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SAE AIR1603

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AUXILIARY POWER SYSTEM CONSIDERATIONS FOR ADVANCED MILITARY AIRCRAFT

FOREWORD

This document has been assembled to aid the engineer in optimizing the auxiliary power system in advanced military aircraft. Frequently the engineer responsible for the early definition of the subsystems is only superficially acquainted with the various subsystems and is expert in one or none. Yet as the aircraft progresses through the phases from conceptual design to production, the subsystem definition specified early in the program may remain, and become ever more firm. This AIR provides such an engineer with enough insight into the various components of the auxiliary power system to enable him to choose a combination that will best suit the projected aircraft. Understandably, as the design of the aircraft evolves, experts will review the design, and the requirements may change. The original selection may, and probably should, be altered to a system that is more appropriate for the final aircraft.

1. SCOPE:

This document provides a brief description of the auxiliary power equipment that is available with enough description and pertinent comments to enable an engineer to make logical preliminary selection of the appropriate equipment for advanced military aircraft programs. The information has been kept as brief as possible to include the maximum amount of equipment in a relatively short document. It is not intended to replace textbook design analysis or detailed information available from the equipment suppliers.

The document describes auxiliary power equipment. Auxiliary power is defined as follows: "Those elements of secondary power [defined as all aircraft nonpropulsive power generation and transmission] related to main engine bleed air and shaft power extraction or power generation separate from the main engines. Included are engine bleed air systems, remote engine driven gearboxes, engine starting systems, auxiliary power units, and emergency power systems." Additional definitions may be found in ARP906A which is the source of this definition.

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SAE AIR1603

1. (Continued):

Some closely related systems which are not discussed in detail, include thermal management, environmental control, electrical, and hydraulic systems.

2. REFERENCES:

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AIR781 Guide for Determining Engine Starter Drive Torque Requirements
 ARP906A Glossary, Aircraft Engine Starting and Auxiliary Power
 AS943A Start, Pneumatic, Aircraft Engine, General Specification For
 AIR944B Pneumatic Ground Power Supplies for Starting Aircraft
 ARP949A Turbine Engine Starting System Design Requirements
 AIR1174A Index of Starting System Specifications and Standards
 AIR1467A Gas Energy Limited Starting Systems
 AS1606 (DRAFT) Specification, Jet Fuel Starter
 ARP1607A Starter Control Valve Specification

2.2 Military Specifications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

Available from Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-F-9490D(USAF) - 6 June 1975 - Flight Control Systems - Design, Installation and Test of Piloted Aircraft, General Specification For

MIL-S-19557D(AS) - 29 January 1988 - Starters; Aircraft Engine, Air Turbine, General Specification For

MIL-V-38398A(USAF) - 8 July 1974 - Valve, Starter Control, Pneumatic, Aircraft Engine - General Specification For

MIL-S-38399A(USAF) - 14 February 1975 - Starter, Pneumatic, Aircraft Engine - General Specification For

MIL-P-85573(AS) - 1983 - Power Unit Aircraft, Auxiliary, Gas Turbine, General Specification For

MIL-A-87229(USAF) - 31 July 1985 - Auxiliary Power Systems, Airborne

MIL-V-81995(AS) - 25 June 1980 - Valves, Starter Control, Aircraft Engine, General Specification For

MIL-S-22518(AS) - 19 March 1982 - Starter, Air Turbine, Accessory Drive Combination A/C Engine, General Specification For

MIL-S-22999B(AS) - 15 June 1981 - Starter, A/C Engine Hydraulic, General Specification For

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3. ENGINE STARTING AND AUXILIARY POWER GENERATION:

3.1 System Configuration:

The auxiliary power system on military aircraft has evolved from a few small miscellaneous accessories conveniently mounted on the propulsion engines to a separate entity, often separately housed from the engines. In future high performance fighter aircraft the accessories probably will be remotely mounted in separate bays, as they are in current similar aircraft, to take full advantage of the benefits of divorcing them from the propulsion engines:

- a. Aircraft performance is improved by taking advantage of the reduction in a maximum cross-section area that may be achieved by careful arrangement of the accessories on gearboxes remote from the propulsion engines. The greatest cross-section area reduction is usually achieved by designing with mirror image gearboxes for a twin engine aircraft with fuselage mounted engines.
- b. Survivability is improved by removing sources of ignition (generators) and flammables (hydraulics) from the engine environment.

Combat experience in the 1960s showed that fires in the engine bays (caused by damage to electrical or hydraulic systems in those bays) significantly contributed to aircraft losses.

- c. Overall aircraft survivability may be enhanced by locating the accessories where they will protect more vital components (like engine fuel feed lines, for example).
- d. Uncluttered engine bays, with no requirement for disconnecting and connecting lines and wires for the accessories, minimizes engine removal and replacement time.
- e. Engines can be removed from shipping containers and installed in the aircraft with no requirement for quick engine change (QEC) kits.

Among military aircraft other than fighter and attack aircraft, the B-1 and B-2 bombers have also been designed with remote accessories, as was the B-70. The trend toward remotely mounted accessories can be expected to become even more nearly universal in future military aircraft with the aim of maximizing performance and supportability.

Military transport-type aircraft, on the other hand, which typically have pod mounted engines, have followed the traditional lead of the subsonic commercial transport aircraft and mounted the accessories on gearboxes integral with the engines. Engine mounted accessories have been demonstrated to provide better accessibility and maintainability for this type of aircraft, particularly when engine replacements are rare.

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3.2 Drive Type Accessory:

Historically, accessories have been driven by shaft power from the main engines, with a few exceptions, namely: Early B-52, A-3, F-105, and early A-4 (Partial). These aircraft used engine bleed air turbines to drive the accessories. This option, as well as electric and hydraulic drive are illustrated schematically in Figure 1 and should be considered in advanced military aircraft design. In selecting the method of providing power for the various aircraft services, the engineer must consider the total impact on the aircraft. Weight, aircraft performance penalty, heat rejection, reliability, and maintainability are all important considerations.

3.2.1 Shaft Drive: Shaft power from the propulsion engines is the source of secondary power on most military aircraft with accessories mounted remotely from the propulsion engines. Subcritical tube-type shafts, generally with diaphragm-type joints to allow for misalignment and deflections, have usually been used between the engines and the airframe mounted accessory drives (AMADs).

a. Advantages

- (1) Maximum efficiency
- (2) Engine starter mounts on AMAD

b. Disadvantages

- (1) Located close to engine
- (2) Speed varies with engine

3.2.2 Pneumatic Drive: Pneumatic drives for hydraulic pumps and generators normally are engine compressor bleed air turbines. Small positive displacement air motors powered by engine bleed air may be used for actuation (the nozzle actuation system on the F100 engine is an example), and positive-displacement air motors powered by high pressure bottled air have been used for APU starting. Bleed air turbine drives were selected for hydraulic and electric power generation on several aircraft in the past, and should be considered as a possible option for advanced military aircraft (particularly when the power is only required for a small portion of the mission or for emergencies).

a. Advantages

- (1) Flexibility of location
- (2) Can be constant speed
- (3) Can be powered from any engine

b. Disadvantages

- (1) Much greater engine performance penalty than shaft power
- (2) Requires high-temperature bleed air ducting to the air turbine motor
- (3) Starter must be separate

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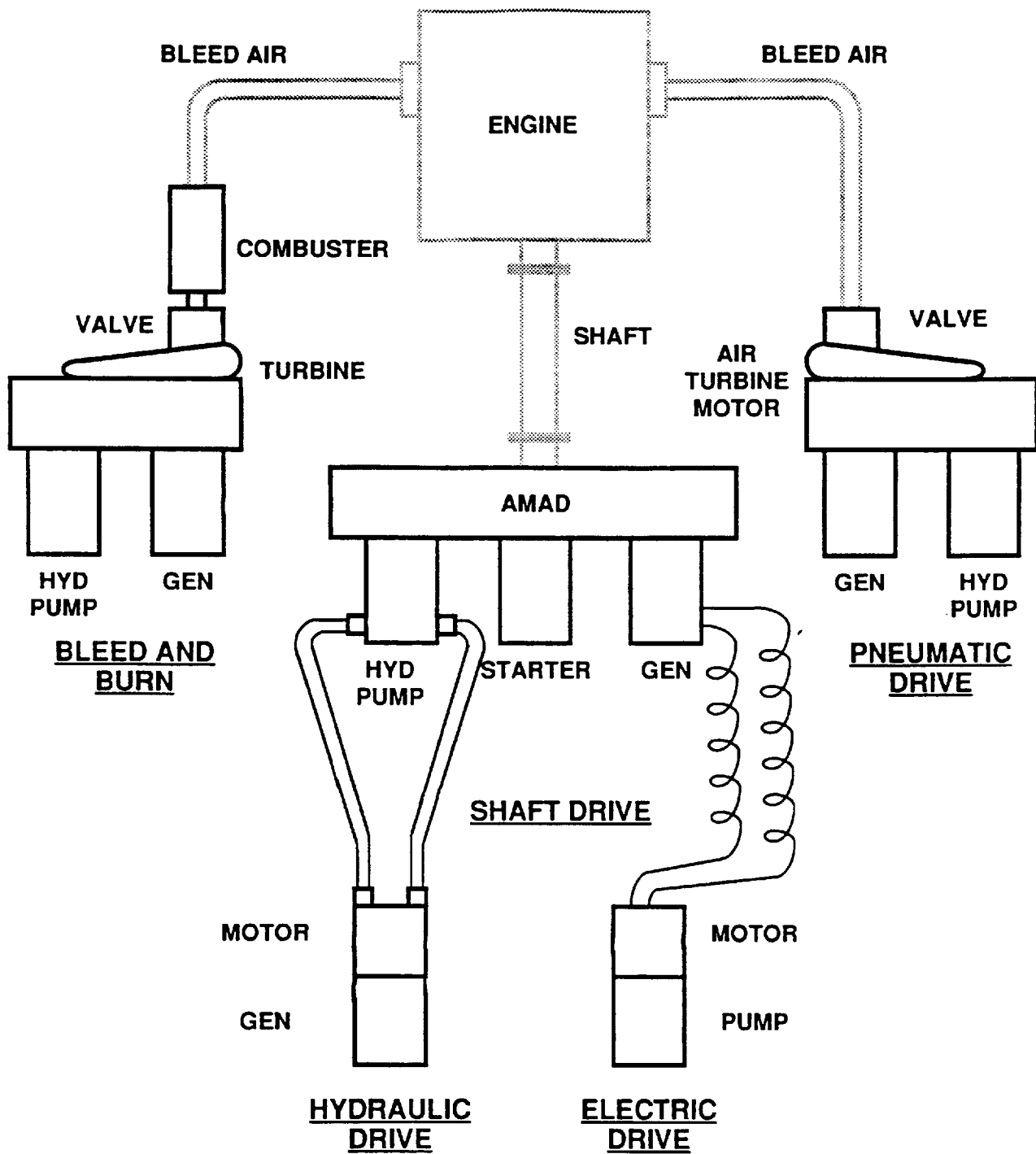


FIGURE 1 - Accessory Drive Types

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3.2.3 Bleed and Burn: The engine performance penalty associated with bleed air extraction can be reduced from that incurred with a bleed air turbine by inserting a combustor ahead of the turbine because less bleed air is used to produce a given amount of power when the temperature is higher. The disadvantage is in the need to route fuel to the machine and the creation of an additional fire zone. This alternative should be weighed whenever a bleed air turbine is considered.

a. Advantages

- (1) Flexibility of location
- (2) Can be constant speed
- (3) Less penalty than bleed air turbine
- (4) Can be powered from any engine

b. Disadvantages

- (1) Requires fire zone
- (2) Requires high temperature bleed air ducting

3.2.4 Hydraulic Drive: Since hydraulics are usually routed throughout the aircraft for flight control actuation and other high force applications, this source of energy may be convenient, particularly for emergency electric power sources. Most of the normal, shaft driven, electric power sources require minimum speeds near engine idle while hydraulic power may be available in even lower engine speed ranges, such as windmilling or engine light off. The heat generated by inefficiencies in the hydraulic drive and its driven accessory can be carried back to a centrally located heat exchanger by the hydraulic fluid. Hydraulic generator drives generally are relatively less efficient than direct shaft power driven generators. The inefficiency comes about, first, because the power has been converted from shaft power to hydraulic power through one inefficiency before it is converted to electrical power, and second, the hydraulic motor normally operates at part power to provide margin for the generator overload requirements, and finally fluid transmission losses contribute to the inefficiencies.

a. Advantages

- (1) Flexible location
- (2) Can be constant speed
- (3) Can be powered from any engine

b. Disadvantages

- (1) Fairly heavy
- (2) Relatively inefficient
- (3) Starter must be separate

3.2.5 Electric Drive: Electric power is frequently used to drive such devices as fuel pumps, flap actuators, cooling fans, or possibly high pressure air compressors. Electric motors remote from the engines also can provide power to drive hydraulic pumps for intermittent use, such as during landing or takeoff. These auxiliary electric-driven pumps would be operated only during the periods of peak hydraulic demand which are generally not coincident with electrical power peak demand. In this way, the central hydraulic pumps can be downsized, reducing the engine power extraction and