SIXTH EUROPEAN ROTORCRAFT AND POWERED LIFT AIRCRAFT FORUM

Paper No. 6

WESTLAND WG30

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ABSTRACT

The Westland WG30 is a private venture derivative of the Lynx, using this helicopter's main rotor components, with small engineering changes, but featuring a tail rotor of new design. The airframe is also completely new and incorporates a large unobstructed cabin offering twice the volume of the Lynx: some systems have also been changed compared with the Lynx.

The paper gives the background to the aircraft configuration, considering firstly, the judgements and influences associated with the sizing of the cabin, these factors being affected by both military and civil markets. It then outlines the adaptation of the Lynx main rotor with external noise and classical aerodynamic effects being discussed. The concept of the re-designed tail rotor is closely bound up with external noise as well and a brief description of the rotor follows.

Attention is turned to the structure and the production engineering concepts implicit in the design are described. The system configurations are then outlined and the reasons for using Lynx systems, or adopting an alternative, are discussed. The anti-vibration means are then described.

To put the design effort into perspective with the timescales of the activity up to first flight, are given, together with the management structure and the manning effort.

Progress during flight development is outlined, including a brief comparison of flight test results for main rotor stresses with prediction; measured external noise levels and progress with the anti-vibration means. A breakdown of the flying to date is given.

The immediate programme to Certification and production is given.

1. BACKGROUND TO THE AIRCRAFT

The suitability of the Lynx dynamic system for extension of the Company's range of products had been apparent, in 1976, for some time. Indeed, the original Anglo French arrangement involved a gunship variant while, in the early Seventies the Company actively studied the possibilities of a civil variant of the multi-role aircraft.

Examination of the Naval and multi-role Lynx variants clearly shows their degree of dedication to the ability to carry external payload, such as torpedoes and ATGW; their internal capacity is strictly limited and is not compatible with their payload potential. Attention was therefore turned to a different dedication, that of internal payload, and, in particular, the carriage of passengers; marketing studies were concentrated on this aspect and it was considered that there was a reasonable possibility of obtaining worthwhile business with a transport variant based on the Lynx dynamic system, but with first cost an almost overriding parameter.

The sizing of the cabin was based on elementary considerations as shown in Fig. 1. Here is seen the necessity to double, for short ranges, the cabin area of the Lynx for the capacity to be compatible with the payload.

Considerations of how best to obtain this increase included the insertion of plugs into the existing Lynx structure but it rapidly became clear that adverse forward CG effects on fatigue life could only be defeated by redesigning the fuel system (the Lynx main tanks are effectively in the fuselage under the engines). Having done this, there was little left which did not need re-design and with the desire to increase cabin internal height to give an attractiveness to the civil market the only practical solution was to opt for a totally new fuselage. This allowed the seating layouts to dictate the structure rather than the reverse and the basic configurations adopted are shown in Fig. 2.

At the time of this work, mid 1976, the Lynx naval variant was being developed to 10500 lb. The project for the new transport variant, now designated WG30, showed that a reasonable performance would necessitate an increase in take-off weight of some 10%. Accordingly, the design all-up-weight was fixed at 11500 lb., increasing to 11750 lb. early on in definition to facilitate vibration attenuation.

Other technical considerations at this time were tail rotor performance and external noise.

Fig. 3 shows a GA of the aircraft.

2. DYNAMIC SYSTEMS

Main Rotor

The all-up-weight was not, of course, decided in a unilateral fashion. It was known that the Lynx blade was manufactured with a ten inch tip extension which was cut off and used as a quality control monitor. Retention of this extension would give a 12% increase in thrust, for a given rotor RPM: accordingly, following the necessary examination of quality control procedures (and some minor modifications to blade tooling to ensure the integrity of the bond through the ten inch extension), the rotor was fixed at 43 ft. 8 inches diameter. Fig. 4 is a reminder of the blade technology - originally designed for the Lynx at an AUW of 8000 lb.

Reassessment of the main rotor system ultimate design cases to cater for the increased CF and thrust showed no necessity for component re-design other than to change the material specification for the tie bar pin to cover the proof case for the increased CF. All other areas of the main rotor hub and the flying control system between the jacks and the blade are unchanged from the uprated Lynx. Fig. 5 shows the rotor head for reference with the tie bar pins identified.

Estimates of main rotor fatigue loading, based on computer simulation of increased diameter rotor performance and high AUW Lynx experience indicated the benefits to be accrued from lower cruise thrust coefficient and advance ratio; which permitted an overall improvement in forward flight envelope combined with a reduction in predicted cruise flight vibratory stress levels with respect to the Lynx rotor.

Confirming these predictions is the vibratory stress level evidence from early flight test work in April 1979, shown in Figs. 6, 7 and 8 for three critical sections:

06.8% Rotor Radius	:	Main Rotor Hub
31.0% Rotor Radius	:	Main Rotor Blade
Main Rotor Track Rod	:	Main Rotor Powered Control System

WG30 data from these sections is compared with some recently available data from Lynx at very high AUW and with the 9500 lb. and 10,500 lb. Lynx data, which formed the basis of the original predictions.

In all cases WG30 shows a distinct improvement on the Lynx at high AUW, typically 15 knots for a given aircraft weight.

Mean stresses in cruise flight are generally little different from those experienced by Lynx. Both the tendency to overcone under increased thrust and lag aft under the slightly higher cruise power requirements have been countered by the increase in centrifugal stiffening from the extra blade length. The increase in mean stress solely due to the increased centrifugal load is generally not significant.

The similarity of the main rotor loading to that of Lynx has enabled us to proceed without any additional fatigue test programmes.

Transmission

The main gearbox is the three pinion derivative of the original Lynx conformal gearbox design: it is shown in Fig. 9. No changes have been made to the box for this application; the general fatigue test programme for the box was altered to take account of the differing spectrum of power for the aircraft compared with Lynx (mainly concerned with take-off power).

More recently, further work has been done to explore this box's potential power of 2000 SHP transmitted before failure (cf WG30 100% Torque limit of 1840 SHP).

The intermediate gearbox, at the base of the fin, is unchanged from the Lynx but the tail rotor gearbox is a completely new design, as is explained below.

Engines

These are two Rolls-Royce Gem 41-1 turboshafts, rated at 1120 S.H.P. maximum contingency power, at ISA Sea Level

This variant of the Gem has a rating structure governed by the needs of the WG30, subsequently it was standardised for Lynx production as well.

The engine installation is essentially as Lynx, the intakes being identical, engine controls are also similar, with only geometrical differences.

Tail Rotor

As mentioned earlier, external noise was considered in the definition stage of the aircraft. Lynx noise levels were thought to be inappropriate to an aircraft which was to be offered to the Civil market and using the knowledge gained during the Lynx development programme, a change of tail rotor was decided. An impetus to this was the increase in main rotor tip speed (746 from 717 ft./sec.).

Compared with the Lynx the direction of rotation was reversed, the tip speed reduced from 717 ft./sec. to 690 ft./sec. and the diameter increased to 8 ft. from 7 ft. 3 inches. At that time, the Company was engaged in a Demonstrator programme for composite construction, advanced aerofoil tail rotor blades for the Sea King and calculations showed that a cropped version of this blade would be suitable dynamically; compared with the Lynx aerofoil an increase in C_{LMAX} at moderate Mach Number of some 20% is obtained.

Fig. 10 shows WG30 relative to Lynx, using measured evidence, for a flyover at 500 ft. altitude, directly under the flight path. (Early flying with WG30 was with a Lynx tail rotor, owing to non-availability of the intended production rotor). The effectiveness of the change is obvious.

Fig. 11 shows detail of the tail rotor blade construction.

3. STRUCTURE

While structural weight was, naturally, a major concern, first cost was equally important. The freedom conferred by a completely new structural design allowed us to consider the relationship between cost and weight and to make judgements concerning the compromise between them.

Two decisions were made before the parametric work commenced: minimise double curvature and restrict honeycomb panels to flat surfaces (this being associated with worries about tooling costs).

Parametric work concentrated on the relationship between the number of components and the weight of an assembly. Fig. 12 shows results for a skin/stringer tail cone, nominally of WG30 geometry, the variables being the number of stringers, cleats and the skin thickness. The huge variation in parts count, with the small absolute difference in weight, is obvious. Ultimately the tail cone was designed with a frame pitch of 900 mm and 12 stringers - shown on the curve.

A similar exercise was conducted for the rear fuselage, Fig. 13 shows weight, this time in lb/ft^2 of surface area as a fraction of the number of parts - again the chosen compromise is shown.

The other decisions governing the structure were to use aluminium honeycomb for bulkheads, roof panels and fuel tank surround structure; to use one stringer section throughout, to minimise the number of different cleats (by examining ideal developed shapes and compromising) and to etch with one immersion only.

It has been judged that, compared with Lynx, the parts count, per pound of structural weight has been halved, for a modest weight penalty (of perhaps some 20 lb.).

Fig. 14 shows the structural layout - note the fuel system has only a minor impact, since it is effectively the bench seats at the ends of the cabin.

The raft anti-vibration system is detailed in Section 5. Only limited structural testing has been done, notably the anti-vibration raft forward corner, and clearance has been by check stress using finite element methods.

4. SYSTEMS

The policy to obtain the lowest unit cost, coupled with minimised development commitment, was applied to the aircraft systems as well as the structure. Lynx systems were considered on their merits, and, given the rules being applied, only the hydraulic system and the power control units were adopted from the outset. For all other systems, the world-wide market was examined, quotations sought, technically examined, the survivors from the examination then being judged on development and production costs.

Fig. 15 shows some salient results - the undercarriage comprises Islander main legs and a Trislander leg for the nose, with off-the-shelf wheels and brakes (the main wheels being Sea King), the DC electrical system is as Lynx, the basic AC system uses inverters (there being no intake or windscreen heating on the basic aircraft), the AFCS is from Louis Newmark.

As a result of this policy a reduction of some 53% was achieved on bought out equipment compared with Lynx - it must be understood, however, that our success in this was dependent upon our being able to make out own rules.

5. VIBRATION ATTENUATION

Analysis of flight tests on the Lynx showed that the major components of vibratory level forcing at blade passing frequency (22 Hz) are pitch and roll moments. At 140 knots, these moments are about 20,000 lb.ins. whereas the inplane and vertical shears are only 200 lb.

The rotor system for the WG30 is almost identical to the Lynx and calculations showed that the magnitude of the vibratory loads would be very similar. Consequently, the design of the WG30 concentrated on the moment excitation problems.

These loads are transmitted to the fuselage via the main gearbox and the magnitude of the resultant loads applied to the fuselage is a function of the stiffness of the gearbox to airframe attachment. Fig. 16 shows the load transmissibility characteristics of a simple soft mounted gearbox system. Clearly, in order to produce a system which attenuates the input load, the ratio of the forcing frequency to the systems natural frequency must be less than 0.71. For Lynx and WG30 this implies a gearbox natural frequency of less than 16 Hz.

For the Lynx, no flexibility was introduced in the mounting system, the philosophy being one of reducing the amplification (rather than providing attenuation) by making the system as stiff as possible. The Lynx solution is indicated on Fig. 16 which shows an amplification of approximately 2. The larger structure associated with the WG30 meant that adoption of the Lynx philosophy would undoubtedly lead to serious problems since it was unlikely that a similar degree of stiffness would be achieved in the structure without considerable weight penalty.

In order to achieve no amplification of the input loads, it was necessary to obtain pitch and roll modes of the gearbox at not more than 16 Hz.

To obtain this frequency by flexible mounting of the gearbox alone very low stiffnesses would have to be employed, leading to significant problems of static deflection to be catered for in the design of flying control and drive shaft couplings. Since the allowable stiffness of the gearbox to airframe interface increases as the apparent mass of the gearbox increases acceptable static and dynamic characteristics can be best achieved by combining the masses of engines and gearbox on a stiff structure.

This combination technique has been employed on the WG30 where main gearbox and engines are mounted on a raft structure which in turn is flexibly mounted to the airframe. Fig. 17 shows the raft together with the elastomeric mounts as originally configured. The design of the flexible mounts is dominated by weight and by the large steady loads that have to be transmitted. If metal were used for the 'springs' they would be both heavy and of large volume: the use of rubber, in shear, gives a compact solution for reasonable weight. This material does of course have the disadvantage of having a stiffness which is dependent on strain. The original design concept for the WG30 raft mounting employed, as shown, four such elastomeric units, one at each corner of the raft.

Subsequent calculations, combined with the results obtained from ground and flight testing of the prototype helicopter have shown that to attenuate both pitch and roll moment excitations equally, a greater degree of flexibility is required in the roll sense. Consequently, a three point raft suspension system has been designed, with the two forward mounts symmetrically placed either side of aircraft centre tail and a single rear mount on the centre line. This means that the roll mode is controlled by only two mounts, whereas the pitch mode is controlled by all three. It is anticipated that this change will provide better attenuation in roll without detriment to pitch behaviour.

6. DESIGN MANAGEMENT

At an early stage in the project study, it was recognised that efficiency of design and product management organisations contributes significantly to the achievement of technical solutions in minimum time and at low cost. Therefore, a review of existing management structures was conducted to improve these organisations. It was decided that the target aim shown in Fig. 18 could best be achieved by the adoption of an 'Ilot' concept organisation, in lieu of a matrix system, with design, technical, production engineering and commercial personnel integrated within a closely knit team. With the importance attached to the WG30 in the overall Company work schedule, the leadership of this Ilot team was placed at Director level with responsibility for design and day to day team guidance being delegated directly to the Assistant Chief Designer. This direct delegation was adopted to improve communication and ensure that staff concerned were fully informed of progress and policy. The prime objective, major activities and constituents of the team are shown in Figs. 19, 20 and 21.

The inclusion of production engineering and commercial personnel in the design team has been demonstrated to be of significant value in the achievement of a cost effective design ensuring only minimum changes between development and production vehicles. In the selection of bought out equipments and fittings again an integrated team approach was adopted with each item being examined simultaneously for technical and commercial suitability.

The co-operation and support of major suppliers in the loan or free supply of equipment has been actively sought and considerable success has been achieved; this represents a further extension of the team approach with the supplier becoming, in effect, a part of the 'team'.

The programme, being a private venture activity, has been subject to continuous cost review and monitoring. The integrated approach has facilitated this task enabling more rapid computation of cost and spend, the latter being obtained in terms of man weeks by name.

It is also felt that the project has benefited from the absence, at least in the early stages, of external authorities and controls. The involvement of the certification authorities has, of course, been active as the development progressed.

7. DEVELOPMENT

The prototype WG30 helicopter flew for the first time on the 10th April 1979 and to the end of June 1980 some 205 hours of development flying experience had been accumulated. Fig. 22 shows the achievement of flying hours during this period.

The test flying completed to date has examined all aspects of operation including performance, stress levels and handling, vibration, automatic flight control system development and assessment of temperature and internal and external noise. Fig. 23 shows an approximate breakdown of the total flight time associated with each of these tasks together with the results achieved.

During this period also, the first helicopter has also conducted a significant number of demonstration flights. The aircraft was exhibited at the Salon d'Aeronautique at Paris in June 1979 and since then has been demonstrated to both British and overseas military and civil operators.

Rotor stress measurements throughout the flight envelope compare well with estimated values and aircraft performance is much as predicted although power required at high forward speed is somewhat higher than anticipated. Some initial deficiencies in aircraft handling qualities have been overcome by progressive modification to airframe stabilising surfaces and to the automatic flight control system such that handling in all flight regimes is now satisfactory. Development of the control system in its own right has also continued with satisfactory results and trimming and runaway characteristics have been progressively improved. Aircraft vibration levels at the extremes of the flight envelope have been higher than predicted by raft design calculations but these have been improved on the prototype by the addition of a rotor head vibration absorber. Modifications to the raft to give further improvements without excess weight penalty are planned for future development. Both internal and external noise measurements have been carried out during the development programme and the aircraft has been shown to exhibit external noise levels close to ICAO limitations (not currently enforced for helicopters) and very low internal levels affording a high degree of passenger comfort.

The prototype helicopter has now commenced a 350 hour programme of endurance type test and certification flying to a schedule agreed with the Civil Aviation Authority which is aimed at the achievement of a full Certificate of Airworthiness for the vehicle.

A second airframe initially constructed as a systems test rig has completed a ground test of the fuel system, in accordance with British Civil Airworthiness Requirements and is now being completed to a flight standard.

8. FUTURE DEVELOPMENT

As previously stated the first helicopter is currently engaged on a programme of type test and certification flying. The programme will result in the achievement of a Certificate of Airworthiness, for visual meteorological conditions, in 1981. The development of the aircraft will then continue, using this vehicle to achieve IFR clearance by mid 1982.

The second helicopter, which is currently in build to flight standard, will be progressively equipped with envisaged customer option equipment for trial installation and development trials as well as for customer demonstration. It is considered that this will enable the delivery times offered to customers to be reduced.

The initial design standard having now been sealed, manufacture has commenced on a lunch batch of twenty basic WG30 helicopters which will be equipped to individual customer requirements subsequent to line build. This latter phase could, if necessary, also include retro-fit of design modifications. The first of the initial batch of production vehicles is scheduled for delivery in mid 1982.

Fig. 24 gives an indication of the major milestones achieved to date and programmed for the future.

The WG30 has been configured not only to provide an immediate extension, in itself, to the Lynx family of helicopters but also to provide a new base for further future development. Whilst the growth of the initial aircraft is limited by the read across of the Lynx dynamic system, originally designed for a vehicle of 8,000 lb all-up-weight, to weights of the order of 12,000 lb., the new structure has been designed to give capabilities beyond this level. Furthermore the design is such that some further development could be made easily, on the production line by changes of skin and stringer gauge. Therefore, in addition to the immediate flight development on the first vehicle, the medium and long term future development of the aircraft is under study at the present time.

ACKNOWLEDGEMENTS

The assistance of all staff of Westland Helicopters, in particular those members of the integrated design and production team, who have contributed to the successful development of this project and the assistance of all suppliers who have contributed in the loan of equipments are hereby gratefully acknowledged.

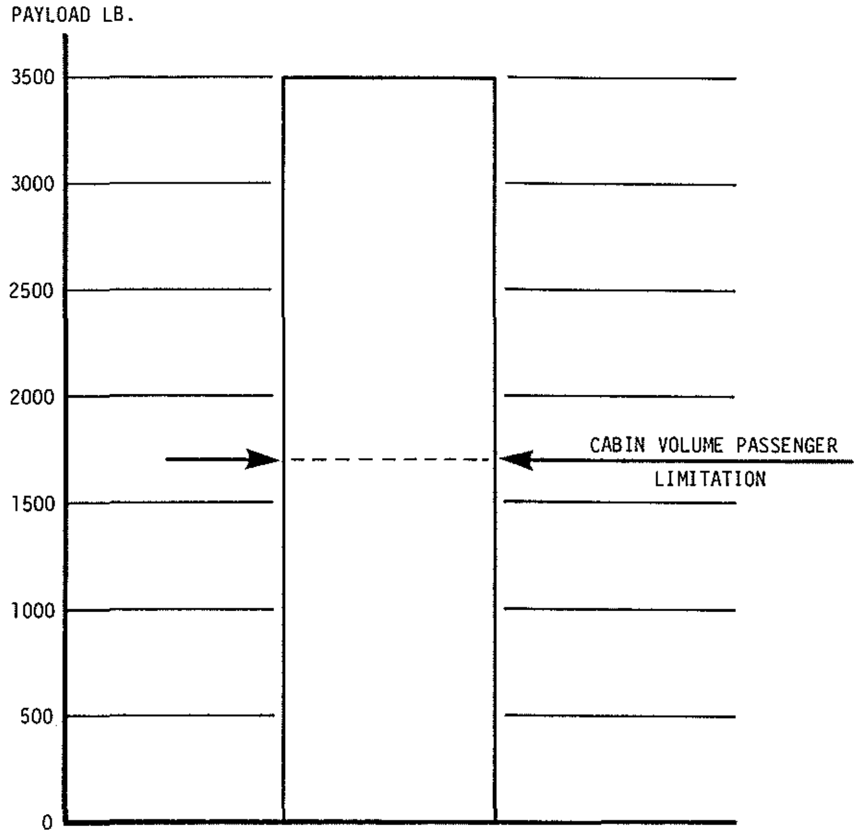


FIG.1. MULTI-ROLE LYNX SHORT HAUL PAYLOAD

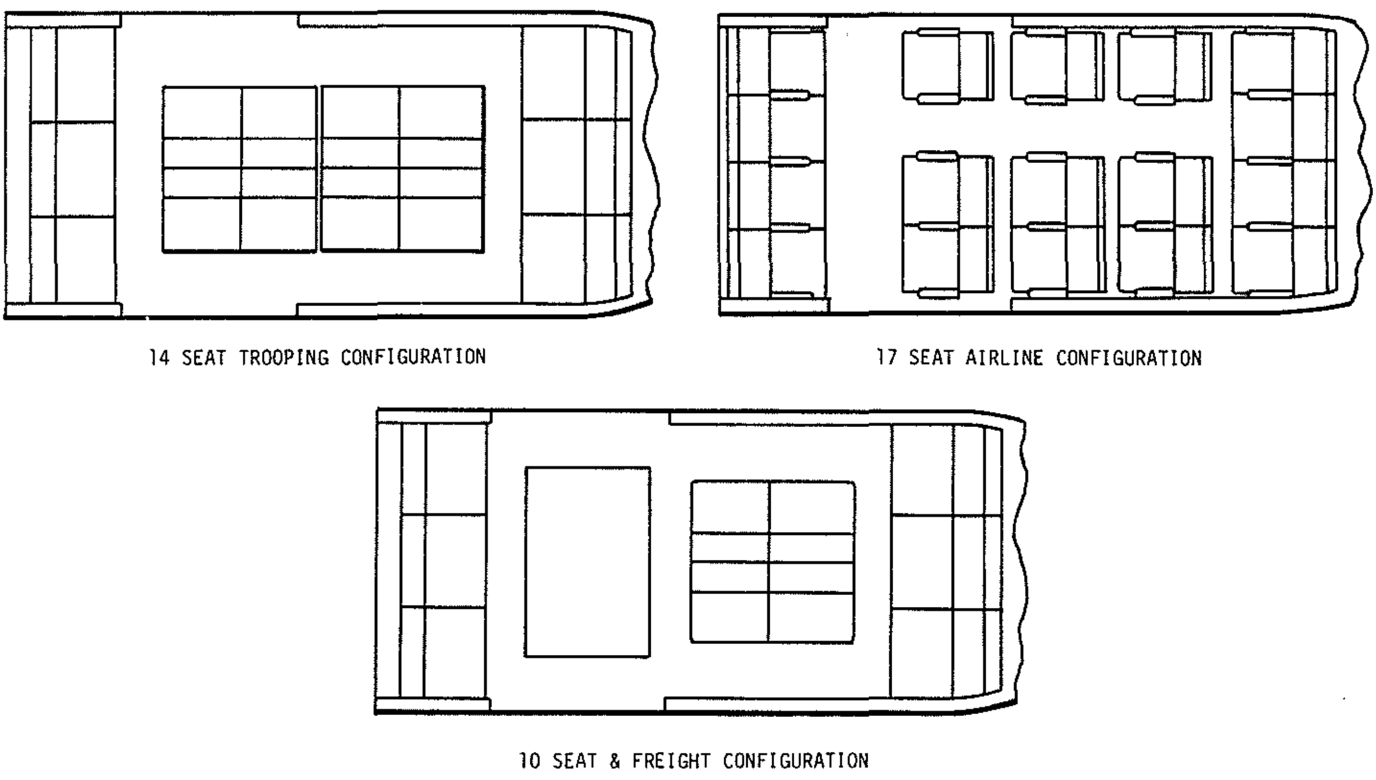


FIG.2. WG.30 SEATING CONFIGURATIONS

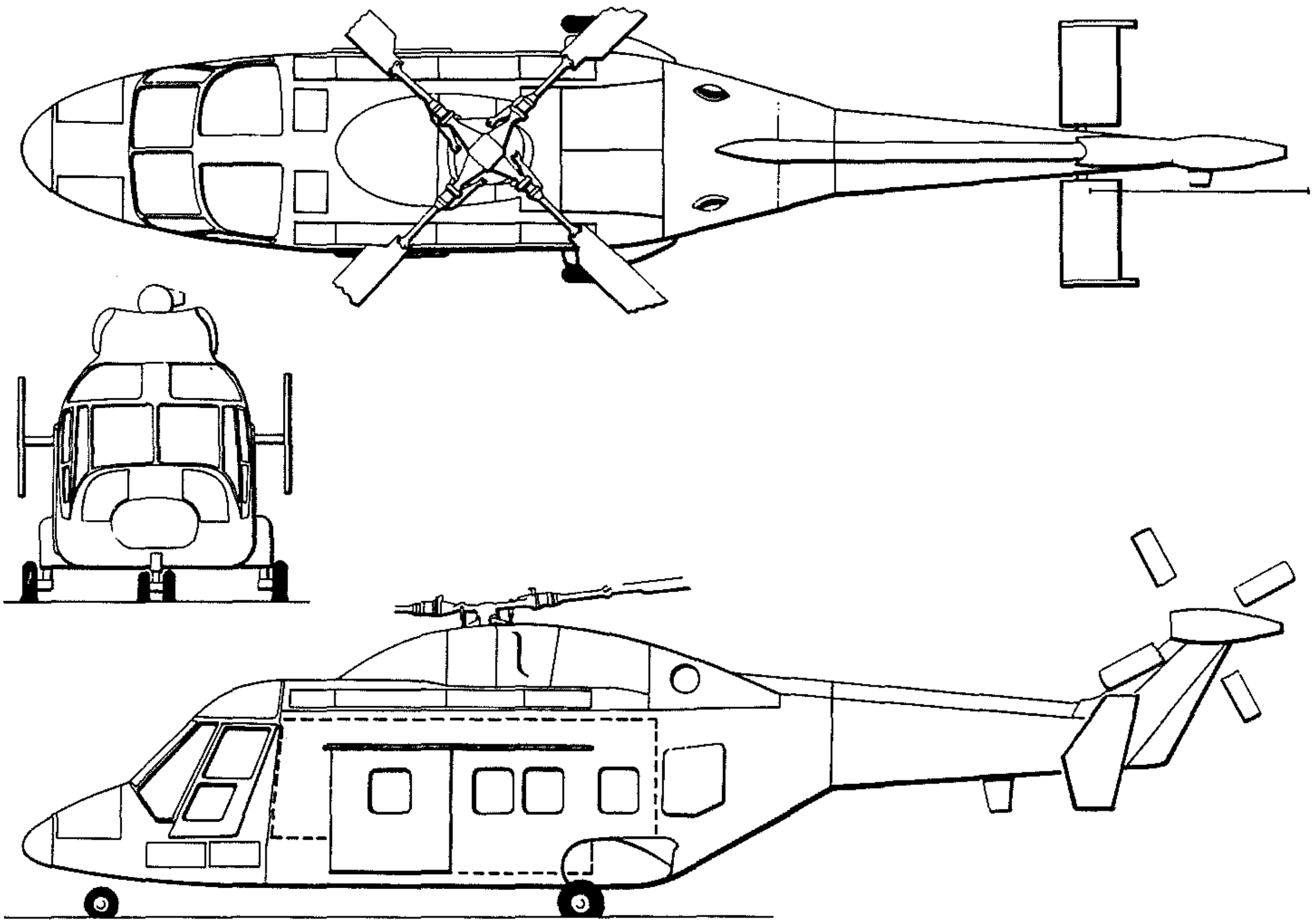


FIG.3. GENERAL ARRANGEMENT

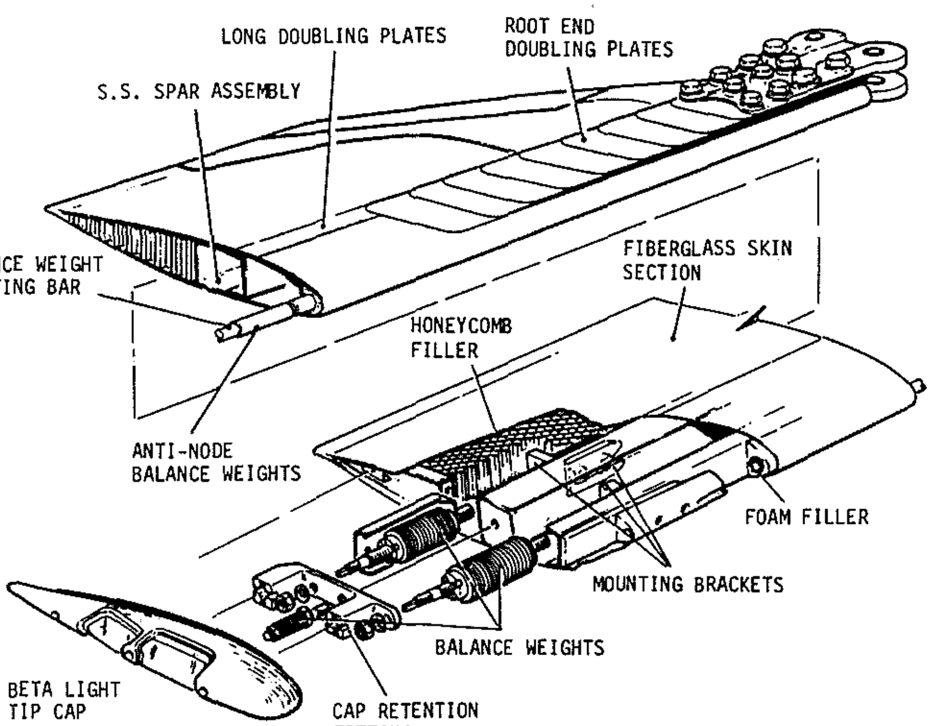


FIG.4. ROTOR BLADE TECHNOLOGY

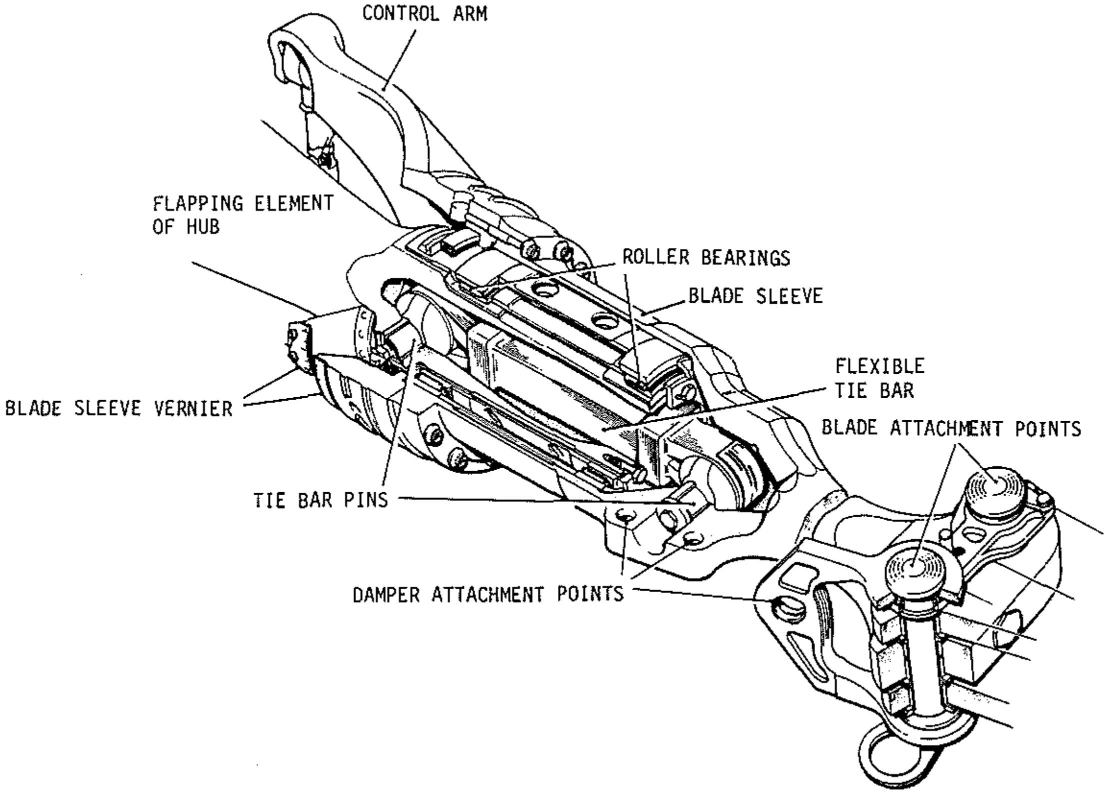


FIG.5. MAIN ROTOR HEAD

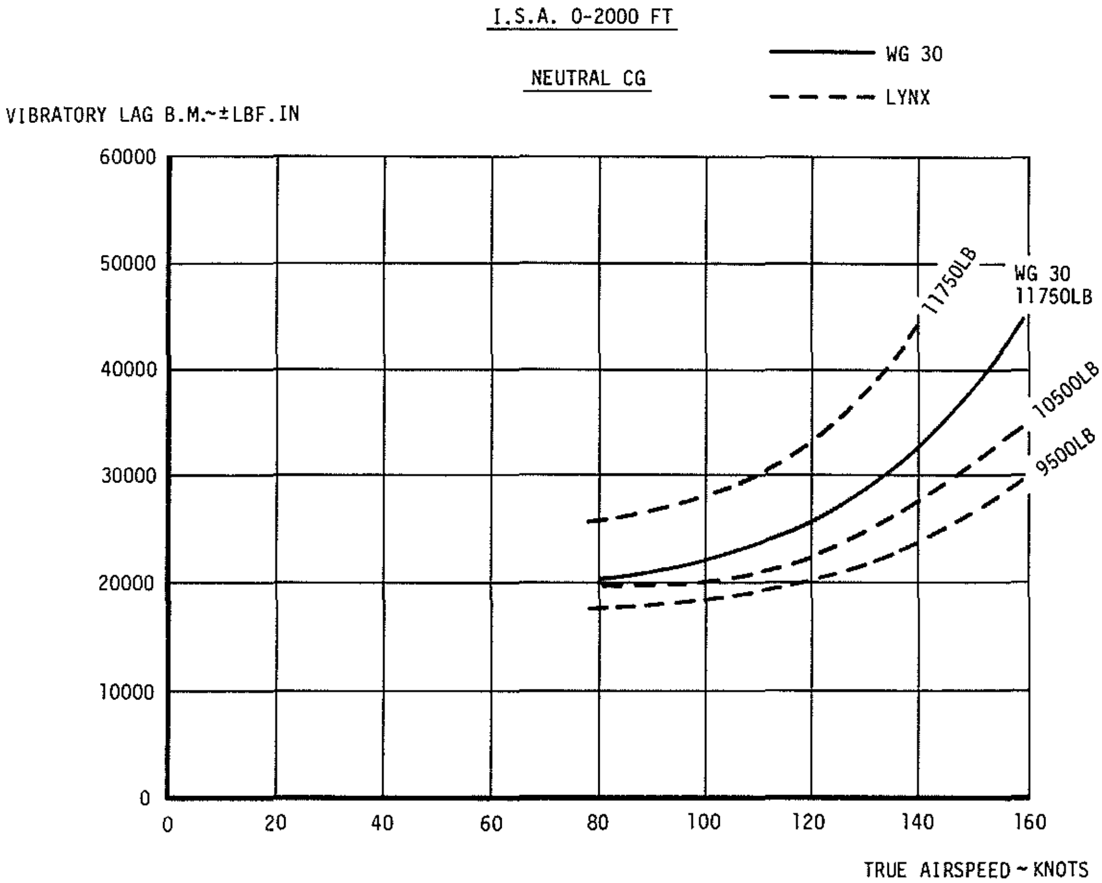


FIG.6. COMPARISON OF 6·8% ROT. RAD. LAG VIBRATORY LOADS WITH LYNX

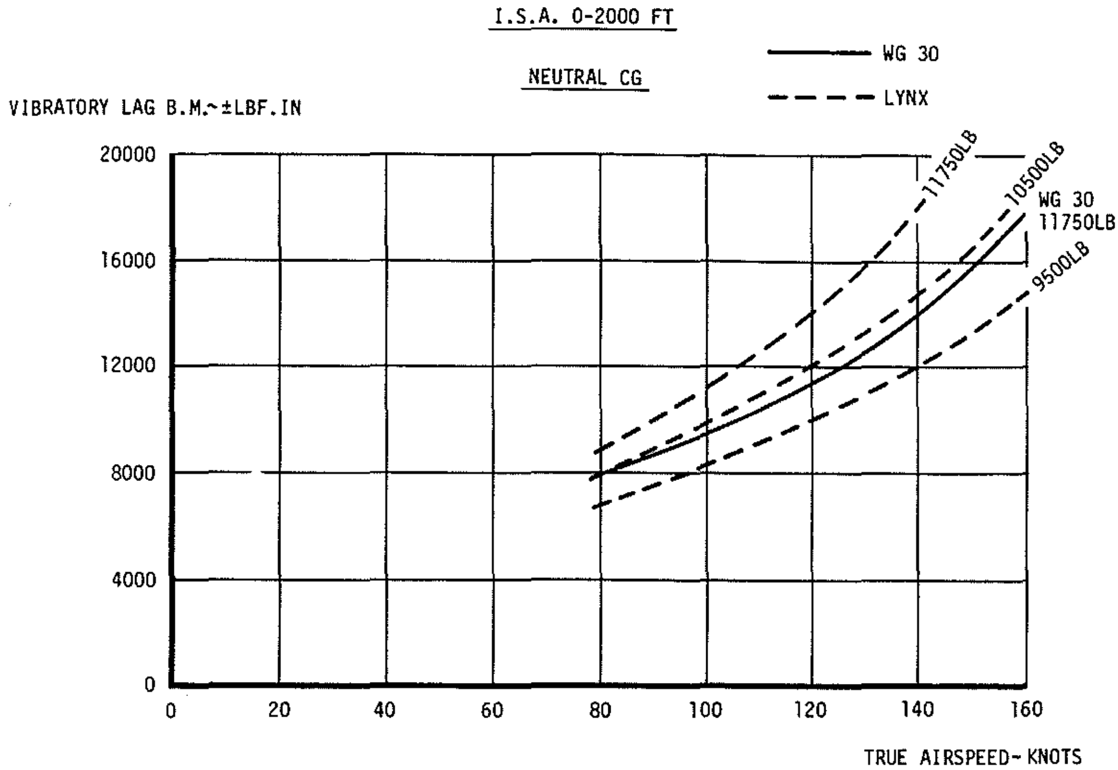


FIG.7. COMPARISON OF 31·0% ROTOR RADIUS LAG VIBRATORY LOADS WITH LYNX

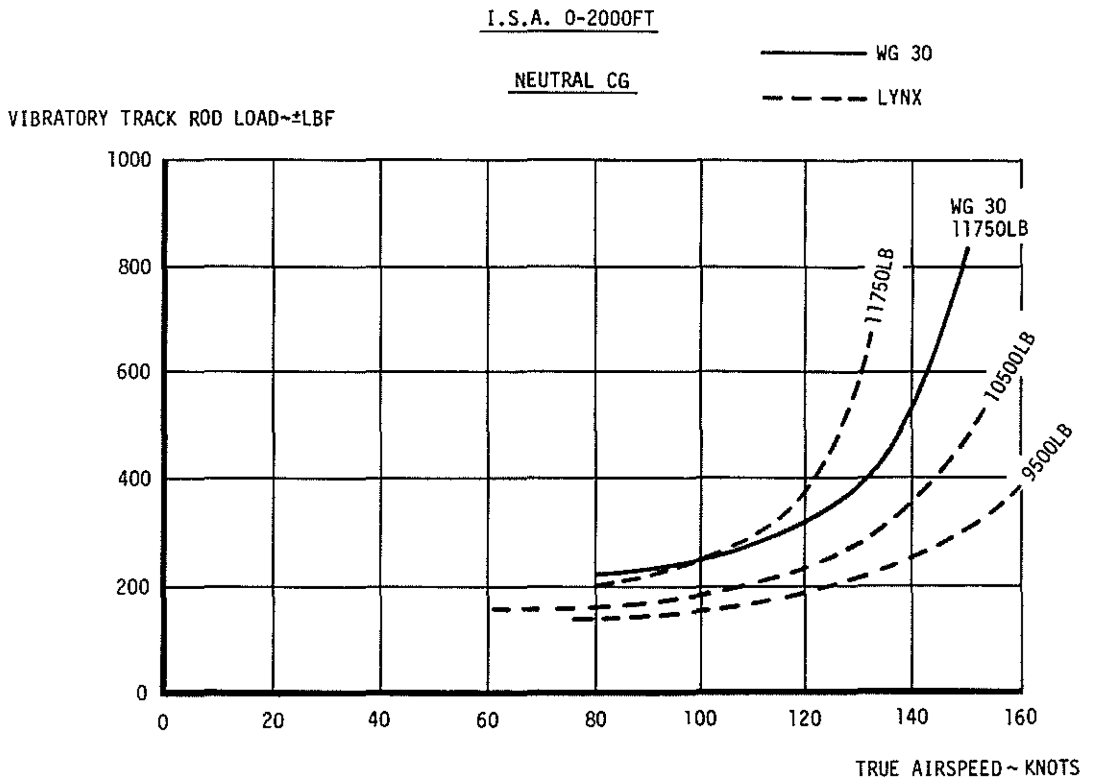
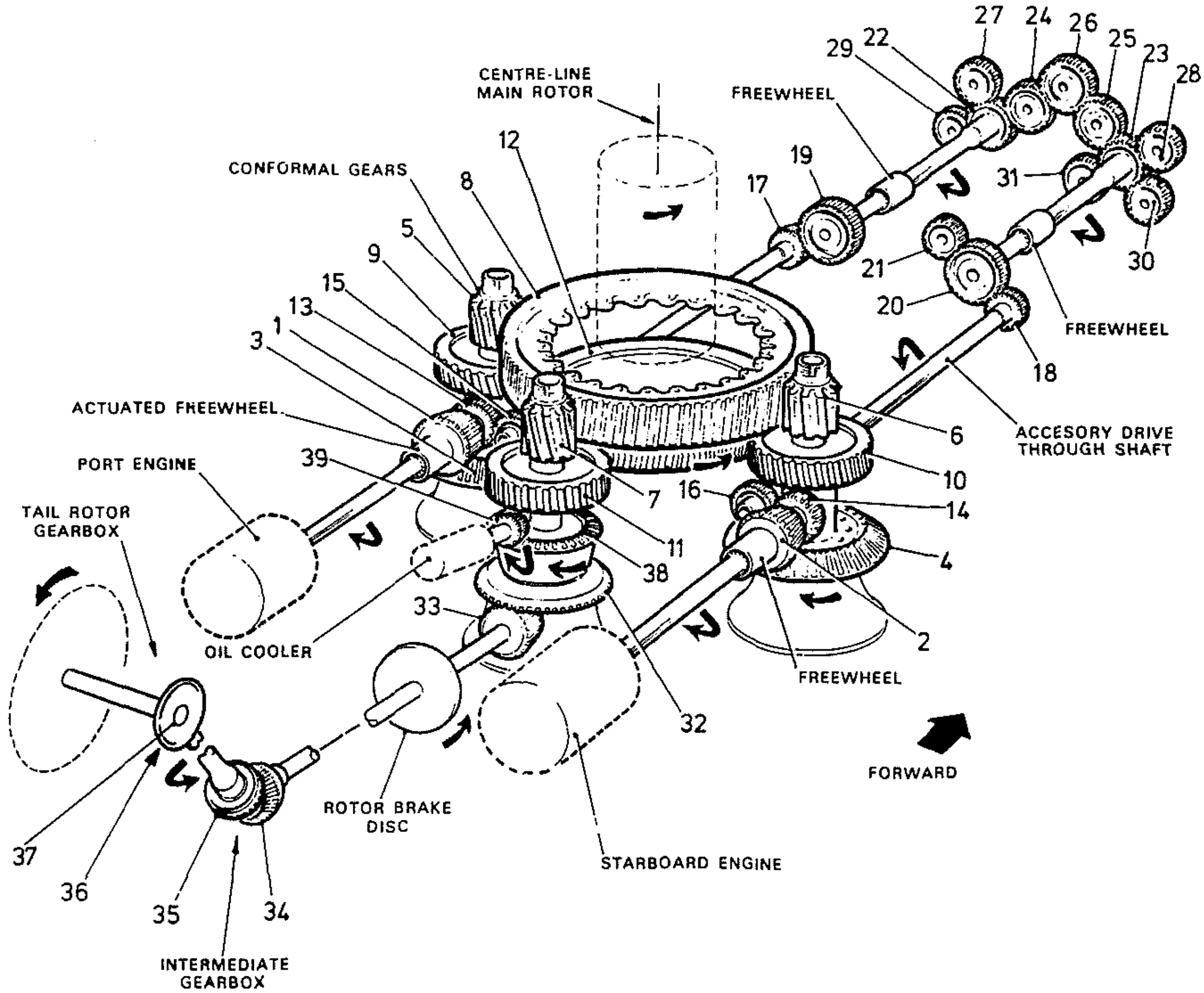


FIG.8. COMPARISON OF MAIN ROTOR TRACK ROD VIBRATORY LOADS WITH LYNX



GEAR	TITLE	GEAR	TITLE
1	Spiral Bevel Driver	21	Tacho Spur
2	Spiral Bevel Driver	22	Free-wheel Housing Spur
3	Spiral bevel Driven	23	Free-wheel Housing Spur
4	Spiral Bevel Driven	24	Idler Spur
5	Conformal Pinion	25	Idler Spur
6	Conformal Pinion	26	Idler Spur
7	Conformal Pinion	27	Generator Spur
8	Conformal Wheel	28	Generator Spur
9	Load Sharing Pinion	29	Hydraulic Pump
10	Load Sharing Pinion	30	Hydraulic Pump
11	Load Sharing Pinion	31	Oil Pump Spur
12	Load Sharing Wheel	32	Tail Take Off Driver
13	Accessory Driver Aft	33	Tail Take Off Driven
14	Accessory Driver Aft	34	Inter GB Input
15	Accessory Driven Aft	35	Inter GB Output
16	Accessory Driven Aft	36	Tail GB Input
17	Accessory Driver Fwd	37	Tail GB Output
18	Accessory Driver Fwd	38	Oil Cooler Driver
19	Accessory Driven Fwd	39	Oil Cooler Driven
20	Accessory Driven Fwd		

FIG.9. TRANSMISSION ARRANGEMENT

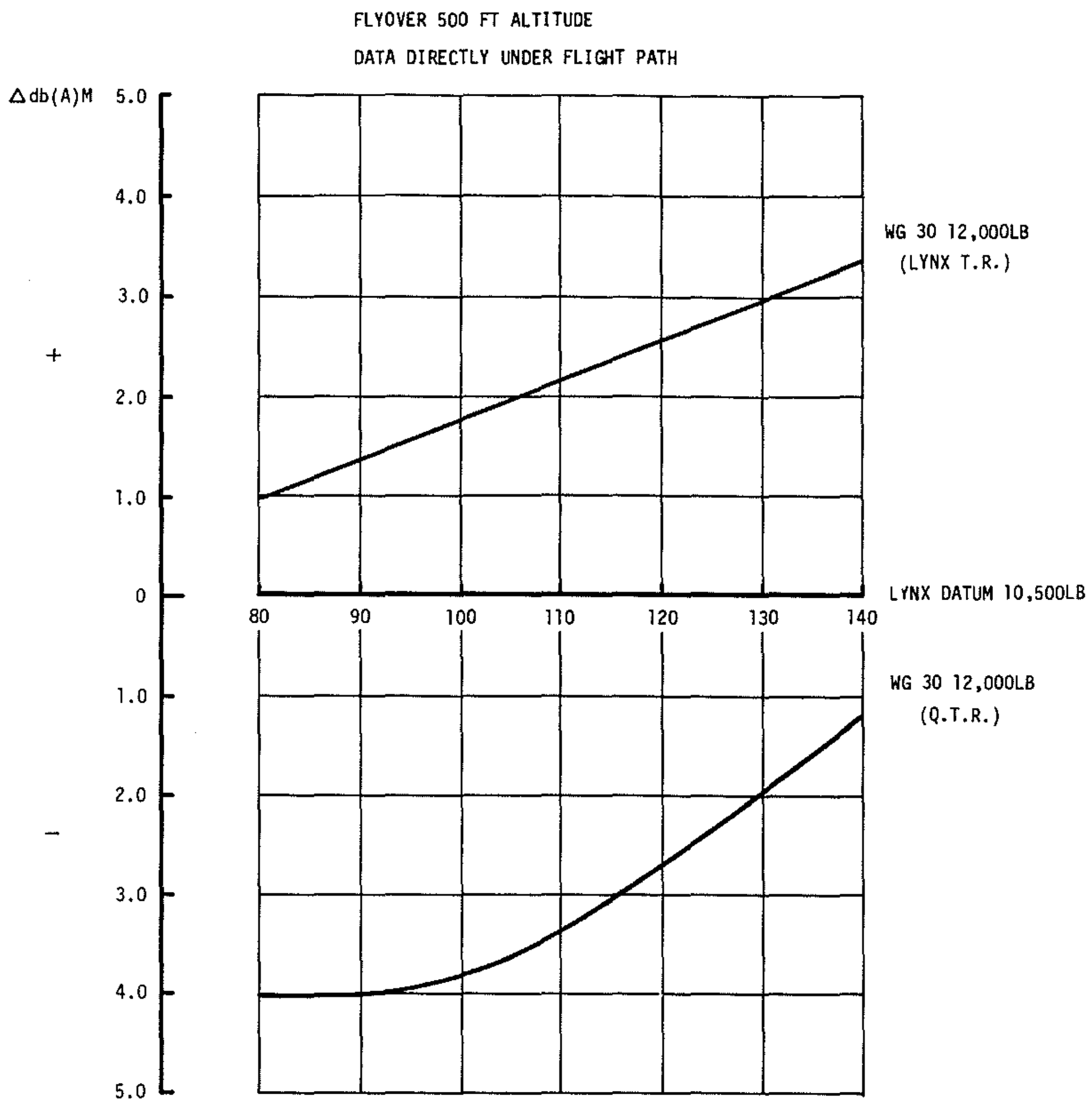


FIG.10. WG.30 EXTERNAL NOISE REDUCTION

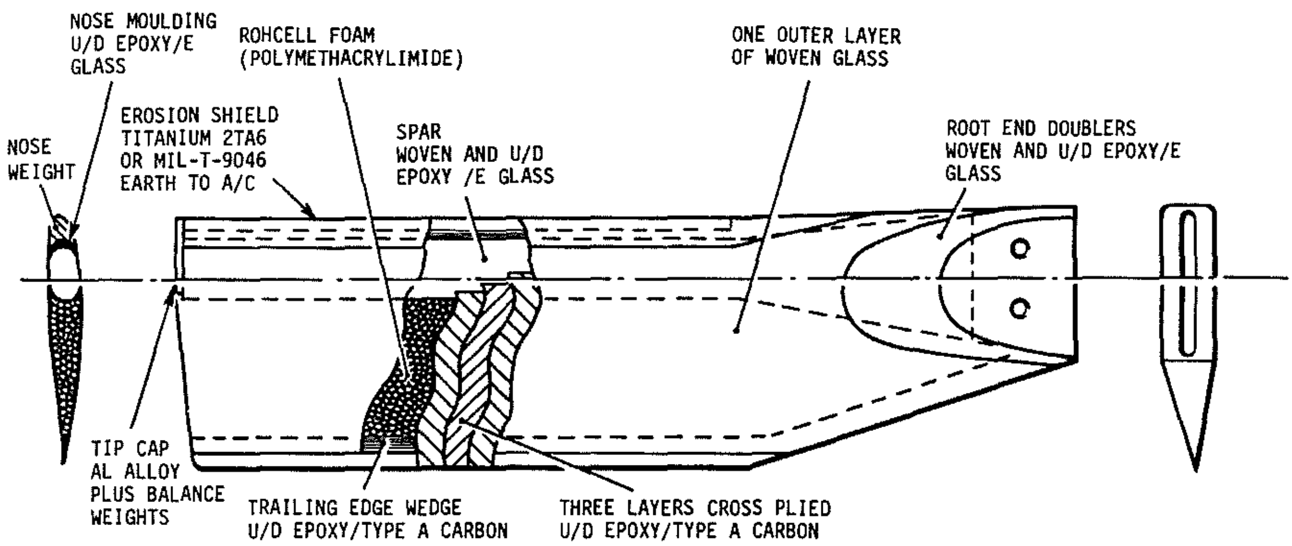
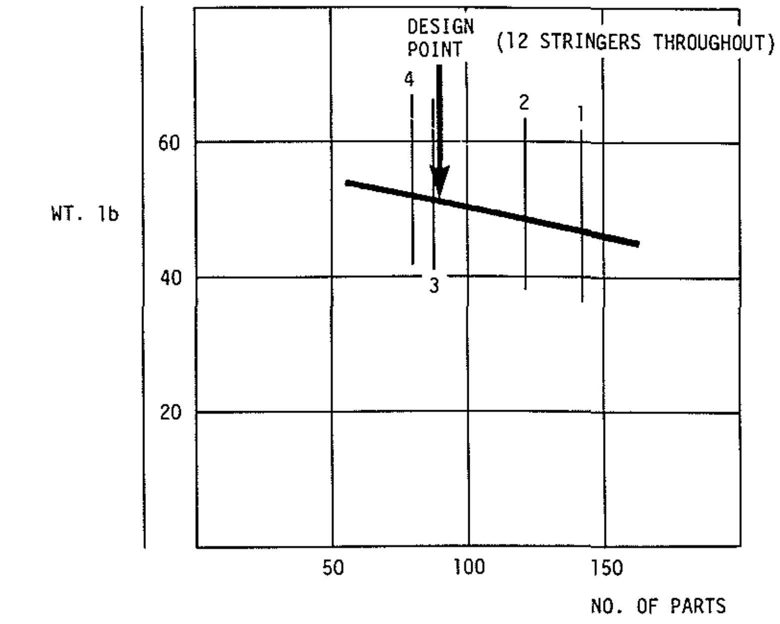


FIG.11. TAIL ROTOR BLADE

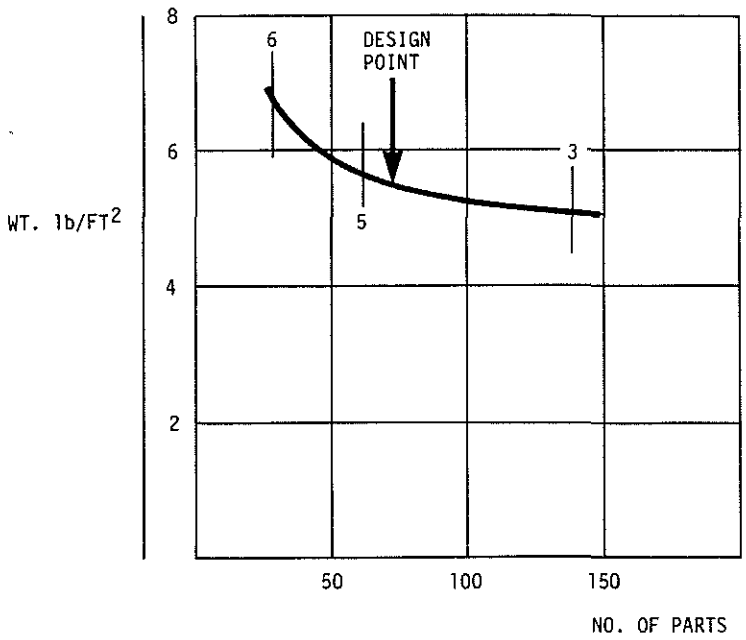


NOTE: NO. OF PARTS IS BASED ON

(1) 1 CLEAT AT EACH FRAME/STRINGER JUNCTION
(2) 1 CIRCUMFERENTIAL SKIN JOINT
(3) 2 LONGITUDINAL SKIN JOINTS
(4) 2 JOINTS PER FRAME ie 2 X 1/2 FRAMES
2 JOINING PLATES

		STN 3900	STN 6700
COND.	1	21 STRS SKIN t = .56	16 STRS SKIN t = .71
	2	16 STRS SKIN t = .71	16 STRS SKIN t = .71
	3	11 STRS SKIN t = .8	10 STRS SKIN t = .9
	4	8 STRS SKIN t = .9	10 STRS SKIN t = .9

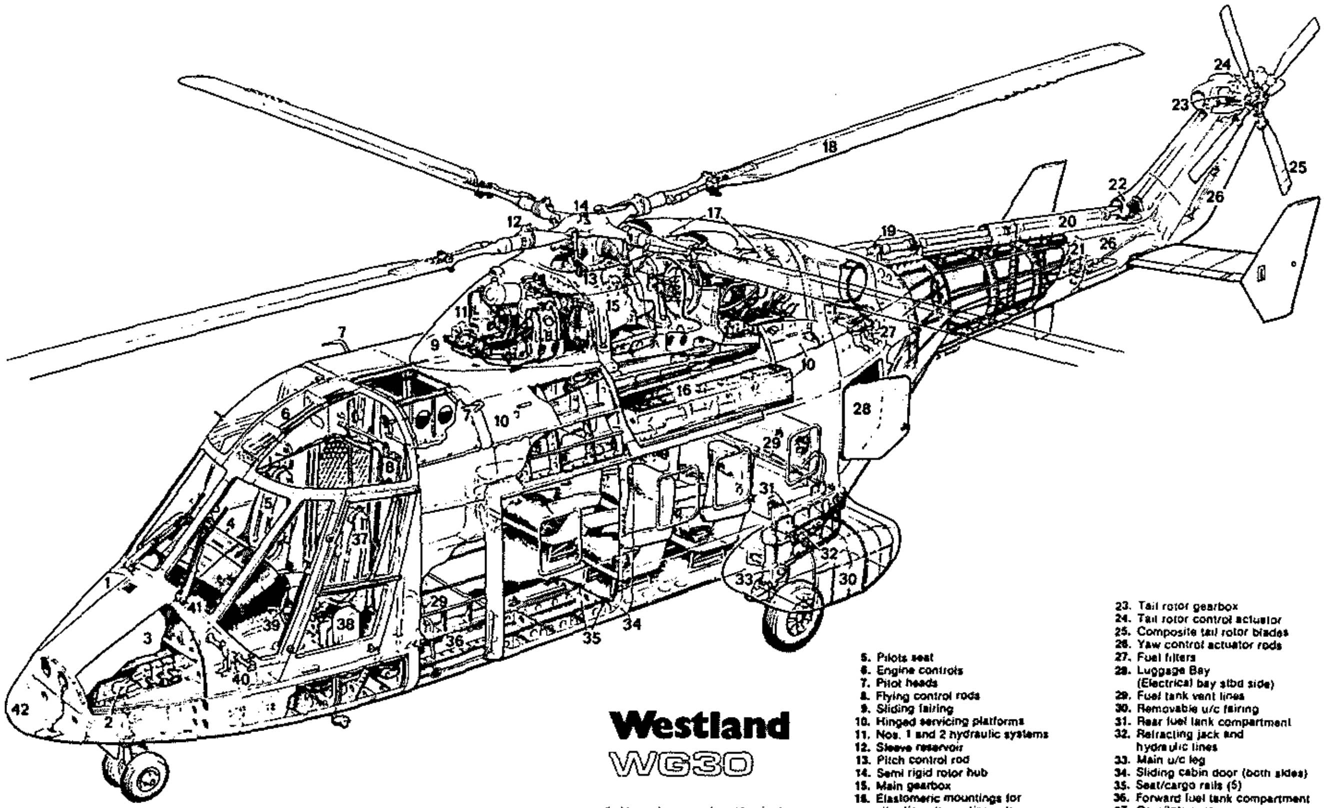
FIG.12. TAIL-CONE : WEIGHT VERSUS NO. OF PARTS



3. MULTI STRINGER - THIN SKINS
5. FEWER STRINGERS - THICKER SKINS
6. 6 LONGERONS & ALUMINIUM HONEYCOMBE PANELS

FIG.13. AFT FUSELAGE : WT. COMPARISONS

FIG.14. WESTLAND WG.30



Westland

WG30

1. Hinged access door to avionics compartment
2. Castoring nosewheel leg and retraction jack
3. Hinged access door to radio compartment
4. Instrument panel
5. Pilots seat
6. Engine controls
7. Pilot heads
8. Flying control rods
9. Sliding fairing
10. Hinged servicing platforms
11. Nos. 1 and 2 hydraulic systems
12. Sleeve reservoir
13. Pitch control rod
14. Semi rigid rotor hub
15. Main gearbox
16. Elastomeric mountings for vibration attenuating raft
17. Two Rolls Royce Gem 4 engines
18. Steel/fibreglass composite blade
19. Drive shaft bearings
20. Tail rotor drive shaft
21. Yaw control cables
22. Intermediate gearbox
23. Tail rotor gearbox
24. Tail rotor control actuator
25. Composite tail rotor blades
26. Yaw control actuator rods
27. Fuel filters
28. Luggage Bay (Electrical bay stbd side)
29. Fuel tank vent lines
30. Removable u/c fairing
31. Rear fuel tank compartment
32. Retracting jack and hydraulic lines
33. Main u/c leg
34. Sliding cabin door (both sides)
35. Seat/cargo rails (5)
36. Forward fuel tank compartment
37. Co-pilots seat
38. Collective stick and housing
39. Cyclic stick
40. Yaw control pedals
41. Windscreen wash/wipers
42. Nose cone and anti collision radar

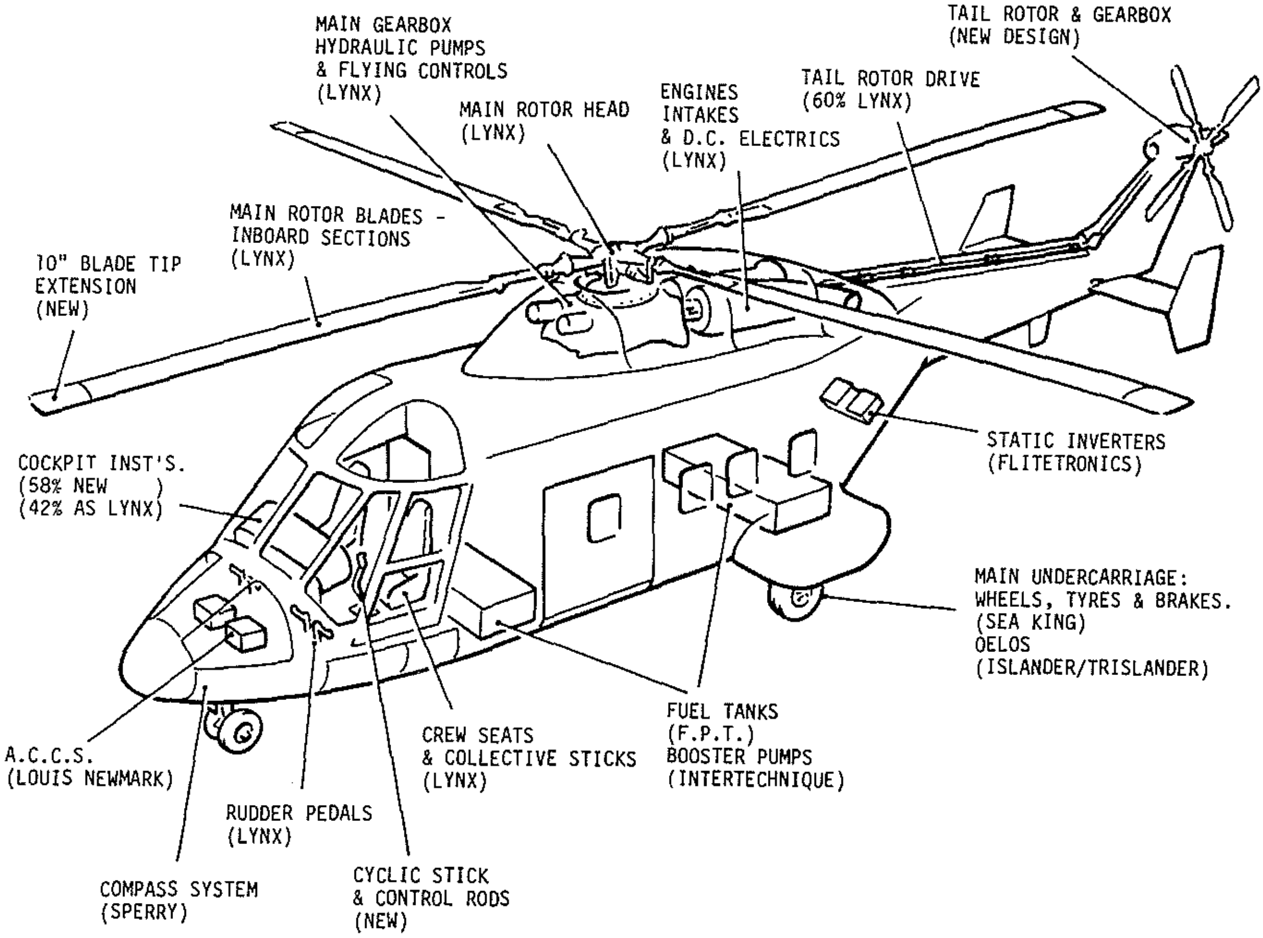


FIG.15. WG.30 MAJOR COMPONENTS

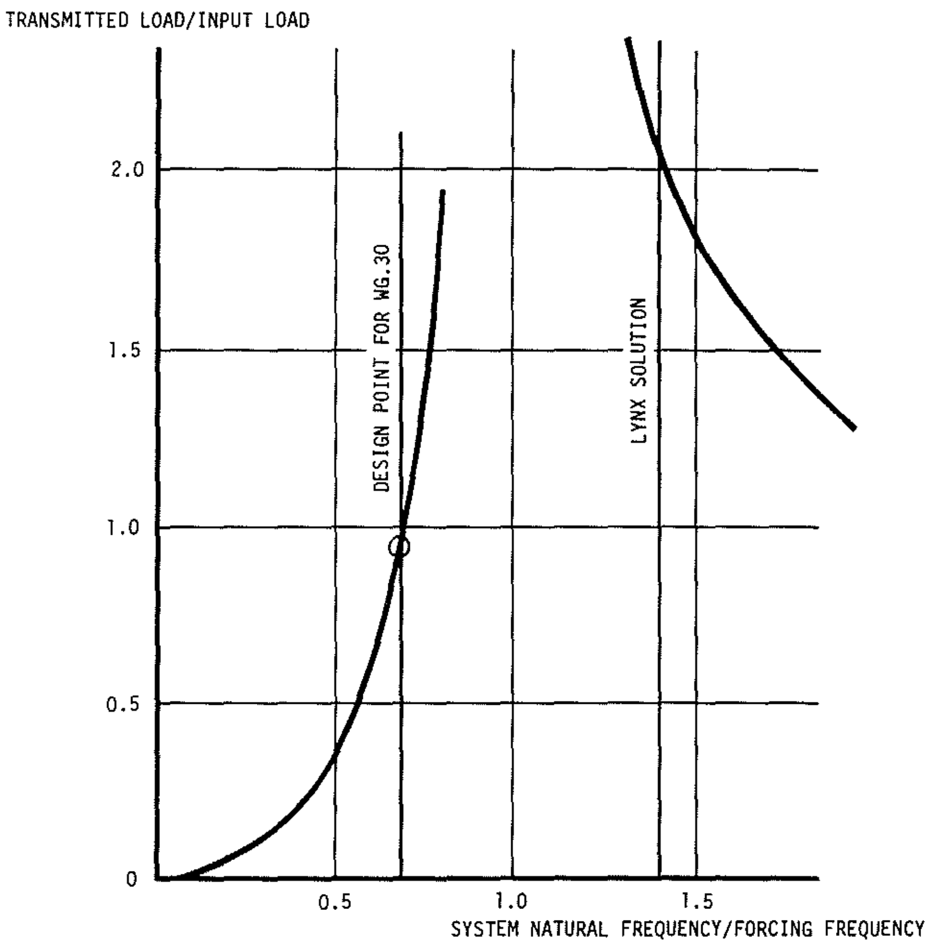


FIG.16. TRANSMISSIBILITY

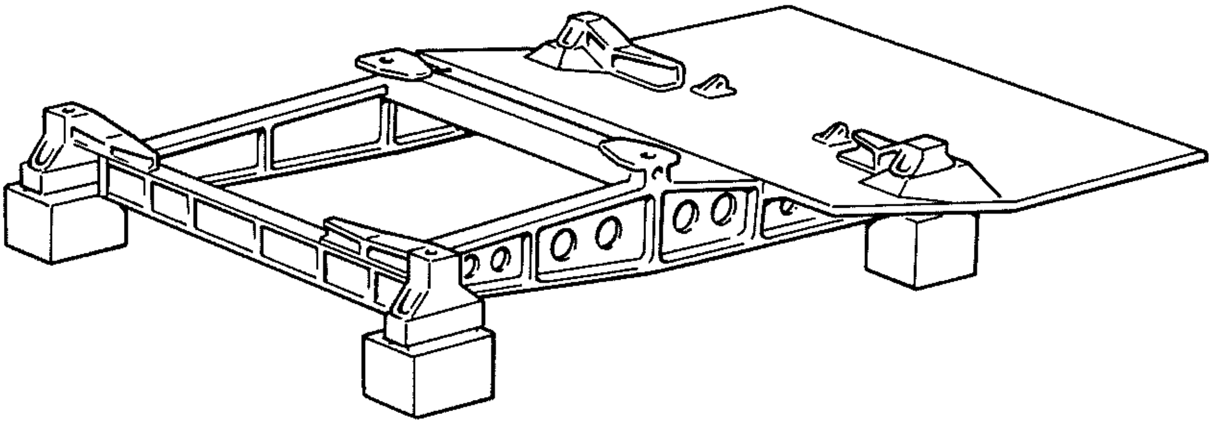


FIG.17. THE 4 POINT SUSPENSION RAFT SYSTEM

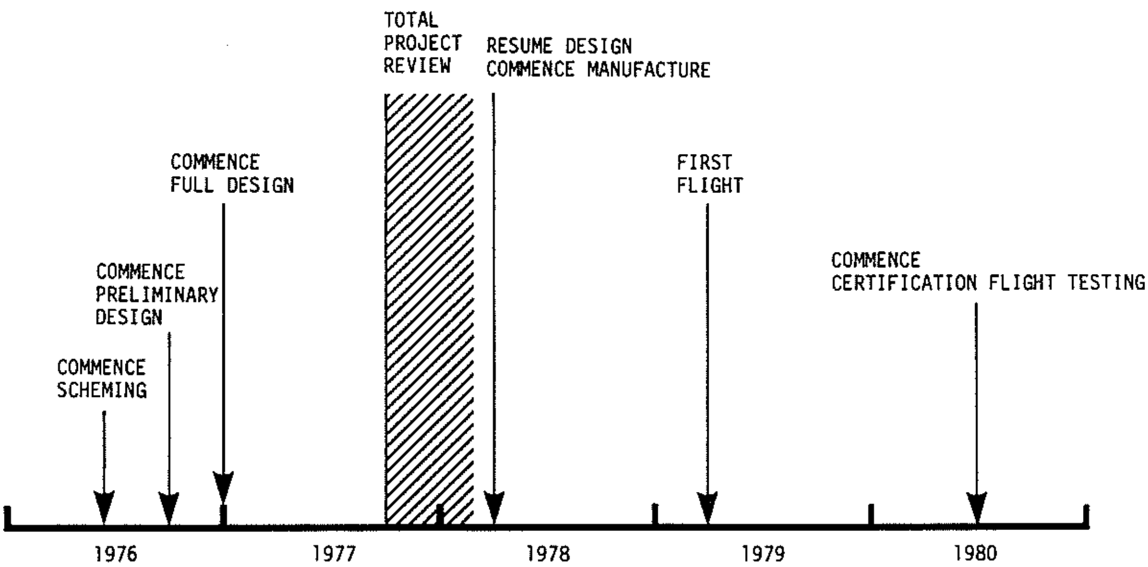


FIG.18. WG.30 PROJECT HISTORY

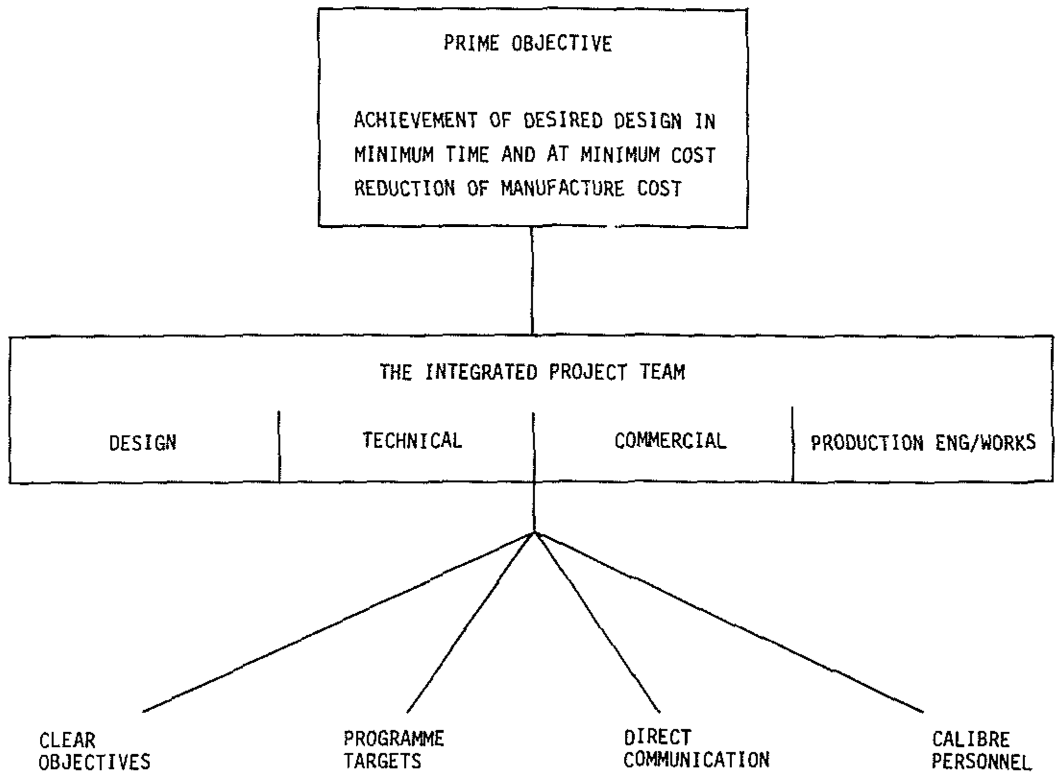


FIG.19. DESIGN TEAM OBJECTIVES & RESOURCES

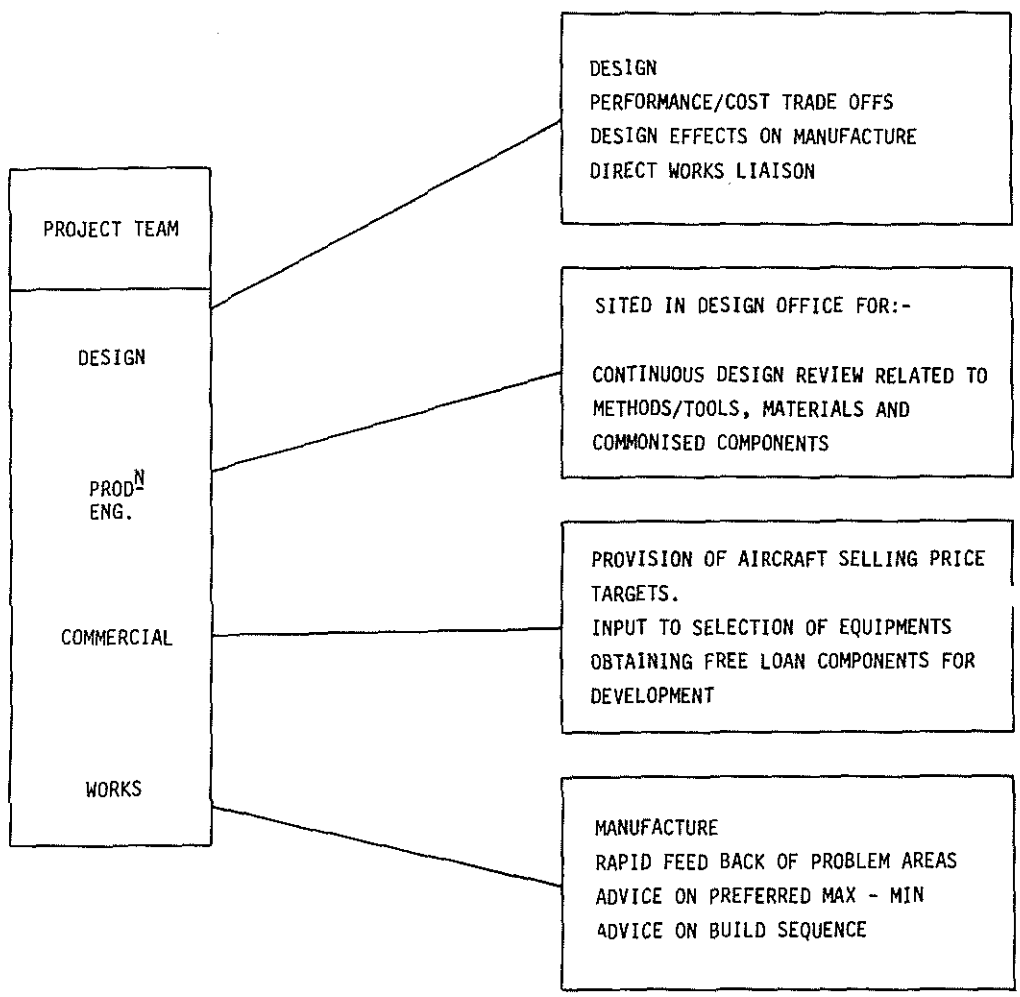


FIG.20. WG.30 PROJECT TEAM ACTIVITIES

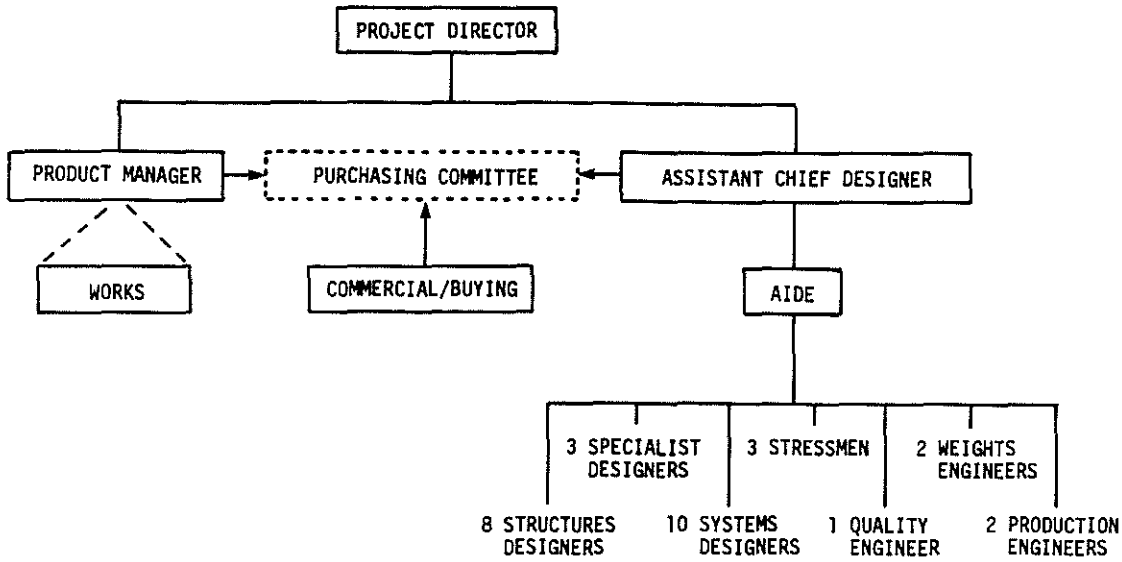


FIG.21. PROJECT TEAM

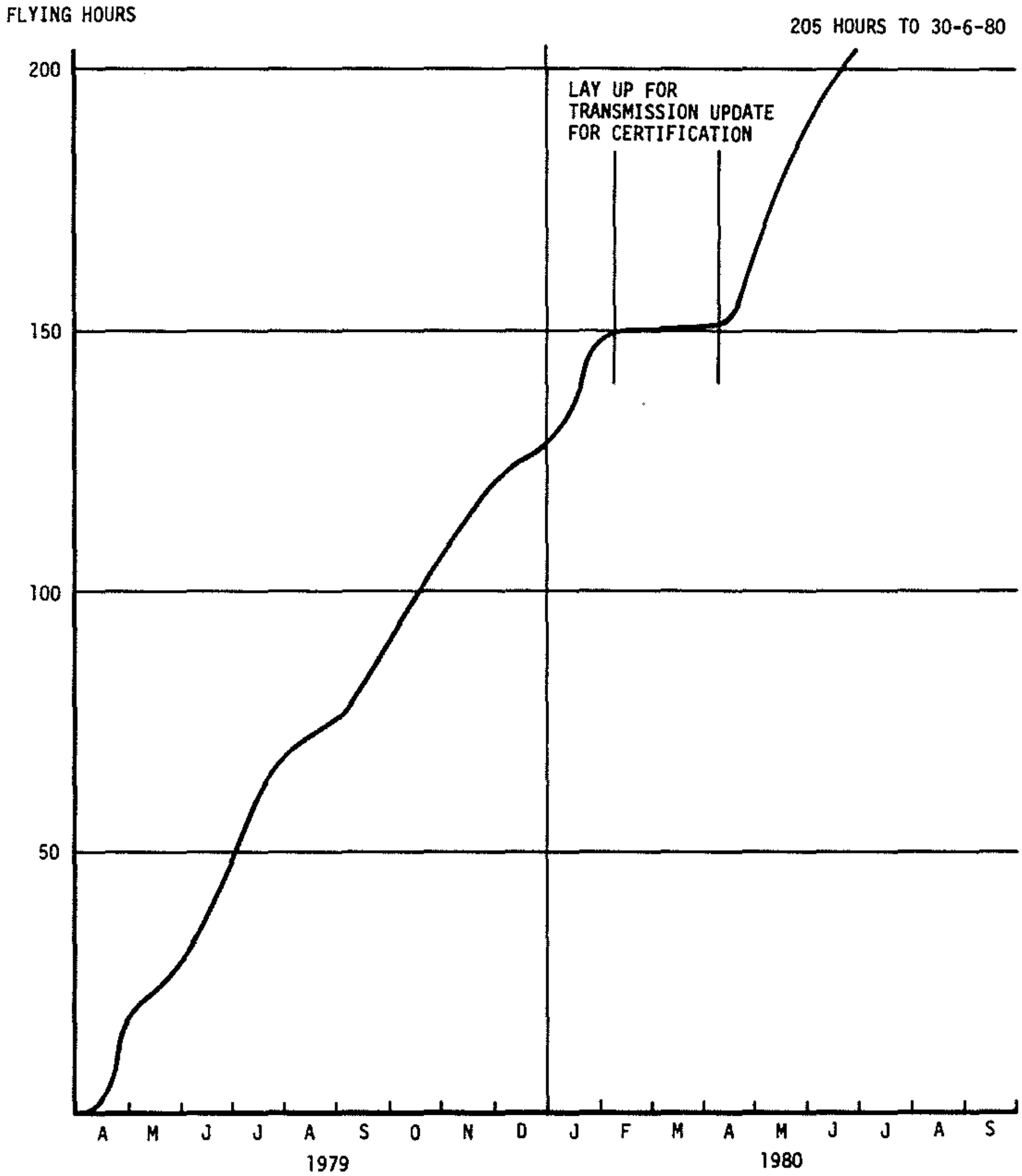


FIG.22. WG.30 FLYING HOURS

TOTAL FLIGHT TIME TO 30TH JUNE 1980 - 205 HOURS

APPROX % FLT. TIME	SUBJECT	RESULTS
20%	VIBRATION	OPTIMISATION OF RAFT SUSPENSION
15%	STRESS LEVELS	SATISFACTORY
20%	A.F.C.S.	SATISFACTORY
5%	NOISE	SATISFACTORY
10%	PERFORMANCE	MUCH AS PREDICTED BUT HIGHER POWERS AT HIGH FORWARD SPEED
5%	TEMPERATURES	SATISFACTORY FOR TEMPERATE CONDITIONS - ENGINE BAY VENT FANS REQUIRED FOR INTERCONTINENTAL MAX.
25%	HANDLING	NOW SATISFACTORY AFTER AERO-MECHANICAL & A.F.C.S. MODS.

FIG.23. WG.30 DEVELOPMENT STATUS

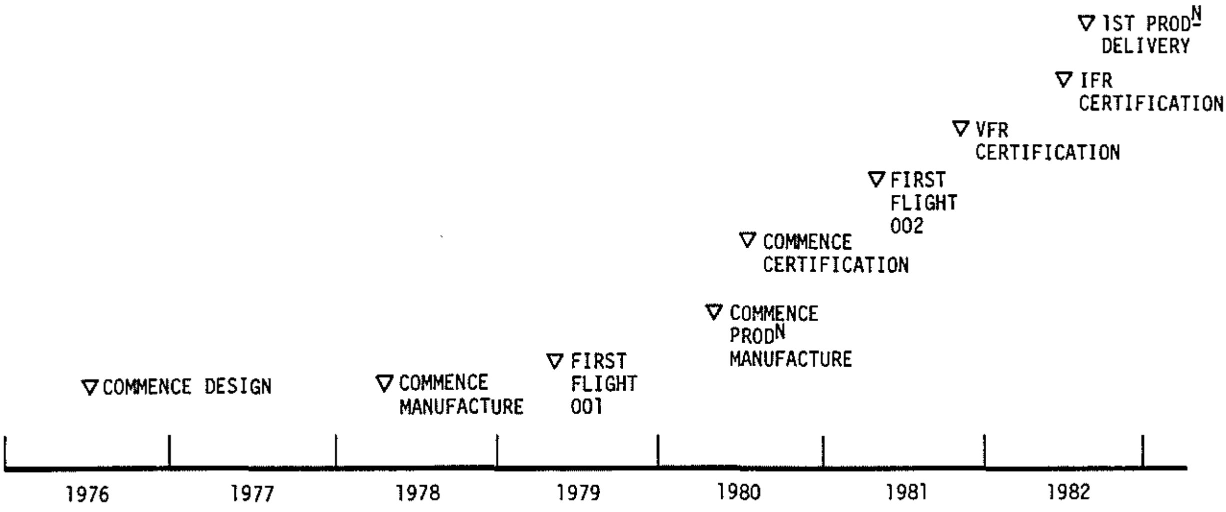


FIG.24. WG.30 MAJOR MILESTONES