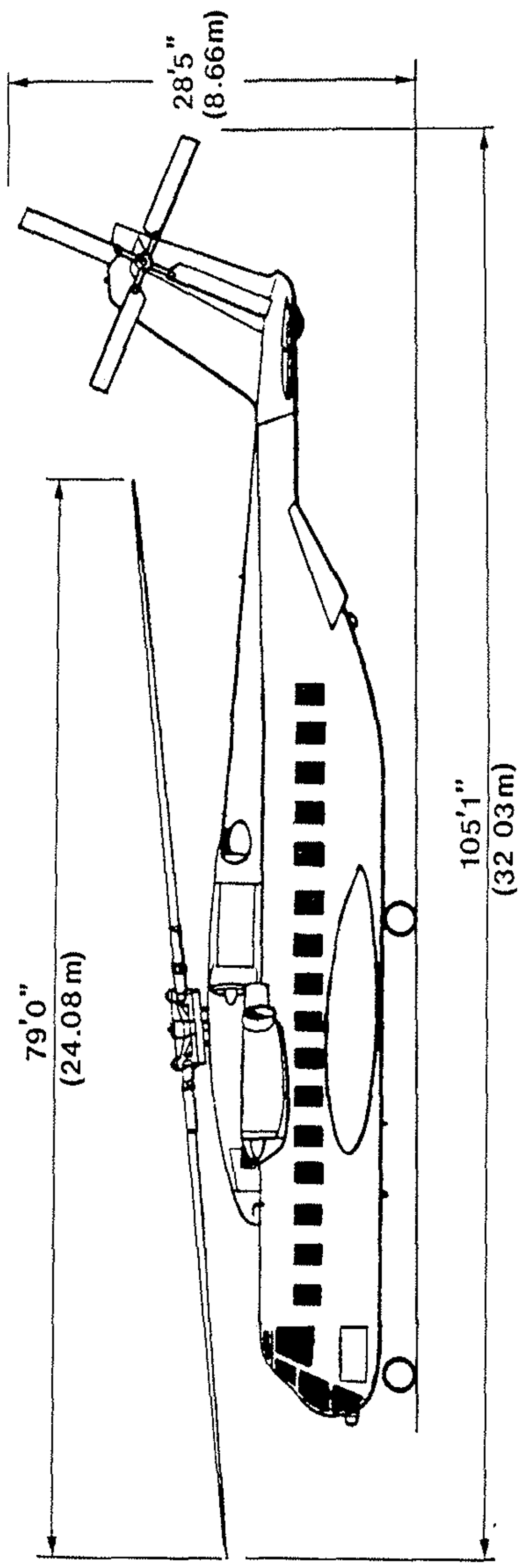


Figure 3.

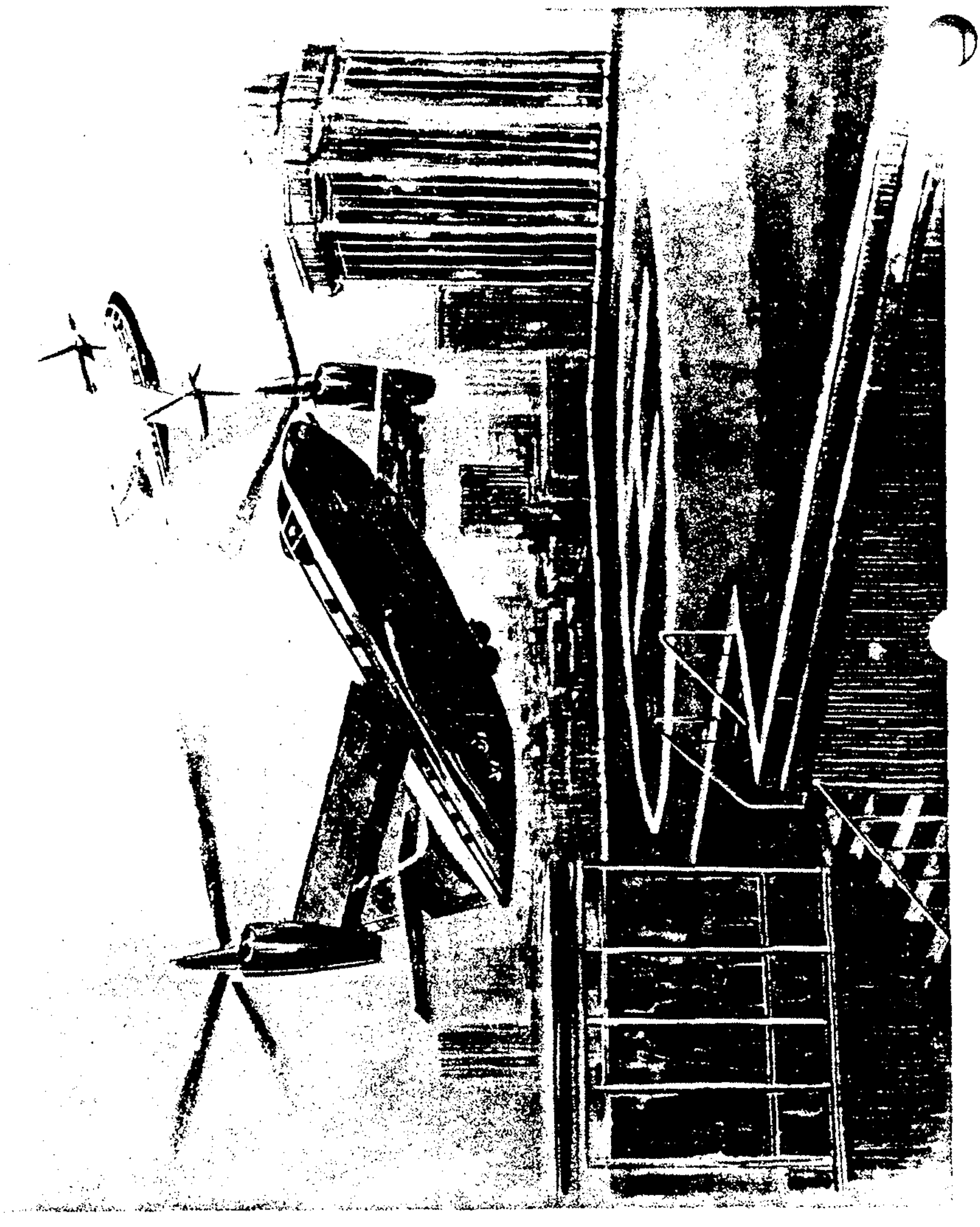
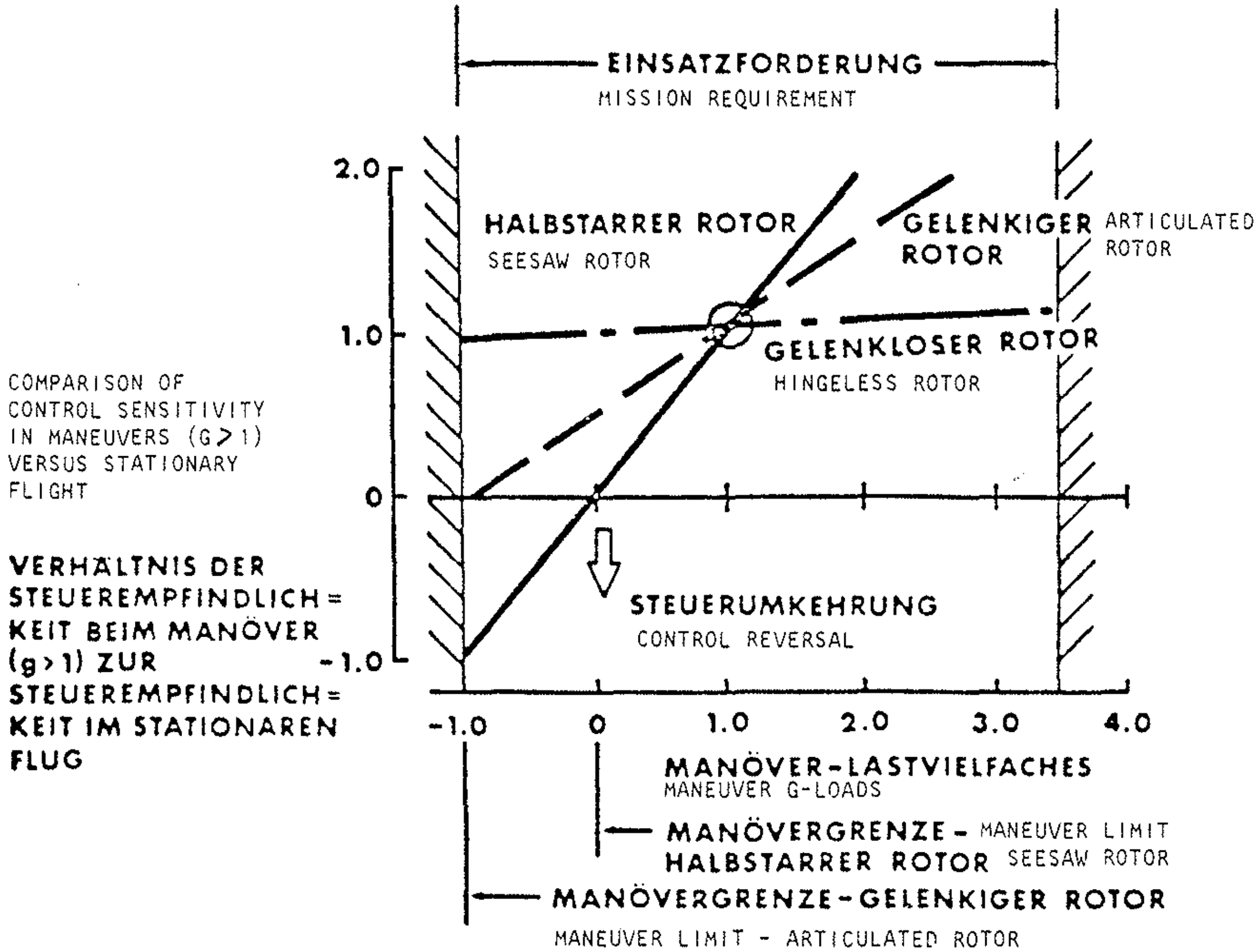


Figure 4.

Figure 5.



MANEUVER G-LOAD LIMITS OF DIFFERENT ROTOR SYSTEMS (COURTESY MBB)

Figure 6.