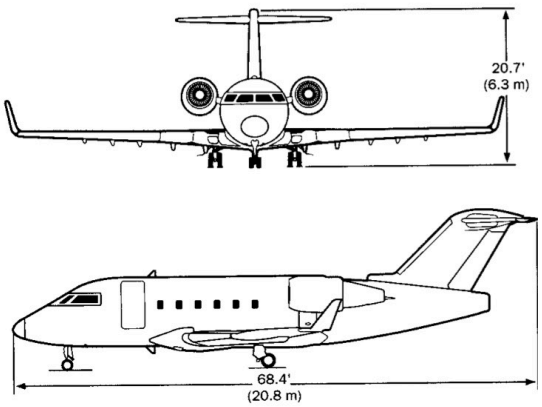
# Assignment 2: Simple Runway Length Calculations

**Date Due: February 6, 2016** Instructor: A. A. Trani

## Problem 1

The Morgantown Municipal Airport-Walter L. Bill Hart Field (MGW) is planning an expansion to serve larger corporate jets in the future. The airport has 78 general aviation aircraft based at the airport. The airport would like to expand the facility to attract larger aircraft like the (shown in Figure 1).




a) For the master plan, estimate a suitable runway length to operate all aircraft safely at the airport. If a runway extension is needed, make a recommendation.

b) Verify if the smaller GA aircraft require more runway than the the corporate jets.

***Figure 1. Bombardier Challenger 604.***

Design Temperature = 83 deg. F (average of high temperatures of the hottest month of the year)

Airport elevation = 1,243.7 feet

Existing Runway length = 5,199 feet

Runway gradient = 0.2%

Design criteria: 100% of the fleet of GA aircraft. Challenger 604 is contained in Table 3.2.

**Location**

FAA Identifier: MGW
Lat/Long: 39-38-36.9435N / 079-55-03.1691W
39-38.615725N / 079-55.052818W
39.6435954 / -79.9175470
(estimated)
Elevation: 1243.7 ft. / 379.1 m (surveyed)
Variation: 09W (2000)
From city: 3 miles E of MORGANTOWN, WV
Time zone: UTC -5 (UTC -4 during Daylight Saving Time)
Zip code: 26505

**Runway 18/36**

| | | |
|---|---|---|
| Dimensions: | 5199 x 150 ft. / 1585 x 46 m | |
| Surface: | asphalt/grooved, in good condition | |
| Weight bearing capacity: | PCN 36 /F/C/W/T | |
| | Single wheel: 65.0 | |
| | Double wheel: 90.0 | |
| | Double tandem: 175.0 | |
| Runway edge lights: | high intensity | |
| | **RUNWAY 18** | **RUNWAY 36** |
| Latitude: | 39-39.040120N | 39-38.191328N |
| Longitude: | 079-55.126200W | 079-54.979435W |
| Elevation: | 1236.1 ft. | 1243.6 ft. |
| Gradient: | 0.2% | 0.2% |
| Traffic pattern: | left | left |
| Runway heading: | 181 magnetic, 172 true | 001 magnetic, 352 true |
| Declared distances: | TORA:5199 TODA:5199 ASDA:5199 LDA:5199 | TORA:5199 TODA:5199 ASDA:5199 LDA:5199 |
| Markings: | precision, in good condition | precision, in good condition |
| Visual slope indicator: | 4-light PAPI on left (3.00 degrees glide path) | 4-box VASI on left (3.00 degrees glide path) |
| Approach lights: | MALSR: 1,400 foot medium intensity approach lighting system with runway alignment indicator lights | |
| Runway end identifier lights: | | yes |
| Touchdown point: | yes, no lights | yes, no lights |
| Instrument approach: | ILS | |

Use Figure 3.2 of the AC 150/5325-4b for this design problem. We use the 60% useful load chart because the airport is located in a rural area.

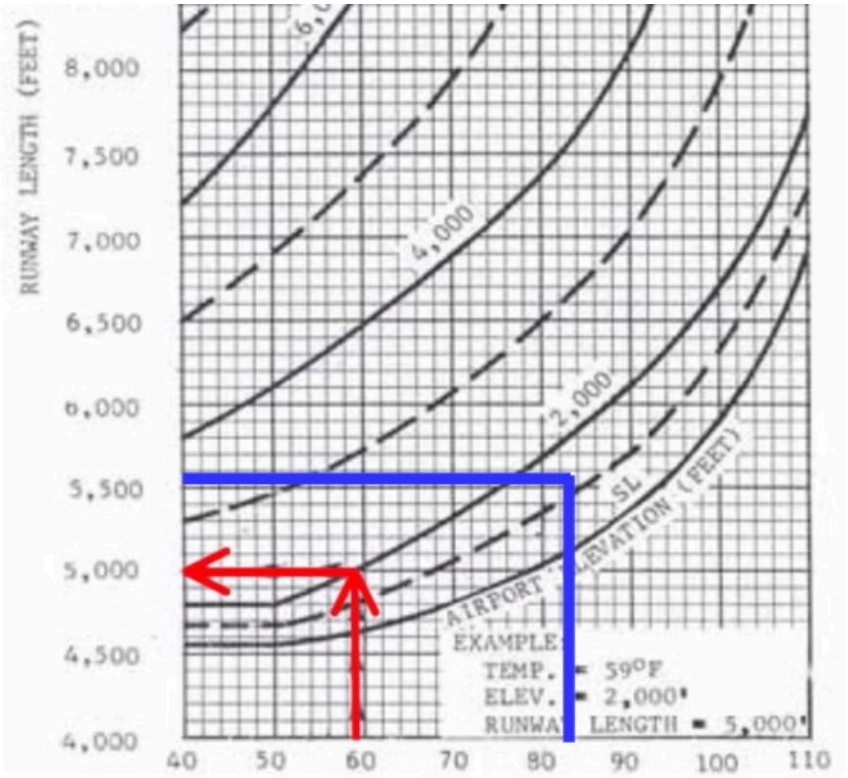



**Figure 1a. Solution of Runway Length for the Problem. Blue line is the solution.**

The runway length required is 5,550 feet.

**Grade Correction:**

Increase 10 feet of each 1 foot of difference in runway centerline elevation. The equivalent difference in elevations is at most (0.2%)(5,199)/100 = 10.4 feet. Therefore, adjust the runway length by 104 feet. The

total runway length adjusted for gradient is then: 5604 feet. We normally round to the nearest 30 feet.
**5,630 feet would be the runway length needed.**

No further correction for wet pavement is needed.The runway is already past the 5,500 feet mark.

## Problem 2

a) Use the fundamental equation of motion explained in class and explain the effect of airport elevation on runway length requirements. Explain which terms contribute to the increase or decrease of runway length.

b) Use the Boeing 787-8 (Dreamliner) document for airport planning (http://www.boeing.com/commercial/airports/plan_manuals.page) to contrast the runway length requirement as a function of temperature. For this analysis consider the Boeing 787-8 departing from Doha (Qatar) at a desired takeoff weight of 490,000 lb. Plot and compare the runway lengths needed at three temperatures provided in the Boeing manual (ISA, ISA+15 deg. C and ISA+25 deg.C.).

**Boeing 787-8 with typical engines**
Takeoff runway length at ISA = 9,400 feet

Takeoff runway length at ISA + 15 deg. C = 9,900 feet

Takeoff runway length at ISA + 25 deg. C. = 14,400 feet


***Figure 2. Boeing 787-8 Dreamliner at Narita Airport (A. A. Trani).***

**Boeing 787-8 with hi-thrust engines**
Takeoff runway length at ISA = 8,050 feet

Takeoff runway length at ISA + 15 deg. C = 8,700 feet

Takeoff runway length at ISA + 25 deg. C. = 10,200 feet

**Figure 2a. Boeing 787-8 Performance from Doha International Airport. Takeoff Weight = 490,000 lb.**

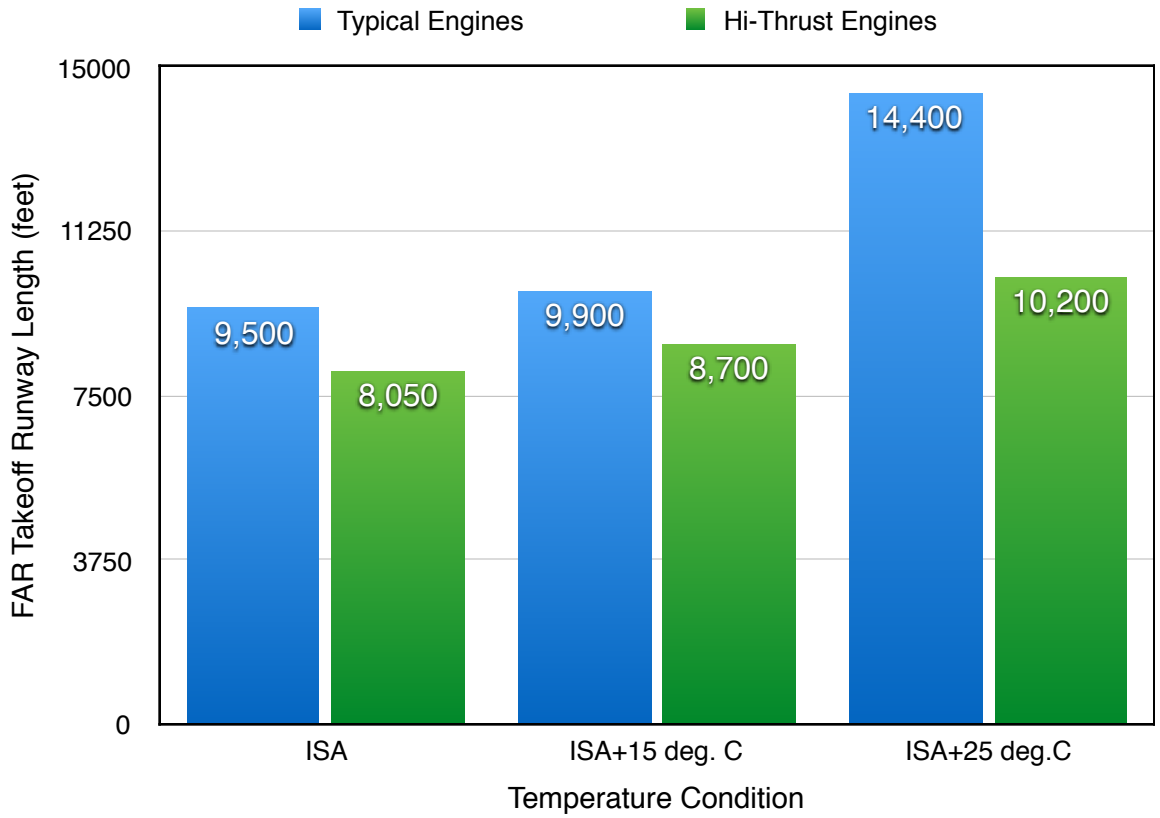

Typical Engines
Hi-Thrust Engines
15000
11250
7500
3750
0
FAR Takeoff Runway Length (feet)
9,500
8,050
9,900
8,700
14,400
10,200
ISA
ISA+15 deg. C
ISA+25 deg.C
Temperature Condition


***Figure 3. Boeing 757-200 at Charlotte (NC) Airport (A. A. Trani).***

## Problem 3

You are evaluating the runways at National Reagan Airport (DCA) in Washington, DC. A new low-cost carrier wants to operate Boeing 757-200 aircraft (Figure 3) from this airport to several destinations the Caribbean (Punta Cana in Dominican Republic and Bridgetown in Barbados). The airline and the airport authority want to know if the longest runway at DCA would be able to accommodate a Boeing 757-200 with PW 2040 engines for these routes. The Boeing 757-200 in question has a maximum takeoff weight of 250,000 lbs. (MTOW). Assume the airline operates the Boeing 757-200 in a single class cabin configuration with 224 seats.

a) Calculate the stage lengths for each service using the great-circle calculator (http://gc.kls2.com/). In your analysis add a 5% route detour factor to account for normal detours due to air traffic control and to avoid weather enroute. Use these corrected distances in your calculations.

b) Find the runway length needed to operate both routes. Comment on the feasibility to offer such service. If the runway is short, state a desired runway extension.

c) How much payload can the aircraft carry on the critical route with a full complement of passengers?

The distance from KDCA to TBPB is 1,803 nm great circle distance. 1,893 nm adjusted with a 5% detour factor. This distance is longer than flying from KDCA to Punta Cana (MDPC).

OEW + PYL = 136,940 lb. + 49,280 lb. = 186,220 lb.

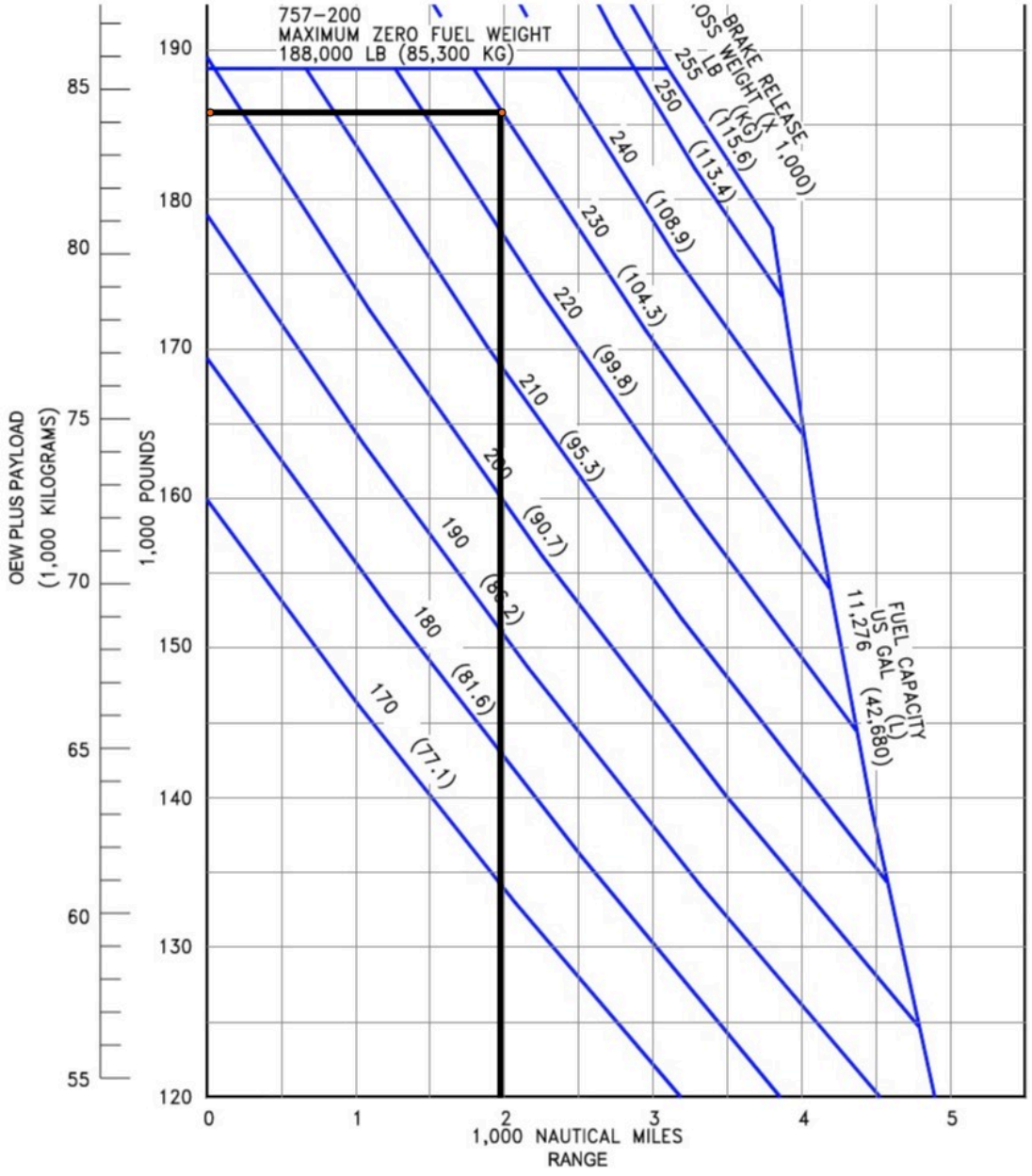
The Desired Takeoff Weight (DTW) for this route is 230,000 lb. using the Boeing 757-200 payload range diagram. Use the ISA + 14 deg. C performance charts. DCA has a design temperature of 89 deg. F (31.6 deg. C). The ISA + 14 deg. chart is within 3 deg. of the desired temperature.

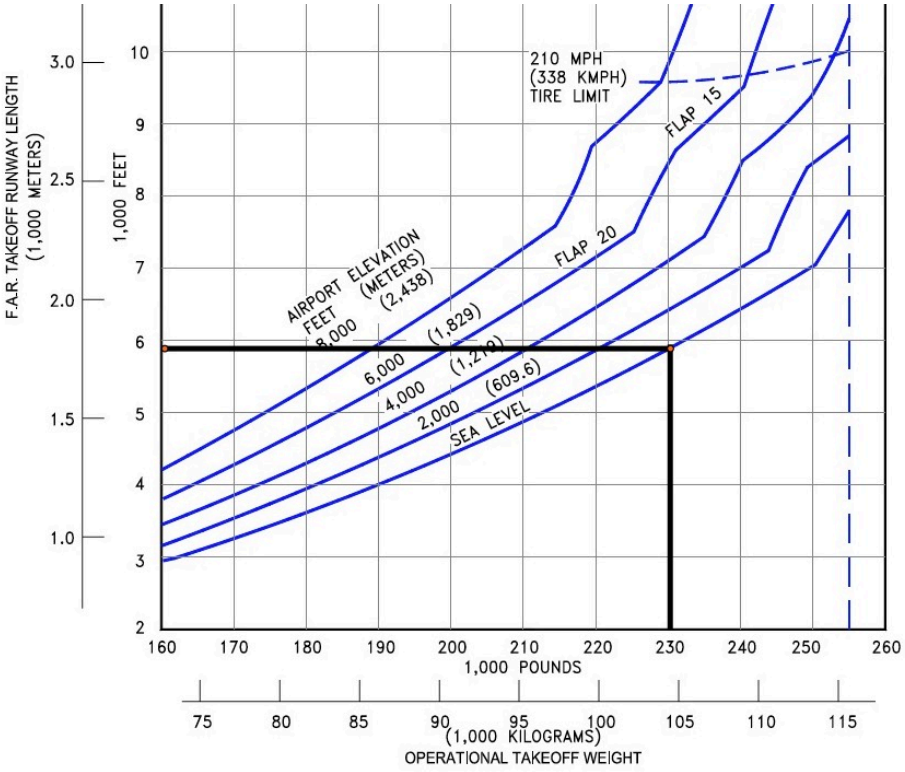
Uncorrected takeoff runway length using ISA + 14 deg. C is 5,900 feet.
Landing runway length using 30 deg. of flaps is 5,900 feet. This applies to a wet runway.

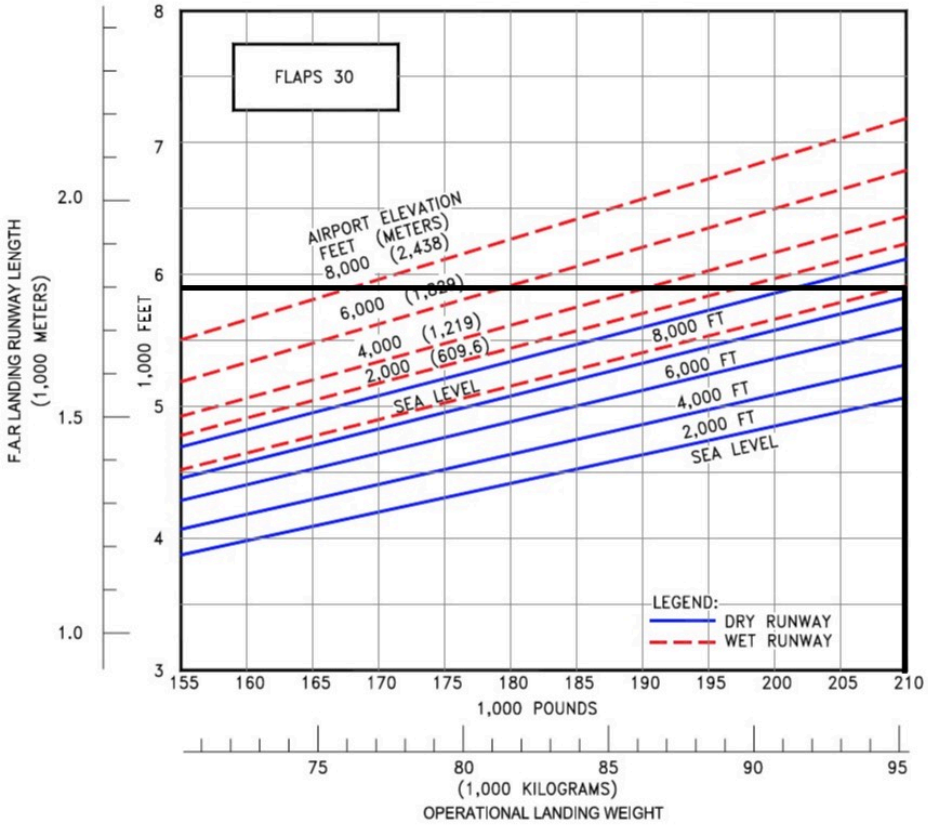
Takeoff runway correction. Runway is almost flat. 0.7 feet difference in elevation between thresholds. Add 70 feet to the takeoff runway length.
**Corrected takeoff runway length = 5,970 feet (or 6,000 feet).**

| CHARACTERISTICS | UNITS | 757-200 | | | | |
|---|---|---|---|---|---|---|
| MAX DESIGN TAXI WEIGHT | POUNDS | 221,000 | 231,000 | 241,000 | 251,000 | 256,000 |
| | KILOGRAMS | 100,250 | 104,800 | 109,300 | 113,850 | 116,100 |
| MAX DESIGN TAKEOFF WEIGHT | POUNDS | 220,000 | 230,00 | 240,000 | 250,000 | 255,000(1) |
| | KILOGRAMS | 99,800 | 104,350 | 108,850 | 113,400 | 115,650(1) |
| MAX DESIGN LANDING WEIGHT | POUNDS | 198,000 | 198,000 | 198,000 | 198,000 | 210,000 |
| | KILOGRAMS | 89,800 | 89,800 | 89,800 | 89,800 | 95,250 |
| MAX DESIGN ZERO FUEL WEIGHT | POUNDS | 184,000 | 184,000 | 184,000 | 184,000 | 188,000 |
| | KILOGRAMS | 83,450 | 83,450 | 83,450 | 83,450 | 85,300 |
| SPEC OPERATING EMPTY WEIGHT | POUNDS | 134,090 | 125,110 | 132,280 | 136,940 | 136,940 |
| | KILOGRAMS | 60,800 | 56,750 | 60,000 | 62,100 | 62,100 |
| MAX STRUCTURAL PAYLOAD | POUNDS | 49,910 | 58,890 | 51,720 | 47,060 | 47,060 |
| | KILOGRAMS | 22,650 | 26,700 | 23,450 | 21,350 | 21,350 |
| SEATING CAPACITY | TWO-CLASS | 186 - 16 FIRST + 170 ECONOMY | | | | |
| | ONE-CLASS | FAA EXIT LIMIT: 224 (2, 239(3) | | | | |
| MAX CARGO - LOWER DECK (4) | CUBIC FEET | 1,790 | 1,790 | 1,790 | 1,790 | 1,790 |
| | CUBIC METERS | 51 | 51 | 51 | 51 | 51 |
| USABLE FUEL | US GALLONS | 11276 | 11276 | 11276 | 11276 | 11276 |
| | LITERS | 42,680 | 42,680 | 42,680 | 42,680 | 42,680 |
| | POUNDS | 75,550 | 75,550 | 75,550 | 75,550 | 75,550 |
| | KILOGRAMS | 34,260 | 34,260 | 34,260 | 34,260 | 34,260 |

***Figure 3a. Boeing 757-200 Characteristics.***


757–200
MAXIMUM ZERO FUEL WEIGHT
188,000 LB (85,300 KG)
BRAKE RELEASE
LOSS WEIGHT (X 1,000)
LB (KG)
255 (115.6)
250 (113.4)
240 (108.9)
230 (104.3)
220 (99.8)
210 (95.3)
200 (90.7)
190 (86.2)
180 (81.6)
170 (77.1)
FUEL CAPACITY
US GAL (L)
11,276 (42,680)
OEW PLUS PAYLOAD
(1,000 KILOGRAMS)
1,000 POUNDS
85
80
75
70
65
60
55
190
180
170
160
150
140
130
120
0
1
2
3
4
5
1,000 NAUTICAL MILES
RANGE


F.A.R. TAKEOFF RUNWAY LENGTH
(1,000 METERS)
1,000 FEET
210 MPH
(338 KMPH)
TIRE LIMIT
FLAP 15
FLAP 20
AIRPORT ELEVATION
FEET (METERS)
8,000 (2,438)
6,000 (1,829)
4,000 (1,219)
2,000 (609.6)
SEA LEVEL
1,000 POUNDS
(1,000 KILOGRAMS)
OPERATIONAL TAKEOFF WEIGHT


FLAPS 30
F.A.R LANDING RUNWAY LENGTH
(1,000 METERS)
1,000 FEET
AIRPORT ELEVATION
FEET (METERS)
8,000 (2,438)
6,000 (1,829)
4,000 (1,219)
2,000 (609.6)
SEA LEVEL
8,000 FT
6,000 FT
4,000 FT
2,000 FT
SEA LEVEL
LEGEND:
DRY RUNWAY
WET RUNWAY
1,000 POUNDS
(1,000 KILOGRAMS)
OPERATIONAL LANDING WEIGHT

c) The longest runway at DCA is 7,170 feet. Reduce the runway length by 70 feet to account for grade and we have 7,000 feet of usable uncorrected runway length. Using the ISA+14 deg. C takeoff curve we find that the maximum operating weight from the airport is 250,000 lb which is the same as the maximum takeoff weight for the aircraft. Technically, the aircraft can carry another 25,000 lb of cargo from DCA. A remarkable performance.

## Problem 4

A new airport is being designed for Mexico City (assume the pressure altitude is ~7000 ft. above sea level). The runway should be enough to satisfy a Boeing 777-200LR. The Boeing 777-200LR (with GE90-115B1 engines) in question has a maximum takeoff weight of 766,000 lbs. (MTOW). See the specifications of the Boeing 777-200LR in the appropriate Boeing document. The mean maximum temperature of the hottest month of the year in Mexico is 23 deg. C. The critical stage length is a non-stop flight to Shanghai, China. In your calculations use a Boeing 777-200LR in a two-class cabin configuration with 279 seats. In your analysis factor a 5% detour factor in your distance calculations.

a) Recommend the runway length needed to operate this service with full passenger payload. Comment on your results.

b) Find the runway length needed with full passenger load plus 12 metric tons of belly cargo.

Critical stage length = 7,322 nm (corrected by 1.05 detour).

OEW + PYL = 320,000 lb. + 61,380 lb. = 381,380 lb.

The Desired Takeoff Weight (DTW) for this route is 630,000 lb. using the Boeing 777-200LR payload range diagram.

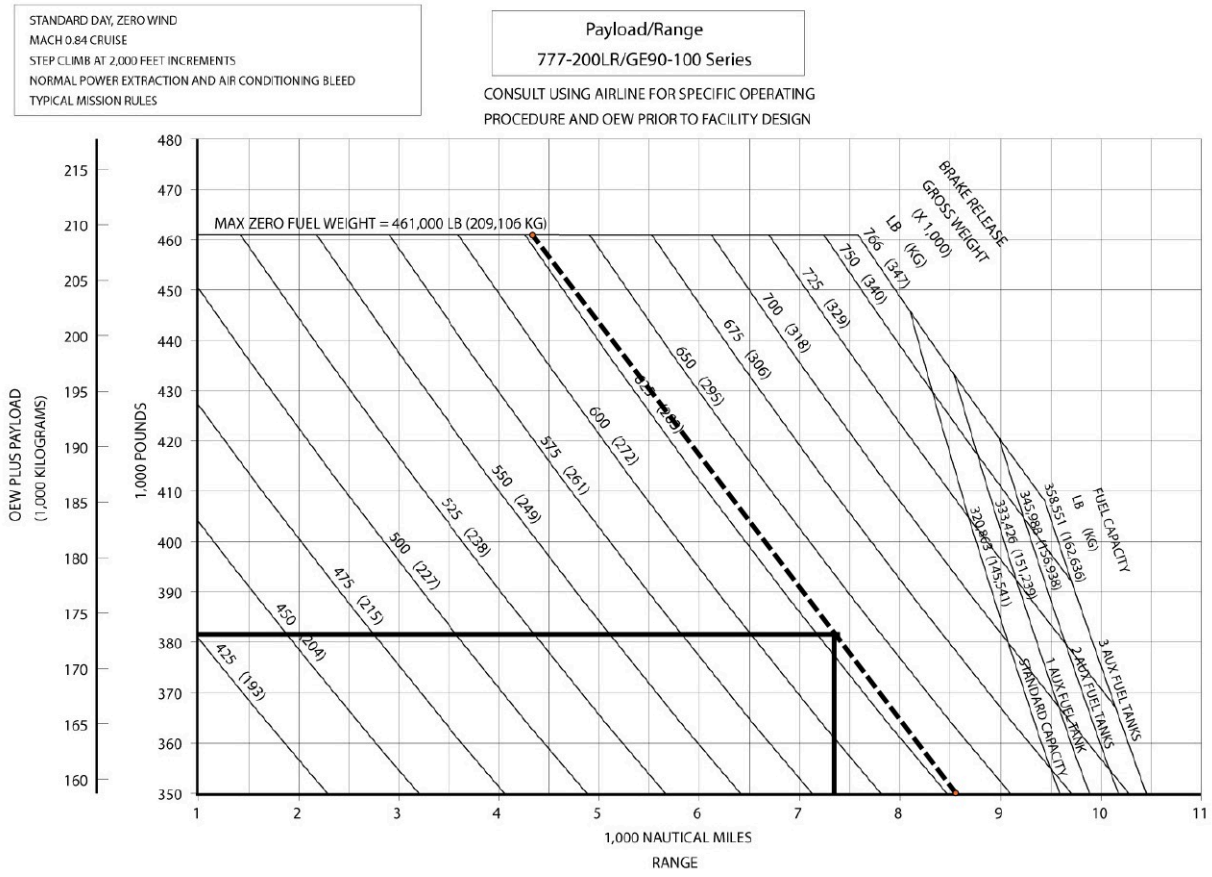
Mexico City ISA temperature conditions would be 0.5 deg. Celsius (using 7,321 feet above sea level). Use the ISA + 27 deg. C performance charts because this is the closest temperature to design point.

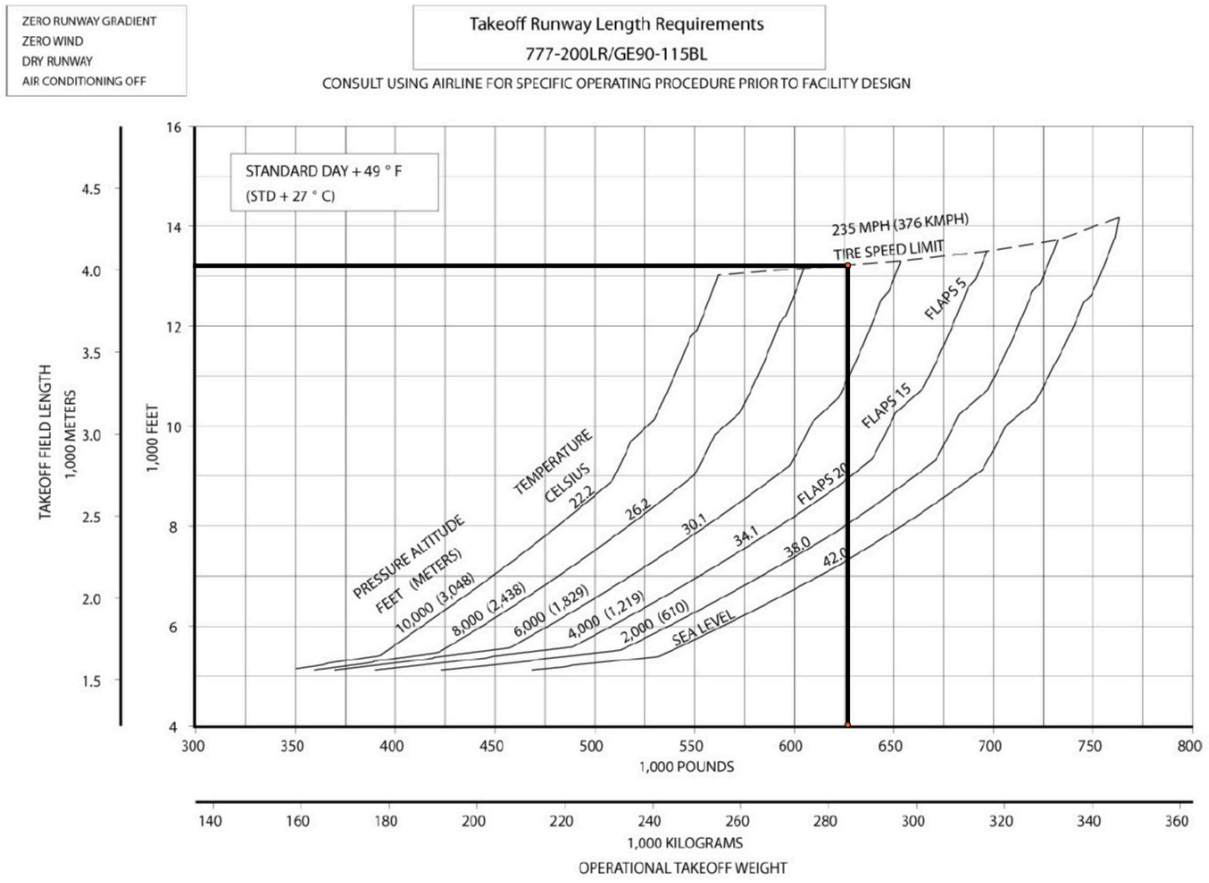

***Figure 4. Boeing 777-200LR at Atlanta Airport (A. A. Trani).***

**The aircraft cannot operate from Mexico City in ISA+27 deg. C conditions at 635,000 lb. The aircraft can operate at 630,000 lb using the ISA + 27 deg. C condition. This means we would have to off-load 5,000 lb of payload (people). This will be equivalent to offloading 22 passengers! At a DTW of 630,000 lb using the ISA + 27 deg. C conditions, the runway length is 13,200 feet.**

**The situation is probably a bit exaggerated because we used a 27 deg. C profile. Note that under ISA+15 deg. conditions, the aircraft requires 10,800 feet or runway. This implies that a 23 degree temperature above ISA may allow the operation closer to 635,000 lb. We will have to ask Boeing to supply a chart for ISA+23 deg. C.**

| CHARACTERISTICS | UNITS | 777-200LR |
|---|---|---|
| MAX DESIGN TAXI WEIGHT | POUNDS | 768,000 |
| | KILOGRAMS | 348,358 |
| MAX DESIGN TAKEOFF WEIGHT | POUNDS | 766,000 |
| | KILOGRAMS | 347,452 |
| MAX DESIGN LANDING WEIGHT | POUNDS | 492,000 |
| | KILOGRAMS | 223,168 |
| MAX DESIGN ZERO FUEL WEIGHT | POUNDS | 461,000 |
| | KILOGRAMS | 209,106 |
| OPERATING EMPTY WEIGHT (1) | POUNDS | 320,000 |
| | KILOGRAMS | 145,150 |
| MAX STRUCTURAL PAYLOAD | POUNDS | 141,000 |
| | KILOGRAMS | 63,957 |
| TYPICAL SEATING CAPACITY | TWO CLASS | 279 (4) |
| | THREE CLASS | 301 (5) |
| MAX CARGO --LOWER DECK | CUBIC FEET | 5,656 (2) |
| | CUBIC METERS | 160.2 (2) |
| USABLE FUEL | U.S. GALLONS | 47,890 |
| | LITERS | 181,283 |
| | POUNDS | 320,863 |
| | KILOGRAMS | 145,538 |






**508. RUNWAY SURFACE CONDITIONS.** The design criterion is to address wet, slippery runway surface conditions for only landing operations and only for turbojet-powered airplanes. The design criteria follows the 14 Code of Federal Regulations requirement that dry runway landing distances for turbojet-powered airplanes must be increased 15 % when landing on wet or slippery runways. Therefore, the obtained runway lengths from this AC for turbojet-powered airplanes are further increased by 15 percent. Many airplane manufacturers' APMs for turbojet-powered airplanes provide both dry runway and wet runway landing curves. If an APM provides only the dry runway condition, then increase the obtained dry runway length by 15 percent. The landing portion of the curves in figures 3-1 and 3-2 are based on dry runway conditions. Thus, as instructed by chapter 3, increase the landing dry lengths for turbojet-powered airplanes by 15 percent to increase the landing length, but not more than 5,500 feet (1,676 meters), whichever is less.