DUKEPILOT™ • HOFFMAN AVIATION, INC.

Wing FLAPS

B60 Duke flaps, photo by Robert Hoffman

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Blank

Flaps

Introduction

Beech Aircraft Corporation marketed the Duke as a short field utility aircraft throughout its production run. Beech marketing produced sales brochures and videos depicting the aircraft operating from short unpaved strips using the approach flap take-off technique, throughout the production run. The Duke flap system is a semi-fowler design which allows the flap to initially extend aft and down from the wing trailing edge, increasing wing area and lift. As flap travel extends beyond the approach setting, movement is downward, creating more drag than lift. The flaps approach position (APH / 15°) is useful for conducting short or soft / rough field takeoffs. The down position (DN / 30°) allows slow approach speeds and short landing distances.

System Description

The wing flaps consist of one section on each wing driven by a single reversible electric motor and gearbox. Each flap extends from the inboard aileron to the junction of the wing and fuselage. The flaps are attached to the wing structure by flap tracks mounted on the aft spar. Roller bearings, Teflon washers, and standard aviation hardware secure the flaps to the tracks.

A flap motor / gear box assembly powers flexible shafts connected to a jackscrew actuators. The flexible shafts are received at the power end of the actuator by a ninety degree adapter. The drive end of the actuator is attached to the inboard flap structure. Rotary motion of the gearbox, flexible drive shaft, ninety degree adapter, and flap screw, is converted to linear motion at the drive end of the actuator to position the flaps. No alternate means of flap actuation is provided. Split flap protection is not provided.

The flaps are controlled by a three position switch located to the right of the control console.. Flap position indicators are located near the flap control. Limit switches are installed on the inboard side of the left flap track to stop flap travel at the position selected by the control switch.

Flap Construction

The wing flaps are constructed of aluminum. The primary components are the main spar, ribs, and skins. The main spar, positioned spanwise to the flap, is the primary structural component. Ribs are attached fore and aft of the main spar and covered with skins. The main spar and nose ribs form a light and structurally sound “D” structure. The aft ribs are covered with corrugated skins for additional strength. The model 60 was manufactured with long chord flaps (P/N 95-160000-609 / 95-160000-610), used on the some Baron and Bonanza models. (Figure 1)

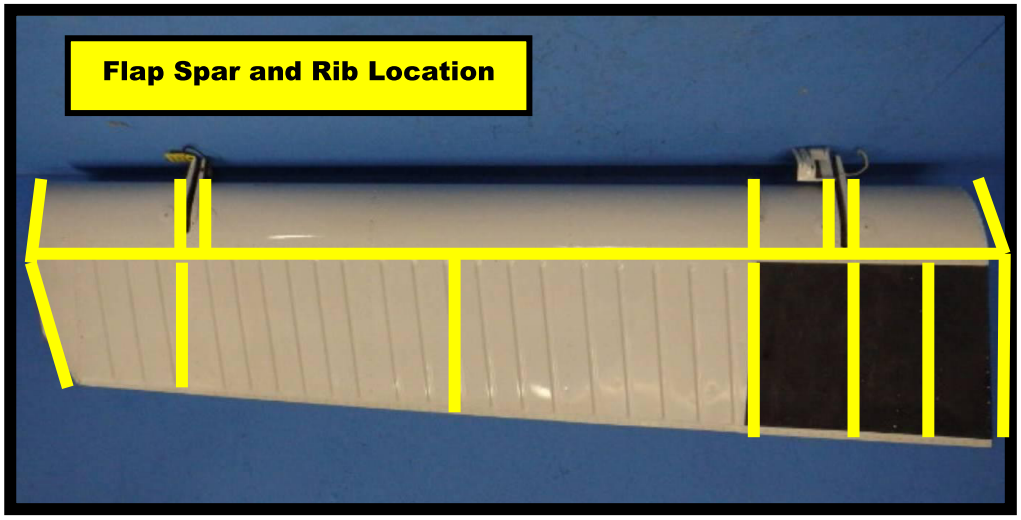

Figure 1. B60 Duke long chord flap, photo by Texas Air Salvage

System Components

The wing flap system consists of the following components:

- Motor
- Gearbox
- Flexible Drive Shaft(s)
- Actuators(s)
- Limit Switches
- Tracks and Rollers
- Bumpers
- Control Switch
- Position Indicator Transmitter
- Position Indicator(s)
- Circuit breaker(s)

Motor

The flap system is driven by a 24 volt, 125 amp DC motor secured to the forward flap gearbox assembly. The motor is powered through the Left Power Bus and Number one bus and protected by a 15A circuit breaker located on the Right Upper Side Panel. The motor is bi-directional, incorporating two sets of motor windings, providing a dynamic brake to prevent flap over travel. (Figure 2)

Gearbox

The flap gearbox is positioned aft of the forward spar carry through structure near the aircraft centerline. The flap motor powers a gearbox via a worm screw drive. The worm screw turns a single gear and shaft which is positioned perpendicular to the worm screw. Flexible drive shafts are attached to each end of the shaft to provide rotational power to the respective flap actuators.

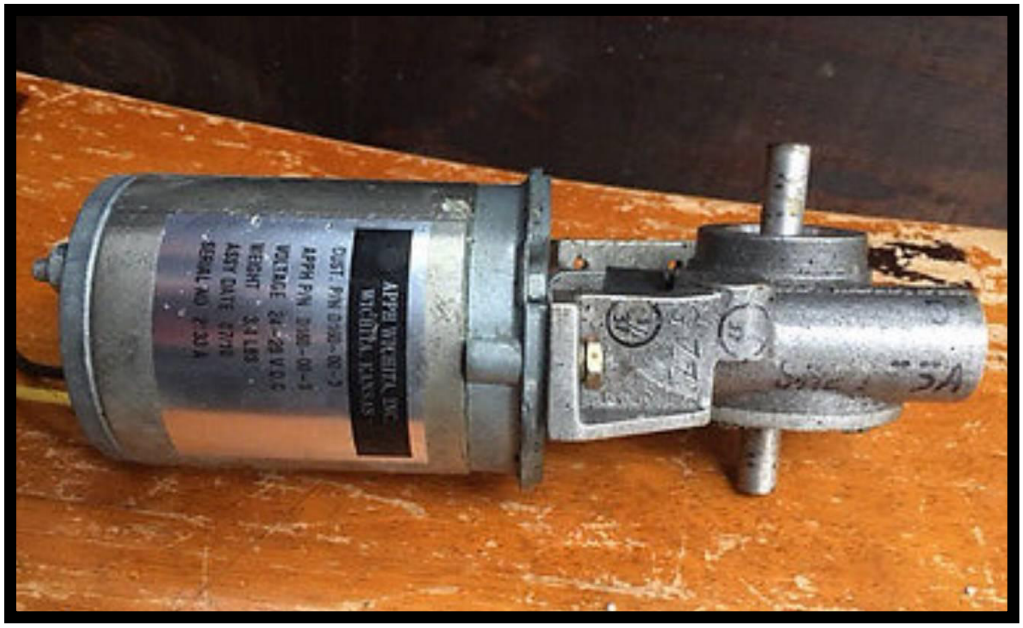

Figure 2. B60 Duke gear motor and gearbox, photo by Robert Hoffman

Flexible Drive Shaft

Two 44.5 inch rotary drive shafts transmit rotary power from the flap gearbox assembly to the flap actuators. The flexible drive shaft is secured to the flap gearbox drive shaft by a retainer, nylon restrictor, and restrictor spring. The actuator end of the flexible drive shaft is secured to the actuator ninety degree drive by a retainer mechanism.

Actuators

The flaps are positioned by a pair of ninety degree drive, electro-mechanical rotary actuators. The power end of the actuator is attached to the inboard aft wing spar structure. The drive, or flap end, is attached to the forward inboard flap structure. Rotary motion of the jackscrew is transmitted to linear motion at the actuator drive to position the flaps. (Figure 3)

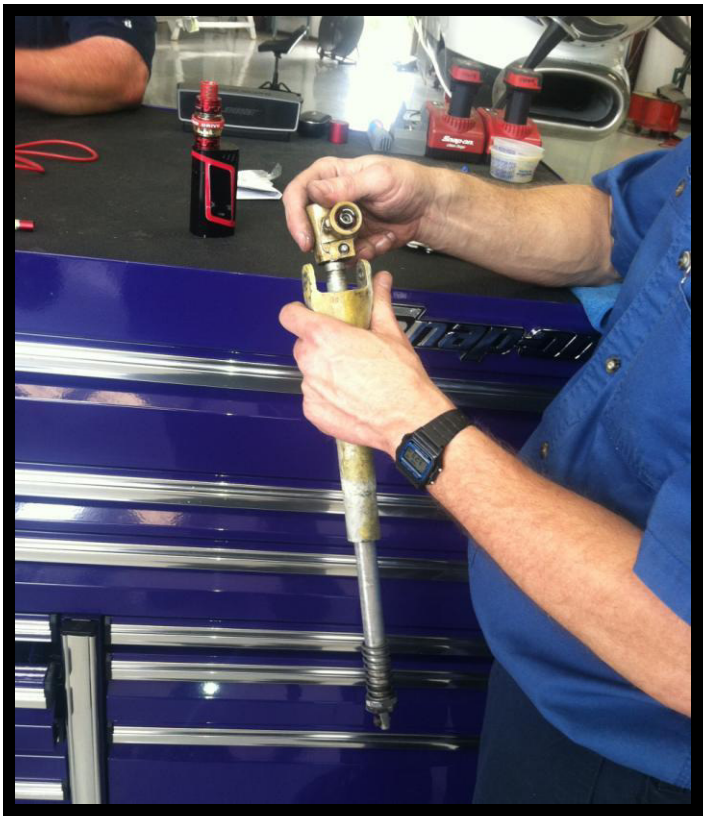

Figure 3. B60 Duke flap actuator, photo by Robert Hoffman

Limit Switches

Four (five on P-247 and later) limit switches are located on the outboard side of the left inboard flap track. The switch assembly consists of a mechanical actuator which activates a pin plunger snap switch. As the flap moves along the track, a mechanical actuator depresses a pin plunger, opening the circuit, removing power from the motor. The switches stop flap travel at 0°, 14°, 16° and 30° depending upon the position of the flap control switch. A second, 16° limit switch is included on aircraft P-247 and later. The flaps cannot be stopped at intermediate positions using the flap control switch. (Figure 4)

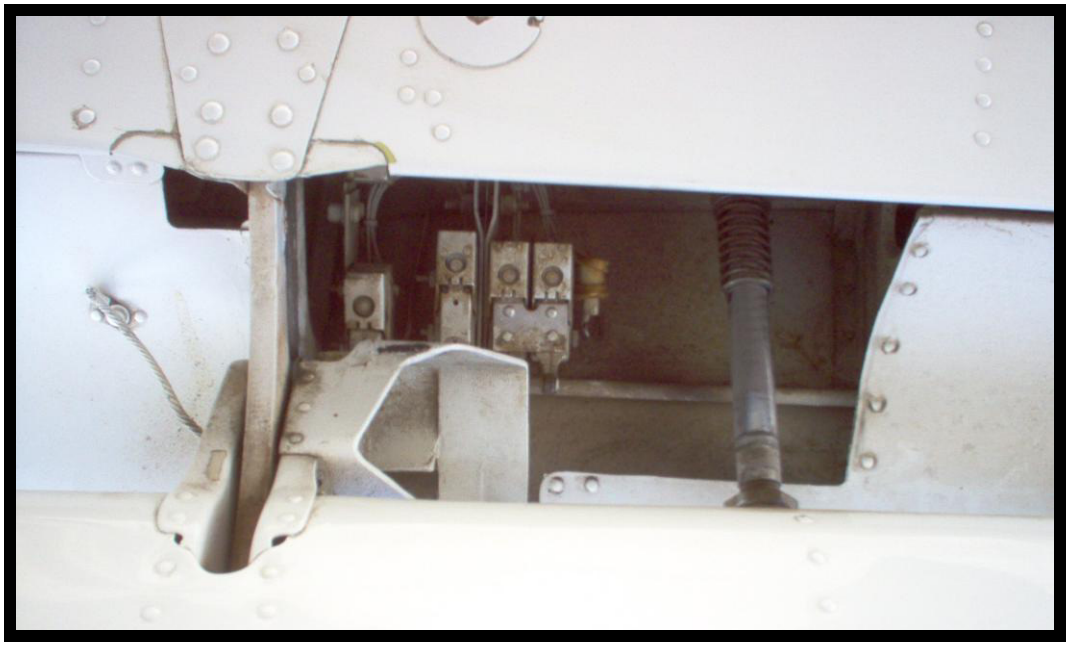

Figure 4. B60 Flap Limit Switches, Photo by Robert Hoffman

Tracks and Rollers

Two flap tracks are located on the inboard aft spar of each wing. The flaps are mounted on the tracks with two roller bearings on each track using standard aviation hardware and Teflon washers. (Figure 5)

Figure 5. B60 Flap rollers, photo by Texas Air Salvage

Bumpers

An adjustable hard rubber flap bumper is secured to the wing structure near the outboard end of each flap. The bumpers mitigate in-flight flap vibration, while in turn, decreasing flap roller ware. (Figure 6)

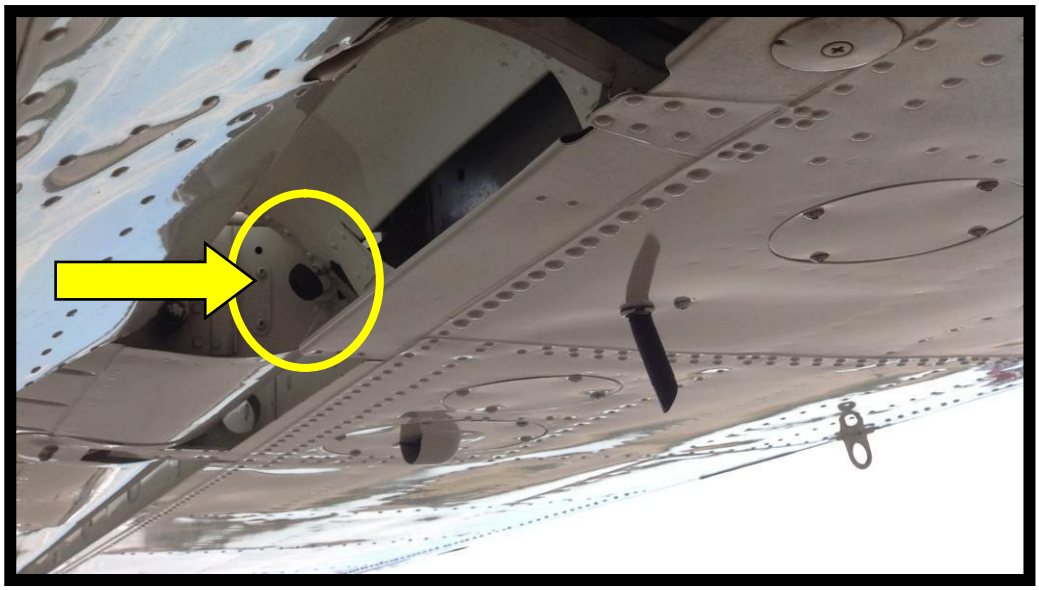

Figure 6. B60 Flap bumper, photo by Robert Hoffman

Control Switch

A flap control switch is located to the right of the control consol on the right sub-panel. The switch allows the pilot to select one of three positions: UP, APH, or DN. (Figure 7)

Figure 7. B60 Flap Control Switch, photo by Robert Hoffman

Position Indicator Transmitter

Flap position is transmitted to the flap position indicator(s) through the right flap position transmitter, P-4 to P-246, or the left flap limit switches, P-247 to P-596.

P-4 TO P-247

A flap position indicator transmitter on the right flap actuator, receives power through the Left Power Bus, Number One Bus, and a 5A circuit breaker labeled IND FLAP & LG.

P-247 TO P-596

Flap position is transmitted to the flap position indicator lights through power received from the Left Power Bus, Number One Bus, and a 5A circuit breaker labeled, IND FLAP & LG.

Position Indication

A flap position indicator is located on the right subpanel to provide a visual indication of flap position.

P-4 TO P-247

A three position pointer indicator displays flap position generated from the flap position transmitter located on the right flap actuator.

P-247 TO P-596

A three light indication system displays flap position generated from the left flap limit switches:

- In Transient – a red light illuminates
- Flaps UP - all lights are extinguished
- Flaps APH – a blue light illuminates
- Flaps DN - an amber light illuminates

The flap indicator lights may be function checked for electrical continuity by pressing the PRESS-TO-TEST switch located above the Annunciator Panel, or on turbine powered aircraft, the L/R Annunciator test lights located below the center glare shield.

Circuit Breakers

Flap motor and indicator circuit breakers are located on the Right Upper Side Panel.

Flap Motor Circuit Breaker

P-4 TO P-596

The flap motor receives power from the Left and Right Power Bus and Number One Bus through a 15A circuit breaker located on the Right Upper Side Panel labeled FLAP. (figure 8)

P-247 TO P-596 WITH STC SA01672SE

The flap motor receives power from the Left Distribution Bus and a 15A circuit breaker located on the Right Upper Side Panel labeled FLAP. (Figure 8)

Flap Indicator Circuit Breaker

P-4 TO P-596

The flap indicator receives power from the Left Power Bus and is protected via a 5A circuit breaker located on the Right Upper Side Panel. The circuit breaker is labeled IND, FLAP & LG. (Figure 8)

P-246 TO P-596 WITH STC SA01672SE

The flap motor receives power from the Left Distribution Bus via a 15A circuit breaker located on the Right Upper Side Panel. The circuit breaker is labeled IND, FLAP & LG. (Figure 8)

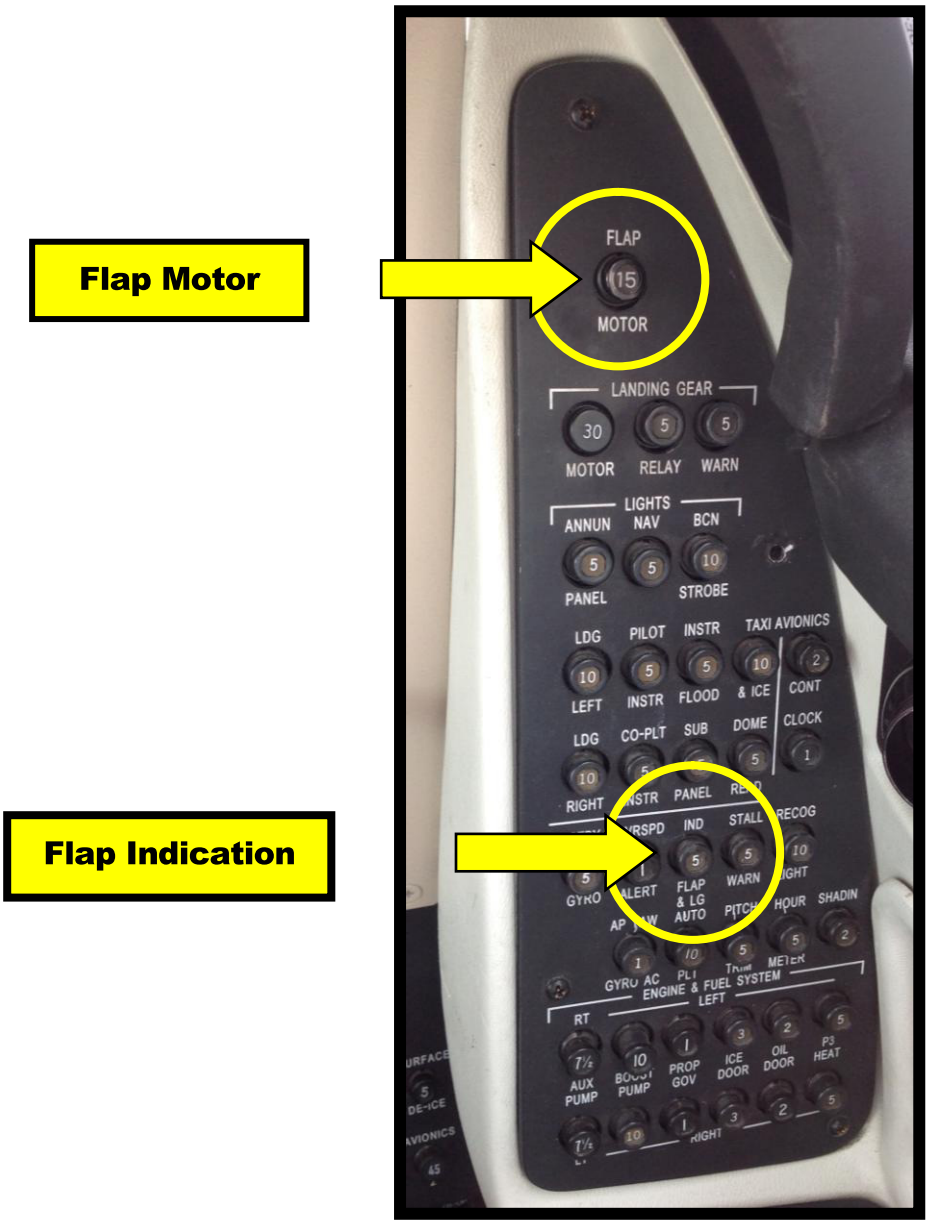

Figure 8. Flap circuit breakers, photo by Robert Hoffman

Limitations

Flap limitations are listed in the AFM/POM, SECTION 1 LIMITATIONS. Additional flap limitations are found in the FAA AIRPLANE FLIGHT MANUAL SUPPLEMENTS, SECTION 5.

The following Flight Manual Supplements contain additional flap limitations:

- Royal Turbine Conversion of the Duke B-60 Aircraft with STC SA01672SE
- Boundary Layer Research, Ltd. Supplemental Type Certificate no. SA00112SE
- Flight in Know Icing Conditions Supplement 60-59-0001-17

Flap Operating Range

- Flaps APH / 15° 174 / 175 KIAS
- Flaps DN / 30° 140 / 141 KIAS

Flight Load Factor

- Flaps UP 3.5 G's
- Flaps Down 2.0 G's

Flight in Known Icing Conditions Supplement (60-590001-17): LIMITATIONS

- Sustained flight in icing conditions with flaps extended is prohibited except for approach and landing

Flight in Known Icing Conditions Supplement (60-590001-17): SEVERE ICING CONDITIONS

- Do not extend flaps while holding in icing conditions. Operation with flaps extended can result in a reduced wing angle of attack with the possibility of ice forming on the upper surface further aft on the wing than normal, possibly aft of the protected area.
- If the flaps are extended (while in severe icing), do not retract them until the airframe is clear of ice.

NO Step Placards

Engineering data is unavailable for the weight bearing capacity of the left flap structures. We know Beech engineers designed the structure for passenger use, since the structure is reinforced, and wing walk material covers the inboard top surface. To contradict the notion that the left flap is meant to be stepped upon, the Beech placed NO STEP decals on the top inboard flap left / right flap structure. (IPC 11-20-01 page 2, 3). We suspect these placards were intended to address product liability claims. Consider that in 1968, an adult male weighted an average 170 lb., while an adult female weighed only 120 lb. With this thought in mind, it would seem prudent to use caution when allowing passengers of size to step on the top of the left flap structure.

Split Flap

The manufacturer publishes no limitation, emergency procedure, non-normal procedure, or general operational guidance regarding split flap protocol.

Part 23 aircraft certification requires an aircraft to "have safe flight characteristics with the flaps retracted on one side and extended on the other" An aircraft "must maintain controllability without having to exert exceptional piloting skill, alertness, or strength under all probable operating conditions." Operator feedback indicates the aircraft is fully controllable in the most extreme circumstances without exceptional piloting skill.

Normal Operation

Section II – Normal Procedures

Section II is a 1940's era training document arranged in a numbered, "how to" format. The section was last revised in 1980, and is rife with obsolete, incorrect, and hazardous practices. Due to the mature nature of the content, operators are advised to exercise a judicious amount of skepticism regarding its technical authority. Please understand that this section represents a technique, rather than the only approved technique for operating the aircraft. Part 91 operators are not bound by regulation to follow this section. An FAA general council opinion dated March, 2011, regarding Section II checklists explains - "For Part 91 operators that are not operating under Subpart K, there is no FAA requirement for acceptance or approval of modified checklists….The FAA encourages all Part 91 operators to utilize checklists when appropriate and ensure their (aircraft manufacturer or operator modified) checklist is complete and contains no errors."

Flap Operation - Normal Procedures

Before Taxi

The wing flaps are a critical item which, if omitted, or incorrectly set could have a severe adverse impact on the safety of the operation. Flaps should be set and verified after engine start and prior to taxi. This task sequence minimizes the risk of interruptions and distractions.

Before Takeoff

Flaps are placed at the beginning of the Before takeoff check because the aircraft has no spit flap, or takeoff configuration warning to protection.

Before Landing

The Before Landing checklist is normally initiated by a triggering event that initiates the Before Landing flow and check. The Before Landing checklist should contain no more than four items. Example: Piston powered aircraft – Landing Gear, Flaps, Lights. Turbine powered aircraft – Landing Gear, Flaps, Lights, Ignition.

After Landing

The After Landing flow and checklist is initiated after the aircraft completes a one-hundred eighty turn on the runway (if applicable), or when all of the aircraft clears the runway obstacle free zone. The After Landing checklist begins with the Flaps selected to UP.

Braking Technique

Maximum braking is achieved by leaving the flaps in the DN position during the landing roll, while placing the control yoke firmly forward and applying moderate braking. Pulling the control yoke aft during the landing roll generates substantial lift, possibly causing the tires to skid, and the aircraft to become airborne.

Balked Landing

The Balked Landing procedure is listed in Section II, page 2-8, sequentially after the Before Landing procedure, and before the After Landing procedure. The procedure is a training guide rather than a checklist. A balked landing requires immediate action that must be accomplished from memory.

The balked landing procedures; formed in a Beech or a Boeing, is elegantly simple – Go Around Thrust, Flaps Approach, Positive Rate of Climb, Gear Up. A trained and proficient aviator will be able to command this procedure without forethought or hesitation.

Section II – Normal Operations: FAA Training or Checking Events

In 2011, David J. Bjellos, while researching a paper published in the Flight Safety Foundation Magazine, requested a formal response from the FAA to the following questions relating to customized checklists:

- What expectations does the FAA have, and what steps can aviation departments take, to address customizing checklists for its individual needs?

- What position does the FAA take on those of us (Part 91 corporate flight departments) who use customized checklists?

- What steps would the FAA recommend that Part 91 corporate flight departments take to ensure our checklists meet "acceptable standard" that exists for Part 121 and Part 135 operators?

The response from the FAA Flight Standards Service on March 25, 2011 was as follows:

"For Part 91 operators that are not operating under Subpart K, there is no FAA requirement for acceptance or approval of modified checklists….The FAA encourages all Part 91 operators to utilize checklists when appropriate and ensure their (aircraft manufacturer or operator modified) checklist is complete and contains no errors." FAA General Council, March, 2011. Pilots in training or checking should be absolutely certain the pilot examiner is in agreement regarding checklists and operating procedures, especially those regarding the use of cowl flaps, flaps, fuel pumps, and propeller controls. If a difference in protocol presents itself, i.e. the insistence upon using Section II checklist and POM procedures, we recommend discontinuing the event until an agreement can be reached. Be the Captain. Be in command.

Flap System Preflight Inspection

With the flaps in the UP position, confirm the flaps are firmly against the flap bumper by attempting to move the trailing edge of the flap with both hands. Note little movement of the flap assembly. Flap visual inspection:

- Confirm the bottom of the flap assembly is not corroded or blistered due to engine exhaust heat.
- The contour of the flap must be within .0625 inch of the contour of the wing on either or both sides.
- The inboard trailing edge of the flap must be within .20 inch above or below the trailing edge of the wing stub on either or both sides.
- The gap between the flap and aileron must be between .13 and .50 inch.

Flap System Function Check Procedure

The flap system should be checked periodically for system functionality. Consider completing this check prior to scheduled maintenance. This is a maintenance check procedure, and should not be conducted in concert with the Before Take-off checklist procedure. The procedure confirms the operation and conformity of the following components:

- Motor
- Gearbox
- Flexible Drive Shaft(s)
- Actuators(s)
- Limit Switches
- Control Switch
- Flap Position Transmitter (P-4 to P-247)
- Position Indicator(s)
- Circuit breaker(s)

FLAP FUNCTION CHECK PROCEDURE (P-4 TO P-247)

1. Visually confirm the area behind and beneath the flaps are clear
2. Confirm the flap motor and indicator circuit breakers are closed
3. Connect a GPU (regulated to 28.25 +/- .25 VDC) to the aircraft, or start an engine(s) and confirm 28.0 VDC power on the electrical bus
4. Confirm the flap control switch is UP, the flap position indicator indicates UP, and both flaps are visually confirmed in the UP position
5. Select flaps APH, verify the flap indicator indicates APH, visually confirm both flaps in the approach position
6. Select the flap control switch to DN, verify the indicator indicates DN, visually confirm both flaps in the down position
7. Select the flap control switch to APH, verify the indicator indicates APH, visually confirm both flaps in the approach position
8. Select the flap control switch to UP, verify the indicator indicates UP, visually confirm both flaps in the UP position
9. Note discrepancies and record for maintenance action

FLAP FUNCTION CHECK PROCEDURE (P-247 TO P-596)

1. Visually confirm the area behind and beneath the flaps are clear
2. Confirm the flap motor and indicator circuit breakers are closed
3. Connect a GPU (regulated to 28.25 +/- .25 VDC) to the aircraft, or start an engine(s) and confirm 28.0 VDC power on the electrical bus
4. Press the Annunciator Panel Test switch, confirm the red transit, blue approach, amber down flap indicator lights illuminate
5. Confirm the flap control switch is UP, the flap position lights are extinguished, and both flaps are visually confirmed in the UP position
6. Select flaps APH, verify the red transit light illuminates, extinguishes, and the blue approach light illuminates, visually confirm both flaps in the approach position
7. Select the flap control switch to DN, verify the red transit light illuminates, extinguishes, and the amber down light illuminates, visually confirm both flaps in the down position
8. Select the flap control switch to APH, verify the red transit light illuminates, extinguishes, and the blue approach light illuminates, visually confirm both flaps in the approach position
9. Select the flap control switch to UP, verify the red transit light illuminates, extinguishes, visually confirm both flaps in the UP position
10. Note discrepancies and record for maintenance action

Performance

The Semi-Fowler flap design increases wing area when selected to APH (15°), allowing for shorter takeoff distances. The flaps DN (30°) position allows lower approach speeds and shorter landing distances.

Normal Takeoff

The manufacturer's Normal Take-off performance charts list cowl flaps OPEN and Flaps UP for takeoff. A flaps APH takeoff decreases the takeoff roll by approximately 19%, while accelerate stop distance is decrease by an undetermined value. However, independent flight testing indicates accelerate stop distance, at a decision speed of 83 KIAS, is decreased by 10%.

Obstacle Takeoff (P-4 to P-246)

The manufacturer's Obstacle Takeoff charts, Page 6-4, under Associated Conditions, List cowl flaps CLOSED and flaps set to APH (15 degrees).

BE60 Takeoff Distances vs Flap UP / APH				
Temperature +30 c / Alt. 1,000 ft. MSL / Wt. 6,500 lb. / Wind +10 HW				
FLAPS	SPEED	GND ROLL	TOD	ASD
UP	93	2,054 ft.	2,600 ft.	3,400 ft.
APH	83	1,650 ft.	2,150 ft.	3,200 ft.*
APH	73	1,343 ft.	1,700 ft.	2,900 ft.*
* Data collected from independent flight testing				

Normal Landing

The manufacturer's Normal Landing performance charts, Page 4-12, lists Flaps DN (30°) for landing. The manufacturer does not provide charts for Flaps APH or Flaps UP landings. The charted associated conditions include an 800 ft. per minute approach profile, to a landing on a Paved, Level, Dry surface, using maximum braking. The charted approach speeds represent 1.3 times Vso for the associated landing weight.

Obstacle Landing (P-4 to P-246)

The manufacturer's Obstacle Landing charts, Page 6-5, lists Flaps DN (30°) for landing. The associated conditions are identical to the Normal Landing performance chart, however, the approach speeds represent 1.15 times Vso for the associated landing weight.

BE60 Landing Distances - Flap DN*				
Temperature +30 c / Alt. 1,000 ft. MSL / Wt. 6,500 lb. / Wind +10 HW				
FLAPS	SPEED	LAND DIST.	GND ROLL	BLR VG's
DN 1.3 Vso	97	2,333 ft.	1,333 ft.	No
DN 1.3 Vso	91	2,300 ft. ?	1,300 ft. ?	BLR VG's
DN 1.15 Vso	85	2,265 ft.	1,265 ft.	No
DN 1.15 Vso	81	2,200 ft. ?	1,200 ft. ?	BLR VG's
* Assumes a 3 degree approach with touchdown on the runway aiming markers (1,000 ft.) at Vso				

Balked Landing Climb

The Balked Landing Climb chart, Page 4-11, demonstrates the aircraft possesses adequate thrust to overcome landing gear and flaps DN (30°) drag, to produce the charted climb performance. Example: A balked landing, at a landing weight of 6,500 lb., at Leadville, CO, on an ISA+20 day, will produce a climb rate of +600 fpm.

Flaps UP Landing

Beech does not provide flaps UP landing charts. Flaps UP landings may be required due to a mechanical failure or an abnormal condition. Example: Electrical failure, Icing, Single Engine Operation, Split Flaps.

Flaps UP Approaches produce flight deck sight pictures resulting in shallower than normal approach profiles. Make every effort to select a runway with an electronic and / or visual glide slope. Add 35% to the normal flaps DN landing distance. Add 10 KIAS to normal flaps DN approach speeds, or alternately, fly the approach at 1.3 Vs for weight listed below.

APPROACH SPEEDS KTS IAS*

	V ref = 1.3 Vs / Vso		
WEIGHT	UP	APH	DN
6,775	107	98	95
6,500	103	95	91
6,000	100	94	87
5,500	92	88	85
***AIRCRAFT EQUIPPED WITH BLR VG's / STC SA5761NM**			

Emergency

The EMERGENCY PROCEDURES Section III of the AFM/POM lists no emergency procedures related to flap operation.

Non Normal Procedures

The following events may be encountered, requiring systems knowledge to address the non normal occurrence.

- Flaps will not extend from UP to APH
- Flaps will not extend from UP to DN
- Flaps will not retract from DN to APH
- Flaps will not extend from APH to DN
- Flaps will not retract from APH to UP
- Flaps will not retract from DN to UP
- Flap circuit breaker OPENS after flaps are selected, and retract to UP
- Flap circuit breaker OPENS after flaps selected to, and extend to DN
- Electrical smoke / fumes during flap motor operation
- Flaps split during extend or retract sequence
- Flap motor will not operate after opening, closing the flap circuit breaker

Maintenance

The Duke 60 Series Maintenance Manual (P/N 60-590001-25A18) advises a replacement or overhaul schedule of the following flap system components:

- Flap Motor and Gearbox: Every 2,000 hours
- Flap Actuators: Every 2,000 hours
- Flap Flexible Drive Shafts: Every 2,000 hours

Common service difficulties:

- Special Airworthiness Information Bulletin SAIB CE-11-21 Date: February 16, 2011, nose rib cracks at actuator attach fitting. (Figure 9)
- Flap motor failure due to failed internal components
- Flap limit switch(s) failure (Figure 10)
- Flap actuator failure
- Worn flap rollers
- Worn flap tracks
- Failure of the bottom L/R lower flap skin due to engine exhaust corrosion

Figure 9. Cracked nose rib, Special Airworthiness Information Bulletin SAIB CE 11-21

Figure 10. Failed 16 degree limit switches. Photo by Robert Hoffman

Review

- ✓ The wing flaps are driven by a 24 volt, 125 amp DC motor and gearbox assembly located aft of the forward spar between the pilots seats. The motor and gearbox assembly transmits power to flap actuators via flexible cables.
- ✓ The system offers no split flap protection
- ✓ The left flap is the master since it houses the flap limit switches.
- ✓ The flap indicator represents the left flap position P-247 to P596, right flap position on P-4 to P-246.
- ✓ The left flap has no published weight bearing limitation, however, persons of size have been known to damage the flap structure.
- ✓ Sustained flight in icing conditions with flaps extended is prohibited except for approach and landing.
- ✓ Do not extend flaps while holding in icing conditions.
- ✓ The flaps should be SET and VERIFIED after engine start and before taxi.
- ✓ We believe checking the flaps pursuant to Section II, Before Takeoff Checklist presents a potential human factors trap. A better alternative is to conduct a flap system function check prior to a scheduled maintenance event.
- ✓ Reconfirm flap position on the before takeoff checklist
- ✓ Maximum braking is achieved by leaving the flaps in the DN position during the landing roll, while placing the control yoke firmly forward and applying moderate braking.
- ✓ A flaps APH takeoff decreases takeoff roll by 19%.
- ✓ Independent flight testing indicates, flaps UP accelerate stop distance is decreased by 10%, with flaps APH at a decision speed of 83 KIAS.
- ✓ The Balked Landing procedure must be committed to memory: Go-Around Thrust, Flaps Approach, Positive Rate of Climb, Gear Up. The procedure should be conducted in a SLOW, methodical manner. Do not hurry.
- ✓ The EMERGENCY PRODEDURES Section III of the AFM/POM lists no flap emergency procedures.

- ✓ Non Normal flap events require systems knowledge to address the occurrence.
- ✓ Flaps UP landings charts are not provided. Flaps UP landings may be required due to a mechanical failure or an abnormal condition. Flaps UP Approaches produce flight deck sight pictures resulting in shallower than normal approach profiles. Make every effort to select a runway with an electronic and / or visual glide slope. Add 35% to the normal flaps DN landing distance. Add 10 KIAS to normal flaps DN approach speeds.
- ✓ Beech suggests the flap motor, gearbox and actuators be overhauled every 2,000 hours.
- ✓ Failed flap motors and limit switches are the primary cause for flap service difficulties.
- ✓ Miss-rigged flaps are the primary casual factor in a split flap event.
- ✓ The aircraft is fully controllable with a split flap at any speed above a stall.

END