Sudan University of Science and Technology

College of Engineering

Aeronautical Engineering Department

Conceptual Design of Fully Automated Autobrake System

A thesis submitted in partial fulfillment for the requirements of the degree of B.Sc. (Honor) in Aeronautical Engineering

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الآيـة

﴿قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا إِنَّكَ أَنْتَ الْعَلِيمُ الْحَكِيمُ﴾

سورة البقرة {٣٢}

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Dedication

This research is dedicated to our grandmothers, fathers who taught us that the best kind of knowledge to have is that which is learned for its own sake, to our mothers who taught us that even the largest task can be accomplished if it’s done one step at a time, to our brothers and sister for their endless support. Many people, especially our classmates and team members itself, have made valuable comment suggestions on this research which gave us an inspiration to improve our project. Finally to our dear friend Eng. Azza Ahmed for her help and support.

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List of Symbols and Abbreviations

ABCU	Alternate Breaking Control Unit.
ADIRS	Air Data Inertial Reference System.
ADIRU	Air Data Inertial Reference Unit.
ARINC	Aeronautical Radio Incorporated.
BITE	Built In Test Equipment.
BSCU	Braking Steering Control Unit.
BTMU	Break Temperature Monitoring Unit.
CFDIU	Centralized Fault Display Interface Unit.
CFDS	Centralized Fault Display System.
ECAM	Electronic Centralized Aircraft Monitoring.
ECAMDU	Electronic Centralized Aircraft Monitoring Display Unit.
EEPROM	Electronic Erasable Programmable Read Only Memory.
FMGC	Flight Management Guidance Computer.
GPS	Global Positioning System.
IR	Inertial Reference.
IRU	Inertial Reference Unit.
MLG	Main Landing Gear.
MMR	Multi Mode Receiver.

Abstract

The fast development in Air Transport Industry created concern of the high rate of accidents happening at approach and landing phases, the environmental impact of aircraft pollution, noise and global warming. The high escalating of high cost of fuel, airport congestion added to economical difficulties Industry.

The air transport industry is engaged with many researches to find solutions for these problems autolysin the fast development of technology, innovations and new operational technique.. They were solved but not 100%, and with the increase of air transport movement and the number of aircrafts an effective solution should be made.

Since a lot of accidents happened in approach and landing phases we studied in this project developing an autobrake system enhance safety improve environmental impact reduces the use of thrust reversal for less fuel consumption. We took a conceder an airbus A320 as a case study a conceptual design made for a fully automatic braking system. We developed the system structure and wrote software program using MATLAB program to test the operation of the system at different aircraft conditions at approach and landing. The system will automatically display to the pilot at approach the best braking force for the best fuel consumption to vacate the runway safely. A runway map is designed to display the best option for the pilot for safe economical options.

We found that our system suggested is almost similar to a system being developed by airbus for its aircraft A380. This encourage us to recommend that our system should be refined, designed and implemented and retrofitted in the current aircrafts.A conceptual design has been achieved appreciable benefit for the problems mentioned. The benefits encouraging further studying, developing, implementing and retrofitting.

Chapter 1: Introduction

Aircraft Landing is the last part of a flight. A normal aircraft flight would include several parts of flight including taxi, takeoff, climb, cruise, descent and landing. Pilots land the aircraft by flying the airplane on to the runway. A flare is performed just before landing, and the descent rate is significantly reduced, causing a light touch down. Upon touchdown, spoilers are deployed to dramatically reduce the lift and transfer the aircraft's weight to its wheels, where mechanical braking, can take effect.

Airports with heavy traffic levels constantly are striving to increase capacity by reducing the time aircraft spend on the runway after their landing touchdown. To ease this growing concern, we have developed an innovative braking system that delivers significant improvements in runway efficiency.

Most accidents happen in this phase causing safety hazards for human lives destruction to equipments plus delays in flight. Thrust reversals are excessively used for stopping the aircraft on landing. This consumed more fuel increasing the noise and pollution impacting the airport and the airport facilities and costing airlines extra operating costs.

The pressures from the society and politicians are to stop further increase in air traffic by imposing restrictive environmental limits beyond 2020. The air transport industry is engaged in a race to keep the growth of air traffic through new technology in aviation and new operational techniques.

1.1 Introduction

A Braking system may be defined as the machine element for applying a force to a moving surface to slow it down or bring it to rest in a controlled manner. In doing so, it converts the kinetic energy of motion into heat which is dissipated into the atmosphere. The basic principle behind any braking operation is to create a controlled friction process that increases the rate of deceleration, acceleration converts heat energy into motion and deceleration converts motion into heat energy. An airplane while landing and takeoff also requires a system which helps in control. Also due to high speed it requires a system to reduce it speed while landing so that it can be brought to halt. For this purpose aircraft braking system was introduced. This system not only helps in slowing down the speed of the aircraft but also in maintaining its balance. Also, on landing, skid phenomena is observed due to runway surfaces, pilot brake demand or due to other factors which creates unsafe for the aircraft while landing. Today, many aircraft-level functions are implemented using diverse and redundant system architectures and capabilities as mitigation techniques. These approaches contribute to an acceptable level of safety at the aircraft level.

An aircraft brake system consists of many systems and airbrake is an integral part of it. Air brakes or speed brakes are a type of flight control surface used on an aircraft to increase drag or increase the angle of approach during landing. Aircraft brakes, for land based aircraft, are almost exclusively located on the main wheels although there have been some aircraft over the years which have also had nose wheel brakes. [1]

1.2 Objectives

1.2.1 Aim

To make a conceptual design which will provide the pilot in the approach with optimum braking based on the data in the system memory. The system will recalculate in case the real touch point is different from that in the memory the optimum auto braking with or without thrust reversal to stop the aircraft safely within the available runway distance.

1.2.2 Objectives

- Study the automatic brake system and review the data available.
- Introduce full automatic system.
- Increase safety level and prevent over run.
- Decelerate the aircraft in an appropriate time.
- Reduce load on the pilot by making him free to do other tasks.
- Advance information needed for braking and safe landing.
- To minimize the use of thrust reversal and thus reduce fuel consumption.
- Reduce wearing and tearing of tires and break hence reduce maintenance.
- Reduce the airport congestion by decreasing runway evacuation time.
- Improve environmental requirement by reduce carbon dioxide and noise to satisfy ICAO recommendations.
- Study advanced technology.

1.3 Problem statement

The pilots on touchdown normally refer to maximum auto braking setting in addition to use thrust reverse instead of selecting optimum braking needed to stop the aircraft safely within the available runway length.

1.4 Motivation

Adding new fully automatic technique in the braking system filed to ensure safe landing operation and to provide the most economical and environmental breaking operation.

1.5 Methodology

We educated our selves very well, collect and review the brake system in general, studied the A320 braking system, we did a conceptual design and applied it as a case study of A320. We explained the operation of our conceptual design and the calculations made to calculate the distance from touch point to exit, the deceleration rate, the brake force and the time needed. For the simulation we used C++ language to write the code for the calculations and MATLAB program to design the monitor. We tested the functionality of the program and then we choose Aldammam airport to apply the program on it. We analyzed the data, compared the results with the design requirements, and discussed the results. Finally we put some recommendations for the future work.

1.6 Thesis content

Chapter1: Introduction.

Chapter 2: Literature review.

Chapter 3: A320 braking system.

Chapter 4: A conceptual design for A320 full automatic brake system.

Chapter 5: Results and Discussion.

Chapter 6: Conclusion and Recommendations.

Chapter 2: Literature Review

Very early aircraft have no brake system to slow and stop the aircraft while it is on the ground. Instead, they rely on slow speeds, soft airfield surfaces, and the friction developed by the tail skid to reduce speed during ground operation. Brake systems designed for aircraft became common after World War I as the speed and complexity of aircraft increased and the use of smooth, paved runway surfaces proliferated. All modern aircraft are equipped with brakes. Most airplanes use disk brakes in conjunction with an advanced anti-skid control system[1].

Operation of the brakes has evolved from a single lever applying all brakes symmetrically, to heel operated pedals, to toe operated brake controls incorporated into the rudder pedals. With the foot operated controls comes the ability to apply left or right brakes independently allowing use of differential braking to steer the aircraft during ground operations and to maintain directional control during that portion of the takeoff or landing roll when the airspeed is too low for the aerodynamic controls to be effective [2].

2.1 Hydraulic system [3]

A hydraulic system uses a fluid under pressure to drive machinery or move mechanical components. Virtually all aircraft make use of some hydraulically powered components. In light, general aviation aircraft, this use might be limited to providing pressure to activate the wheel brakes. In larger and more complex aeroplanes, the use of hydraulically powered components is much more common. Depending upon the aircraft concerned, a single hydraulic system, or two or more hydraulic systems working together, might be used to power any or all of the following components:

- wheel brakes.
- nose wheel steering.
- landing gear retraction/extension.
- flaps and slats.
- thrust reversers.
- spoilers/speed brakes.
- flight control surfaces.

- cargo doors/loading ramps.
- windshield wipers.
- propeller pitch control.

A hydraulic system consists of the hydraulic fluid plus three major mechanical components. Those components are the "pressure generator" or hydraulic pump, the hydraulically powered "motor" which powers the component concerned and the system "plumbing" which contains and channels the fluid throughout the aircraft as required. Most modern transport aircraft use hydraulic power to operate the brakes because of its advantages:

- High power to weight ratio.
- Relatively low initial costs.
- Acceptable maintenance costs.
- Flexibility of installation.
- Good reliability.
- Self-lubrication.

2.2 Brake[1]

The proper function of the brakes is relied upon for safe operation of the aircraft on the ground .The brakes slow the aircraft and stop it in a reasonable amount of time. Besides the primary task of stopping the aircraft, brakes are used to control speed while taxiing, to steer the aircraft through differential action, and to hold the aircraft stationery when parked and during engine run-up. Wheel brakes produce friction at the wheel assembly to slow or stop the rotation of the wheel. Light aircraft use a simple single disc type brake but large transport aircraft require multiple discs to deal with the forces generated. In the typical brake system, mechanical and/or hydraulic linkages to the rudder pedals allow the pilot to control the brakes. Pushing on the top of the right rudder pedal activates the brake on the right main wheel(s) and pushing on the top of the left rudder pedal operates the brake on the left main wheel(s).Modern aircraft equipped with an autobrake. It is a type of automatic wheel-based hydraulic brake system for advanced airplanes.

The autobrake is normally enabled during takeoff and landing procedures when the aircraft's longitudinal deceleration system can be handled by the automated systems of the aircraft itself. Modern aircraft typically use disc brakes. The disc rotates with the turning wheel assembly while a stationary calliper resists the rotation by causing friction against the disc when the brakes are applied. The size, weight, and landing speed of the aircraft influence the design and complexity of the disc brake system. Single, dual, and multiple disc brakes are common types of brakes. Segmented rotor brakes are used on large aircraft. Expander tube brakes are found on older large aircraft. The use of carbon discs is increasing in the modern aviation fleet.

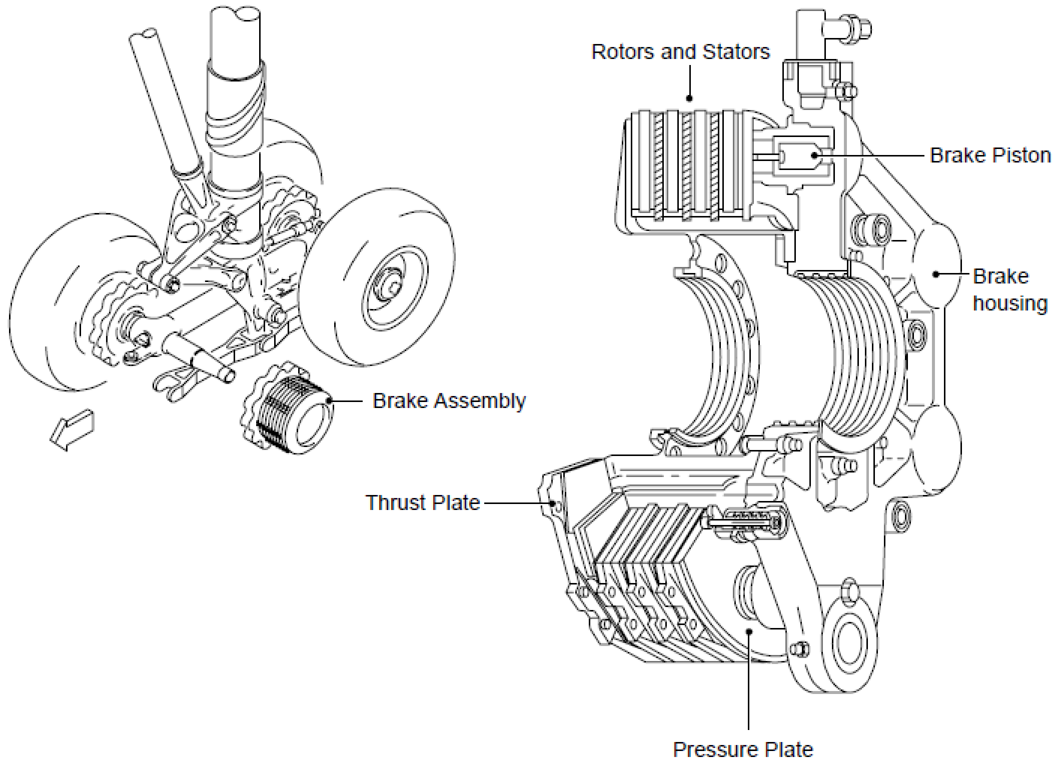


Figure 2.1: brake assembly.

Types and construction of aircraft brakes

2.2.1 Single Disc Brakes

Small, light aircraft typically achieve effective braking using a single disc keyed or bolted to each wheel. As the wheel turns, so does the disc.

Figure 2.2: A single disc brake is a floating-disc, fixed caliper brake.

2.2.2 Floating Disc Brakes

A floating disk brake has three cylinders bored through the housing, but on other brakes this number may vary. Each cylinder accepts an actuating piston assembly comprised mainly of a piston, a return spring, and an automatic adjusting pin. Each brake assembly has six brake linings or pucks. Three are located on the ends of the pistons, which are in the outboard side of the calliper. They are designed to move in and out with the pistons and apply pressure to the outboard side of the disc. Three more linings are located opposite of these pucks on the inboard side of the calliper. These linings are stationary. The brake disc is keyed to the wheel. It is free to move laterally in the key slots. This is known as a floating disk.

2.2.3 Fixed-Disc Brakes

This is the design of a common fixed-disc brake used on light aircraft. The brake is manufactured by the Cleveland Brake Company and is shown below:

Figure 2.3 : fixed-disc brake.

2.2.4 Dual-Disc Brakes

Dual-disc brakes are used on aircraft where a single disc on each wheel does not supply sufficient braking friction. Two discs are keyed to the wheel instead of one. A center carrier is located between the two discs. It contains linings on each side that contact each of the discs when the brakes are applied. The caliper mounting bolts are long and mount through the centre carrier, as well as the back plate which bolts to the housing assembly.

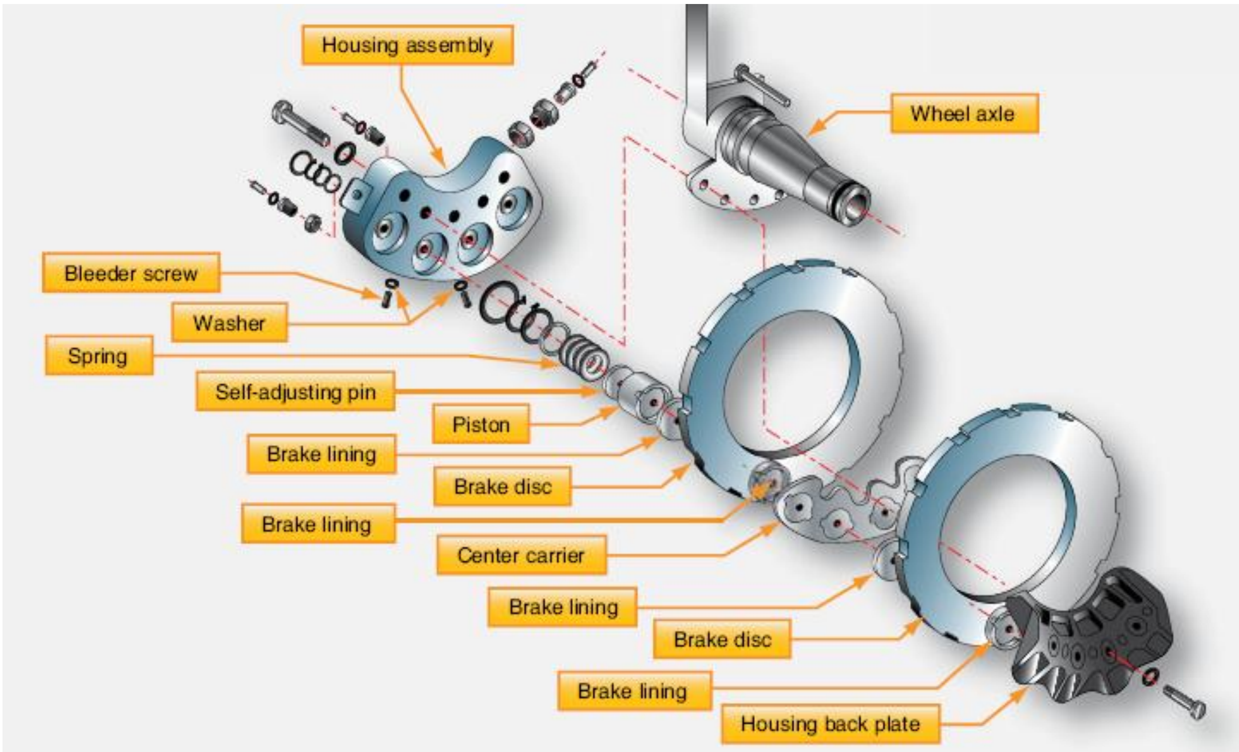


Figure 2.4 : A dual-disc brake

2.2.5 Multiple-Disc Brakes

Large, heavy aircraft require the use of multiple-disc brakes. Multiple-disc brakes are heavy duty brakes designed for use with power brake control valves or power boost master cylinders. Hydraulic pressure applied to the piston causes the entire stack of stators and rotors to be compressed. This creates enormous friction and heat and slows the rotation of the wheel.

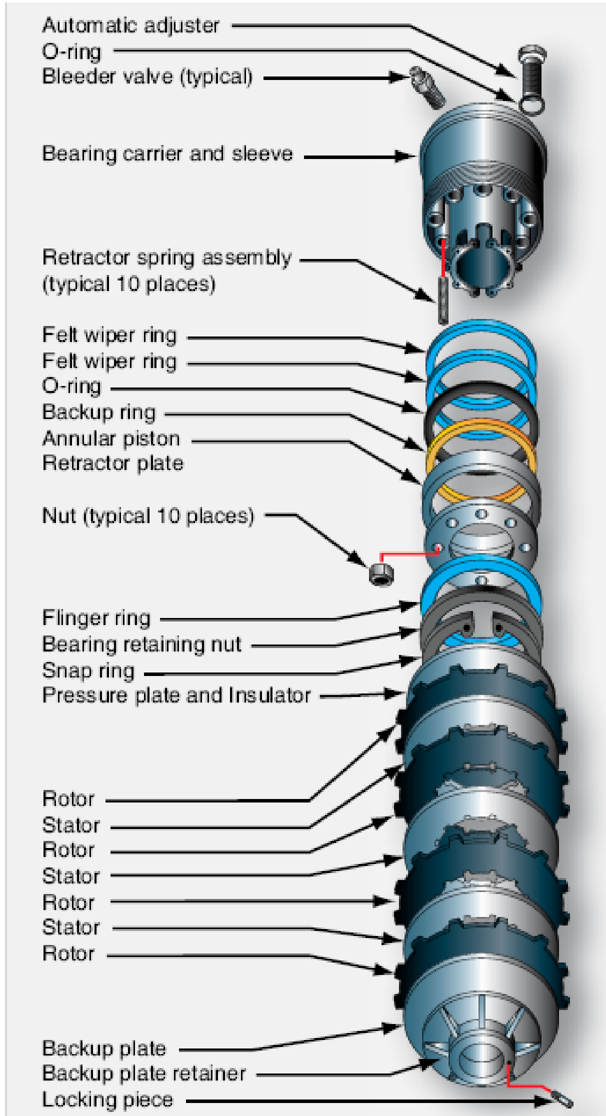


Figure 2.5: A multiple disc brake

2.2.6 Segmented Rotor-Disc Brakes

The large amount of heat generated while slowing the rotation of the wheels on large and high performance aircraft is problematic. To better dissipate this heat, segmented rotor disc brakes have been developed. Segmented rotor-disc brakes are multiple-disc brakes but of more modern design than the type discussed earlier. Segmented rotor-disc brakes are heavy-duty brakes especially adapted for use with the high pressure hydraulic systems of power brake systems. Braking is accomplished by means of several sets of stationary, high friction type brake linings that make contact with rotating segments. The rotors are constructed with slots or in sections with space between them, which helps dissipate heat and give the brake its name. Segmented rotor multiple-disc brakes are the standard brake used on high performance and air carrier aircraft. The brake assembly consists of a carrier, a piston and piston cup seal, a pressure plate, an auxiliary stator plate, rotor segments, stator plates, automatic adjusters, and a backing plate.

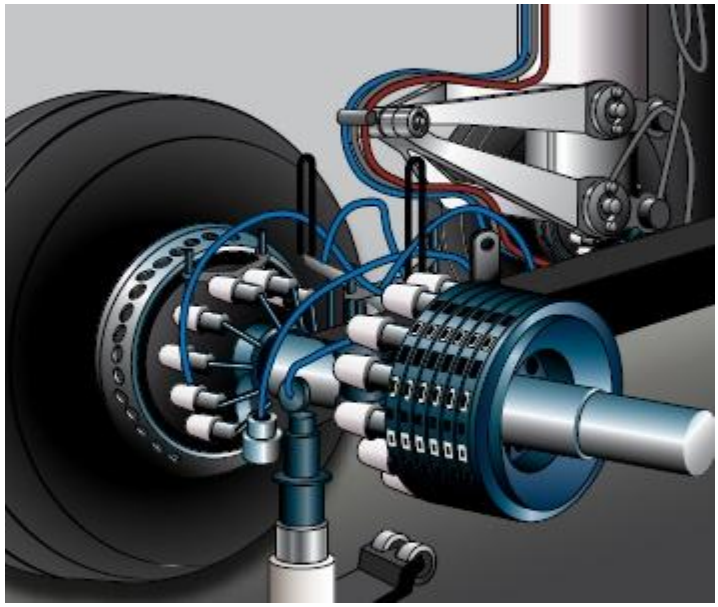


Figure 2.6: segmented rotor disc brakes

2.2.7 Carbon Brakes

The latest iteration of the multiple-disc brake is the carbon-disc brake. It is currently found on high performance and air carrier aircraft. Carbon brakes are so named because carbon fiber materials are used to construct the brake rotors. Carbon brakes are approximately forty percent lighter than conventional brakes. On a large transport category aircraft, this alone can save several hundred pounds in aircraft weight. The carbon fiber discs are noticeably thicker than sintered steel rotors but are extremely light. They are able to withstand temperatures fifty percent higher than steel component brakes. The maximum designed operating temperature is limited by the ability of adjacent components to withstand the high temperature. Carbon brakes have been shown to withstand two to three times the heat of a steel brake in non aircraft applications. Carbon rotors also dissipate heat faster than steel rotors. A carbon rotor maintains its strength and dimensions at high temperatures. Moreover, carbon brakes last twenty to fifty percent longer than steel brakes, which results in reduced maintenance. The only impediment to carbon brakes being used on all aircraft is the high cost of manufacturing. The price is expected to lower as technology improves and greater numbers of aircraft operators enter the market.

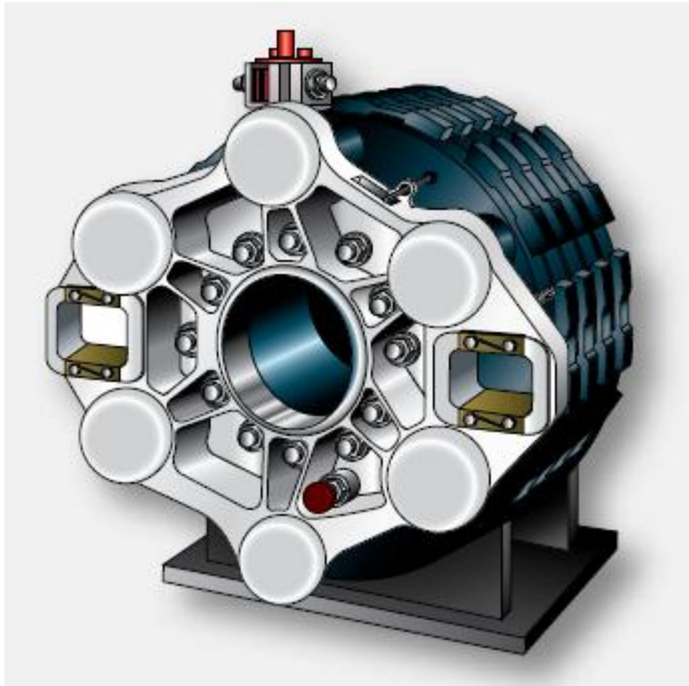


Figure 2.7: carbon brake

2.2.8 Expander Tube Brakes

An expander tube brake is a different approach to braking that is used on aircraft of all sizes produced in the 1930s–1950s. It is a lightweight, low pressure brake bolted to the axle flange that fits inside an iron brake drum. A flat, fabric-reinforced neoprene tube is fitted around the circumference of a wheel like torque flange. The exposed flat surface of the expander tube is lined with brake blocks similar to brake lining material. Two flat frames bolt to the sides of the torque flange. The expander tube is fitted with a metal nozzle on the inner surface. Hydraulic fluid under pressure is directed through this fitting into the inside of the tube when the brakes are applied. The tube expands outward, and the brake blocks make contact with the wheel drum causing friction that slows the wheel.

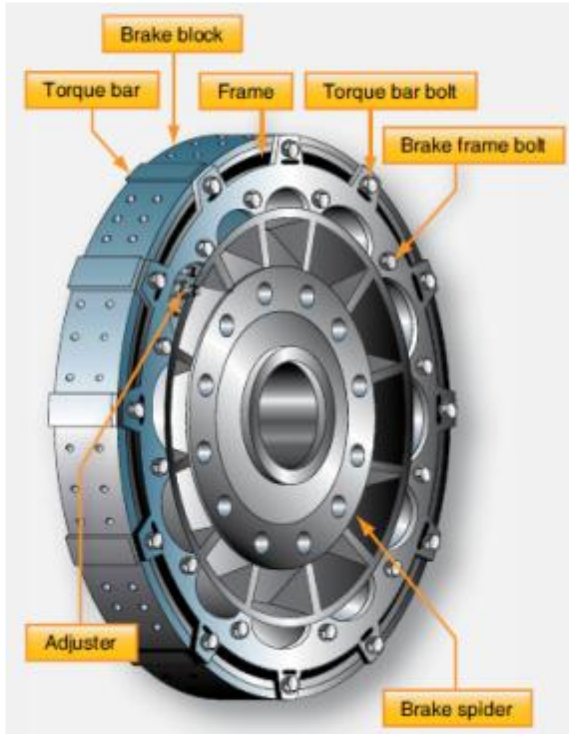


Figure 2.8: expander tube brake

2.3 Anti-Skid Systems

Maximum retardation from wheel braking is achieved when the maximum braking force is applied to a rotating wheel without stopping it. If the wheel locks the tyre will skid over the surface of the runway. Skidding produces significantly less retardation than a properly braked wheel. The problem for the pilot is knowing how much pressure to apply to the brakes. Too little pressure and he may not slow the aircraft adequately. Too much pressure and he may lock the wheel. A locked wheel not only produces less friction but the skid itself very quickly wears away the tyre crown. At best this results in ruined tread requiring a new tyre. But it might also cause the tyre to be weakened to the point where it bursts. The solution to this dilemma is the anti-skid system.

An anti-skid system works by monitoring wheel rotation. If a spinning wheel starts to slow down quickly the system interprets this as an impending skid. It then intervenes to release brake pressure and then quickly reapply it. The process happens very quickly, several times a second, but ultimately it ensures that, no matter how much brake force is demanded by the pilot, the wheels never lock. Anti-skid systems provide skid protection when braking on normal, dry runways and on wet runways. They will also provide skid protection on runways contaminated with snow and ice.

Chapter 3: Airbus A320 braking system[4]

Introduced for airline service in March 1988, the A320 represents the largest single advance in civil aircraft technology since the introduction of the jet engine and results in a major stride forward in airline profitability. The A320 is narrow body, twin-engined, short / medium-range aircraft. It offers an increased fuselage cross-section leading to an increased revenue potential through: greater passenger comfort with wider seats and aisle, greater overhead baggage volume, greater cargo capacity, wide-body compatible container capability and quicker turn rounds. Advanced technology applied to aerodynamics, structure, systems and power plant offer reduced costs through: unmatched fuel efficiency, more accurate flight path control, reduced maintenance costs, increased reliability and reduced trouble-shooting time.

What made the aircraft so different and unique from other airliners was that it was the first airliner to have a fly-by-wire (FBW) system implemented. One other unique feature was the elimination of the control column and replaced by what is known as a side stick. The FBW system replaced the conventional system of cables and hydraulics. In a conventional aircraft when the pilot moves the yoke or stick or the rudder pedals, this directly manipulates cables that displace the control surfaces. This is still used effectively on light aircraft however on airliners since the control surfaces are bigger it requires a greater effort from the pilot to operate, so the hydraulic system is used instead.

Today, the A320 has become Airbus Industries best selling aircraft, with well over 8,000 aircraft ordered. Out of these a total of 5010 have been delivered.

3.1 A320 Hydraulic system

The aircraft has three main hydraulic systems. They are identified as the Green, Blue and Yellow systems. Together they supply hydraulic power at 3000 psi (206 bar) to the main power users. These include the flight controls, landing gear, cargo doors, brakes and thrust reversers. Services which are not used during flight (cargo doors, brakes, landing gear and nose wheel steering) are isolated from the main supply. The three systems are not hydraulically connected. Where possible they are kept apart to keep to a minimum the effect of engine or tire burst, or other damage. There are no hydraulic pipes in the passenger cabin or flight compartment. High pressure (HP) pipes which are not in fire zones are made of titanium alloy and are not painted. HP pipes in fire zones are made of stainless steel. Low pressure (LP) pipes are made of light alloy and are painted for protection against corrosion. In certain special areas (landing gear bays), the LP pipes are made of stainless steel or titanium alloy. Stainless steel and titanium alloy pipes are electrically bonded with bonding leads and clips. It is not necessary to bond light alloy pipes. Flexible pipes are used where it is necessary because there is vibration or movement between components.

Manifolds are used where possible in both the HP and LP systems. The maximum quantities of components are installed on the manifolds to prevent damage to or movement of the pipes when components are replaced. The manifolds have bobbin type connections for some components. An air bleed from the pneumatic system of the aircraft pressurizes the reservoirs to 50 psi (3.5 bar). This makes sure that there is a sufficient supply of fluid to the pumps in all conditions. There are electrically-operated motorized valves in the suction lines to the two engine pumps. They close automatically when the engine fire handles are operated and stop the supply of hydraulic fluid to the pump.

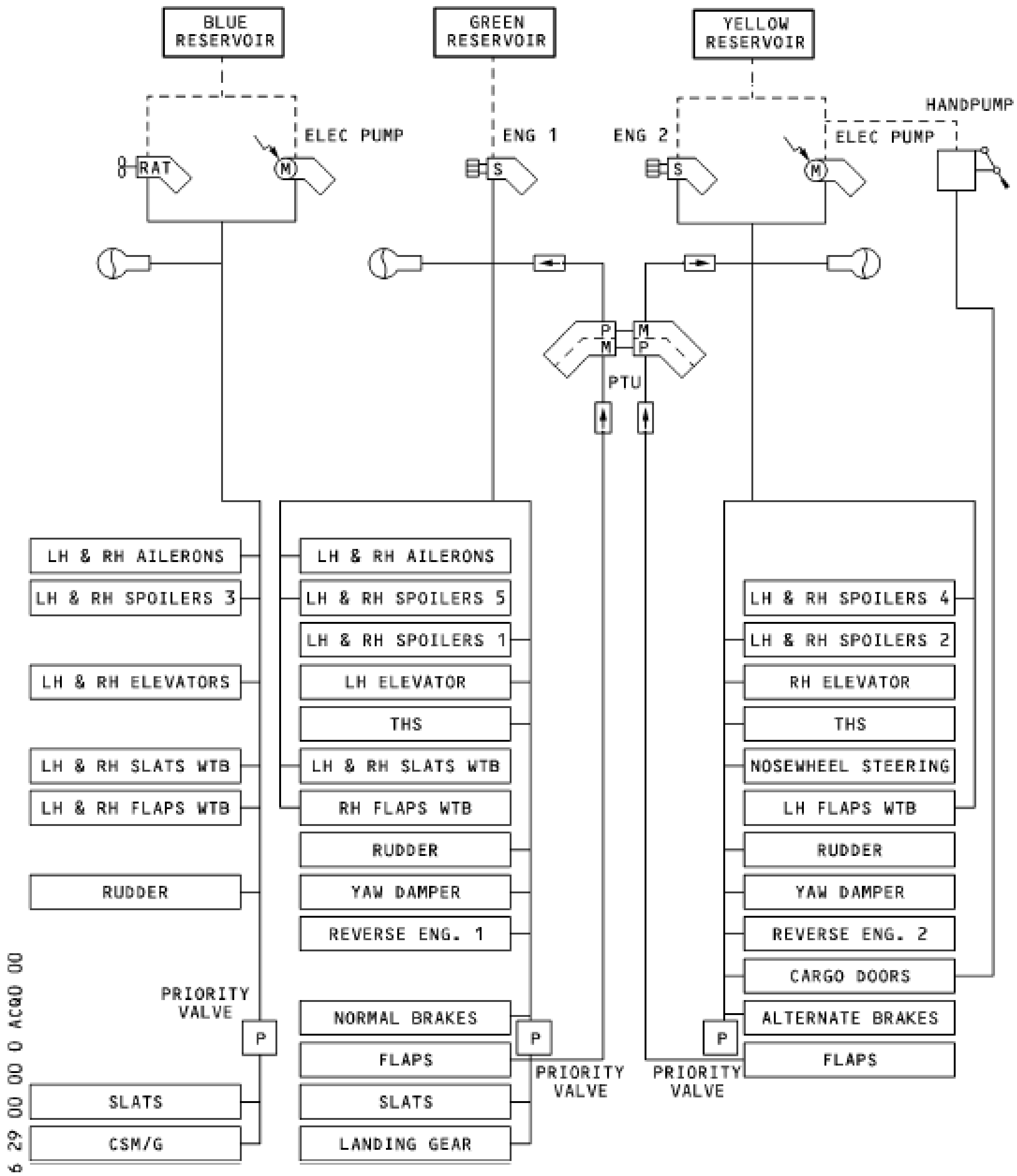
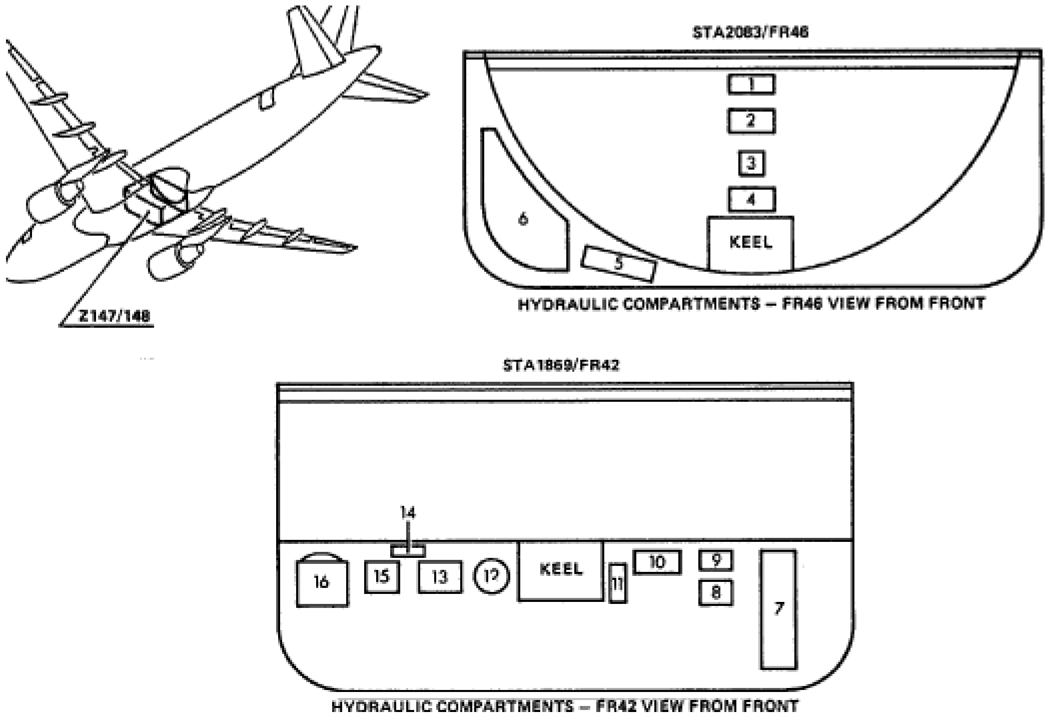


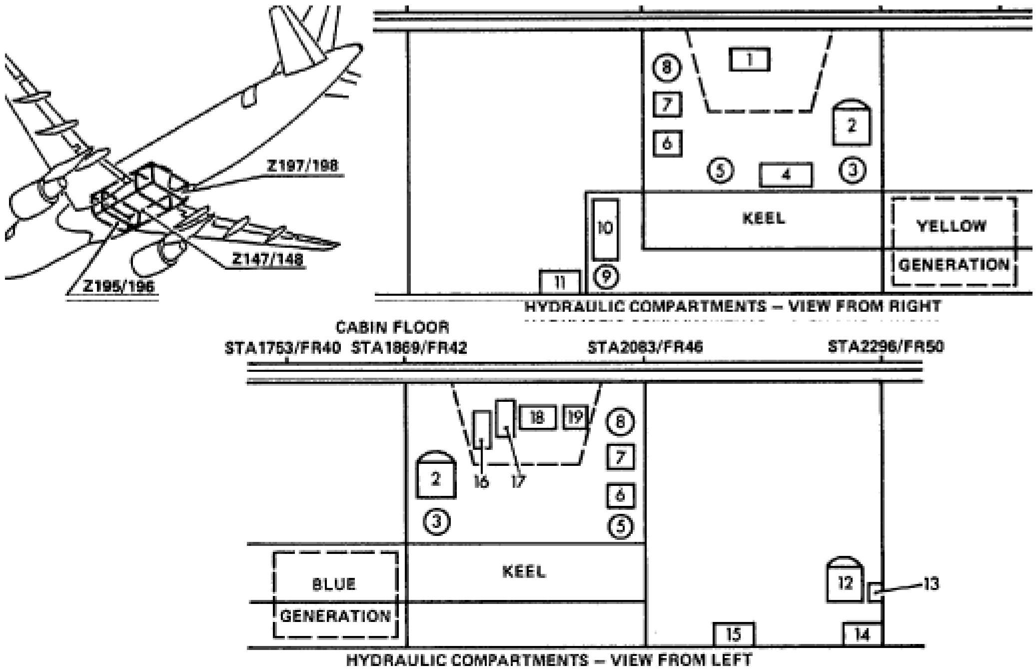
Figure 3.1: hydraulic system schematic



* G = GREEN
B = BLUE
Y = YELLOW

ITEM	SYSTEM*	COMPONENT
1	G/Y	FLAP POWER CONTROL UNIT
2	G/Y	POWER TRANSFER UNIT
3	Y	POWER TRANSFER UNIT MANIFOLD
4	B	CONSTANT SPEED MOTOR/GENERATOR
5	Y	BRAKE ACCUMULATOR
6	G/Y	BRAKE SYSTEM COMPONENTS
7	B	RAM AIR TURBINE SYSTEM
8	B	HP MANIFOLD
9	B	LEAKAGE MEASUREMENT MANIFOLD
10	B	ELECTRIC PUMP
11	B	SYSTEM ACCUMULATOR
12	Y	ELECTRIC PUMP
13	Y	RETURN FILTER
14	Y	LEAKAGE MEASUREMENT MANIFOLD
15	Y	HP MANIFOLD
16	Y	RESERVOIR

Figure 3.2: hydraulic system location



* G = GREEN
B = BLUE
Y = YELLOW

ITEM	SYSTEM*	COMPONENT
1	G	LEAKAGE MEASUREMENT MANIFOLD
2	G	RESERVOIR
3	G/B	SLAT POWER CONTROL UNIT
4	G	LANDING GEAR SELECTORS
5	B	CONSTANT SPEED MOTOR/GENERATOR
6	Y	PTU MANIFOLD
7	G/Y	POWER TRANSFER UNIT (PTU)
8	G/Y	FLAP POWER CONTROL UNIT
9	Y	BRAKE ACCUMULATOR
10	G/Y	BRAKE SYSTEM COMPONENTS
11	Y	GROUND SERVICE PANEL
12	B	RESERVOIR
13	B	RETURN FILTER
14	B	GROUND SERVICE PANEL
15	G	GROUND SERVICE PANEL
16	G	SYSTEM ACCUMULATOR
17	G	RETURN FILTER
18	G	HP MANIFOLD
19	G	PTU MANIFOLD

Figure 3.3: hydraulic system location

3.1.1 System description

The three systems are each pressurized by one main pump. The Green system pump is connected to the left engine and the Yellow system pump is connected to the right engine. The Green and Yellow pumps supply hydraulic power when their engine operates. The electric pump of the Blue system starts automatically when anyone of the engines operates. The three system main pumps are usually set to operate permanently. If necessary (because of a system fault, or for servicing), the pumps can be set to off from the flight compartment. Most of the components of the systems are in the three hydraulic compartments. The Green system components are in the main landing gear compartment. The Yellow system components are in the hydraulic compartment in the right belly fairing. The Blue system components are in the hydraulic compartment in the left belly fairing. The two hydraulic compartments (Blue and Yellow) are forward of the main landing-gear compartment.

3.1.2 Auxiliary Systems

The auxiliary hydraulic power generation systems are:

- The Ram Air Turbine (RAT) of the Blue system.

- The Power Transfer Unit (PTU) of the Green/Yellow system.

- The electric and hand pumps of the Yellow system.

NOTE: The Blue Electric pump can be used as a auxiliary power unit for maintenance purposes when the aircraft is on the ground.

3.1.3 Power Supply

The hydraulic system gets electrical power from the AC and DC systems of the aircraft.

These circuits have a 115 V AC supply:

- The electric pump of the Yellow system,

- The electric pump of the Blue system.

These circuits have a 28 V DC supply:

- RAT.

- The monitoring and control circuit of the Green system pump.

- The monitoring and control circuit of the Yellow system (engine-driven) pump.

- The warning and control circuit of the Blue system.

- Eng 1 and Eng 2 fire valves.

- The low level indicator circuit of the reservoirs.

- The system pressure transmitters.

- The leak test solenoid valves.

- The PTU solenoid valves.

- The Yellow auxiliary system.

This circuit has a 26 V AC supply:
Reservoir Quantity Indication System

3.1.4 Control

Control of the main systems is usually automatic but the crew can control the systems from the flight compartment when necessary. Most of the controls are on the two overhead panels 40VU and 50VU.

Panel 40VU has the pushbutton switches for:
- Engine No. 1 Hydraulic pump (Green).

- Engine No. 2 Hydraulic pump (Yellow).

- Electric pump (Blue).

- PTU.

- Electric pump (Yellow).

It also has the RAT hydraulic override switch to deploy the RAT. Panel 50VU has the pushbutton switches which control the three leakage measurement selectors. These are used for servicing only. Also on panel 50VU is the override switch of the Blue electric pump. This switch makes it possible to operate the electric pump of the Blue system when the aircraft is on the ground and the two engines are stopped.

The FIRE pushbutton switches on the overhead panel (section 20VU) control the motorized valves in the suction lines to the engine pumps. The electrical override switch to deploy the RAT is on panel 21VU.

3.1.5 Indication

There are two primary types of indication:

- **mechanical indicators** :

Which are gages in the hydraulic compartments and wings. These include pressure gages on the system accumulators, air pressure gages on the reservoirs and contents gages on the reservoirs. The content of the three reservoirs is also shown on the reservoir quantity indicator on the ground service panel of the Green system.

- **indications related to the electronic centralized aircraft monitoring (ECAM) system:**

These are shown on the HYD page of the system display, the engine/warning display and on the overhead panel.

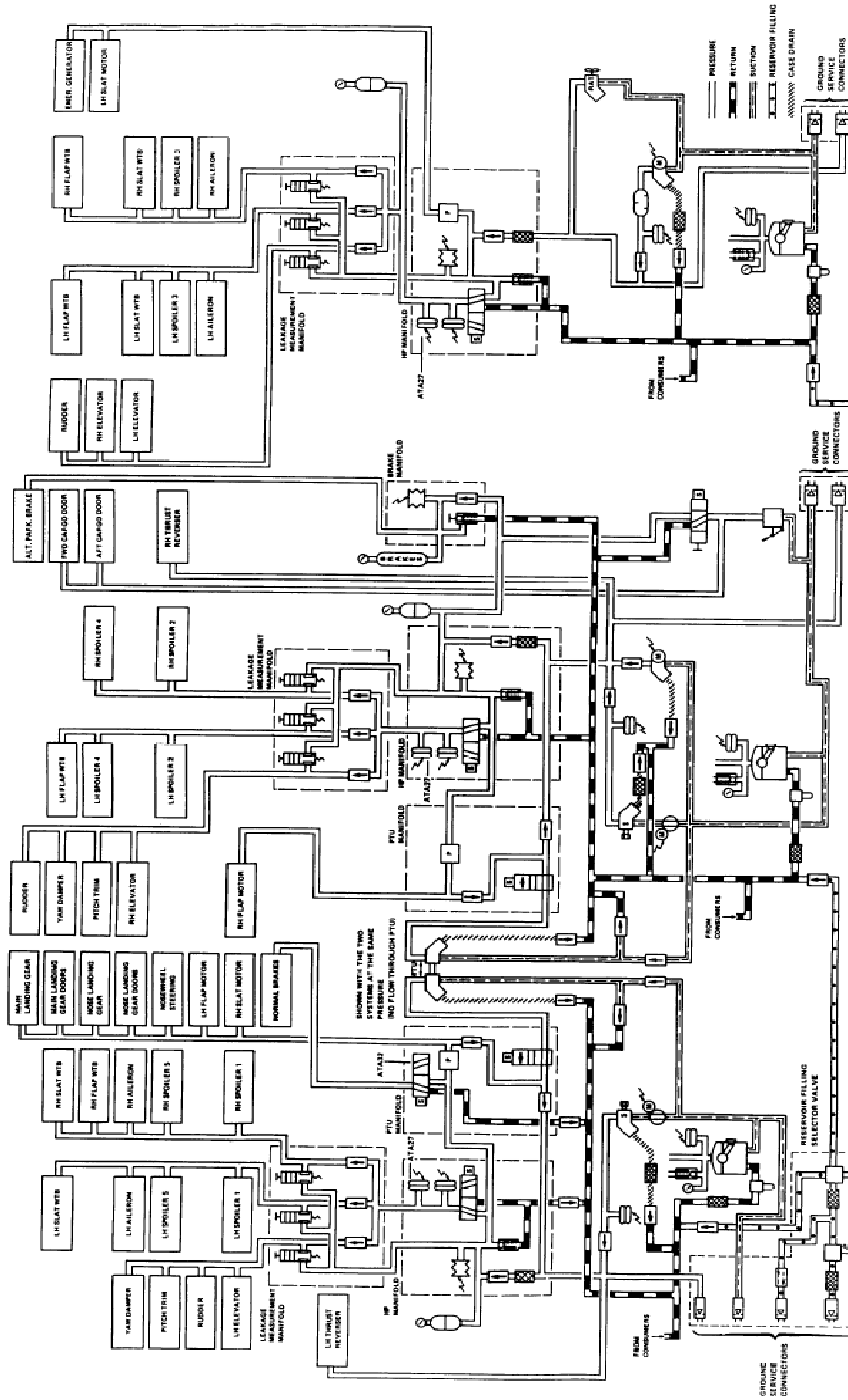


Figure 3.4: hydraulic system schematic

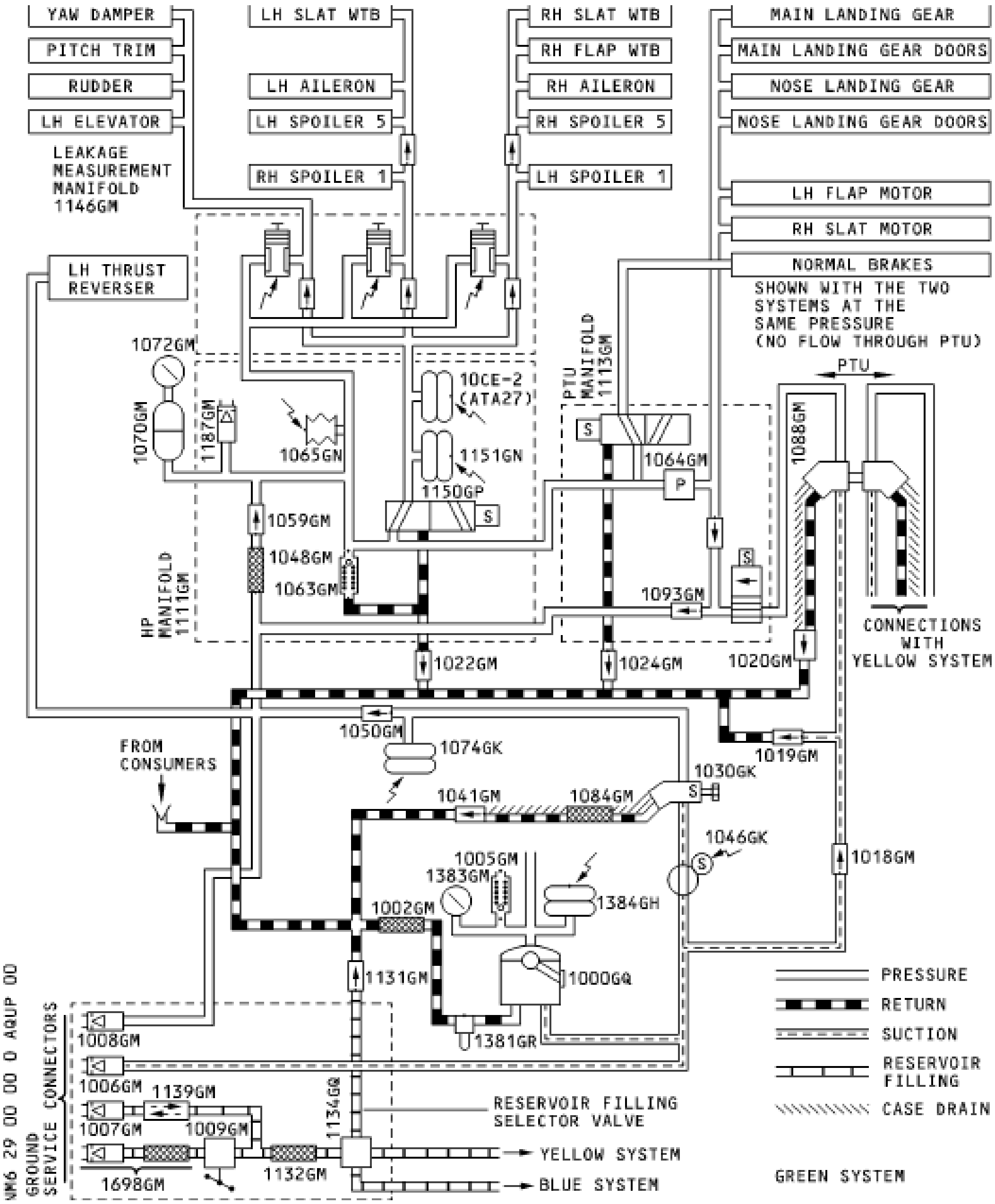


Figure 3.5:Green hydraulic system

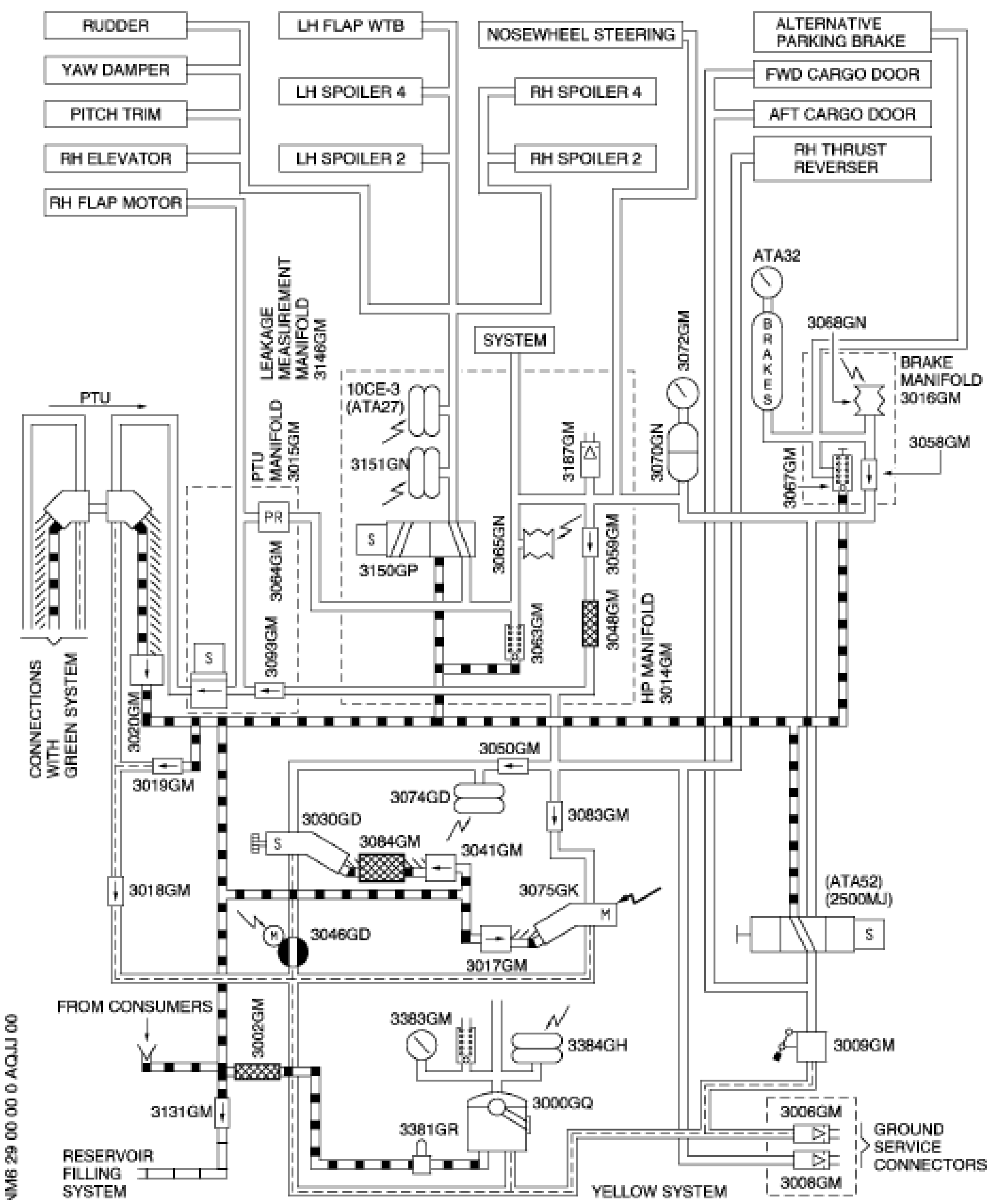


Figure 3.6: yellow hydraulic system

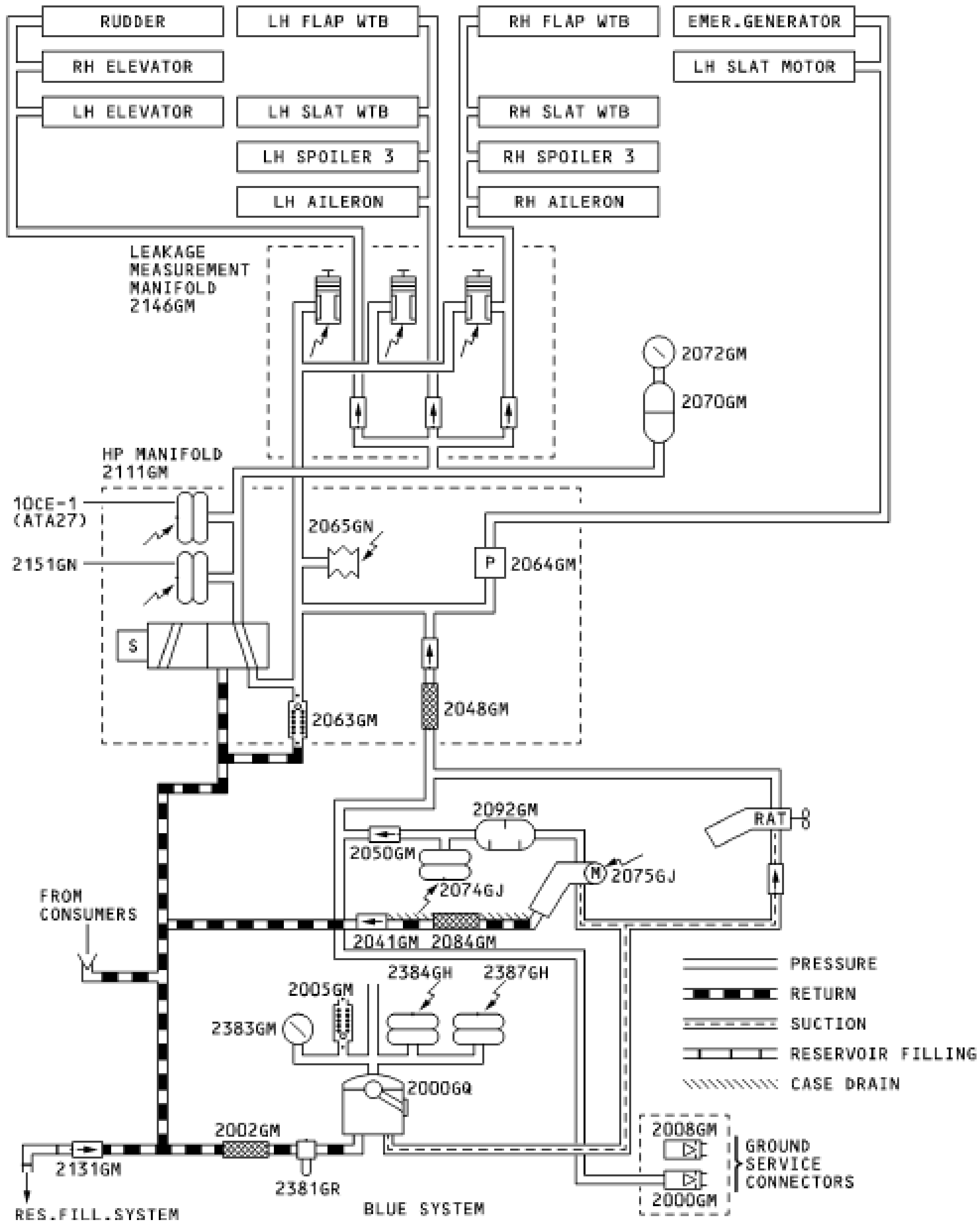


Figure 3.7: blue hydraulic system

3.2 Brake system

The main gear wheels have multidisc carbon brakes that two sets of independently supplied pistons operate; the Green hydraulic system supplies one set, the Yellow hydraulic system supplies the other set with the aid of one brake Yellow pressure accumulator. Each brake has automatic adjusters, two wear pin indicators and a temperature sensor. The main gear wheels include fusible plugs which protect the wheel and the tire against burst if an overheat occurs. The wheels have radial tires. There are two brake systems (normal and alternate) that can independently operate the brake units. The alternate system has different modes of operation.

The systems and their modes of control and operation are given as follow:

- Normal Braking.

- Alternate Braking with Anti Skid.

- Alternate Braking without Anti Skid.

- Parking/Ultimate Emergency Braking.

The brake systems have a computer which has Built-In Test Equipment (BITE). This continuously monitors the operation of the brake and steering systems. The brake units include a Brake Temperature Monitoring System.

3.2.1 Normal Braking

The Normal braking system is electro hydraulic and includes a computer, which is the Braking / Steering Control Unit (BSCU). The BSCU controls the operation of the electro hydraulic valves in the system to decrease the speed of the aircraft. The hydraulic pressure that operates the brake pistons is supplied from the Green Main Hydraulic Power system.

The system has two modes of operation, manual and automatic, and gives automatic anti skid protection in each mode. Each brake unit gets separate pressure control to supply the anti skid protection. A switch (A/SKID) in the cockpit lets you cancel the system. If the switch is set to OFF, brake operation will go to the Alternate Braking without Anti Skid system.

You get normal braking when:

- The Green hydraulic high pressure is available.

- The A/SKID & NOSE WHEEL switch is in the ON position.

- The PARK BRK control switch is in the OFF position.

You get the control which is electrical:

- Through the pedals.

- Automatically: on the ground by the autobrake system or in flight when the landing gear control-lever is placed in the UP position during 3 seconds. No indicator of Normal brake pressure is used. The regulation is performed on the four Normal brake servo valves.

The normal braking system is electrically controlled and hydraulically operated. The system has:

- A manual mode of operation, (the necessary rate of decrease in speed set at the brake pedals).

- An automatic mode of operation, (the necessary rate of decrease in speed set at the AUTO/BRK control panel).

Each of the two modes of operation gives automatic anti-skid protection at each wheel when the aircraft moves at more than ten metres a second. The system includes electrical components that control hydraulic components. The hydraulic components control the quantity of hydraulic pressure that goes to the brakes.

3.2.1.1 Manual braking mode

During manual braking, the input signals to the computer come from the two pairs of brake pedals (through the related transmitter unit) in the flight deck. Thus the quantity of hydraulic pressure that goes to the brake units is in proportion to the travel of each related brake pedal. Each pedal independently controls braking to the related MLG. In the manual braking mode, operation of the brake pedals causes a signal to be sent to the BSCU. The BSCU energizes the brake selector valve and the servo valves which supply the correct pressure to the brake units. The BSCU automatically releases the pressure (servo valve control) in the necessary brakes during anti skid control.

Manual braking is available when the Green hydraulic pressure is more than 150 bar (2176 psi) and one of these conditions occur:

- The left MLG or the right MLG is on the ground.

- The average computed wheel speed is more than a specified value.

- The ground speed (from the ADIRS) is less than a specified value.

The operation of the brake pedal(s) causes the control lever(s) of the brake pedal transmitter unit (at the first officers position) to turn. The control lever(s) turns its related potentiometer which gives an electrical output to the BSCU. This output is in proportion to the angle through which the pedal(s) turn. Differential braking is available when the travel of the left and right brake pedals is different. The left pedal gives the quantity of braking at the left MLG. The right pedal gives the quantity of braking at the right MLG.

When the output from the transmitter unit is more than a specified value, the BSCU:

- energizes the brake selector valve to open the valve.

- sends a control current to the related servo valves in proportion to the pedal movement to give the specified pressure at the brakes (max 175 bar (2538 psi)).

The brake selector valve opens to connect the Green hydraulic pressure to the normal braking system. The fluid goes through the HP filter and goes freely to the individual manifolds on the landing gear. The pressure transducer at the filter outlet sends data to the BSCU. This lets the BSCU make sure that the system is pressurized. At each manifold and valve assembly the hydraulic pressure divides equally to supply the servo valves. The servo valves are energized with the necessary control current to supply the correct hydraulic pressure to the individual brakes. The pressure transducers continuously monitor the pressure in their related brake service line. A signal that agrees with the pressure is sent to the BSCU. If the fluid pressure changes, the control current sent to the related servo valve is changed to adjust the pressure.

3.2.1.2 Automatic braking mode

Three pushbutton switches in the cockpit There are three deceleration modes (LO, MED or MAX).MAX mode is selected before Take-off. If a brake pedal supplies an input signal which is more than the set auto value it cancels the automatic braking program. If specified failures occur in the system, control automatically changes to the Alternate Braking system or In the automatic braking mode the BSCU uses the braking program that is set to control the rate of the aircrafts deceleration. The BSCU starts the braking program when the necessary specified conditions are available. It calculates the correct brake pressure required and controls the servo valves to get the correct deceleration rate. The BSCU also controls the anti skid function. To do this it compares the actual wheel speeds with the aircraft speed. The BSCU then releases the brake of the wheel that starts to be in a skid condition. The BSCU also puts the brakes on for a short time during retraction of the landing gear.

3.2.2 Alternate Braking with Anti Skid

The Alternate braking system with anti skid is the secondary, electro hydraulic braking system. It automatically becomes available if:

- Specified failures occur in the Normal braking system.

- The pressure of the Green main hydraulic power supply is less than a specified value.

An analog computer ABCU (Alternate Braking Control Unit) controls the operation of the alternate braking system. Braking inputs can only be made at the brake pedals and the BSCU provides the anti-skid control. The hydraulic pressure that goes to the second set of pistons in the brakes is supplied from the Yellow Main Hydraulic Power supply. The quantity of hydraulic pressure that goes to the brake units is in proportion to the travel of each related brake pedal. Each pair of brake units (on the same gear) get separate pressure control to supply the anti skid function.

3.2.3 Alternate Braking without Anti Skid

The alternate braking without anti skid system is the secondary mode of operation of the alternate braking with anti skid system. The system is automatically available when the anti skid function is not available. This occurs when:

- The A/SKID switch is set to OFF.

- The Yellow Main Hydraulic Power supply is not available.

- The Anti skid function of the BSCU is faulty.

The system uses the same hydro mechanical components as the alternate braking with anti skid system. If the Yellow Hydraulic Power supply is lost, the accumulator (filled from the Yellow HP) gives sufficient power for at least seven full brake applications. A triple pressure indicator in the cockpit shows the braking accumulator pressure and the pressure at the brakes.

3.2.4 Parking/Ultimate Emergency Braking

The parking brake system is an electro hydraulic system. It uses the components of the alternate braking system to send pressure to the brakes. Its primary function is to prevent movement of the aircraft when it is parked. It can also be used to stop the aircraft during towing or in an emergency. The parking brake system gets its hydraulic power supply from the accumulator of the Alternate braking system or the Yellow Main Hydraulic

Power system The accumulators have sufficient capacity to hold the brakes on for a minimum time of twelve hours. The brake pressure supplied to each MLG and the hydraulic pressure available to the system are shown on the triple pressure indicator.

3.2.5 Ground Tests and Brakes and Steering Built-in Test Equipment BITE

The BITE function of the braking/steering control unit (BSCU) permanently monitors the electrical control and regulation functions. The faults found are memorized and shown on the CFDIU.

The BSCU includes hardware and software which:

- Continuously monitors the systems for failures.
- does automatic system tests at specified times.
- permits specified system tests during ground maintenance.
- Do a power-up test of parts of the system when the system is energized.
- keep a record of the failures.
- send the failure data to the CFDS.

3.2.6 Brake system temperature monitoring system

The brake temperature system measures the temperature at each of the four brakes. The sensor on each brake sends analog signals to the related BTMU. The BTMU sends the signals to the BSCU. The BSCU changes the analog data to ARINC data and sends it to the EIS. The temperature values are shown on the lower ECAM DU.

The brake temperature system:

- measures the temperature at each of the four brakes.
- shows the temperature values on the lower ECAM DU.
- tells the flight crew to delay take off or extend the gear (messages on the upper ECAM DU).

3.2.7 Brake Cooling Fans (Optional)

The brake cooling fans permit high speed cooling of the brakes. They thus decrease the turnaround time of the aircraft if you make short flights with high energy braking. One fan is installed on each wheel of the main gear. A BRK FAN pushbutton switch is used to operate the fans. When the brakes are hot, the HOT legend of the pushbutton switch comes on.

3.2.8 Anti Skid System

The anti skid system gives the maximum braking efficiency as it keeps the wheels at the limit of skidding. The brake release orders generated are sent to the four Normal or four Alternate brake servo valves and to the ECAM system. This system gives a display of the released brakes and of the actions and limitations associated with the various possible failures. The A/SKID & NOSE WHEEL switch on the center instrument panel is used to disconnect the anti skid system and the nose wheel steering.

3.2.9 Braking Modes

The four braking modes available depend on:

- the hydraulic system used.

- the position of the A/SKID & NOSE WHEEL switch and PARK BRK control switch.

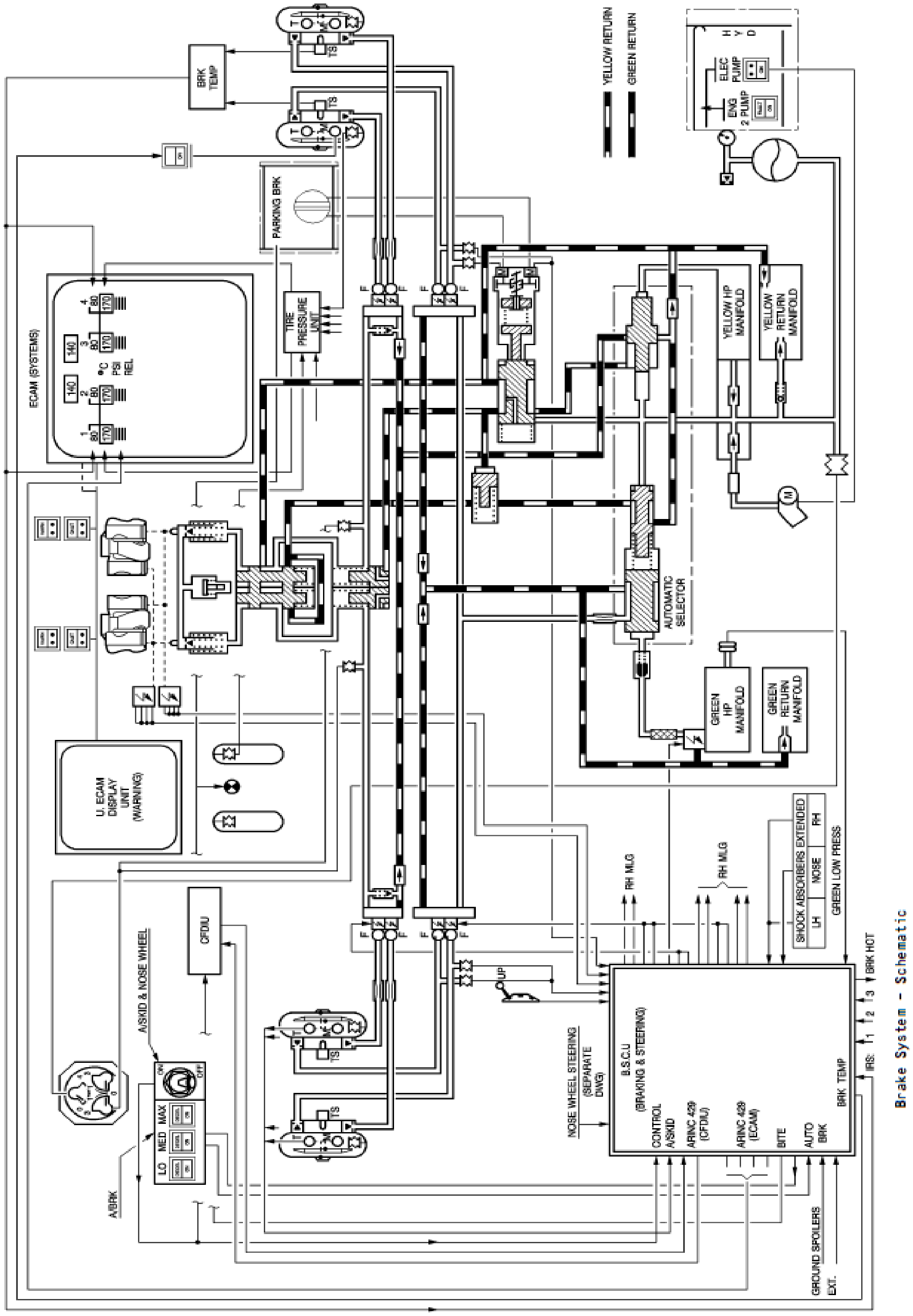


Figure 3.8:brake system schematic

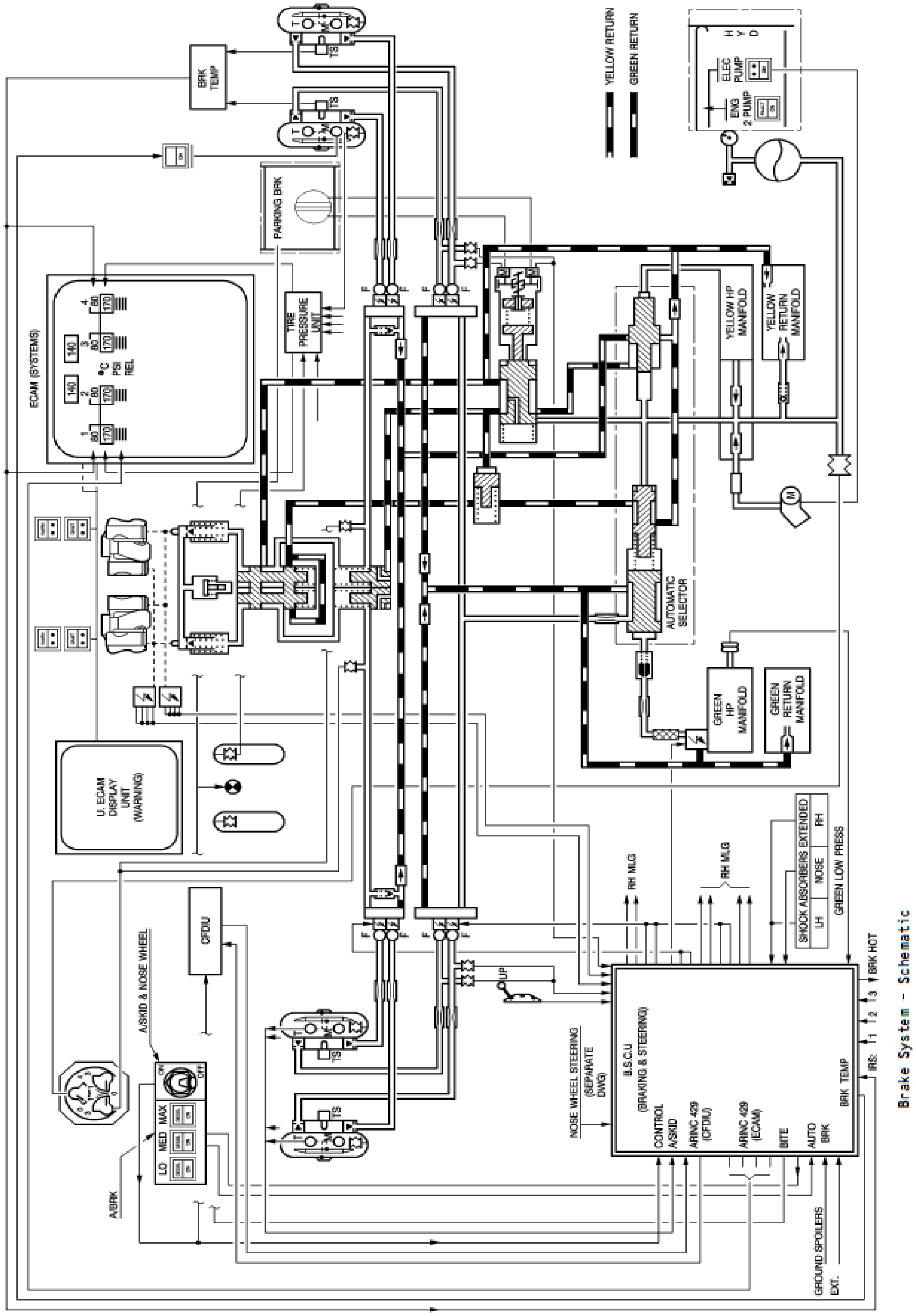


Figure 3.9: brake system shematic

3.2.10 Auto Brake

This system:

- decreases the number of flight crew actions if an acceleration-stop (MAX mode) occurs,

- or keeps the deceleration to a pre-set limit (LOW or MED) when landing.

The flight crew pushes the LO, MED or MAX pushbutton switch to arm the system. The blue ON legend on the lower half of the pushbutton switch comes on if the Normal braking is operational. The ground spoiler extension command starts the braking action. The Green DECEL legend on the upper half of the pushbutton switch comes on:

-when you get the set deceleration rate, i.e.: 2 m/s 2 in LOW mode or 3 m/s 2 in MED mode.

-or when you get a 0.27 g deceleration in the MAX mode.

The auto brake system is disengaged and disarmed:

- if one (or more) of the arming conditions is (or are) lost.

- if you apply sufficient pressure to the pedals with the aircraft on the ground (takeover through brake pedals). The failure of the auto brake is shown on the upper ECAM DU before and after the selection.

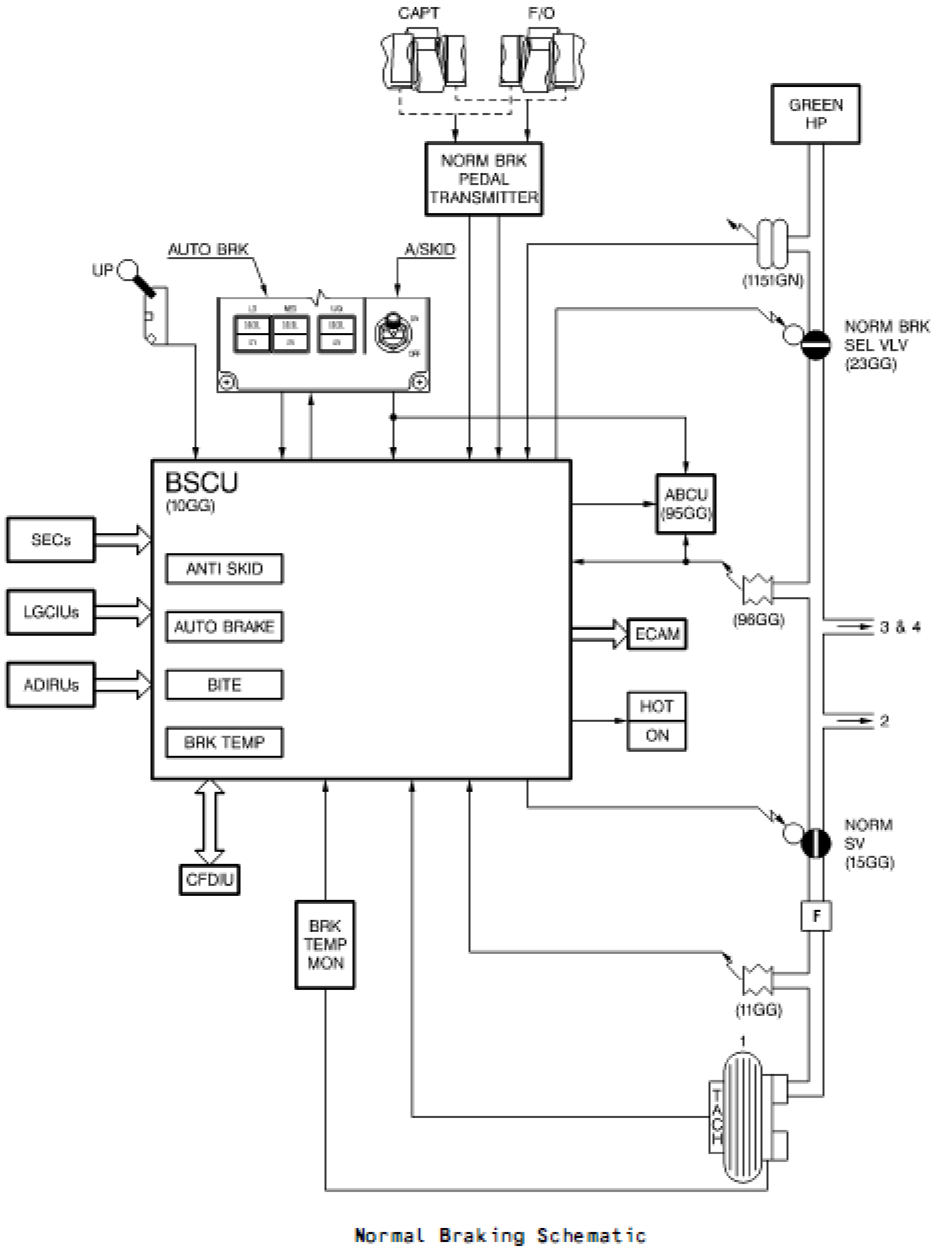


Figure 3.10:normal braking schematic

3.2.11 Electrical System Components

The electrical control system has two independent sub-systems that are isolated from each other. The two sub-systems connect to these components in the brake system:

- An anti-skid (A/SKID & N/W STRG) switch.

- Three autobrake pushbutton switches (LO, MED and MAX).

- A normal brake pedal transmitter unit mechanically connected to the brake pedals.

- A control channel of the BSCU.

- A tachometer on each axle.

The A/SKID & N/W STRG switch has two positions, in the ON position it sets the BSCU to make the normal braking system available. In the OFF position, normal braking is not available. In this condition the Alternate Brake Control Unit (ABCU) gives the control to the Alternate Braking without anti-skid. When an autobrake mode (LO, MED or MAX) is selected, the BSCU sends a controlled pressure to the brakes until the deceleration measured by the IRU(s) matches the programmed deceleration. Before takeoff, the pilot select the MAX mode.

The brake pedals apply the related brakes of the left or right MLG. The brake pedals are installed in pairs and are mechanically connected together. The two left pedals are connected together and the two right pedals are connected together. Each pedal is connected to a spring operated unit that:

-supplies an artificial feel when the brake pedals are operated.

-puts the pedals back to their initial position when released.

The brake pedals operate the brake pedal transmitter unit which is installed below the pedals at the first officers position. The transmitter unit contains two potentiometers each with four tracks. One potentiometer is for the left MLG. The other potentiometer is for the right MLG. The BSCU sends an electrical supply to the potentiometers. When a brake pedal is operated, the related potentiometer sends an output to the BSCU. This output is in proportion to the angle through which the brake pedal moves.

The BSCU controls the operation of the electro hydraulic valves in the system to supply these primary functions:

- the quantity of braking.

- the anti-skid function (to give maximum braking efficiency).

- the automatic braking of the main gear wheels during the L/G retraction.

- the test of the brake system and nose wheel steering system before a landing.

- the nose wheel steering.

The BSCU also has these secondary functions, it:

- monitors the temperature of each brake.

- calculates the wheel speed.

- uses Built-In Test Equipment (BITE) to do software controlled tests when the aircraft is on the ground.

- supplies data to other systems in the aircraft.

The BSCU has two systems, System 1 and System 2. These systems are isolated from each other and each connects to its related electrical sub-system. Only one system (the active system), controls the operation of the braking system. The other system (the standby system) is available if the active system becomes unserviceable. If available, the two systems monitor the operation of the braking system.

When the BSCU is supplied with power system 1 becomes active. After each landing the BSCU makes a record in an Electrically Erasable Programmable Read-Only Memory (EEPROM) that identifies which system was active during the landing. Before the next landing, the BSCU reads the EEPROM and makes active the system that was in standby mode during the last landing.

A tachometer is installed in the end of each MLG axle. A drive assembly connects the tachometer to the related wheel. The tachometer measures the speed of the wheel and sends this data to the BSCU. The BSCU uses this data to control the hydraulic pressure supply to the related brake for anti-skid and autobrake functions.

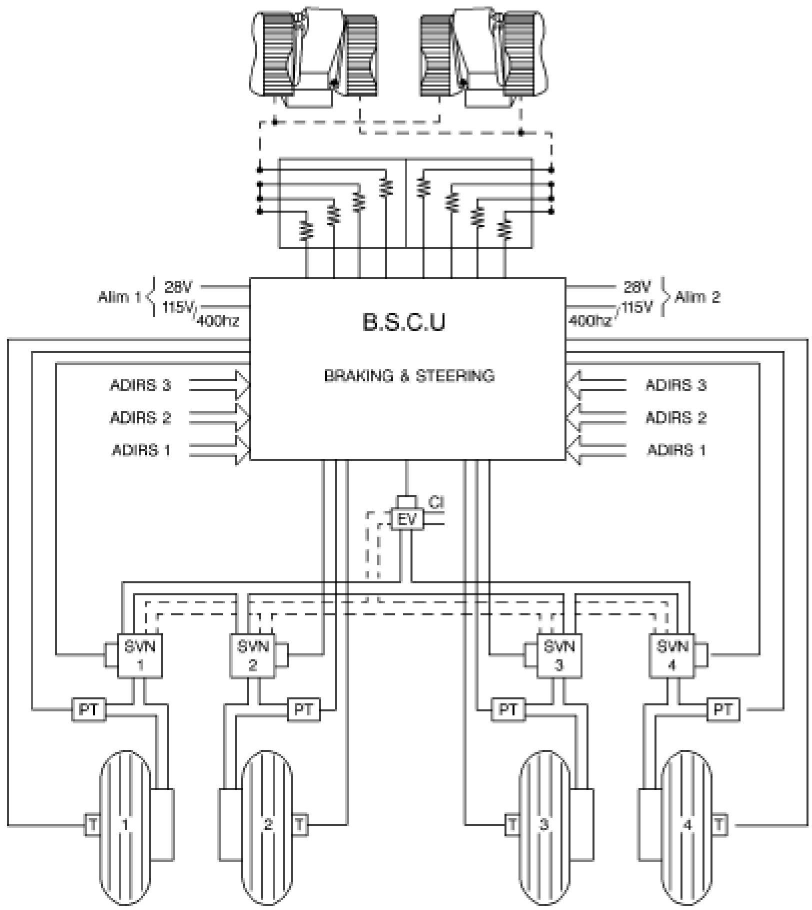


Figure 3.11:BSCU circuit

When the brake pedals go back to their initial position, the output from the transmitter unit returns to a set value (set for the initial pedal position). When the output is less than a specified value this causes the BSCU to de-energize the brake selector valve. At the same time it decreases the control current it sends to the servo valves which releases the brakes.

When the brake selector valve is de-energized, it connects the HP filter to the LP manifold (Port A) of the Green hydraulic system.

When the servo valves are de-energized, they operate to connect their related brake service line to the LP manifold of the Green hydraulic system.

3.2.12 Automatic Braking

The automatic braking system has these functions:

- Generation of the arming or disarming orders to the system.

- serving of the aircraft deceleration to a programmed deceleration rate.

- braking control when the spoiler signals are present, depending on the requested deceleration.

When an autobrake mode (LO, MED or MAX) is selected, the BSCU sends a controlled pressure to the brakes until the deceleration measured by the IRUs matches the programmed deceleration. The anti skid system operates to avoid wheel lock-up.

The auto brake system advantages are:

- get the optimum deceleration rate compatible with the length of the runway.

- decrease the pilot workload during landing.

- decrease the number of pilot actions in case of rejected take-off (one action on throttle instead of two actions: braking + throttle).

- improve passenger comfort.

Before landing, the pilot sets the deceleration rate he thinks to be adapted to the runway. For this purpose, he uses the AUTO BRK LO and MED on the centre instrument panel. The pilot can disengage the autobrake when he depresses the pedals or when he pushes again the AUTO BRK LO and MED. Before takeoff, the pilot selects the MAX mode.

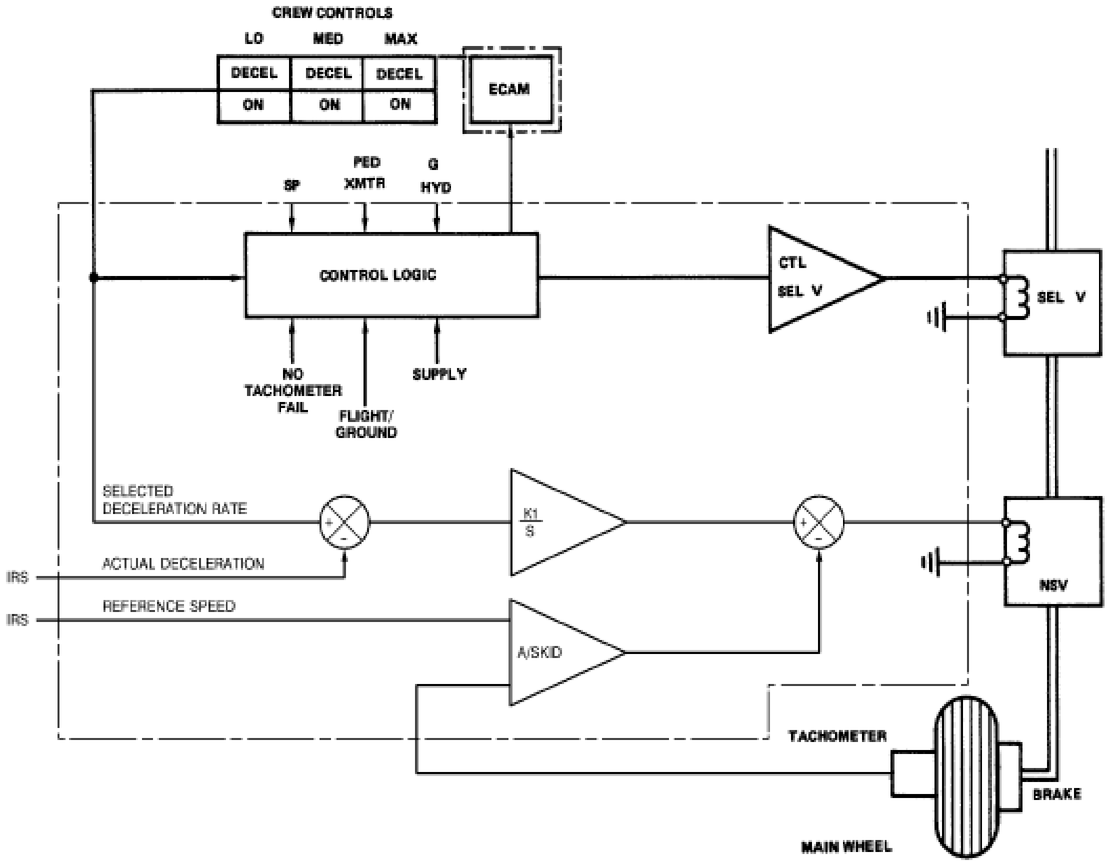


Figure 3.12:Autobrake circuit

3.2.13 Indicating

Each lighted pushbutton switch is divided into two parts:

- the lower part (ON legend) comes on blue to show that the pushbutton switch has been selected and the system armed.

- the upper part (DECEL legend) comes on green: when 80% of the corresponding deceleration rate has been reached, (LO and MED pushbutton switches) or when you have a deceleration rate higher than 0.27 g (MAX pushbutton switch).

3.2.14 Auto brake logic

The auto brake logic is located in the BSCU on the control and monitoring boards of the SYS 1 and SYS 2. The signals below are sent to the logic circuits of the auto brake:

- 3 signals that the AUTO BRK LO/MED and MAX on the centre instrument panel supply:

2 deceleration rates, LOW = 1.7 m/square second (LOW type 1) and MED = 3 m/ square second (2 m/square second in MED limited) , and a MAX = 10 m/square second (higher than the maximum possible deceleration of the aircraft) there is a LOW type 2 mode = 2m/square second depending of the aircraft pin programmation.

- 3 signals which tell that the ground spoilers are commanded. Two of them must be present to permit the automatic braking.

- a signal which gives the pedal position.

- a signal which tells that the pressure in the Green system is low.

- a signal which gives the longitudinal deceleration of the aircraft ADIRs.

- no tachometer failure.

- GROUND/FLIGHT information.

The auto brake logic supplies:

- the command for the energization of the selector valve.

- the braking command to the four servo valves.

- the information below to the lighted pushbutton switches:

the system is armed or the deceleration rate that you get.

- to the ECAM system:

the deceleration rate that you select or the AUTOBRK disarm signal or the AUTO BRK FAULT signal if arming is not possible.

3.3 Global Positioning System (GPS)

3.3.1 GPS Receiver

The GPS is a radio aid to worldwide navigation which provides:

- the crew with a readout of accurate navigation information, e.g position, track and speed.

- the Flight Management and Guidance Computer (FMGC) with position information, after hybridization in the Air Data/Inertial Reference Unit (ADIRU) with inertial parameters, for accurate position fixing.

**Each ADIRU receives data from the two GPS portions of the MMRs on the primary and secondary inputs. Position initialization of the ADIRU is transmitted to the MMR for its own initialization.

**MMR receivers are controlled from FMGCs. The latitude and longitude pair processed for position initialization is received from the same source (FMGC 1, FMGC 2 or CDU).

3.3.2 GPS Operation

(1) Normal operation

In normal operation, the GPS 1 data are used by the ADIRUs 1 and 3; the GPS 2 data by the ADIRU 2.

NOTE : In order to reduce GPS initialization time, the GPS 1(2) receives data from the ADIRU 1(2).

The Inertial Reference (IR) portion of the ADIRU 1(2) provides the FMGC 1(2) with:

- pure IR data.

- pure GPS data (in this case the ADIRU operates as a relay).

- hybrid GPIR data.

The hybrid GPIR 1(2) data are used by the FMGC 1(2) for position fixing purposes.

The pure GPS data are used for display on the MCDU 1 and 2. In case of one GPS failure, the three ADIRUs automatically select the only operative GPS to compute hybrid GPIR data.

In case of ADIRU 1 failure, the FMGC 1 uses ADIRU 3/GPS 1 data.

In case of ADIRU 2 failure, the FMGC 2 uses ADIRU 3/GPS 2 data.

NOTE : The primary source of the ADIRU 3 being the GPS 1, it is necessary to select the secondary input port of the ADIRU 3 (GPS 2) by means of the ATT HDG selector switch (13FP) to preserve side 1/side 2 segregation (GPS 1/ADIRU 1/FMGC 1 and GPS 2/ADIRU 3/FMGC 2 architecture). In case of failure of two ADIRUs, the two FMGCs use only the operative ADIRU.

The primary function of the MMR is to receive and process ILS and GPS signals.

The MMR receives RF signals through an active GPS antenna. The GPS receiver filters, mixes, and performs analog-to-digital conversions. The resulting data is processed by microprocessors that output position, velocity, time, and integrity data to the system processor. The GPS receiver simultaneously tracks signals from up to twelve GPS satellites. The signals are processed to generate a three-dimensional position and a precise time. The receiver generates an estimate of the positional accuracy provided. An integrity alert is activated if an unannounced satellite malfunction is detected. The receiver has the capability of excluding satellites that are malfunctioning.

3.3.3 GPS MONITOR

The GPS data are displayed on the GPS MONITOR page of the MCDU. To get the GPS MONITOR page, push the DATA key on the MCDU, then the line key adjacent to the GPS MONITOR indication. The upper part is dedicated to GPS 1 data, the lower part to GPS 2 data.

The following data are displayed:

- GPS position (lat/long).

- True track.

- GPS altitude.

- Figure of merit (in meters).

- Ground speed.

- Number of satellites tracked.

- Mode.

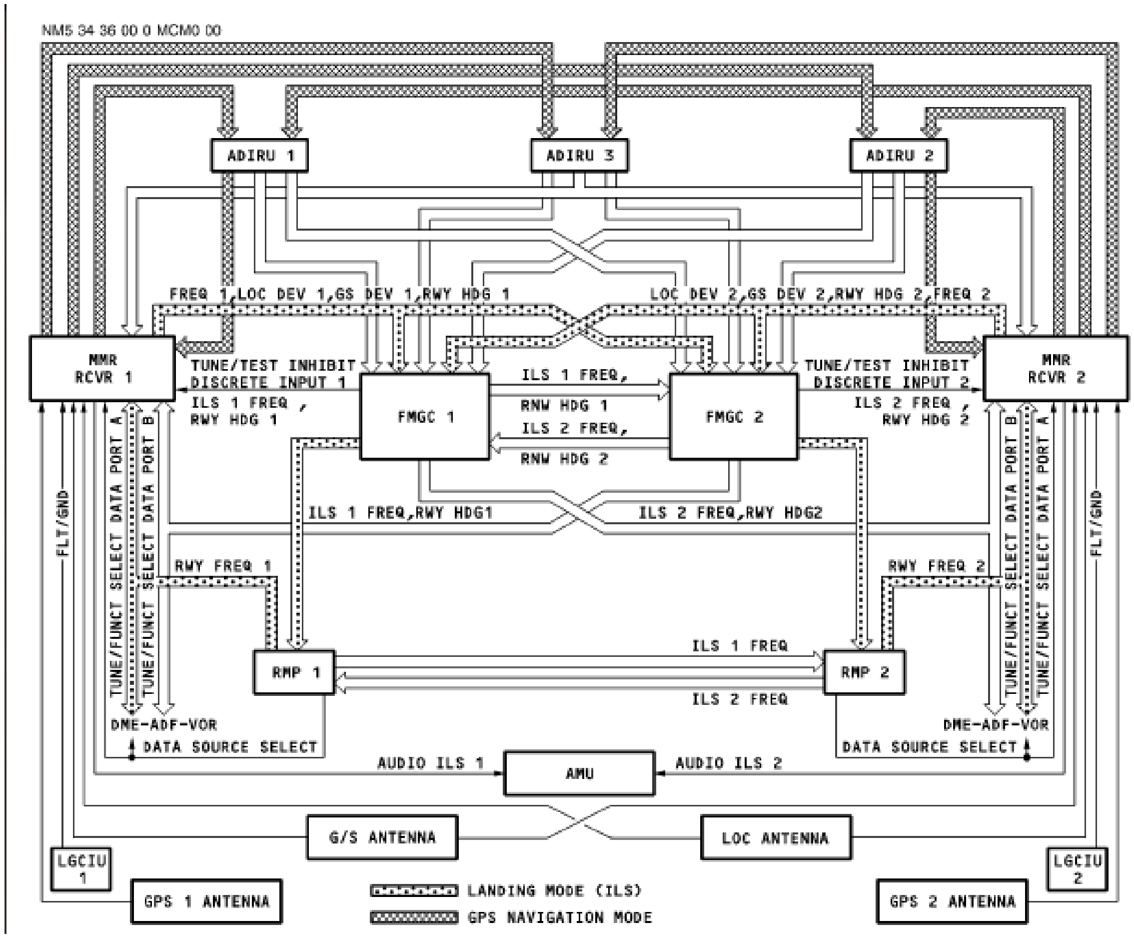


Figure 3.13: GPS signal circuit

Chapter 4: Full Automatic Brake System

In this Chapter we explain a new developed automatic brake system, this system designed to improve the existing system and to solve its problems.

4.1 Operation:

After touch down the spoilers will automatically deploy, a signal will be sent to the BSCU, the system is activated. Then the remaining distance will be calculated according to the position data from GPS, the velocity of aircraft at touchdown is given from ADIRU, then the deceleration rate will be calculated from our program and finally calculating the force needed to brake the aircraft before the exit that pilot selected. If the force calculated exceeds the design force limited by the hydraulic system the program will inform the pilot to select another exit or to use the thrust reverser.

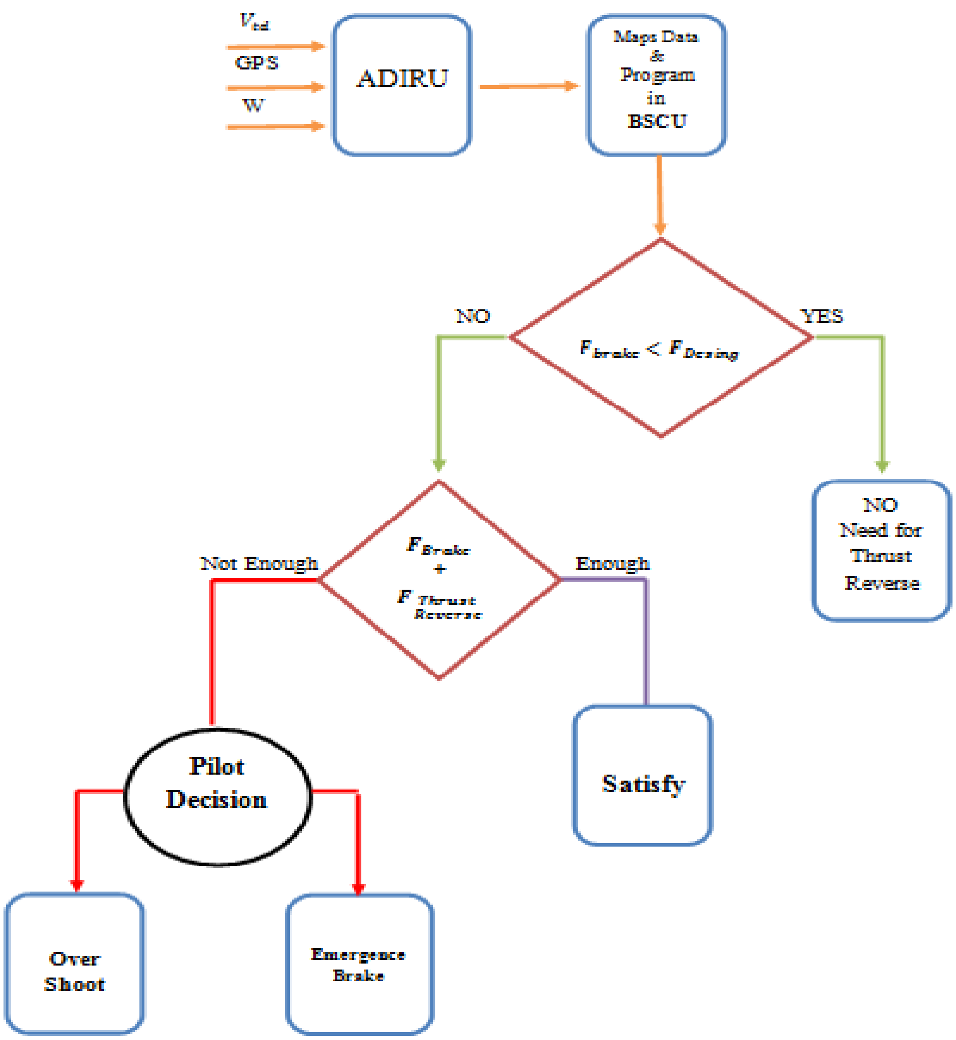


Figure 4.1: system operation

4.2 Calculation:

The following table provides characteristics of Airbus A320 design limits:

Aircraft Characteristics	
Maximum Landing Weight (MLW)	64 500 kg
Maximum Zero Fuel Weight (MZFW)	60 500 kg
Maximum Final approach speed*	70 m/s

Table 4.1:Aircraft characteristics

* Maximum Final approach speed defined as the indicated airspeed at threshold in the landing configuration, at the certificated maximum flap setting and Maximum Landing Weight (MLW), in standard atmospheric conditions.

GPS gives location as (longitude, latitude) ≡ (x, y).

Aircraft location defined as: (x_1, y_1).

Exit location defined as: (x_2, y_2).

The distance between these two points could be calculated by this equation:

$$S = \left(\sqrt{X^2 + Y^2}\right) \times R \quad \text{-----} \quad (4.1)$$

While:

$$X = (x_2 - x_1)\left(\frac{\pi}{180}\right) \times \cos\left[\left(\frac{y_2 + y_1}{2}\right)\left(\frac{\pi}{180}\right)\right] \quad \text{-----} \quad (4.2)$$

$$Y = (y_2 - y_1)\left(\frac{\pi}{180}\right) \quad \text{-----} \quad (4.3)$$

S ≡Distance [meter].

R ≡ Earth mean radius. (R=6371000) [meter].

The deceleration rate could be calculated by the equation below:

$$D = \frac{{V_{end}}^2 - {V_{td}}^2}{2S} \text{ -- } (4.4)$$

While:

D≡ Deceleration Rate [$\frac{meter}{Second^2}$].

V_{end} ≡ Final velocity (taxi speed) [$\frac{meter}{Second}$].

V_{td} ≡ Touchdown speed [$\frac{meter}{Second}$]. $V_{td} = 0.982V_{app}$

The total force to be applied to stop the aircraft can be calculated by this equation:

$$F_{total} = m * D \text{ --- } (4.5)$$

While:

$$m = \frac{W}{g} \text{ -- } (4.6)$$

m≡ Aircraft mass. [kg]

F_{total} ≡ Total force. [Newton]

W≡ Aircraft weight. [kg* $\frac{meter}{Second^2}$]

g≡ Acceleration of gravity. [$\frac{meter}{Second^2}$]

The time need to brake the aircraft:

$$t = \frac{V_{end} - V_{td}}{D} \text{ -- } (4.7)$$

t ≡time. [Second]

4.3 Simulation:

We use the C++ programming language and MATLAB program to write a code to simulate the system, the simulation programmed code will calculate the:

-Distance Between the aircraft touch point and the selected exit.

- The rate of deceleration.

- The force needed to decelerate the aircraft.

The System has a monitor in the aircraft cockpit which displays:

-The aircraft position.

-The aircraft velocity.

-Selection of the exit.

-The deceleration rate.

-Braking force.

-Braking time.

* The C++ programmed code is attached in the appendix.

4.4 Simulation case:

We choose King Fahad International airport in Dammam City (DMM)_KSA as a case to operate our simulation program. We got the DMM airport aerodrome chart saved in the system map data base, the map will appear to the pilot as the figure below:

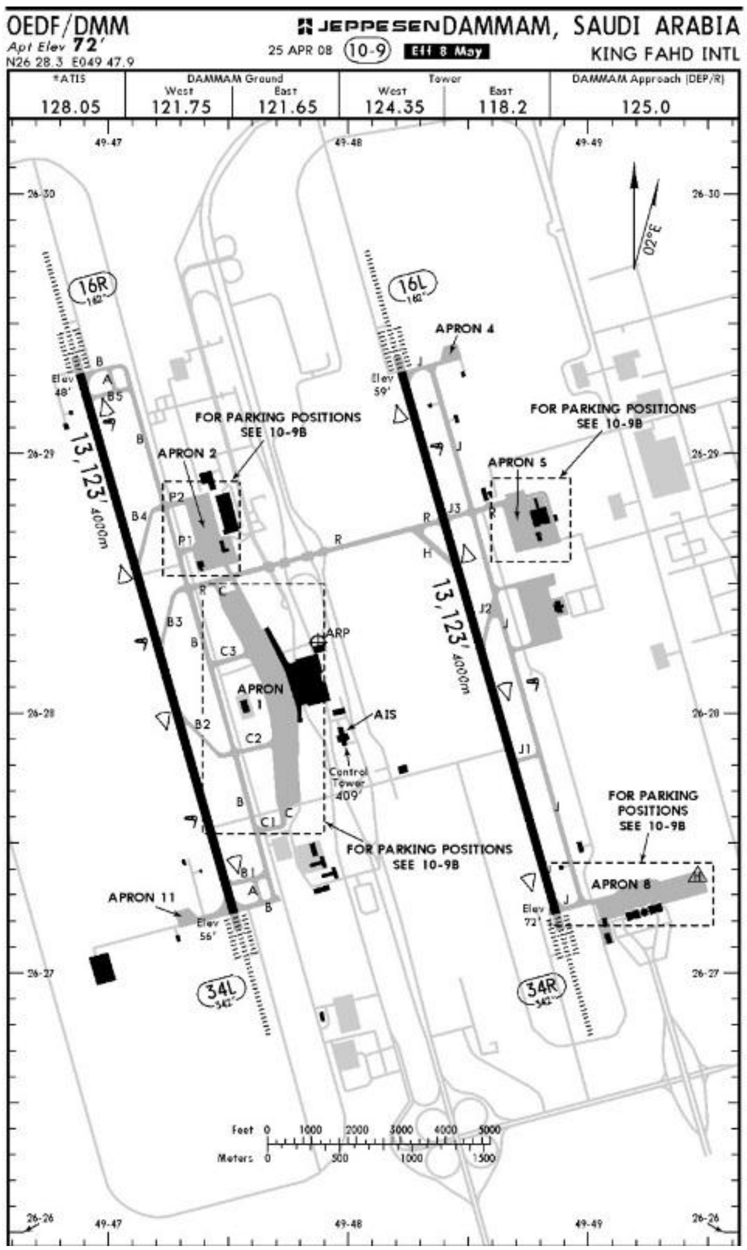


Figure 4.2: dammam airport aerodrom chart

The figure below shows the MATLAB GUI monitor we designed, which will appear to the pilot.

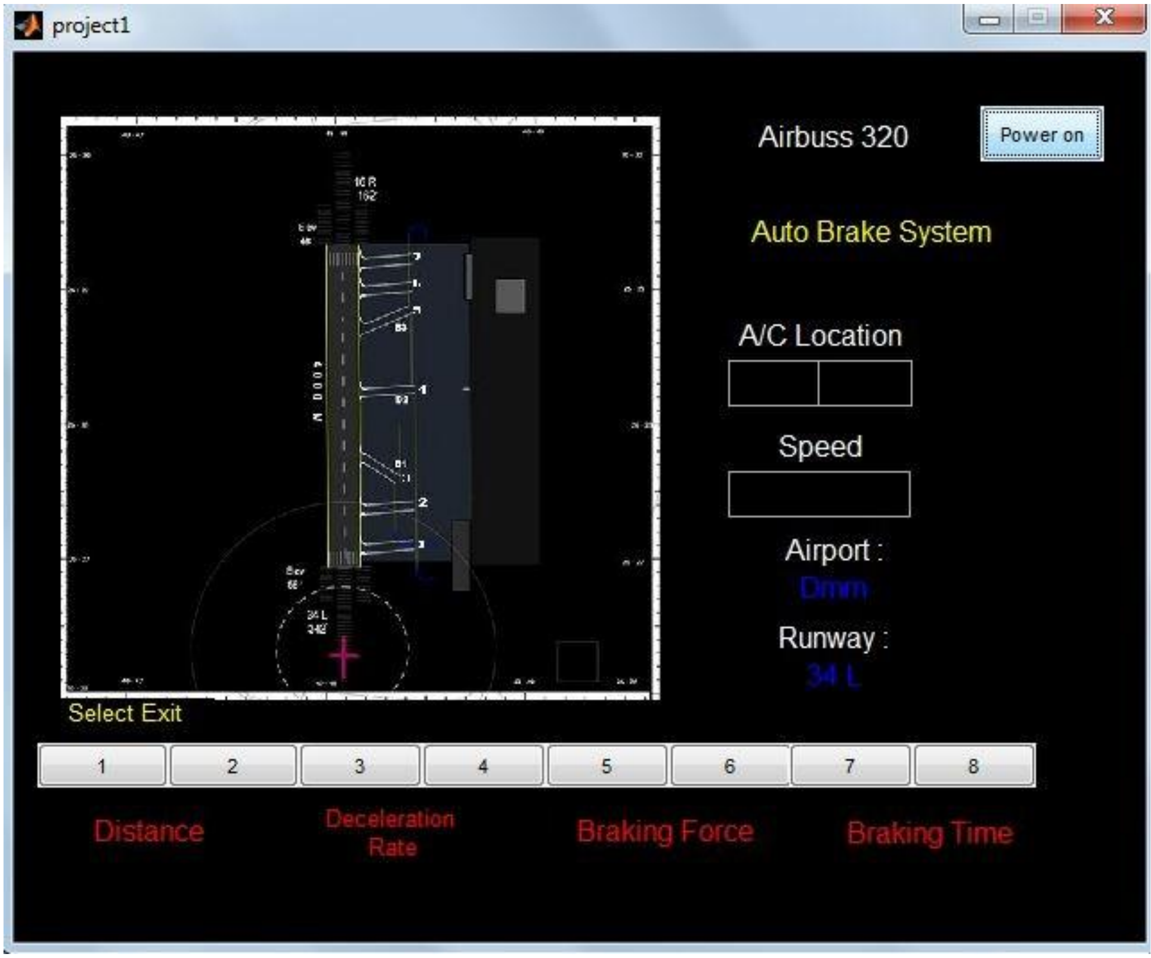


Figure 4.3:monitor screen

In our simulation case in the approach phase the pilot get an oral order to get through a specific exit from these seven exits according to the availability, then the pilot should select the ordered exit from these seven exits buttons appear in the monitor the button number 8 refer to the end of the runway. Then the system will automatically do these calculations:

Aircraft touch point location is:

Longitude: 26.4590055º   Latitude: 49.7905158 º

Selected exit location: for example we select exit number 4

Longitude: 26.4708317 º   Latitude: 49.7868596 º

$$X = (26.4708317\ - 26.4590055) \times \cos\left(\frac{49.7868596 + 49.7905158}{2}\right) \times (\frac{\pi}{180})$$

X= 0.000183293

$$Y = (49.7868596 - 49.7905158)(\frac{\pi}{180})$$

Y=-0.0000637804

Distance Between these two points :

$$S = \left(\sqrt{(0.000183293)^2 + 0.0000637804^2}\right) \times 6371000$$

S = 1236.436643 [meter]

The deceleration rate equal :

$$D = \frac{11^2 - 70^2}{2(S - 10)}$$

D= -1.948327305

The mass of the aircraft at touch point :

$$m = \frac{64000}{9.81}$$

$$m = 6524\ [kg]$$

$$F_{brake}\ = 6524 \times -1.948327305$$

F_{brake} =-12710.88734 [Newton]

The time of braking equal:

$$t = \frac{11-70}{-1.948327305}$$

t=30.28239 [second].

The tables below shows the values of distance, deceleration rate, time to reach the taxi velocity and the force that applied by the autobrake system, All of these tables calculated by using Microsoft Office Excel program. The table below shows results according to maximum design limits of weight and velocities:

Number of exit	V_{td}	x1	y1	x2	y2
1	70	26.4590055	49.7905158	26.4544443	49.7919196
2	70	26.4590055	49.7905158	26.4556428	49.7915525
3	70	26.4590055	49.7905158	26.4664597	49.7882108
4	70	26.4590055	49.7905158	26.4708317	49.7868596
5	70	26.4590055	49.7905158	26.4759677	49.7852768
6	70	26.4590055	49.7905158	26.4867955	49.7819287
7	70	26.4590055	49.7905158	26.4880145	49.7815526
Runway End	70	26.4590055	49.7905158	26.4886212	49.7813668

X	Y	Distance	Deceleration	Brake Force [N]	Time
-7.07856E-05	2.44885E-05	477.1998788	-5.114513314	-33367.08486	11.5358
-5.21811E-05	1.80847E-05	351.8454084	-6.990001742	-45602.77136	8.440627
0.000115572	-4.02094E-05	779.6002429	-3.104858687	-20256.09808	19.00248
0.000183293	-6.37804E-05	1236.436643	-1.948327305	-12710.88734	30.28239
0.000262787	-9.13914E-05	1772.57706	-1.355685408	-8844.4916	43.52042
0.000430164	-0.000149797	2901.989868	-0.826247708	-5390.440047	71.40716
0.000448989	-0.000156358	3028.999862	-0.791487284	-5163.663038	74.54321
0.000458357	-0.000159599	3092.155148	-0.775269214	-5057.856354	76.1026

Table 4.2: Case calculation

The table below shows the effect of using thrust reverser in previous table:

Exit Number	total force	deceleration	Distance with thrust	time with thrust reverser
1	-43377.210	-6.64	369.384	8.873
2	-59283.602	-9.08	272.958	6.492
3	-26332.927	-4.03	602	14.617
4	-16524.153	-2.53	953.412	23.294
5	-11497.839	-1.76	1365.828	33.477
6	-7007.572	-1.07	2234.607	54.928
7	-6712.761	-1.02	2332.307	57.340
Runway end	-6575.213	-1.00	2380.888	58.540

Table 4.3:effect of using thrust reverser

-When the weight change from 64000 kg (maximum landing weight) to 63000kg without thrust reverser:

Number of exit	V_{td}	Distance	Deceleration	Brake Force [N]	Time
1	70	477.199	-5.114	-32845.404	11.535
2	70	351.845	-6.990	-44889.791	8.440
3	70	779.600	-3.104	-19939.402	19.002
4	70	1236.436	-1.948	-12512.157	30.282
5	70	1772.577	-1.355	-8706.211	43.520
6	70	2901.989	-0.826	-5306.162	71.407
7	70	3028.999	-0.791	-5082.931	74.543
Runway End	70	3092.155	-0.775	-4978.778	76.102

Table 4.4: Force result when the weight =63000 kg

The table below shows the effect of using thrust reverser in previous table:

Exit Number	total force	deceleration	Distance with thrust	time with thrust reverser
1	-42699.025	-6.544	375.092	9.014
2	-58356.728	-8.944	277.134	6.595
3	-25921.223	-3.973	611.402	14.849
4	-16265.805	-2.493	968.396	23.664
5	-11318.075	-1.734	1387.362	34.008
6	-6898.011	-1.057	2269.940	55.801
7	-6607.810	-1.012	2369.192	58.251
Runway end	-6472.412	-0.992	2418.545	59.47025105

Table 4.5:effect of using thrust reverser

-When the weight was 62000kg without thrust reverser:

Number of exit	V_{td}	Distance	Deceleration	Brake Force [N]	Time
1	70	477.199	-5.114	-32323.724	11.535
2	70	351.845	-6.990	-44176.811	8.440
3	70	779.600	-3.104	-19622.706	19.002
4	70	1236.436	-1.948	-12313.428	30.282
5	70	1772.577	-1.355	-8567.931	43.520
6	70	2901.989	-0.826	-5221.885	71.407
7	70	3028.999	-0.791	-5002.199	74.543
Runway End	70	3092.155	-0.775	-4899.701	76.102

Table 4.6: Force result when the weight =62000 kg

The table below shows the effect of using thrust reverser in previous table:

Exit Number	total force	deceleration	Distance with thrust	time with thrust reverser
1	-42020.841	-6.440	380.984	9.160
2	-57429.854	-8.802	281.445	6.702
3	-25509.518	-3.910	621.109	15.089
4	-16007.457	-2.453	983.864	24.046
5	-11138.311	-1.707	1409.592	34.557
6	-6788.451	-1.040	2306.414	56.701
7	-6502.859	-0.996	2407.268	59.191
Runway end	-6369.611	-0.976	2457.417	60.430

Table 4.7:effect of using thrust reverser

When the weight was 61000kg without thrust reverser:

Number of exit	V_{td}	Distance	Deceleration	Brake Force [N]	Time
1	70	477.199	-5.114	-31791.814	11.535
2	70	351.845	-6.990	-43449.850	8.440
3	70	779.6002	-3.104	-19299.801	19.002
4	70	1236.436	-1.948	-12110.802	30.282
5	70	1772.577	-1.355	-8426.940	43.520
6	70	2901.989	-0.826	-5135.955	71.407
7	70	3028.999	-0.791	-4919.884	74.543
Runway End	70	3092.155	-0.775	-4819.073	76.102

Table 4.8: Force result when the weight =61000 kg

The table below shows the effect of using thrust reverser in previous table:

Exit Number	total force	deceleration	Distance with thrust	time with thrust reverser
1	-41329.359	-6.334	387.191	9.313
2	-56484.806	-8.658	285.987	6.814
3	-25089.742	-3.845	631.333	15.341
4	-15744.043	-2.413	1000.158	24.448
5	-10955.022	-1.679	1433.009	35.136
6	-6676.742	-1.023	2344.835	57.650
7	-6395.850	-0.980	2447.376	60.182
Runway end	-6264.795	-0.960	2498.365	61.441

Table 4.9:effect of using thrust reverser

When the weight was 60000kg without thrust reverser:

Number of exit	V_{td}	Distance	Deceleration	Brake Force [N]	Time
1	70	477.1998788	-5.114513314	-31280.36343	11.5358
2	70	351.8454084	-6.990001742	-42750.85065	8.440627
3	70	779.6002429	-3.104858687	-18989.31573	19.00248
4	70	1236.436643	-1.948327305	-11915.9698	30.28239
5	70	1772.57706	-1.355685408	-8291.371954	43.52042
6	70	2901.989868	-0.826247708	-5053.330982	71.40716
7	70	3028.999862	-0.791487284	-4840.736226	74.54321
Runway End	70	3092.155148	-0.775269214	-4741.546515	76.1026

Table 4.10: Force result when the weight =60000 kg

The table below shows the effect of using thrust reverser in previous table:

Exit Number	total force	deceleration	Distance with thrust	time with thrust reverser
1	-40664.47246	-6.233058317	393.3591599	9.465658269
2	-55576.10585	-8.518716408	290.5000056	6.925926064
3	-24686.11045	-3.783891853	641.4926781	15.59241181
4	-15490.76074	-2.374426845	1016.348123	24.84810181
5	-10778.78354	-1.652174056	1456.276191	35.710
6	-6569.330277	-1.006948234	2383.01176	58.592
7	-6292.957094	-0.964585698	2487.229348	61.166
Runway end	-6164.01047	-0.944820734	2539.051188	62.445

Table 4.11: effect of using thrust reverser

After calculations of: deceleration, force and time they will appear in the monitor screen, the value of force will be applied to the brake system after touchdown.

Chapter 5: Results & Discussion

The results we got after doing the calculations by programs mentioned before were a positive results. The output results were:

- Deceleration rate for an aircraft with maximum landing weight.

The figure below shows the relation between the selected exit and the deceleration rate for every exit.

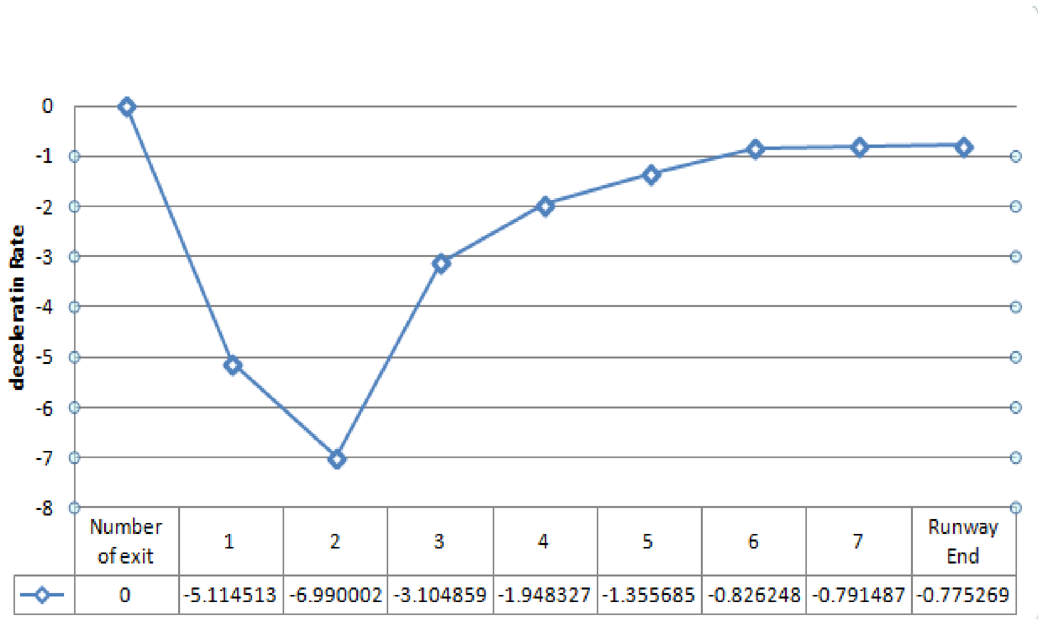


Figure 5.1:Deceleration rate with number of exit

- Brake force that aircraft needs to be decelerated:

the figure below shows the force needed to be applied according to the selected exit.

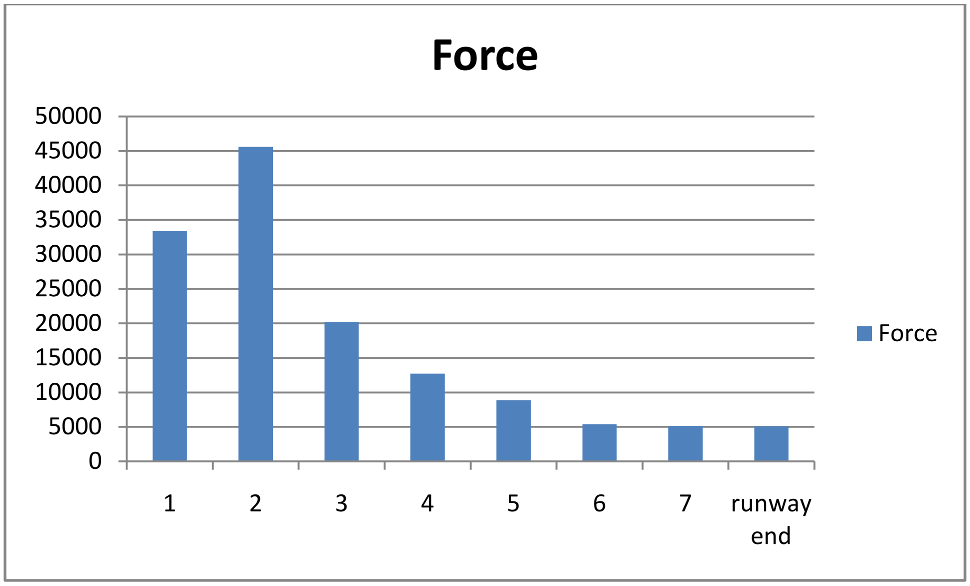


Figure 5.2 : Relation between force and number of exit

- Time of braking that aircraft taken to reach the selected exit :

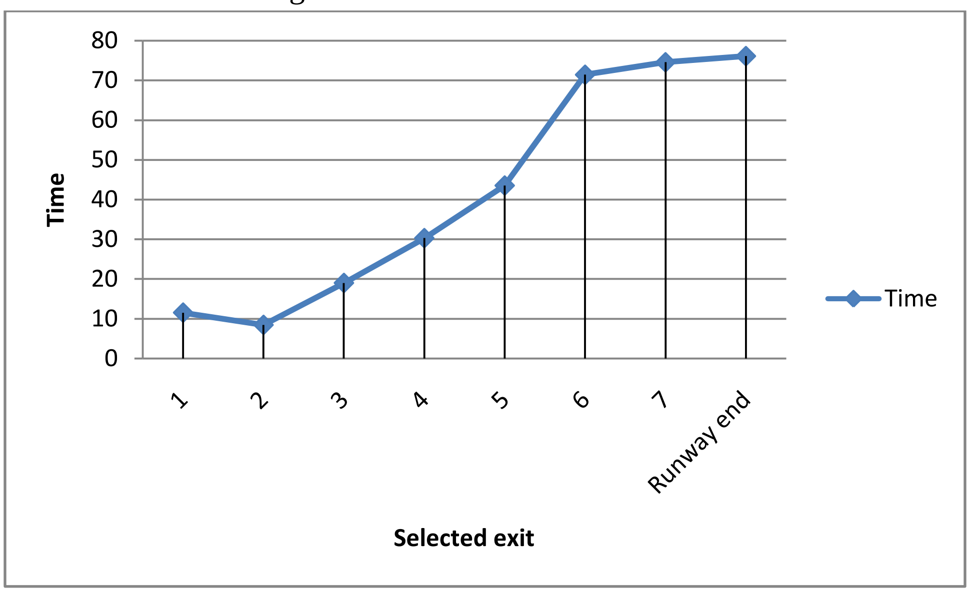


Figure 5.3: Time to get selected exit

The effect of changing weight on the value of braking force:

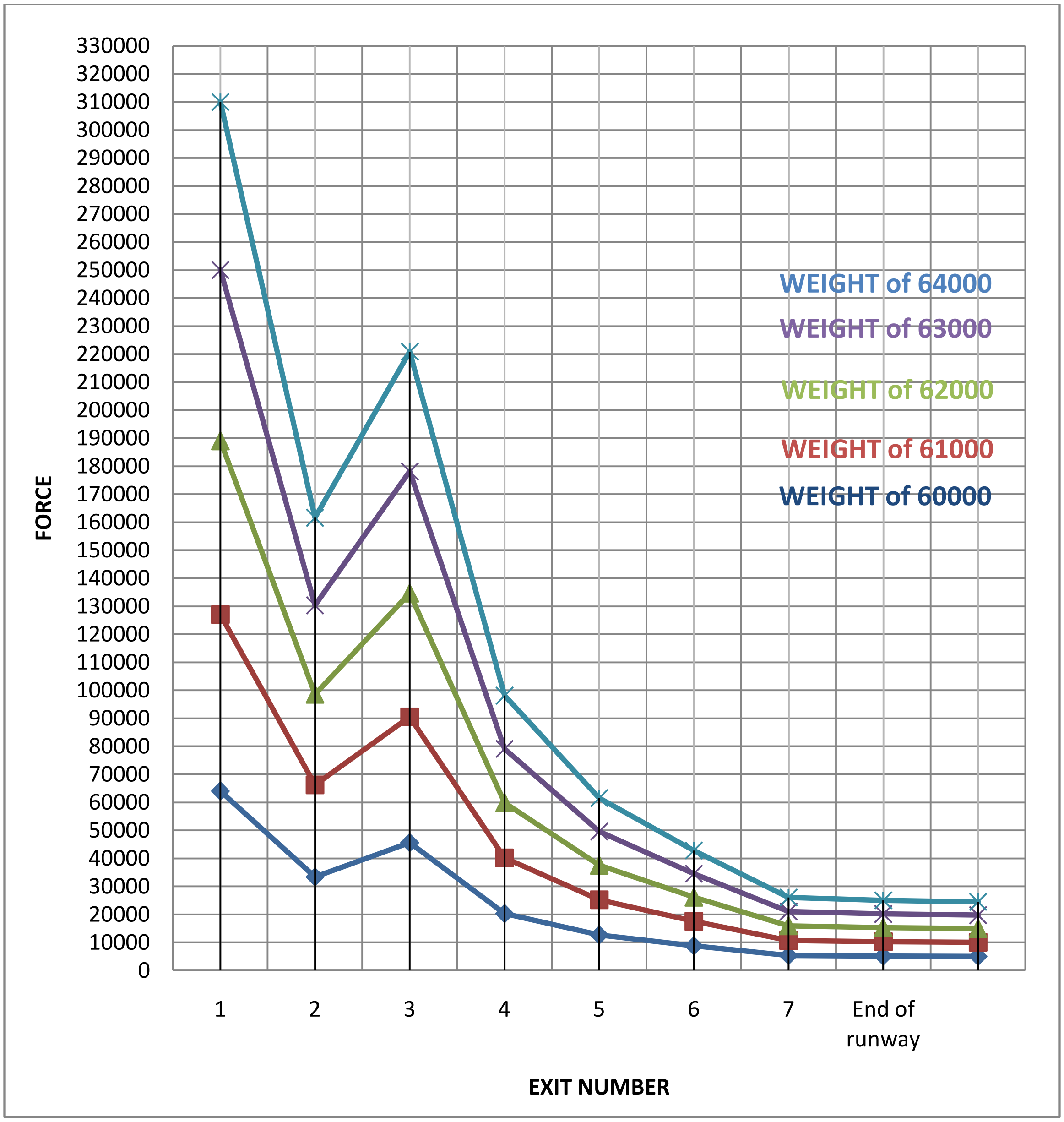


Figure 5.4: Effect of weight on the braking apply force

From the results before, the value of the force is the brake force only and brake force with thrust reverser. If the selected exit remaining distance from touch point need an excessive force than the design condition of braking force, or the pilot landed farther than the touch point so additional force to stop the aircraft is needed. This additional force is the thrust reversal force and when applied it has been added to the brake force.

When using the thrust reversal the thrust reversal force is equal to 30 % of the total force, hence the total force equals to:

$$F_{total} = F_{brake} + F_{thrust}$$

So in previous results take an example the force to stop the aircraft with maximum weight in exit number 4

Brake force needed = 12710.88734 N.

The thust reverser take 30% of the Total force so, if we want to minimize the force of braking or to get additional force we can use thrust reverser that geven 30% of the braking force so :

F_{thrust} = 12710.88734*30%

F_{thrust} = 3813.266202

$$F_{total} = 12710.88734 + 3813.266202$$

$$F_{total} = 16524.153 \text{ [Newton]}$$

If the brake force is enough and the runway condition is suitable there is no need to use thrust reverser.

If the total force isn’t enough to stop the aircraft in the selected exit the pilot should be informed to select another exit, if all exits are not available then he should use manual braking to stop the aircraft manually before the end of the runway.

In the case of emergency if the pilot selected an exit and there was no possibility to stop the aircraft in it or in any another exit or before the end of the runway, the system indicates the pilot that the braking operation isn’t possible. The pilot has to decide either to use the emergency brake to stop the aircraft within the end of the runway, or to over shoot.

Chapter 6: Conclusion & recommendation

During our research we found that the airbus manufacturers are developing a system named BTV (Brake To Vacate) joined with another system named OANS (On board Air Navigation System) which will be available on the A380 .The OANS analysis the airport map and the BTV allows pilots to select the appropriate runway exit during descent or approach preparation. The Airbus-patented innovative system uses the GPS (Global Positioning System), Airport Navigation, Auto-Flight and Auto-Brake Systems to regulate deceleration, enabling the aircraft to reach any chosen exit at the correct speed in optimum conditions.. Then we continued our research to design a system in our case study A320 to meet our objectives by our own procedure.[5]

Figure 6.1:BTV Screen

BTV system is coupled to a Runway Overrun Prevention system, also called ROW/ROP.

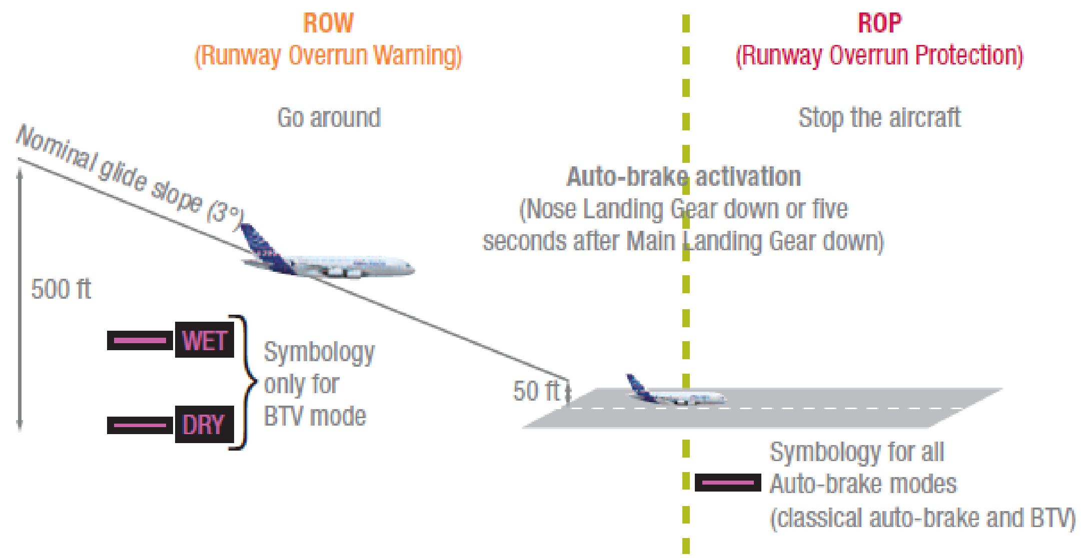


Figure 6.2: BTV landing operation

The developed fully automated autobrake System meet the requirements and all objectives. It will achieve a safety level, give pilot time and options and achieve fuel economy level.

We recommend ourselves and other researchers to continue improving this system. The system should be refined, design and implement. Manufactures should think to retrofit this system in the current aircrafts.

Appendix:

C++ code :

```
#include <iostream>
#include <cmath>
using namespace std;
const double pi = 3.142;
const char newline = '\n';
float ve=0 ;
float vt , a  ,ft , m ,t,n ;
float w= 64000,r=6371000 ;
float g=9.817;
int main ()
{
  double s;
long double x1=0.0000000,x2=0.0000000,y1=0.00000000,y2=0.000000000,x,y;
 cout << "Please enter Touch down velocity  m/s  :";
 cin >> vt;
  cout << newline;
   cout << newline;
     cout << "Please enter the number of your exit :";
              cout << newline;
   cout << newline;
        cin >> n;
   if (n==1)
   {x2=26.4544443;
   y2=49.7919196;
   }
   if (n==2)
   {x2=26.4556428;
   y2=49.7915525;
   }
   if (n==3)
   {x2=26.4664597;
   y2=49.7882108;
   }
   if (n==4)
   {x2=26.4708317;
   y2=49.7868596;
   }
```

```
  if (n==5)
  {x2=26.4759677;
  y2=49.7852768;
  }
   if(n==6)
  {x2=26.4867955;
  y2=49.7819287;
  }
  if(n==7)
  {x2=26.4880145;
  y2=49.7815526;
}
  if(n==8)
  {x2=26.4886212;
  y2=49.7813668;
}
cout << " exit location = (" << x2 << "," << y2 << ")";
 cout << newline;
 cout <<"enter aircraft location : X1 then Y1 :";
 cout << newline;
  cin >> x1;
   cin >> y1;
 cout << newline;
 cout << " aircraft location is (" << x1 << "," << y1 << ")";
 x =(x2-x1)*cos((y2+y1)/2)*(pi/180) ;
cout << newline;
 y =(y2-y1)*(pi/180);
cout << newline;
  s =(sqrt((x*x)+(y*y)))*r;
 cout <<"distance s  = "<<s;

  cout << newline;
   cout << newline;
  a = ( (ve*ve) - (vt*vt) ) / (2 *( s-10));
  m = w/g;
  ft=m*a ;
   t= (ve-vt)/a ;
  cout << " deceleration  a =" << a << " m/s" ;
   cout << newline;
  cout << newline;
  cout << " the time needs to stop the aircraft is :" << t<< "s" ;
  cout << newline;
  cout << newline;
```

```
 cout << " The total force Ft = " << ft<< "N" ;
  cout << newline;
return 0;}
```

C++ Code output:

```
Please enter Touch down velocity  m/s   :70


Please enter the number of your exit :

4
 exit location = (26.4708,49.7869)
enter aircraft location : X1 then Y1 :
26.4590055
49.7905158

 aircraft location is (26.459,49.7905)

distance s   = 1237.22

 deceleration  a =-1.99638 m/s

 the time needs to stop the aircraft is :35.0635s

 The total force Ft = -13015N

--------------------------------
Process exited after 57.57 seconds with return value 0
Press any key to continue . . .
```

References:

[1] f. a. administration, *Aviation Maintenance Technician Handbook-Airframe* vol. Volume 2.

[2] S. Vats, "Preliminary Study of Aircraft Braking System with Emphasis on Fail-safe Technology," B.Tech Student, Department of Aerospace Engineering, University of Petroleum & Energy Studies, India, 2013.

[3] SKYbrary. (2014). *Hydraulic Systems*.

[4] A. S.A.S, *A320 AIRCRAFT MAINTENANCE MANUAL*. France: Airbus customer service, 2002.

[5] F. VILLAUME. (2009) Brake-to-Vacate system. *FAST 44*. 36.