



AEROSPACE INFORMATION REPORT

AIR5388™

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Unique Wheel and Brake Designs

RATIONALE

AIR5388 has been reaffirmed to comply with the SAE Five-Year Review policy.

INTRODUCTION

Wheels and brakes in current use are generally very similar in design configuration. This has resulted from the sum of experience gained through the years as various designs were tried to meet unique requirements. Typical of modern brakes are the steel and carbon heatsink brakes shown in Figures 1 and 2. They consist of a forged aluminum piston housing, forged steel torque tube and a heat sink consisting of a pressure plate, alternating rotors and stators and a backing plate. Mechanical adjusters are used, generally of an extruding tube design. On carbon-carbon composite heat sink brakes, the adjusters are integral with the piston assemblies. On steel brakes, they are generally separate units. For bogie gears, the brake is bearing mounted on the axle, with one bearing being integral with the piston housing and the second at the mid-length of the torque tube. On two-wheel twin gears, the brake may be either bearing mounted or flange mounted.

Figure 3 shows a typical wheel design. Wheels are typically forged aluminum with an "A" cross-section. To accommodate the large brakes required, the web is normally offset significantly to the outboard side. Fuse plugs and over pressurization protection devices are included.

This Aerospace Information Report describes wheel and brake designs that are not typical, resulting from unique requirements and in some cases working very successfully.

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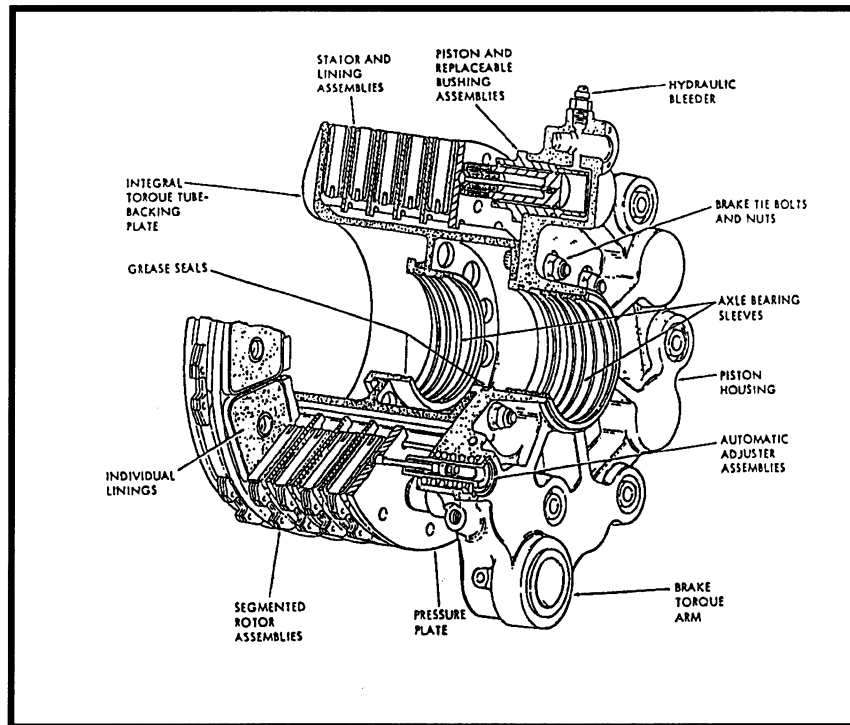


FIGURE 1 - Typical Steel Heat Sink Brake

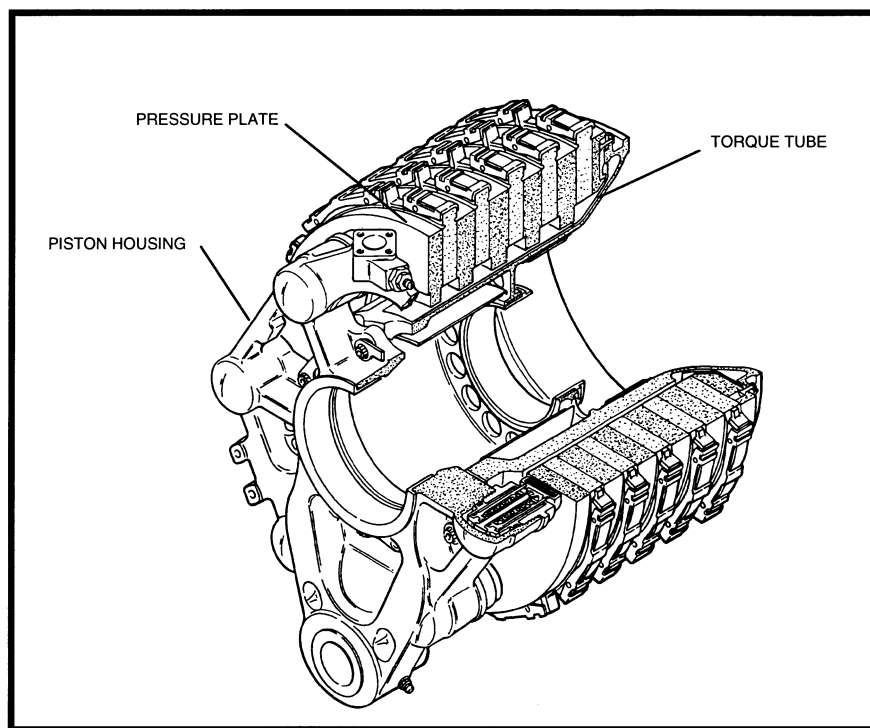


FIGURE 2 - Typical Carbon Heat Sink Brake

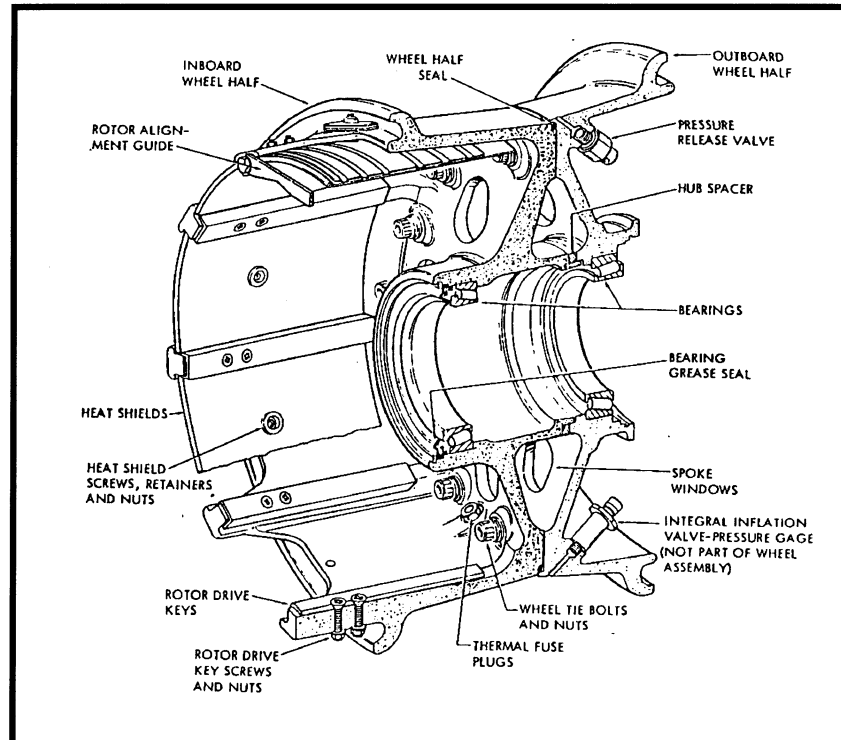


FIGURE 3 - Typical Current Wheel Design

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1. SCOPE:

This SAE Aerospace Information Report (AIR) has been prepared by a panel of the SAE A-5A Committee and is presented to document unique design approaches used for aircraft wheels and brakes.

1.1 Purpose:

The purpose of this AIR is to describe wheel and brake designs possessing unique features or approaches to allow them to meet the requirements of the particular airplane for which they were intended. Wherever possible, the requirements driving these design and the lessons learned are documented. This AIR is intended to document the ingenious solutions that have lead eventually to the wheel and brake designs in use today and pointing to the brakes for tomorrow.

2. REFERENCES:

There are no referenced publications specified herein.

3. UNIQUE WHEEL AND BRAKE DESIGNS:

3.1 Liquid Cooled Brake:

In the early 1950's, BF Goodrich became interested in alternate braking methods because of the introduction of the commercial jet aircraft. The older propeller-type aircraft could generate large retarding forces by reversing the pitch of the propellers. RTO energies were in the range of 10 to 20 million ft lb, and the wheels had a 20 to 22-inch bead seat diameter. With the introduction of jet powered aircraft, the energy requirements increased to the 20 to 50 mft-lb while the bead seat diameter was reduced to 16 to 18 inch range.

One alternative method that BF Goodrich decided to proceed with was a liquid cooled brake. In its final form the brake consisted of a two-rotor brake, a closed loop primary heat exchanger, and a secondary heat exchanger system using plain water. The primary system used a special glycol/ water fluid, to prevent freezing, with inhibitors and anti-foaming agents added. A pump driven by a ring gear attached to the wheel was used to circulate the fluid used in the primary system. The fluid was pumped through the brake to a liquid-to-liquid heat exchanger where the energy was transferred from the primary fluid to the secondary fluid. The secondary fluid was plain water (distilled or de-ionized water to reduce scale buildup).

An expansion tank was provided to allow expansion of the heated primary fluid, and to provide a way to pressurize the primary fluid to reduce cavitation at the pump inlet during spin up. During development the expansion tank/pressurization system was changed to a bladder type accumulator. Figure 4 shows the general schematic of the system.

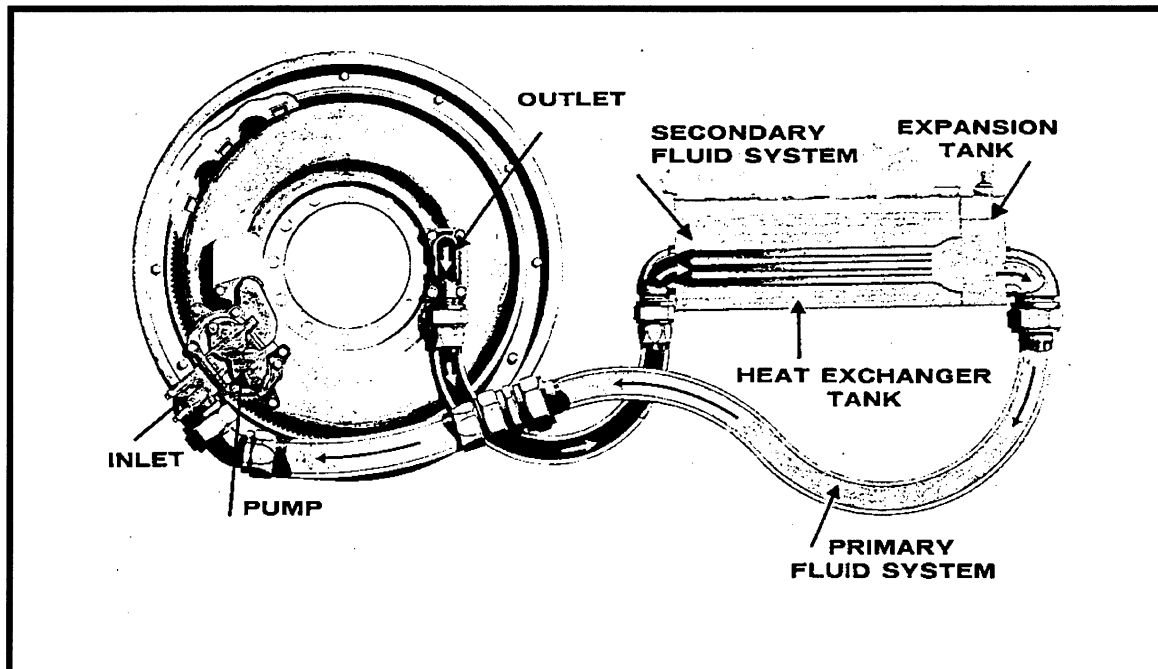


FIGURE 4 - Liquid Cooled Brake Schematic

3.1 (Continued):

Figure 5 shows a cross-section of the brake. The primary fluid enters the brake to a plenum chamber. One-fourth of the fluid is routed to the fluid passage in each annular piston and one-half is routed to the center section (stator). The two rotors rub against four copper surfaces. Heat is generated as energy is absorbed, and is transferred to the primary fluid behind the copper face. The fluid flow turns 180° to another plenum chamber in the brake and then exits to the heat exchanger.

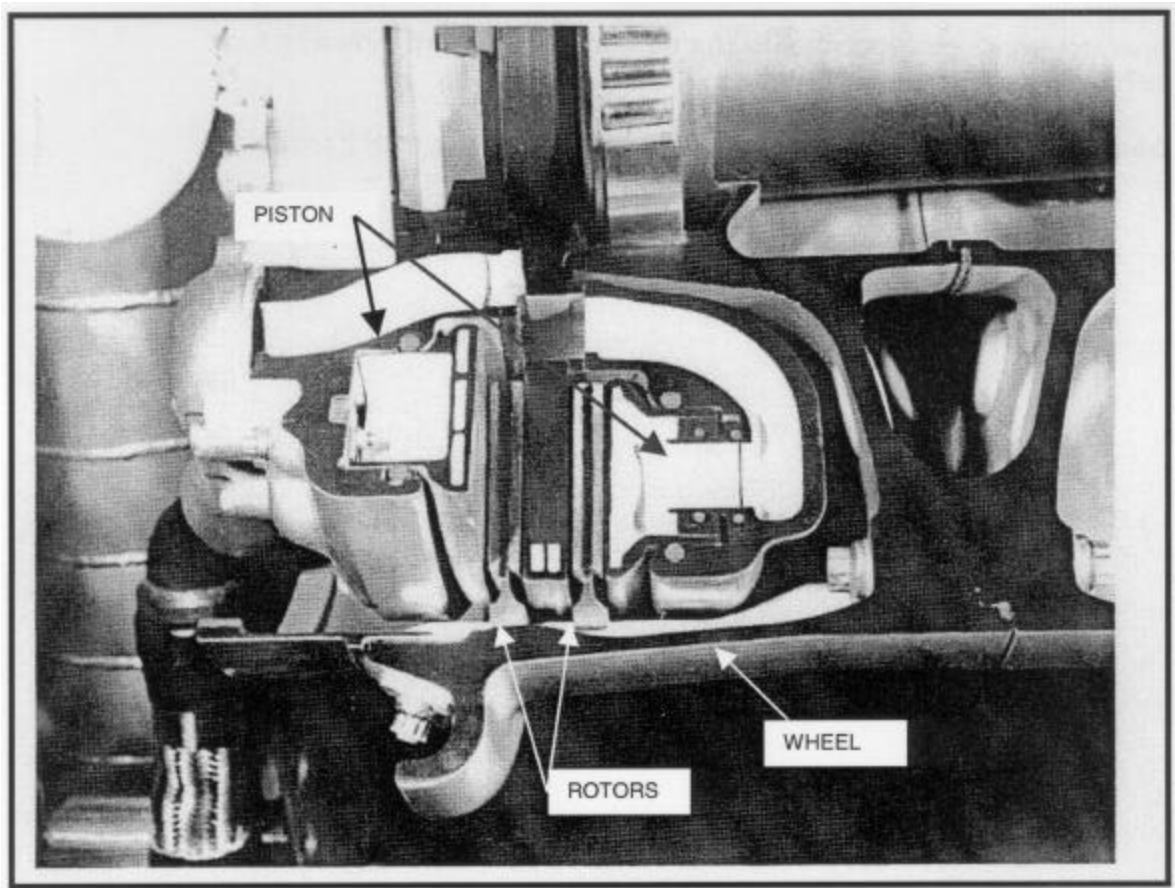


FIGURE 5 - Liquid Cooled Brake Cross-Section

3.1 (Continued):

The actuation fluid is the same glycol/water compound as the primary fluid. This allows the use of the same compound for all the seals in the brake. The two large annular pistons are activated by a master cylinder type transfer valve which converts the 3000 psi aircraft skydrol system to the lower pressure glycol/water system. The emergency air system also acts through the same master cylinder at the shuttle valve.

The LCB was first tested on a clipped wing B-26 for ground testing. An installation on the Boeing 367-80 (Dash 80) was made at in 1957 and an updated installation was made in 1959 and a third installation was made on a United 720 in 1961.

3.1 (Continued):

The first 727 installation was made in 1963 on United E29. During the test work for this installation, a unit was developed which pulled a negative pressure on the system then filled the primary system with fluid under pressure. This unit was successful in reducing the entrained air in the fluid, and greatly reduced the cavitation problem. The unit was also used to fill the actuation system and eliminated the need for a tedious bleeding procedure. The aluminum heat exchanger, which worked so well in the lab, developed weld cracks when exposed to the cantilevered environment of the aircraft strut and was replaced with a stainless steel design. It was also found that the torque level had to be increased to compete with the seven rotor steel brake.

This work resulted in the installation and certification on a United 727, 049U, in 1963. The 727 installation is shown in Figure 6.

The other significant feature, when using the LCB, was the notable improvement in tire life. The improved tire life was probably due to several factors:

1. The spin-up load of the LCB is only about 5% of that of the steel brake mass.
2. The smoothness of braking generated far less skid control activity at the high speed end of the stop which reduced tire scrubbing.
3. The lower wheel and brake temperatures; especially, during certification testing, saved a lot of tires.

The weight of the LCB system was approximately 5% greater than the seven-rotor steel brake. It was considered possible to offset this if the LCB could have been considered in the preliminary design stage of the aircraft instead of retrofitting an existing strut design.

While not a commercial success, the LCB was a technical success in that a research lab curiosity was certified for use on the 727. The fact that a system was developed which pumped heat out of the wheel, brake, tire package, and dissipated it by a phase change liquid may yet have some future application.

3.2 XB-70:

The XB-70, like most supersonic aircraft, lack room for storage of the landing gear. This resulted in tire and wheel sizes that did not provide sufficient room for the required brakes. Figure 7 shows the XB-70 gear retraction sequence. The solution in this case was the use of one large brake for the two wheels on each axle. An internal shaft connected the two wheels. Brake rotors were keyed to this shaft.

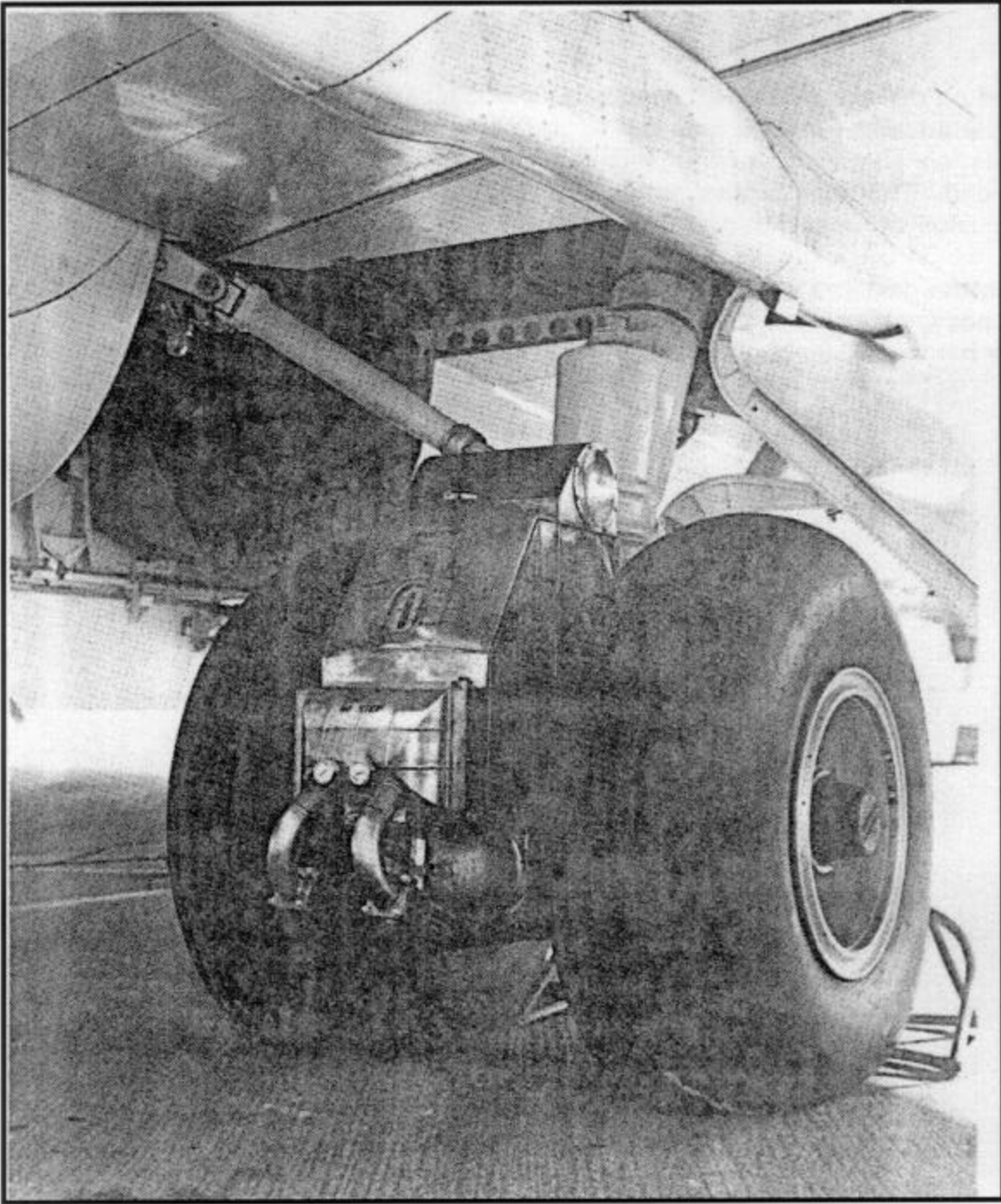


FIGURE 6 - Liquid Cooled Brake Installation on 727

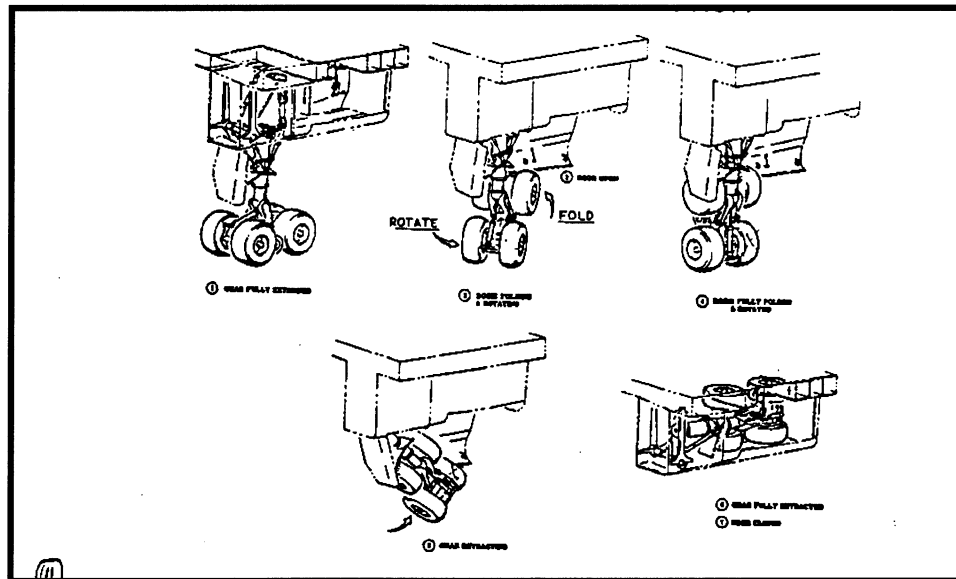


FIGURE 7 - XB-70 Gear Retraction Sequence

3.2 (Continued):

The general configuration of the landing gear was a four-wheel bogie with two wheels in-line forward and two wheels in-line aft. The wheel bearings rode on a large diameter axle. Inside the axle, an internal shaft was used to mechanically connect the inboard and outboard wheels. The middle of the shaft (lengthwise) was keyed to drive the brake rotors. The stators were keyed on their outer diameter and engaged a frame. The frame was, in essence, a torque tube bolted the bogie (see Figure 8). If the internal shaft is removed, the heatsink could be removed by unbolting the frame from the bogie, without jacking or wheel removal.