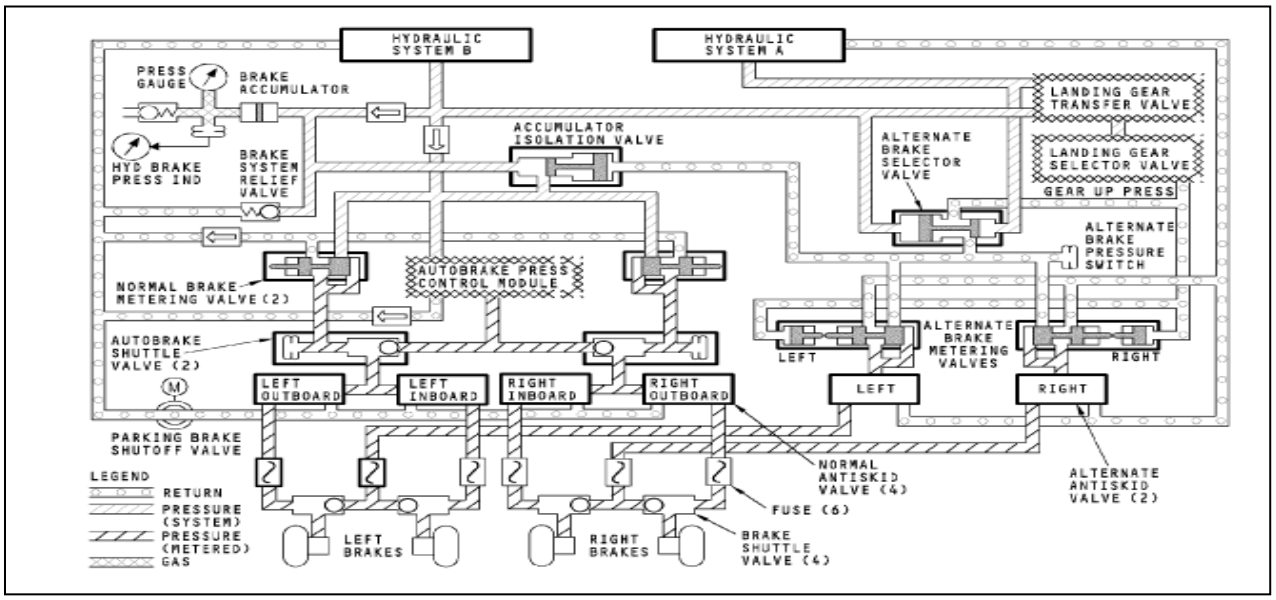
BRAKING CONSIDERATIONS

Ludo's Brief

- **How it works:** Each main gear wheel has a multi–disc hydraulic powered brake. The brake pedals provide independent control of the left and right brakes. The nose wheels have no brakes.



The brake system includes:

- **normal brake system**
  [powered by hydraulic system B]
- **alternate brake system**
  [automatically powered by hydraulic system A if hydraulic system B is too low or fails]
- **brake accumulator**
  [pressurized by hydraulic system B. If both normal and alternate brake system pressure is lost, trapped hydraulic pressure in the brake accumulator can still provide several braking applications or parking brake application].
- **antiskid protection**
  [provided in the normal and alternate brake systems. Both normal and alternate brake systems provide skid, locked wheel, touchdown and hydroplane protection. Antiskid protection is available even with loss of both hydraulic systems].
- **autobrake**
  [Uses hydraulic system B pressure to provide maximum deceleration for rejected takeoff and automatic braking at preselected deceleration rates immediately after touchdown. Autobrake operates only when the normal brake system is functioning. Antiskid system protection is provided during autobrake operation].
- **normal brake system**
  [can be set with either A or B hydraulic systems pressurized. If A and B hydraulic systems are not pressurized, parking brake pressure is maintained by the brake accumulator. Accumulator pressure is shown on the HYD BRAKE PRESS indicator. A fault in the parking brake system may cause the ANTISKID INOP light to illuminate].

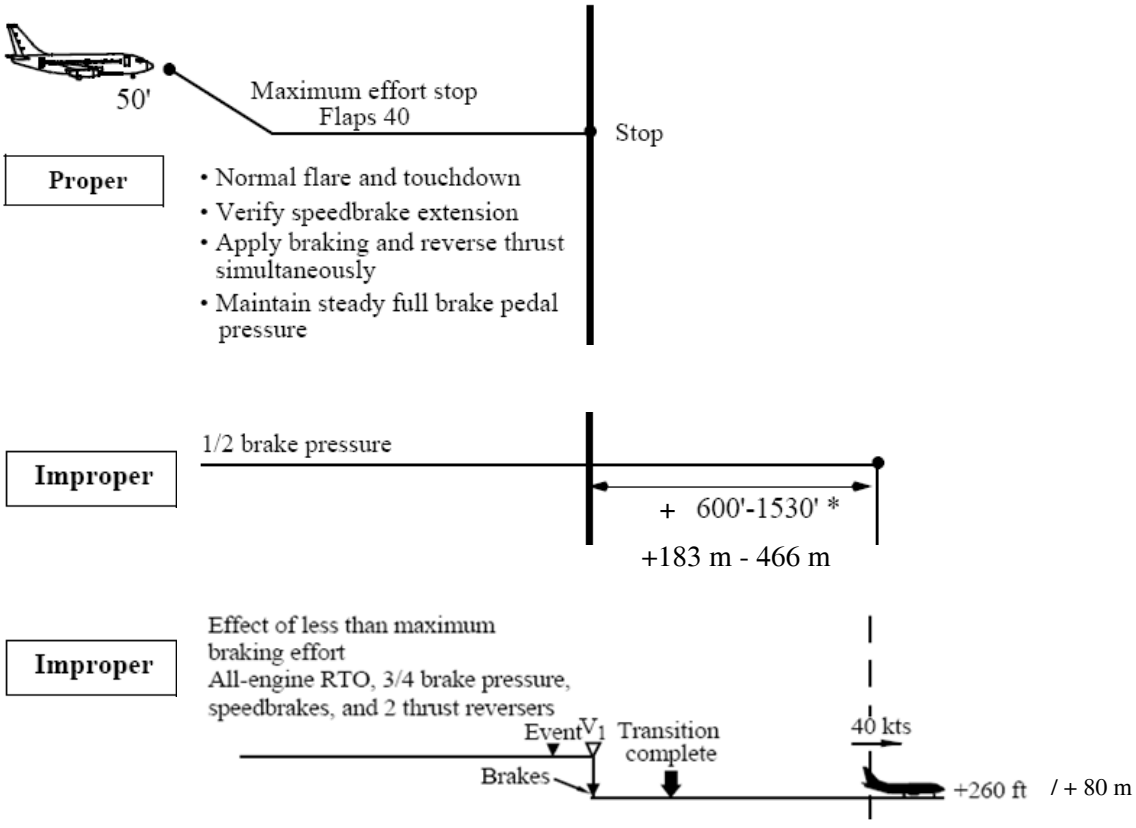
- The red PARKING BRAKE ON light will not illuminate until the battery switch is turned on. The brakes pressure gauge is inoperative until AC power is applied.

- Official stopping distance includes the distance traveled while initiating the stop and is based on the measured stopping capability as demonstrated during certification flight test. During certification, maximum manual braking and speedbrakes are used.

- Braking force is proportional to the force of the tires on the runway and the coefficient of friction between the tires and the runway. The contact area normally changes little during the braking cycle. The perpendicular force comes from airplane weight and any downward aerodynamic force such as speedbrakes.The coefficient of friction depends on the tire condition and runway surface, (e.g. concrete, asphalt, dry, wet or icy).

- Correct Braking process (automatic or manual) is a top priority during rejected takeoff and should be executed with the maximum of accuracy, according to your operator's procedures.

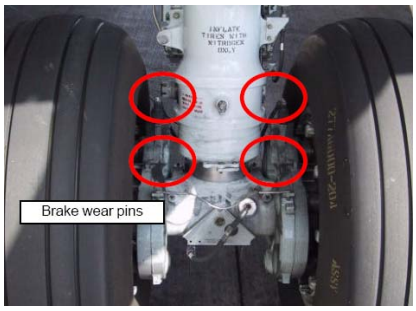
- A proper braking use landing sequence should always be realized:



*__Note:__ *Landing distance varies with runway condition, wet or dry. Data excludes contaminated runway considerations.*

DOs !

- The pilot's seat and rudder pedals should be adjusted so that it is possible to apply maximum braking with full rudder deflection.



- During walkaround, check Brake Wear Indicators for length remaining.

  If pin is recessed or flush with brake flange with brakes set, check with Maintenance staff.

- One firm brake application causes less wear than several light applications. During taxi, apply steady braking to decelerate the airplane, release brakes as lower speed is achieved. After the airplane accelerates, repeat the braking sequence. Allow for decreased braking effectiveness on slick surfaces.

- With antiskid inoperative, tire damage or blowouts can occur if moderate to heavy braking is used. With this condition, it is recommended that taxi speed be adjusted to allow for very light braking.

- During 180° turns light intermittent braking on the inside main gear helps decrease turn radius. Stopping the airplane in a turn is not recommended unless required to reduce the turn radius. This technique results in a low speed turn and less runway being used. It does not impose undue stress on the landing gear and tires provided the wheel brakes are not locked during the turn. If the nose gear skids, a good technique is to apply the inside wheel brake briefly and keep the airplane turning with asymmetric thrust as needed. If the turnaround is planned on a surface significantly greater in width than the minimum required, a turn entry could be made, without stopping, at 5-10 knots speed, using intermittent inside wheel braking and thrust as needed. Wind, slope, runway or taxiway surface conditions, and center of gravity may also affect the turning radius.

- When taxiing on a slippery or contaminated surface, particularly with strong crosswinds, differential braking may be more effective than nose wheel steering on slippery or contaminated surfaces. If speed is excessive, reduce speed prior to initiating a turn.

- When landing on slippery runways contaminated with ice, snow, slush or standing water, the reported braking action must be considered. Advisory information for reported braking actions of good, medium and poor is contained in the PI section of the Boeing QRH. The performance level associated with good is representative of a wet runway. The performance level associated with poor is representative of a wet ice covered runway. Also provided in the QRH are stopping distances for the various autobrake settings and for non-normal configurations.

  Note: *Crews should use extreme caution to ensure adequate runway length is available when poor braking action is reported.*

- During landing, always check speedbrakes are raised after touchdown, braking effectiveness may be reduced initially as much as 60%, since very little weight is on the wheels and brake application may cause rapid antiskid modulation.

  Note: *For landing, some operators use a special call-out for speedbrake extension or non-extension (called generally by the PNF) like* ***"SPEEDBRAKE UP"*** *(or* ***"SPEEDBRAKE NOT UP"*** *in case of malfunction at touchdown)*

- During hot weather operations brake temperature levels may be reached which can cause the wheel fuse plugs to melt and deflate the tires. Consider the following actions:
  - Be aware of brake temperature buildup when operating a series of short flight sectors. The energy absorbed by the brakes from each landing is accumulative
  - Extending the landing gear early during the approach provides additional cooling for tires and brakes.
  - In–flight cooling time can be determined from the "Brake Cooling Schedule" in the Performance–Inflight section of the Boeing QRH.

- When Securing for Overnight (or parking for an extended Period with aircraft unattended), release parking brake to eliminate possibility of brakes freezing.

MANUAL BRAKING ON LANDING

- When using manual brakes, apply wheel brakes smoothly with steadily increasing pedal pressure as required for runway condition and runway length available. Maintain deceleration rate with constant or increasing brake pressure as required until stopped or desired taxi speed is reached.

- Immediately after main gear touchdown, smoothly apply a constant brake pedal pressure for the desired braking. For short or slippery runways, use full brake pedal pressure.
  - do not attempt to modulate, pump or improve the braking by any other special techniques
  - do not release the brake pedal pressure until the airplane speed has been reduced to a safe taxi speed
  - the antiskid system stops the airplane for all runway conditions in a shorter distance than is possible with either antiskid off or brake pedal modulation.

AUTOBRAKES ON LANDING

- Boeing recommends that whenever runway limited, using higher than normal approach speeds, landing on slippery runways or landing in a crosswind, the autobrake system be used.

- The use of autobrakes is recommended in many non normal situations because maximum autobraking may be more effective than maximum manual braking due to timely application upon touchdown and symmetrical braking. However, the Advisory Information in the PI chapter of the Boeing QRH provides Non-normal Configuration Landing Distance data based upon the use of maximum manual braking. When used properly, maximum manual braking provides the shortest stopping distance

- For normal operation of the autobrake system select a deceleration setting.
  Settings include:
  - MAX: Used when minimum stopping distance is required. Deceleration rate is less than that produced by full manual braking
  - 2 or 3: Should be used for wet or slippery runways or when landing rollout distance is limited
  - 1: This setting provides a moderate deceleration suitable for all routine operations

  Experience with various runway conditions and the related airplane handling characteristics provide initial guidance for the level of deceleration to be selected.

Immediate initiation of reverse thrust at main gear touchdown and full reverse thrust allow the autobrake system to reduce brake pressure to the minimum level. Since the autobrake system senses deceleration and modulates brake pressure accordingly, the proper application of reverse thrust results in reduced braking for a large portion of the landing roll.

Note: *Check your SOPs for the correct use of the autobrake system.*

- The speed at which the transition from autobrakes to manual braking is made depends on airplane deceleration rate, runway conditions and stopping requirements. Normally the speedbrakes remain deployed until taxi speed, but may be stowed earlier if stopping distance within the remaining runway is assured.
  When transitioning to manual braking, use reverse thrust as required until taxi speed. The use of speedbrakes and reverse thrust is especially important when nearing the end of the runway where rubber deposits affect stopping ability. When transitioning from the autobrake system to manual braking, the PF should notify the PM. Techniques for release of autobrakes can affect passenger comfort and stopping distance.

  These techniques are:
  - stow the speedbrake handle. When stopping distance within the remaining runway is assured, this method provides a smooth transition to manual braking, is effective before or after thrust reversers are stowed, and is less dependent on manual braking technique
  - smoothly apply brake pedal force as in a normal stop, until the autobrake system disarms. Following disarming of the autobrakes, smoothly release brake pedal pressure. Disarming the autobrakes before coming out of reverse thrust provides a smooth transition to manual braking

  Note: *Although the autobrake system can be disarmed by placing the Auto Brake Select Switch in the "OFF" position, Boeing recommends the use of manual braking to disarm the autobrake system. Flight crews may also disarm the autobrakes by moving the SPEED BRAKE lever to the down detent if speed brakes are not further required to assist stopping. Check your SOPs for the correct use of the autobrake system.*

BRAKING USE FOR NON NORMAL SITUATIONS	
SITUATION	**ACTIONS**
Nose wheel steering INOP	- If any crosswind exists, consideration should be given to landing on a runway where braking action is reported as good or better. - Braking action becomes the primary means of directional control below approximately 60 knots where the rudder becomes less effective. If controllability is satisfactory, taxi clear of the runway using differential thrust and brakes.
Flat Tire	Generally use differential braking as needed for directional control. - **Flat nose wheel tire:** slowly and gently lower the nose wheels to the runway while braking lightly. Autobrakes may be used at the lower settings - **Flat main gear tire(s)** cause a general loss of braking effectiveness and a yawing moment toward the flat tire with light or no braking and a yawing moment away from the flat tire if the brakes are applied harder. Maximum use of reverse thrust is recommended. No autobrakes! - If uncertain whether a nose tire or a main tire has failed, slowly and gently lower the nose wheels to the runway and do not use autobrakes. Differential braking may be required to steer the airplane.
Partial Gear Up Landing	- **One Main Gear Extended and Nose Gear Extended:** after all gear, or the engine nacelle where the gear is not extended, have made contact with the runway, braking on the side opposite the unsupported wing should be used as needed to keep the airplane rolling straight. - **One Main Gear Only Extended:** After all gear, or the nose or the engine nacelle in the case of gear that do not extend, have made contact with the runway, braking on the side opposite the unsupported wing should be used as needed to keep the airplane rolling straight.
Antiskid INOP	- Boeing QRH requests the AUTOBRAKE to be selected OFF - Ensure that the nose wheels are on the ground and the speedbrakes are extended before applying the brakes - Initiate wheel braking using very light pedal pressure and increase pressure as ground speed decreases - Brake with caution apply steady pressure and do not pump! ***Note:*** *Flight testing has demonstrated that braking effectiveness on a wet grooved runway is similar to that of a dry runway. However caution must be exercised when braking on any wet, ungrooved portions of the runway with antiskid inoperative to avoid tire failure.*
Landing Gear Lever Not Moving UP After Takeoff	If the landing gear lever will not move up after takeoff due to a failure of the air/ground sensor, the autobrakes will be inoperative.
Loss of HYD System B	Alternate brakes are available (using system A): no autobrakes, reduced anti-skid operation, no touchdown and locked wheel protection.
Loss of HYD System A	Alternate brakes are inoperative.
Manual Reversion	Inboard and outboard brakes have accumulator pressure only: on touchdown apply steady moderate braking: do not pump!
Landing on Standby Power	Partial anti-skid and autobrakes inoperative.

BRAKING USE FOR NON NORMAL SITUATIONS [continued]	
SITUATION	**ACTIONS**
Brake pressure indicator Zero PSI	This indicates the nitrogen precharge in the brake accumulator has leaked out, and accumulator braking is not available. With hydraulic systems indications normal, brake operation is unaffected. There is no leak on the hydraulic side of the brakes.
Overweight Landing	Autobrake stopping distance guidance is contained in the Performance Inflight section of the Boeing QRH. If adequate stopping distance is available based upon approach speed, runway conditions, and runway length, the recommended autobrake setting should be used.
Jammed or Restricted Flight Controls	Asymmetrical braking and asymmetrical thrust reverser deployment may aid directional control on the runway.
Flaps UP Landing **Leading Edge / Trailing Edge Device Malfunctions**	- Use of autobrakes is recommended. Autobrake setting should be consistent with runway length. - Use manual braking if deceleration is not suitable for the desired stopping distance.
Airspeed Unreliable	Use autobraking if available. If manual braking is used, maintain adequate brake pedal pressure until a safe stop is assured.

BRAKING COOLING

- A series of taxi-back or stop and go landings without additional in-flight brake cooling can cause excessive brake temperatures. The energy absorbed by the brakes from each landing is cumulative. Extending the gear a few minutes early in the approach normally provides sufficient cooling for a landing. Total in-flight cooling time can be determined from the Performance Inflight section of the Boeing QRH.

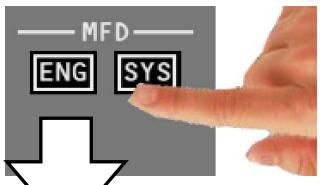
- Close adherence to recommended landing roll procedures ensures minimum brake temperature build up.

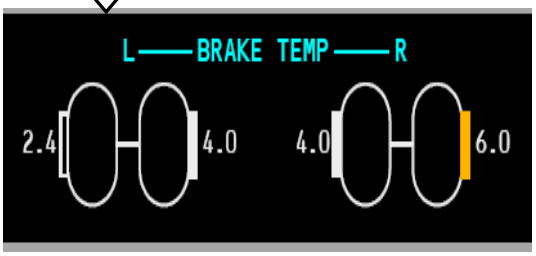
- The optional brake temperature monitoring system may be used for additional flight crew guidance in assessing brake energy absorption. This system indicates a stabilized value approximately 15 minutes after brake energy absorption. Therefore, an immediate or reliable indication of tire or hydraulic fluid fire, wheel bearing problems, or wheel fracture is not available.

  The brake temperature monitor readings may vary between brakes during normal braking operations.

  Note: *Brake energy data provided in the QRH should be used to identify potential overheat situations.*

 **RIGHT FWD PANEL**	Illuminated (amber) - Temperature of one or more brakes is excessive. Extinguishes when a hot brake condition is no longer indicated on the display unit.

	MFD System (SYS) When the switch is pushed, it displays brake temperature indications on lower DU; or if the lower DU is unavailable, displays it on upper DU or inboard DU based on the position of the display select panel selector Second push blanks lower DU.

 **LOWER DISPLAY UNIT**	Brake Temperature indicates a relative value of wheel brake temperature values range from 0.0 to 9.9 - Displayed (white): normal brake temp. [range from 0.0 to 4.9] - Displayed (amber) - high brake temp [> 4.9] - Blank Brake symbol indicates any brake less than 2.5. - Solid white indicates the hottest brake on each main gear truck, within the range of 2.5 to 4.9. - Solid amber indicates brake overheat condition on each wheel within the range of 5.0 to 9.9. Symbol remains until value is less than 3.5.

MINIMUM BRAKE HEATING

- Consider using the following technique if landing overweight or other factors exist that may lead to excessive brake temperatures. A normal landing, at weights up to maximum landing weight, does not require special landing techniques.

  Note: *Autolands are not recommended by Boeing for overweight landings.*

- To minimize brake temperature build-up, use the following landing techniques:
  - select the longest runway available but avoid landing downwind.
  - use the largest available landing flap setting.
  - use an autobrake setting, consistent with reported runway conditions, that will result in the use of all available runway length. A stopping distance safety margin should be used in accordance with airline policy.
  - ensure all of the headwind correction is bled off prior to touchdown to avoid landing with excessive airspeed.
  - use a normal gear touchdown aim point (NO FLOATING!)
  - ensure the spoilers deploy immediately after touchdown
  - select maximum reverse thrust as soon as possible after main gear touchdown. Do not wait for nose gear touchdown
  - as soon as stopping is assured in the remaining runway, turn the autobrakes off and continue slowing the airplane with reverse thrust
  - if stopping in the remaining runway is in doubt, continue use of autobrakes or take over manually and apply up to maximum braking as needed
  - for airplanes without operative brake temperature monitoring systems: If the last ground time plus present flight time is less than 90 minutes, extend the landing gear 5 minutes early or 7 minutes prior to landing
  - for airplanes with operating brake temperature monitoring systems, extend the landing gear approximately 1 minute early for each unit of brake temperature above normal.

- During stop, internal friction of the rotors and stators of the brakes cause brake heating. The temperature rise in the brakes will dissipate throughout the wheel.The Quick Turnaround Requirement is a requirement which addresses the increase of temperature in the wheels.

- Brake cooling chart provides recommended cooling times to decrease the residual brake energy to a level low enough to avoid tire deflation on subsequent landings. Times do not ensure that brakes will be cool enough to absorb the energy resulting from a high energy RTO. It has to be used after landing in non normal configuration or after a RTO.

  Advisory information is provided to assist in avoiding the problems associated with hot brakes. For normal operation, most landings are at weights below the AFM quick turnaround limit weight. Use of the recommended cooling schedule will help avoid brake overheat and fuse plug problems that could result from repeated landings at short time intervals or a rejected takeoff.

  1. Enter the Recommended Brake Cooling Schedule table with the airplane weight and brakes on speed, adjusted for wind at the appropriate temperature and altitude condition. Instructions for applying wind adjustments are included below the table. Linear interpolation may be used to obtain intermediate values. The resulting number is the reference brake energy per brake in millions of foot-pounds, and represents the amount of energy absorbed by each brake during a rejected takeoff.

     Notes: *providing adjustments for wind are included below the table.*

  2. To determine the energy per brake absorbed during landing, enter the appropriate Adjusted Brake Energy Per Brake table (No Reverse Thrust or 2 Engine Reverse) with the reference brake energy per brake and the type of braking used during landing (Max Manual, Max Auto, or Autobrake).The resulting number is the adjusted brake energy per brake and represents the energy absorbed in each brake during the landing.

  3. The recommended cooling time is found in the final table by entering with the adjusted brake energy per brake. Times are provided for ground cooling and inflight gear down cooling.

     [Option] Brake Temperature Monitor System (BTMS) indications are also shown. If brake cooling is determined from the BTMS, use the hottest brake indication 10 to 15 minutes after the airplane has come to a complete stop, or inflight with gear retracted to determine recommended cooling schedule.

DON'Ts !

- Do not use airplane brakes to stop the airplane during pushback or towing. This can damage the nose gear or the tow bar.

- Brakes are not normally held with thrust above idle unless a static run-upin icing conditions is required.

- On landing, do not attempt to hold the nose wheels off the runway. Holding the nose up after touchdown for aerodynamic braking is not an effective braking technique and may result in high nose gear sink rates upon brake application.

  Note: *Speedbrakes fully deployed, in conjunction with maximum reverse thrust and maximum manual antiskid braking provides the minimum stopping distance.*

- Avoid prolonged brake application to control taxi speed as this causes high brake temperatures and increased wear of brakes. If taxi speed is too high, reduce speed with a steady brake application and then release the brakes to allow them to cool.

  Braking to approximately 10 knots and subsequent release of the brakes results in less heat build-up in the tires and brakes than when the brakes are constantly applied. Under normal conditions, differential braking and braking while turning should be avoided.

- During low fuel conditions, heavy braking should be avoided [runway conditions permitting] to prevent uncovering all fuel pumps and possible engine flameout during landing roll.

MANUAL BRAKING ON LANDING

- Do not attempt to modulate, pump or improve the braking by any other special techniques.

  Note: *The antiskid system adapts pilot applied brake pressure to runway conditions by sensing an impending skid condition and adjusting the brake pressure to each individual wheel for maximum braking. When brakes are applied on a slippery runway, several skid cycles occur before the antiskid system establishes the right amount of brake pressure for the most effective braking.*

  If the pilot modulates the brake pedals, the antiskid system is forced to readjust the brake pressure to establish optimum braking. During this readjustment time, braking efficiency is lost.

  Low available braking coefficient of friction on extremely slippery runways at high speeds may be interpreted as a total antiskid failure. Pumping the brakes degrades braking effectiveness. Maintain steadily increasing brake pressure, allowing the antiskid system to function at its optimum.
  Although immediate braking is desired, manual braking techniques normally involve a four to five second delay between main gear touchdown and brake pedal application even when actual conditions reflect the need for a more rapid initiation of braking. This delayed braking can result in the loss of 800 to 1,000 feet of runway. Directional control requirements for crosswind conditions and low visibility may further increase the delays. Distractions arising from a malfunctioning reverser system can also result in delayed manual braking application.

- Do not release the brake pedal pressure until the airplane speed has been reduced to a safe taxi speed