CHAPTER 8 — WEIGHT AND BALANCE

CONTENTS — MAINTENANCE PROCEDURES

FIGURES

WEIGHT AND BALANCE

8-1. WEIGHT AND BALANCE.

The center of gravity (CG) is considered to be the balancing point of a body for weight and balance purposes. The helicopter can be compared to a pendulum; the point of suspension being where the main rotor hub intersects the mast (the pendulum weight being the helicopter). If the pendulum weight is allowed to stop, it will come to rest directly below the suspension point. For example: If the CG of a helicopter is aft of the hub-mast intersection, the helicopter will be tail low in flight. The pilot can correct this condition by moving the cyclic control stick forward. If the required movement of the stick is great enough, the pilot will use all available control, thus limiting maneuverability and forward speed. Since such loss of maneuverability is unsafe, care shall always be taken to keep the helicopter center of gravity within operational limits. Moving the CG is accomplished by adding or removing ballast.

NOTE

For additional weight and balance information, operators in territorial United States shall refer to FAR 29. Operators outside territorial United States shall refer to information issued by the licensing authority.

8-2. LEVELING.

NOTE

Leveling plate (2, figure 8-1) is graduated in increments of 1/4°. The plate is located on cabin floor just inside left passenger cargo door. A slotted hole in upper door frame is provided for suspension of a plumb bob (1).

1. Support helicopter on jacks (Chapter 7).

2. Hang plumb bob (1) in slotted opening in door frame with point of plumb bob just above leveling plate (2) on cabin floor.

3. Adjust height of jacks to bring plumb bob exactly over the point where two lines intersect at 0° on leveling plate. Helicopter is now leveled both longitudinally and laterally.

4. Remove plumb bob.

8-3. WEIGHING.

The helicopter should be weighed in a configuration as near Weight Empty as possible.

NOTE

Weight Empty condition is the basic helicopter together with seats, ballast, special equipment, transmission oil, hydraulic fluid, unusable fuel, and undrainable oil. Refer to FAR 29.

1. All kits, transmission oil, and hydraulic fluid may remain aboard.

2. Ensure baggage compartment is empty.

3. Scale accuracy shall be within plus or minus 1.0 lbs.

4. Position scales in an approximately level area, and check for proper adjustment to zero position.

CAUTION

WEIGHING SHOULD NOT BE ATTEMPTED IN AN OPEN AREA BECAUSE OF THE ADVERSE EFFECTS OF WIND.

5. Position a scale and jack assembly under each jack pad or under each forward jack pad and one aft jack pad. Raise helicopter clear of floor.

1. Plumb Bob
2. Leveling Plate

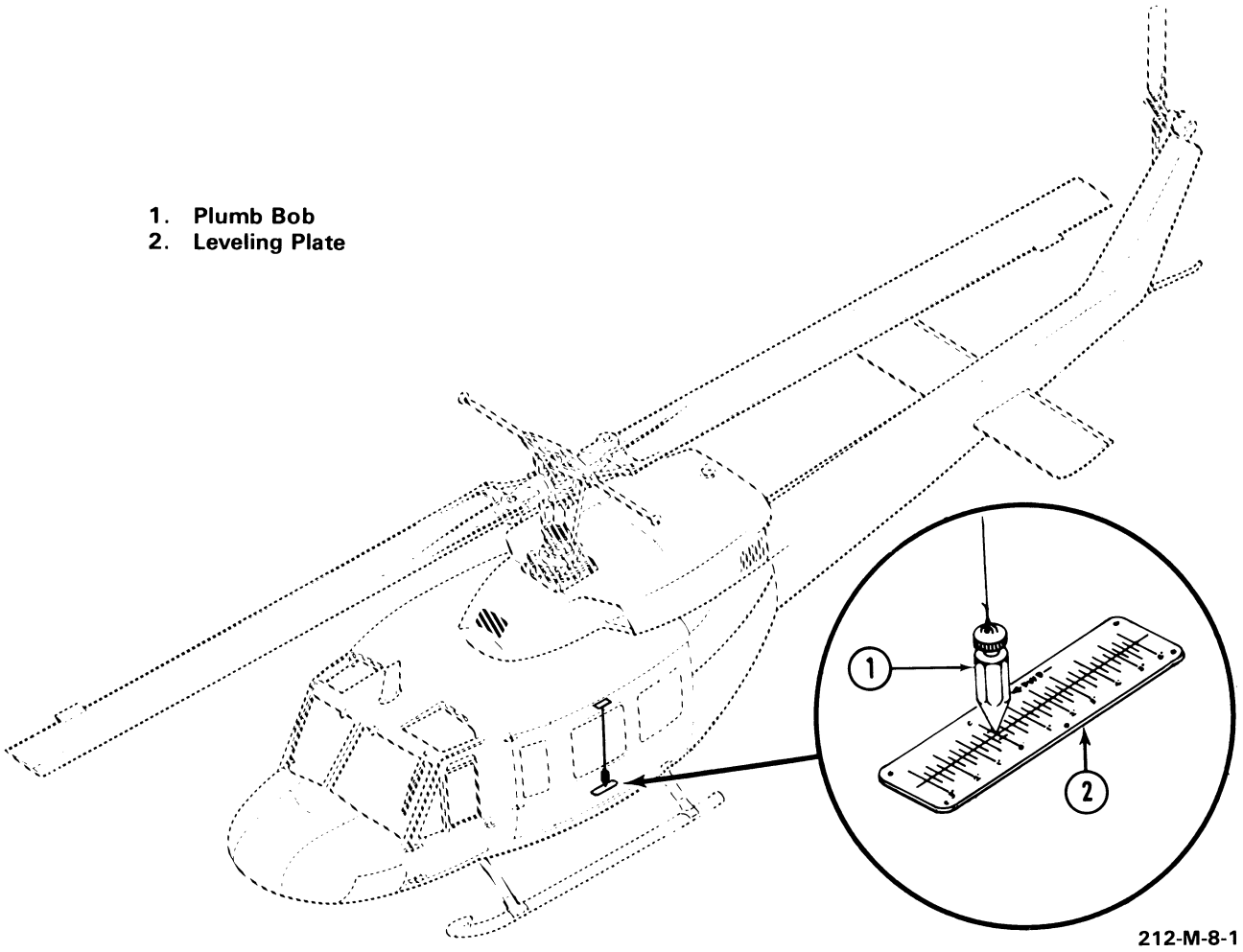


Figure 8-1. Leveling

NOTE

For electronic scales, ensure load cells and adapters are fastened securely to jacks. Accomplish scale manufacturers recommended warm up time and zero each load cell.

6. Level helicopter (paragraph 8-2).

7. Balance each scale and record its reading.

8. Lower helicopter to surface. Weigh jacks, blocks, and any other equipment used between scales and helicopter. Deduct this weight (tare) from actual (first) scale readings to obtain net scale weights.

NOTE

For electronic scales, lower helicopter and verify each cell returns to zero setting. Variations from zero are considered tare and shall be added or subtracted from readings.

9. Total "As Weighed" weight is the sum of the individual net scale weights.

8-4. DETERMINING CENTER OF GRAVITY LOCATION.

CAUTION

THE WEIGHT EMPTY CENTER OF GRAVITY CHARTS ARE PRESENTED AS A GUIDE TO PROPERLY BALLAST THE HELICOPTER. IF HELICOPTER CANNOT BE BALANCED WITHIN THESE RESTRICTIONS, THE GROSS WEIGHT VERSUS CENTER OF GRAVITY LIMITS PRESENTED IN THE APPROPRIATE FLIGHT MANUAL SHALL NOT BE EXCEEDED.

1. This distance from F.S. 0.0 to a line through centers of forward jack pads is called the forward arm. The distance from F.S. 0.0 to a line through the center of aft jack pads is called the aft arm. The forward arm is 61.69 in. (15.64 cm) and the aft arm is 211.58 in. (53.74 cm) (figure 8-2).

2. Multiply total net weight of forward scales by forward arm. The product is called forward moment and is expressed in inch pounds (in.lbs.).

3. Multiply total net weight of aft scales by aft arm. This is aft moment in in.lbs..

4. Add forward and aft moments and divide by total "As Weighed" weight. The quotient is helicopter "As Weighed" CG in inches aft of F.S. 0.0.

NOTE

The above procedure may be stated in equation form as follows:

As Weighed CG =

$$\frac{\begin{array}{l}\text{(Net Wt. Fwd Scales) (61.69) +} \\ \text{(Net Wt. Aft Scales) (211.58) =}\end{array}}{\text{Total Net (As Weighed) Weight}}$$

(TABLE I.D. 910404)

8-5. DETERMINING AMOUNT OF BALLAST REQUIRED.

1. Weight Empty center of gravity chart (figure 8-3) is to be used for all configurations except when following kits are installed.

a. Auxiliary Fuel, 205-706-044,

b. Auxiliary Fuel, 205-706-045,

c. Auxiliary Fuel, 212-899-243,

d. Emergency Flotation, 212-706-021,

e. Floats, 205-706-050.

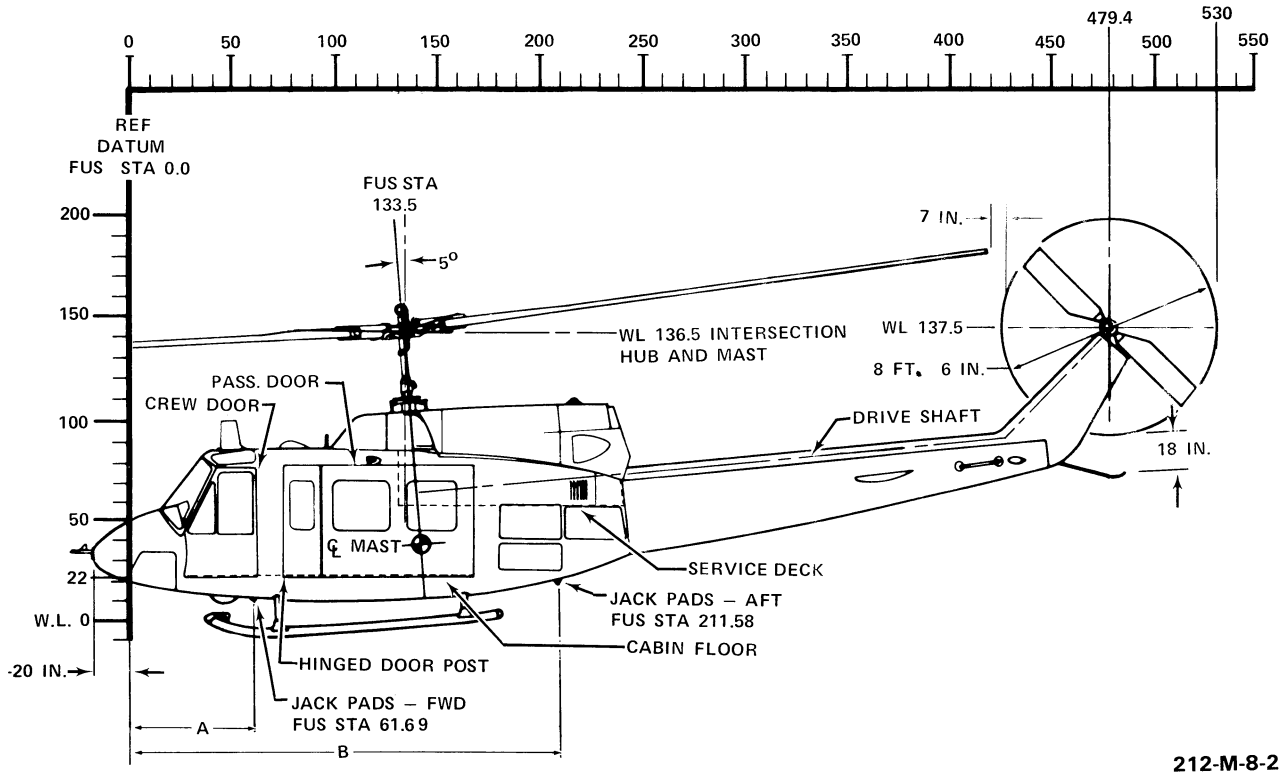


Figure 8-2. Weight and balance

NOTE

For center of gravity charts applicable when above listed kits are installed, refer to paragraph 8-6 .

2. Figure 8-3 has a forward CG limit for VFR flights, a forward CG limit for IFR flights and an aft CG limit. The CG limits are for the following flight configurations.

a. Line A is forward CG limit for basic or IFR configuration helicopters for VFR flights if adding tail ballast.

b. Line B is forward CG limit for IFR configuration helicopters on IFR flights if adding tail ballast.

c. Line C is aft CG limit for basic or IFR configuration helicopters for IFR or VFR flights, if adding nose ballast.

3. Actual Weight Empty CG can fall anywhere between aft and forward CG limit (VFR or IFR, whichever is applicable) and be acceptable; however, if derived Weight Empty CG is forward of forward limit (VFR or IFR flights, as applicable) then only add sufficient tail ballast, not to exceed 50 lbs. (22.68 kg), to move CG to applicable forward CG limit, if derived weight CG is aft of aft limit, add only sufficient nose ballast, not to exceed limits specified in figure 8-14 , to move CG to aft limit.

4. When Weight Empty CG is not within acceptable range shown in figure 8-3 , use following formula to determine approximate amount of ballast required.

$$\frac{\text{Ballast - arm required ARM}}{\text{Ballast - arm required ARM}} = ?$$

NOTE

Derived weight and CG are “as weighed” values plus those Weight Empty items which may have been omitted, and minus those items which are not part of Weight Empty.

“Required CG” is approximated by intersection of derived weight and nearest CG limit line on figure 8-3 .

5. Check derived weight plus ballast and resultant CG on figure 8-3 ; add or remove ballast if necessary to arrive at desired CG.

NOTE

For weight and balance sample problem, refer to paragraph 8-9 .

8-6. WEIGHT EMPTY CENTER OF GRAVITY CHARTS - KITS.

1. When any of following kits are installed, the applicable referenced center of gravity chart shall be used.

NOTE

Weight Empty Center of Gravity Charts are guidelines provided by Bell Helicopter Textron to simplify ballast computations for the operators. The limits are derived using Gross Weight Center of Gravity. Envelope and extreme forward and aft loading configurations include combinations of standard crew and passenger weights and various fuel loadings from the tables. Seating restrictions and crew weight ranges are accounted for in the derivations, but baggage compartment loading is not.

Whenever a helicopter has a unique situation such as: Nonstandard seating arrangement, nonstandard crew and/or passenger weights, baggage compartment being loaded, or weight empty exceeds chart, the forward and aft extremes for that configuration should be computed and checked against Gross Weight Center of Gravity Envelope to compute ballast requirements. The Gross Weight Center of Gravity Envelope is the final authority for determining ballast requirements. Refer to weight and balance chapter in appropriate BHT-212-FM manual for additional information.

Actual Weight Empty CG can fall anywhere between aft and forward limit. The dashed section of forward limit allows a 0.10 in. (2.54 mm) tolerance range for actual CG.

a. Emergency flotation, 212-706-021 (figure 8-4).

b. Emergency flotation, 212-706-021, with 205-706-044 auxiliary fuel tanks (figure 8-5).

c. Emergency flotation, 212-706-021, with 205-706-045 auxiliary fuel tanks (figure 8-6).

d. Emergency flotation, 212-706-021, with 212-899-243 auxiliary fuel (one 90 gallon and one 20 gallon tank installed) (figure 8-7).

e. Emergency flotation, 212-706-021, with 212-899-243 auxiliary fuel (one 90 gallon tank installed) (figure 8-8).

f. Auxiliary fuel tanks, 205-706-044, except when 212-706-021 emergency flotation or 205-706-050 floats are installed (figure 8-9). The CG limits on figure 8-9 are as follows:

(1) Line A is forward CG limit for VFR flights if adding tail ballast.

(2) Line B is forward CG limit for IFR flights if adding tail ballast.

(3) Line C is aft CG limit for IFR or VFR flights if adding nose ballast.

g. Auxiliary fuel tanks, 205-706-045, except when emergency flotation, 212-706-021, or floats, 205-706-050, are installed, figure 8-10 . If helicopter is used for IFR flights, Weight Empty should be ballasted to fall within 0.10 in. (2.54 mm) of aft limit, provided ballast limits are not exceeded. If helicopter is used for VFR flights, Weight Empty can fall anywhere between aft and forward limit.

h. Auxiliary fuel tanks, 212-899-243 (one 90 and one 20 gallon tank installed), except when emergency flotation, 212-706-021, or floats, 205-706-050, are installed, figure 8-11 . The CG limits on figure 8-11 are as follows:

(1) Line A is forward CG limit for VFR flights if adding tail ballast.

(2) Line B is forward CG limit for IFR flights if adding tail ballast.

(3) Line C is aft CG limit for IFR or VFR flights if adding nose ballast.

i. Auxiliary fuel, 212-899-243 (one 90 gallon fuel tank installed), except when emergency flotation, 212-706-021, or floats, 205-706-050, are installed, figure 8-12 . The CG limits on figure 8-12 are as follows:

(1) Line A is forward CG limit for VFR flights in adding tail ballast.

(2) Line B is forward CG limit for IFR flights if adding tail ballast.

(3) Line C is aft CG limit for IFR or VFR flights if adding nose ballast.

j. Floats, 205-706-050 (figure 8-13). The Weight Empty CG may fall anywhere between forward and aft limit.

2. Use applicable Service Instructions for ballast installation instructions.

8-7. NOSE BALLAST INSTALLATION AND REMOVAL.

1. Determine amount of ballast to be added or removed and moment arm. Refer to figure 8-14 for nose ballast station and butt line (B.L.) moment arms. Add or remove nose ballast weight as symmetrically as possible.

2. If ballast weight must be added, refer to figure 8-14 to determine allowable number of ballast plates in each location. Inspect nose compartment to determine where additional ballast plates may be added.

3. If ballast weight must be removed, inspect nose compartment to determine locations where ballast weight plates may be removed.

8-8. TAIL SKID BALLAST.

1. Installation of equipment at forward stations and nose of helicopter may require addition of ballast (2 and 3, figure 8-15) and/or inside tail skid (5) to aft section of tailboom (6).

2. After installation of equipment, a weight and balance check shall be accomplished. Ballast required to correctly locate center of gravity should be installed on or in tail skid (5).

3. Ballast may be added to a maximum of 50 lbs. (22.68 kg) on and in tail skid. Ballast weights should be installed in a combination to provide amount required by weight and balance check.

NOTE

Ballast weights (2 and 3) shall be installed in combination with washers (1) and clamps (4) on tail skid (figure 8-15).

4. Ballast, when required, should be installed on that portion of tail skid located inside tailboom (figure 8-15) or inside tail skid.

NOTE

When ballast is installed inside tail skid, tail skid shall be filled completely full, approximately 15 lbs. (6.8 kg).

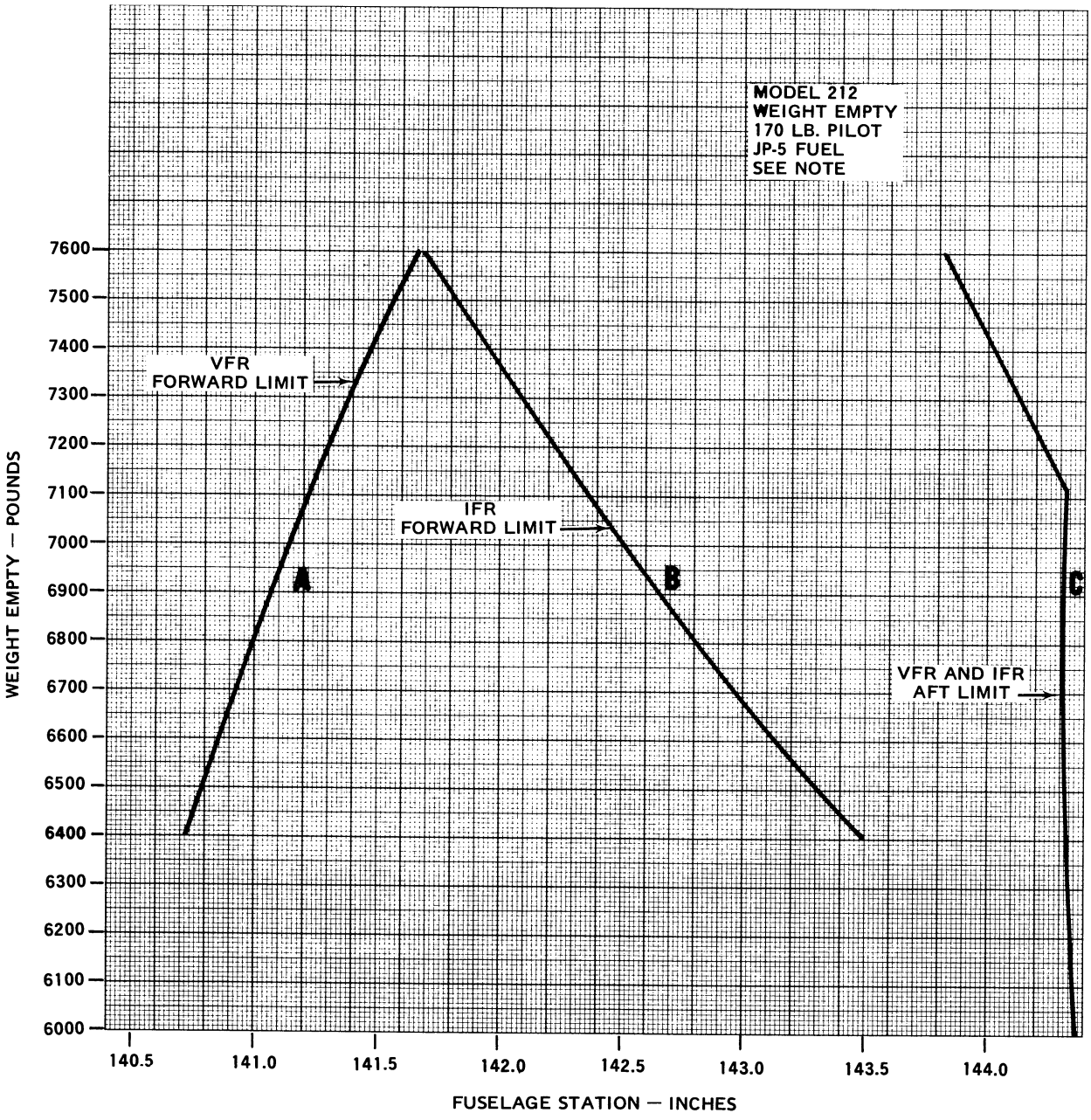
5. Install ballast inside tail skid as follows:

a. Remove weight and record tail skid weight.

b. Remove phenolic plug from forward end of tail skid.

c. Completely fill tail skid with lead shot.

d. Install phenolic plug in forward end of tail skid and reweight tail skid. Determine amount of ballast added (subtract tail skid empty weight from filled tail skid weight). Stencil forward end of tail skid, and inboard



NOTES

1. **This chart to be used for all configurations except when the following kits are installed.**

    1. **Auxiliary fuel 205-706-044**
    2. **Auxiliary fuel 205-706-045**
    3. **Auxiliary fuel 212-899-243**
    4. **Emergency flotation 212-706-021**
    5. **Floats 205-706-050**

2. **Use this chart when 212-706-032 or 212-706-042 float kit is installed.**

212-M-8-3

Figure 8-3. Weight empty center of gravity

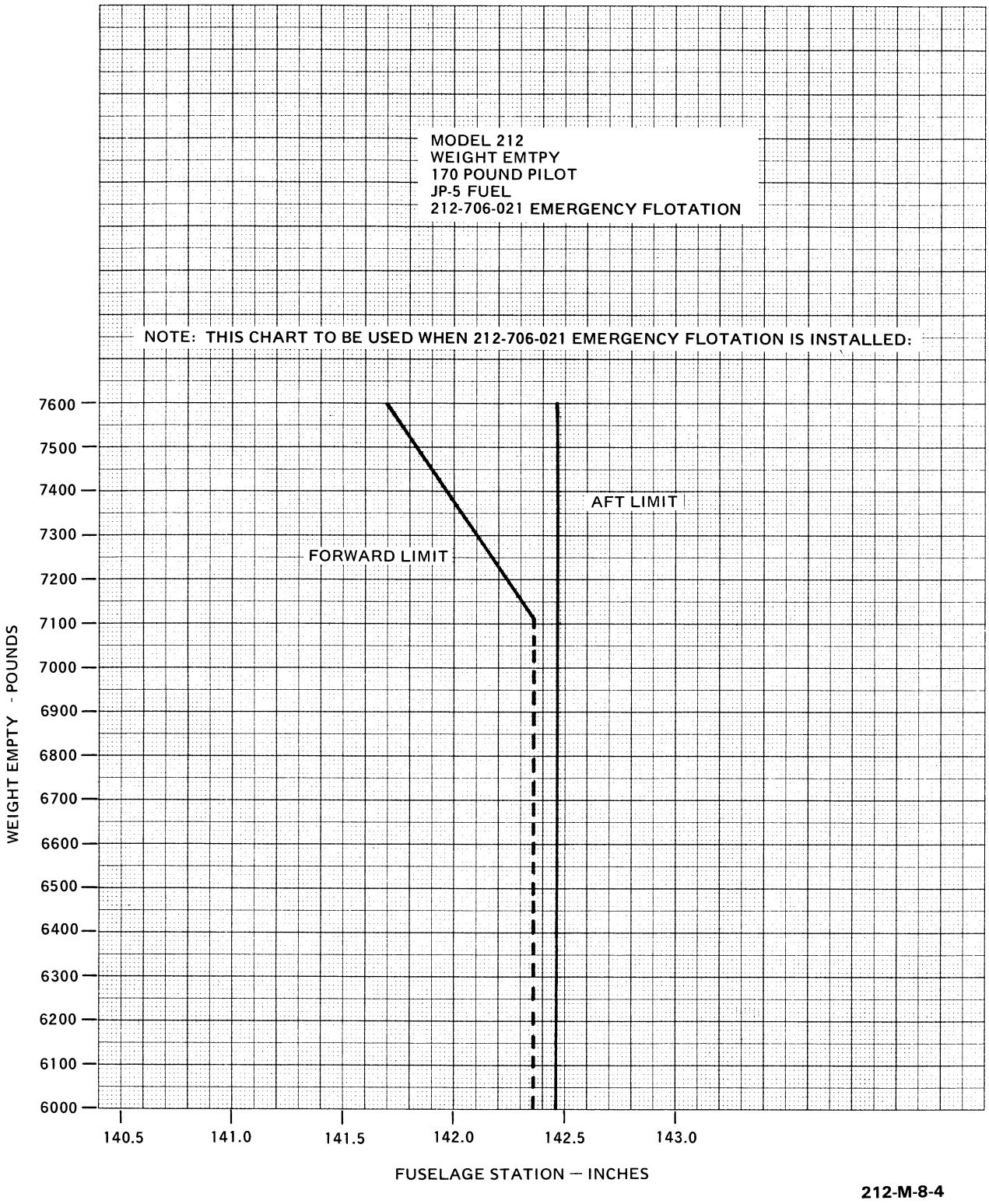
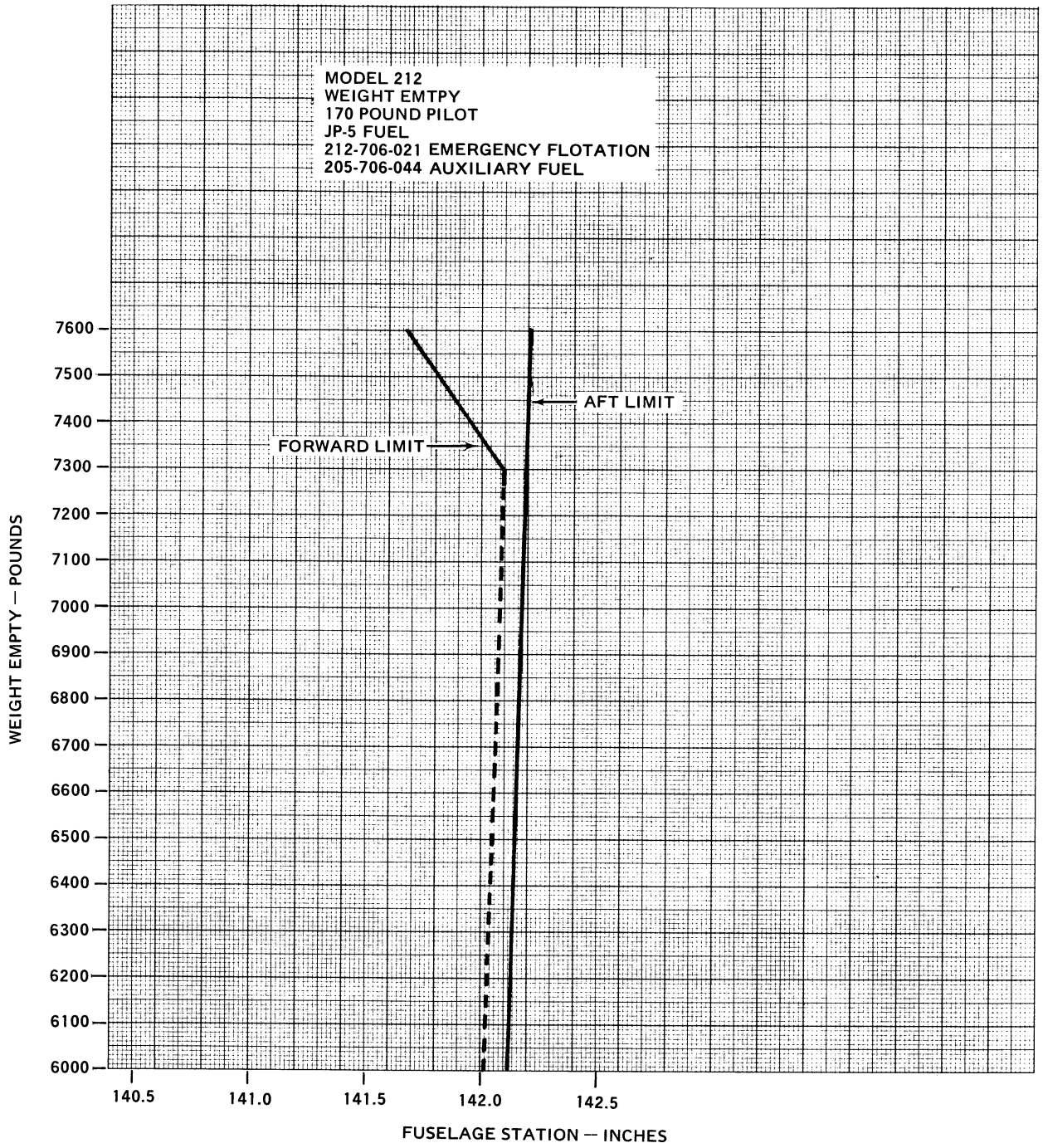


Figure 8-4. Weight empty center of gravity with emergency flotation, 212-706-021



NOTE

This chart to be used when emergency flotation 212-706-021 and auxiliary fuel tanks 205-706-044 are installed.

212-M-8-5

Figure 8-5. Weight empty center of gravity with emergency flotation, 212-706-021, and auxiliary fuel tanks, 205-706-044

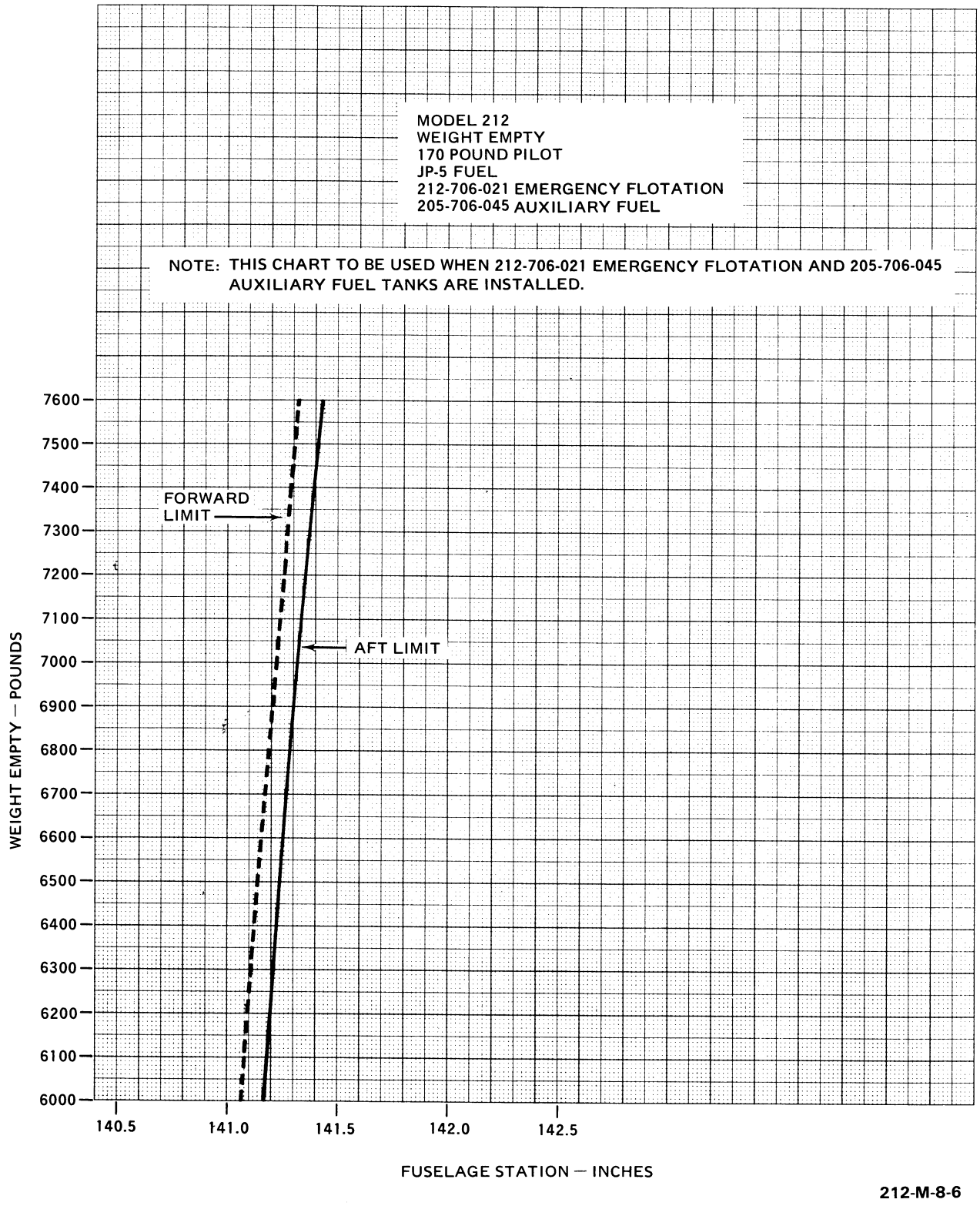


Figure 8-6. Weight empty center of gravity with emergency flotation, 212-706-021, and auxiliary fuel tanks, 205-706-045

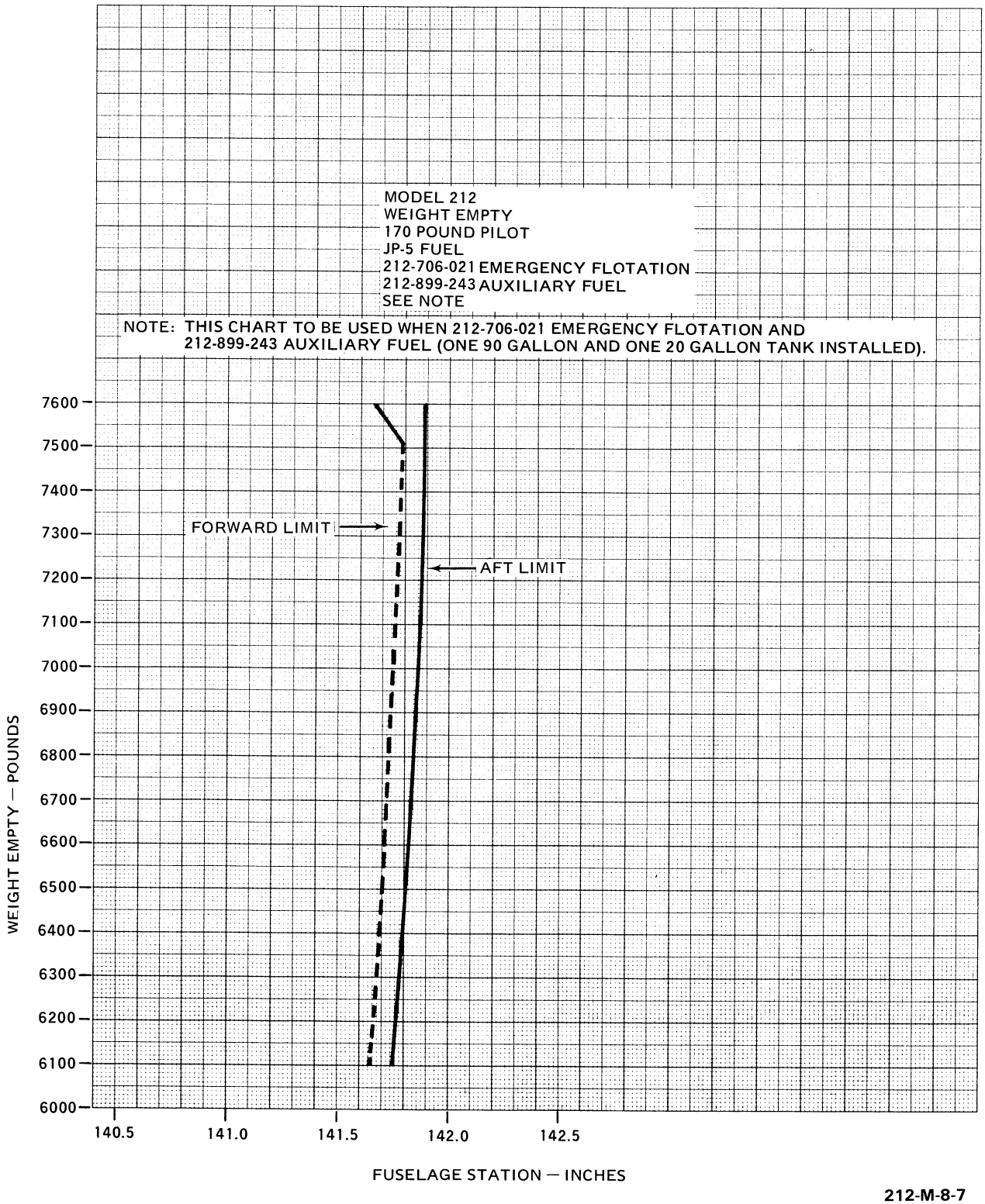


Figure 8-7. Weight empty center of gravity with emergency flotation and auxiliary fuel tanks, 212-899-243 (one 90 and one 20 gallon tank installed)

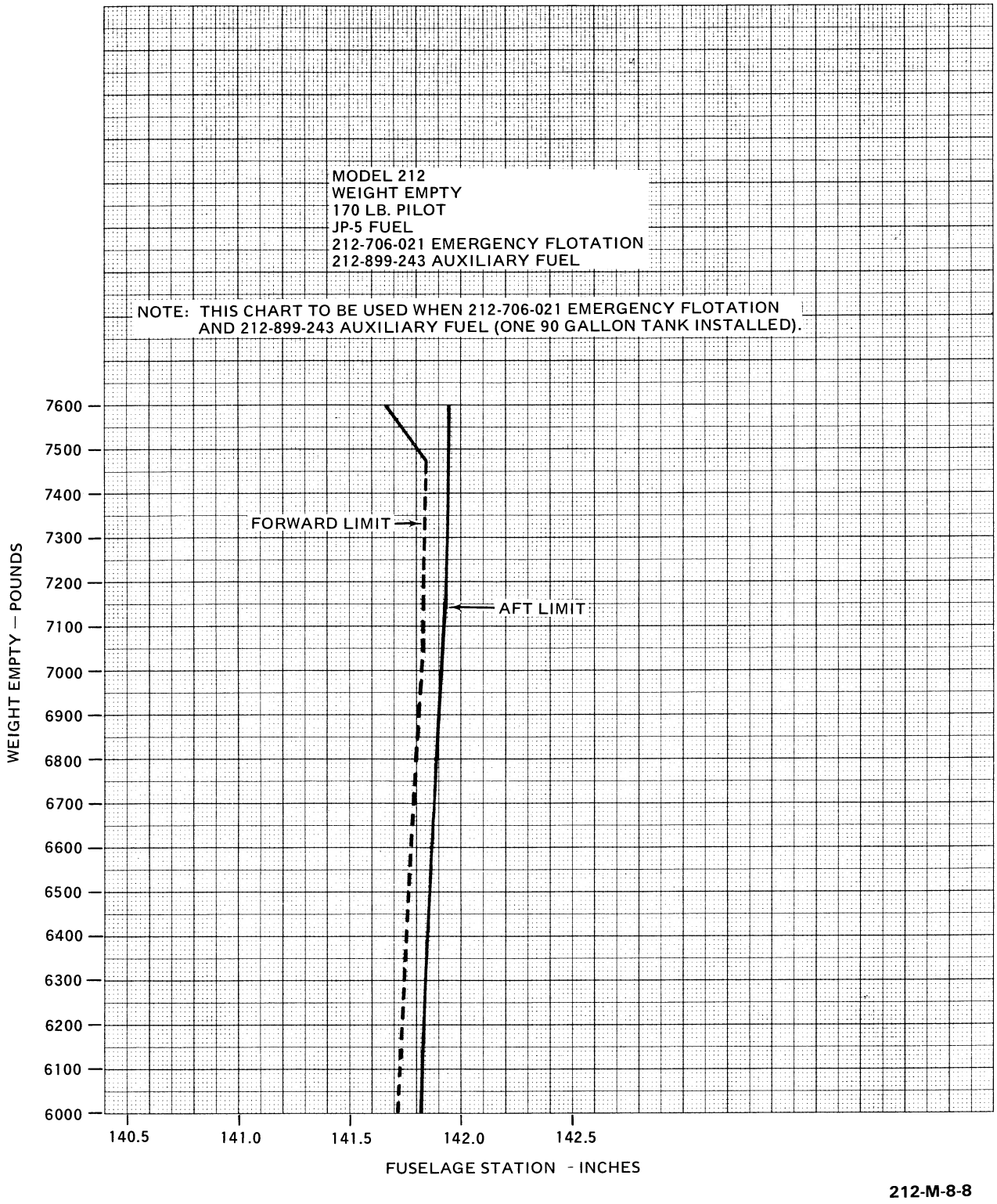
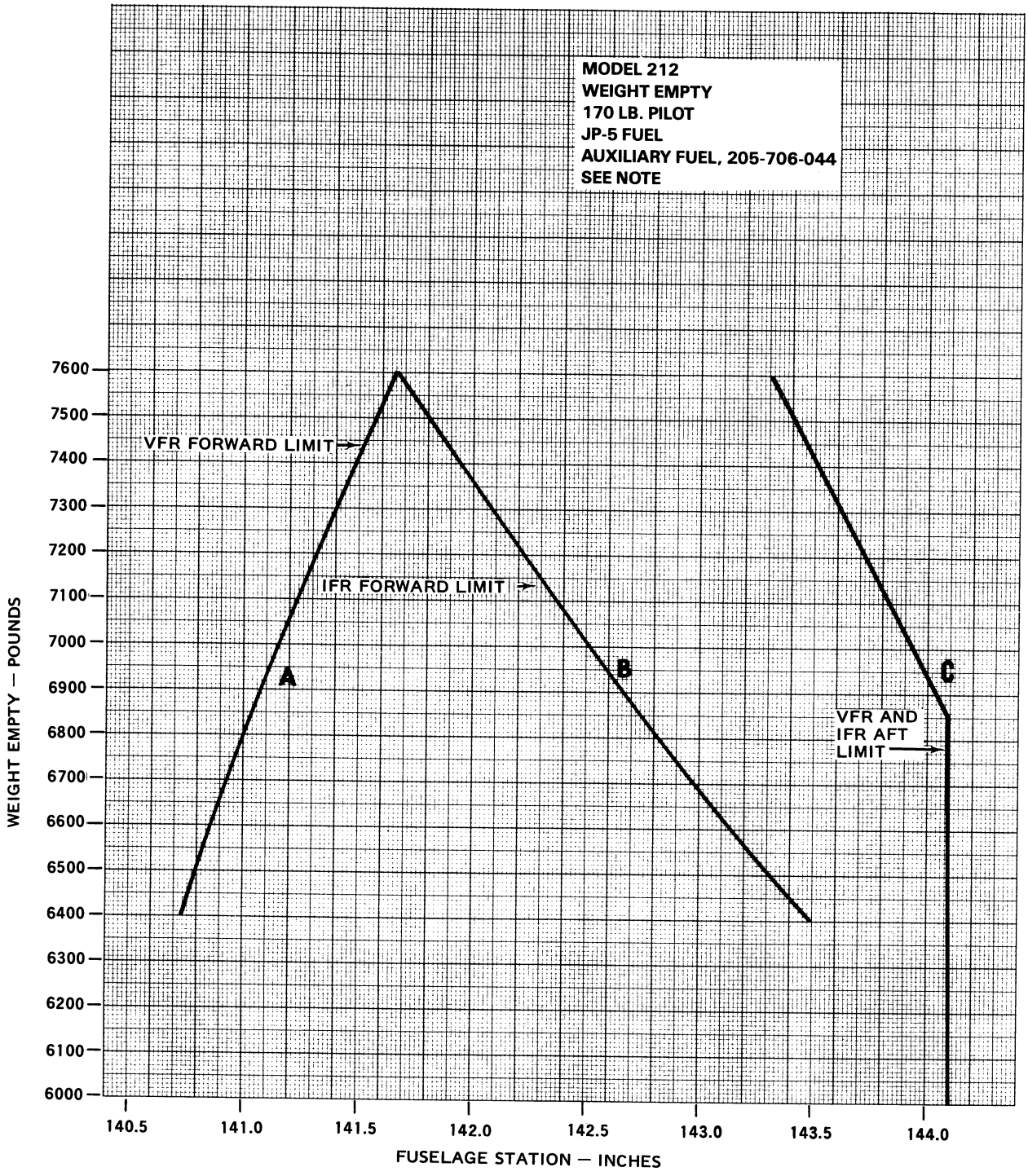


Figure 8-8. Weight empty center of gravity with emergency flotation, 212-706-021, and auxiliary fuel tank, 212-899-243 (one 90 gallon tank installed)

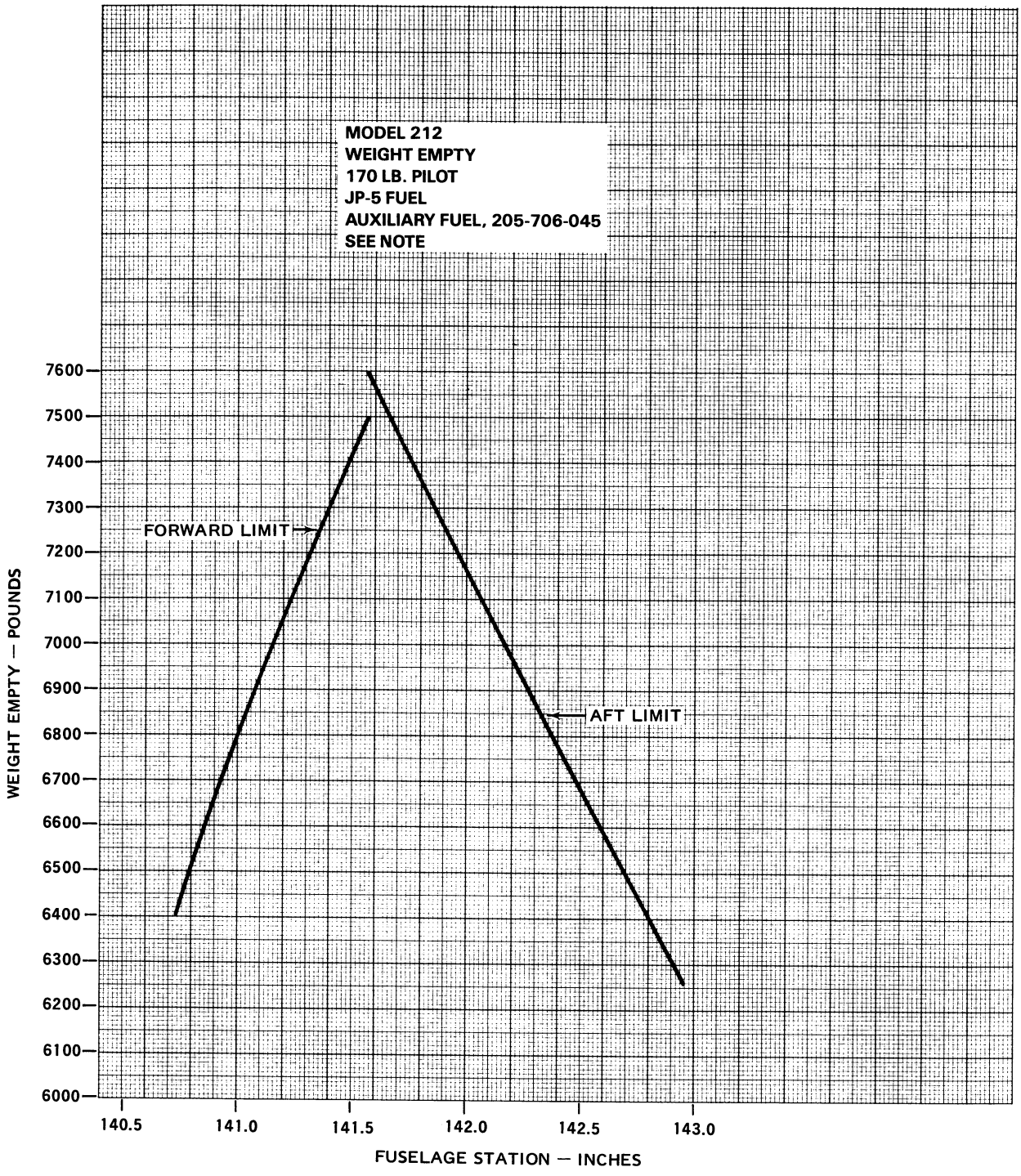


NOTE

Do not use this chart when emergency flotation, 212-706-021 or floats, 205-706-050 are installed.

212-M-8-9

Figure 8-9. Weight empty center of gravity with auxiliary fuel tanks, 205-706-044

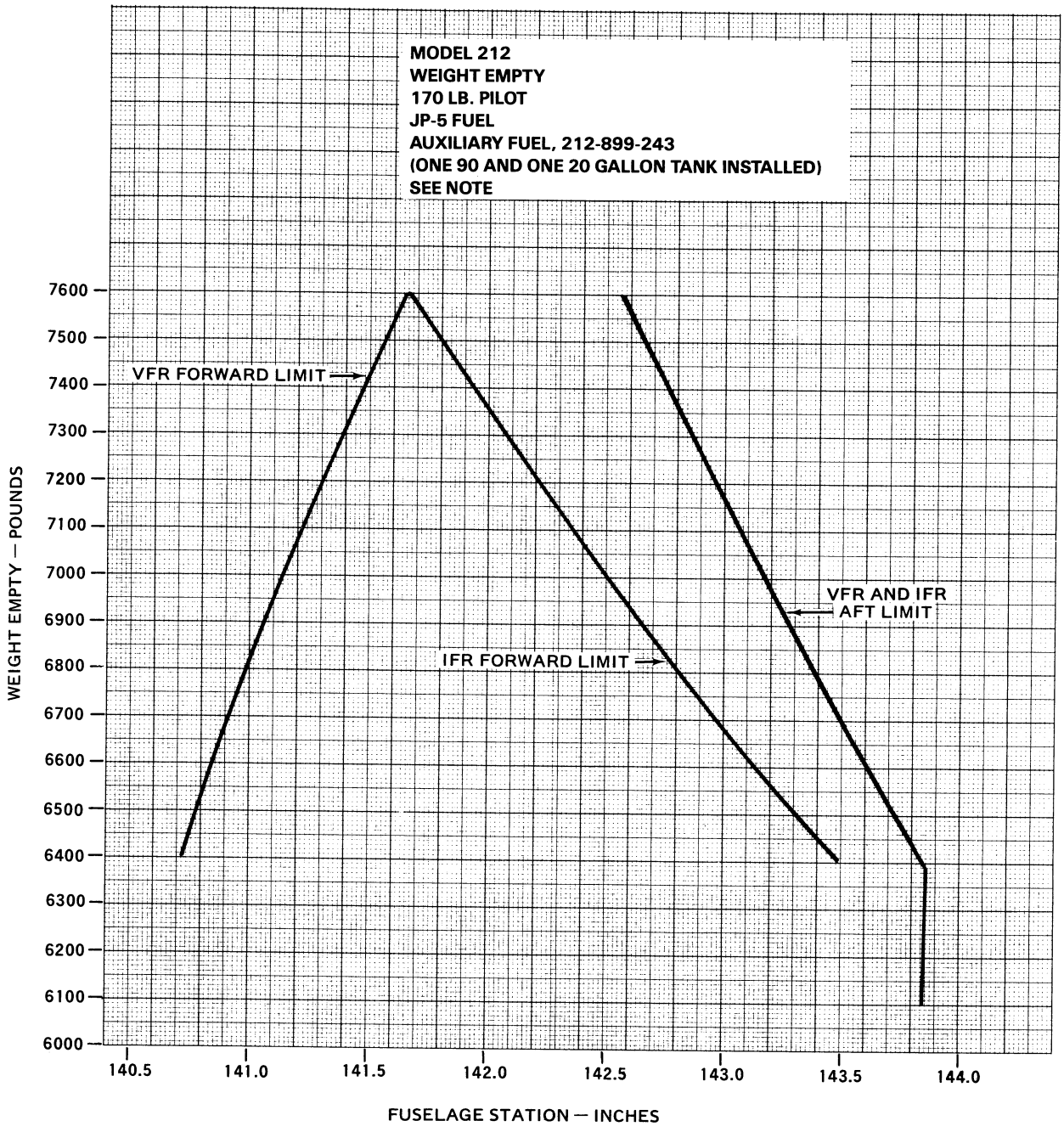


NOTE

Do not use this chart when emergency flotation, P/N 212-706-021 or floats, P/N 205-706-050 are installed.

212-M-8-10

Figure 8-10. Weight empty center of gravity with auxiliary fuel tanks, 205-706-045



NOTE

Do not use this chart when emergency flotation, 212-706-021 or floats, 205-706-050 are installed.

212-M-8-11

Figure 8-11. Weight empty center of gravity with auxiliary fuel tanks, 212-899-243 (one 90 and one 20 gallon tank)

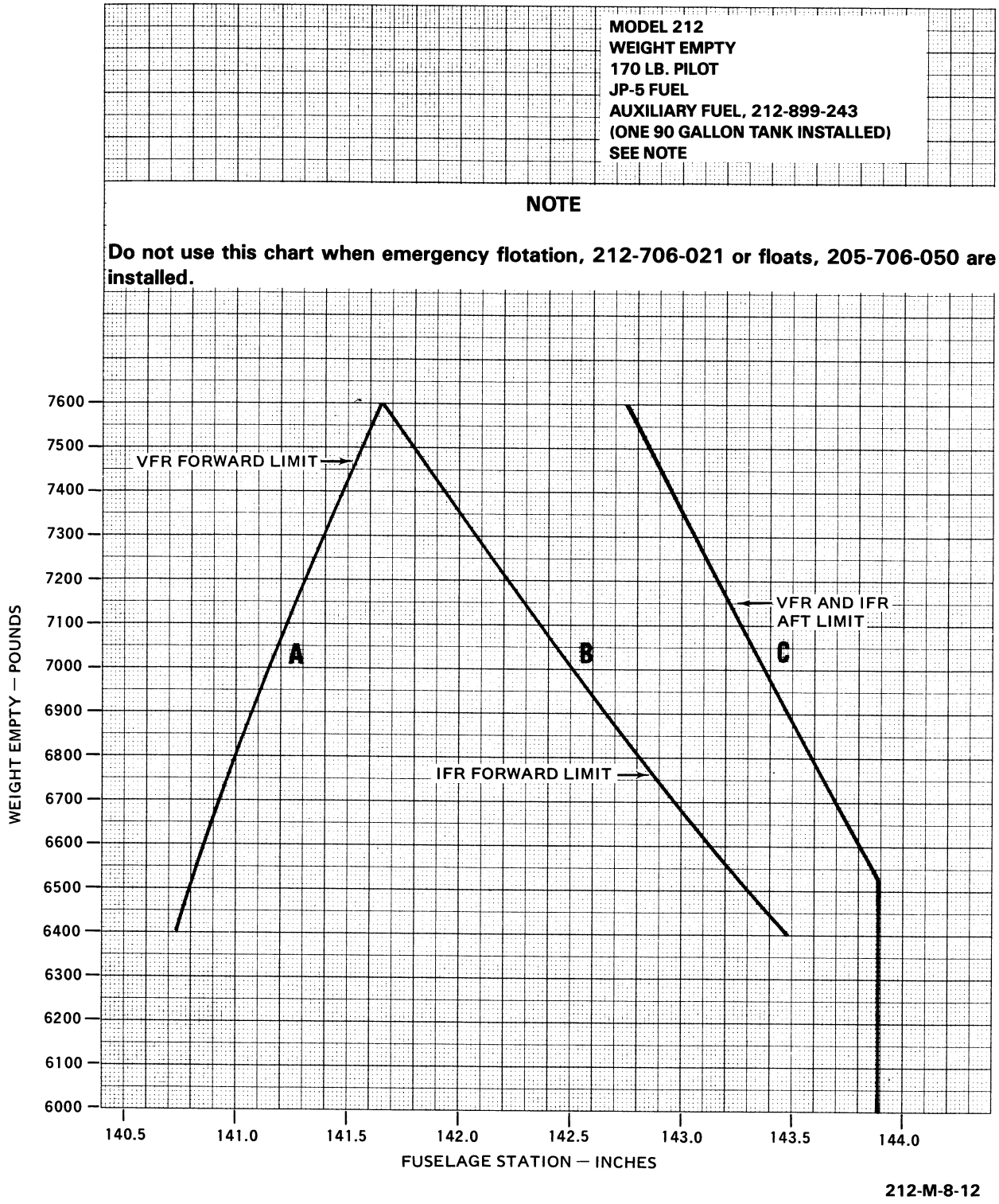


Figure 8-12. Weight empty center of gravity with auxiliary fuel, 212-899-243 (one 90 gallon tank installed)

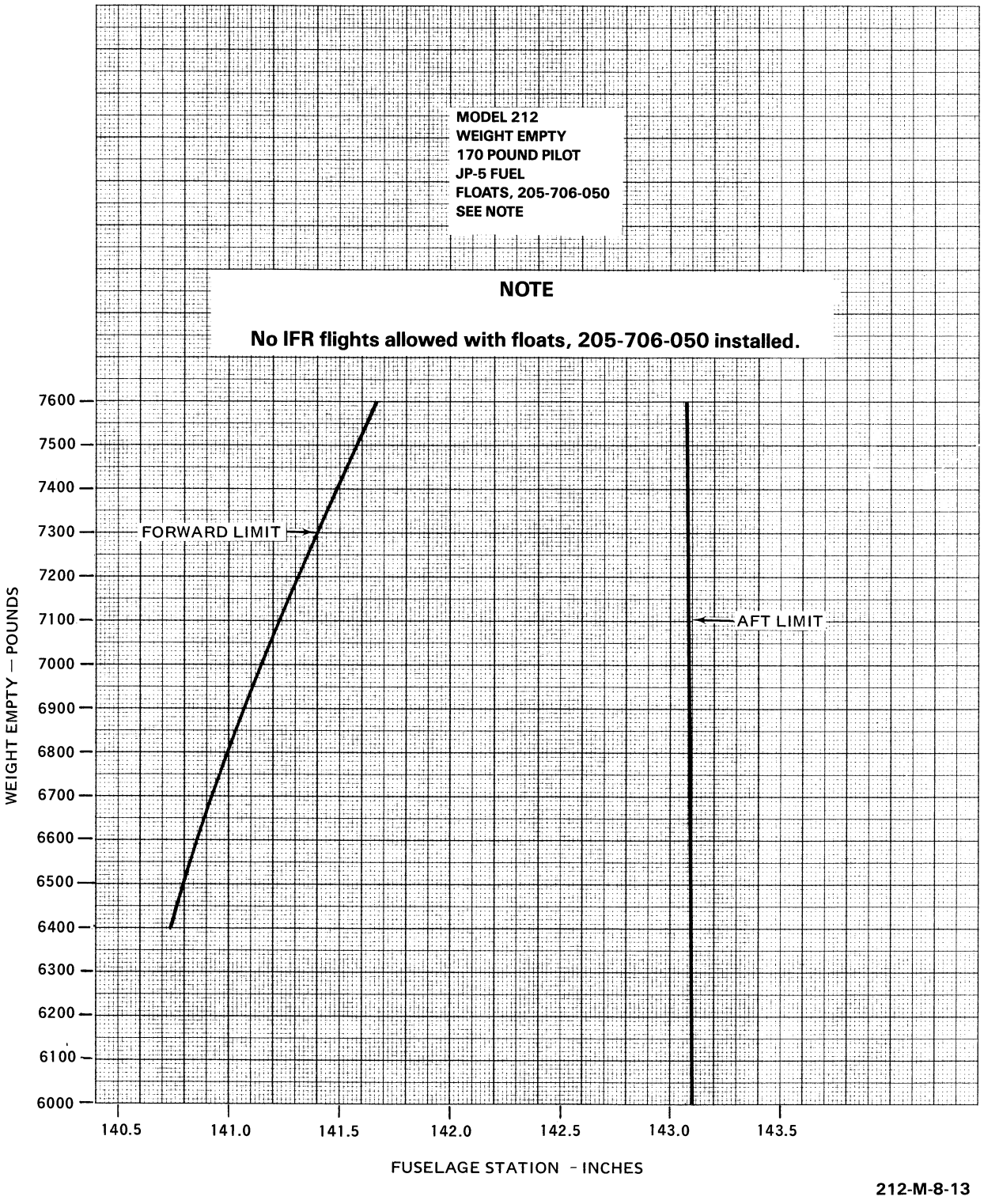
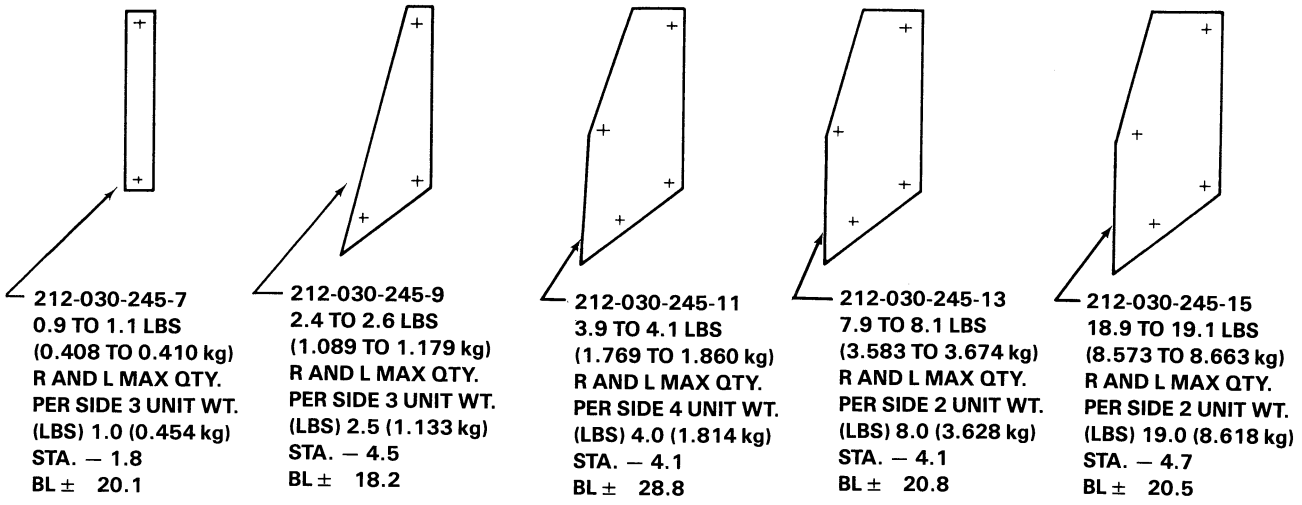
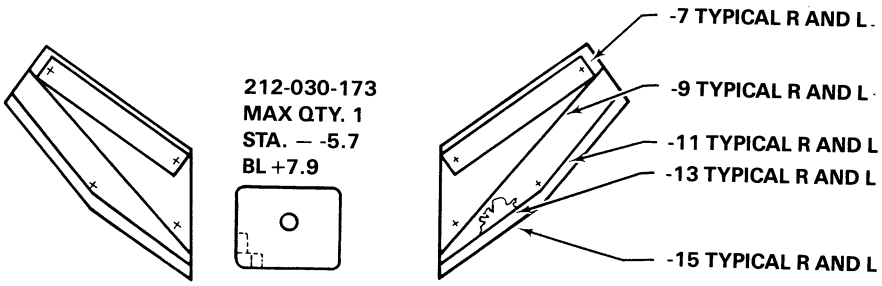
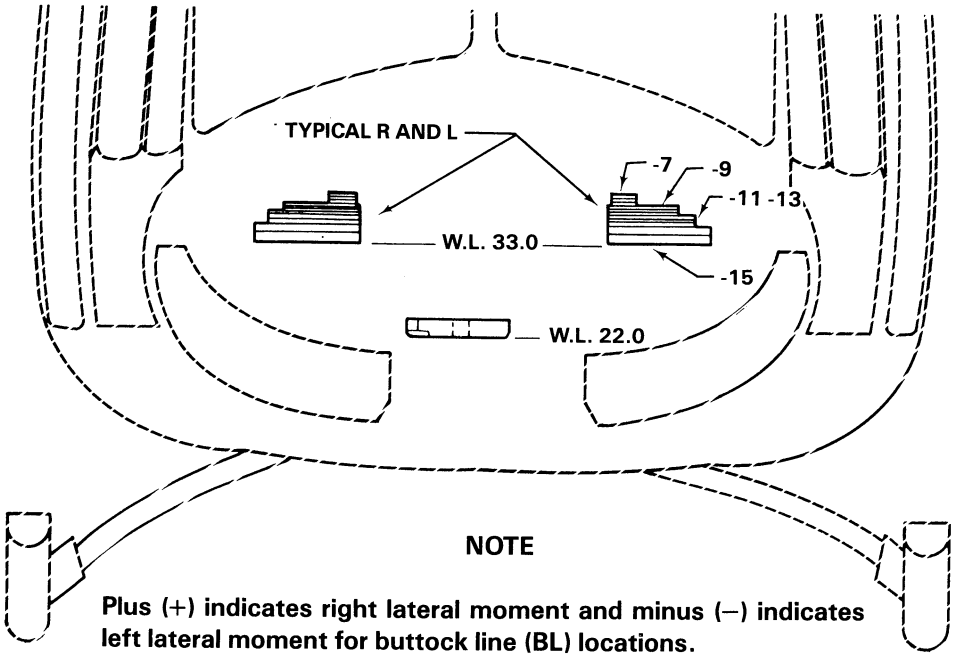


Figure 8-13. Weight empty center of gravity with floats, 205-706-050





ACTUAL WEIGHT IS STAMPED ON EACH WEIGHT, 212-030-173

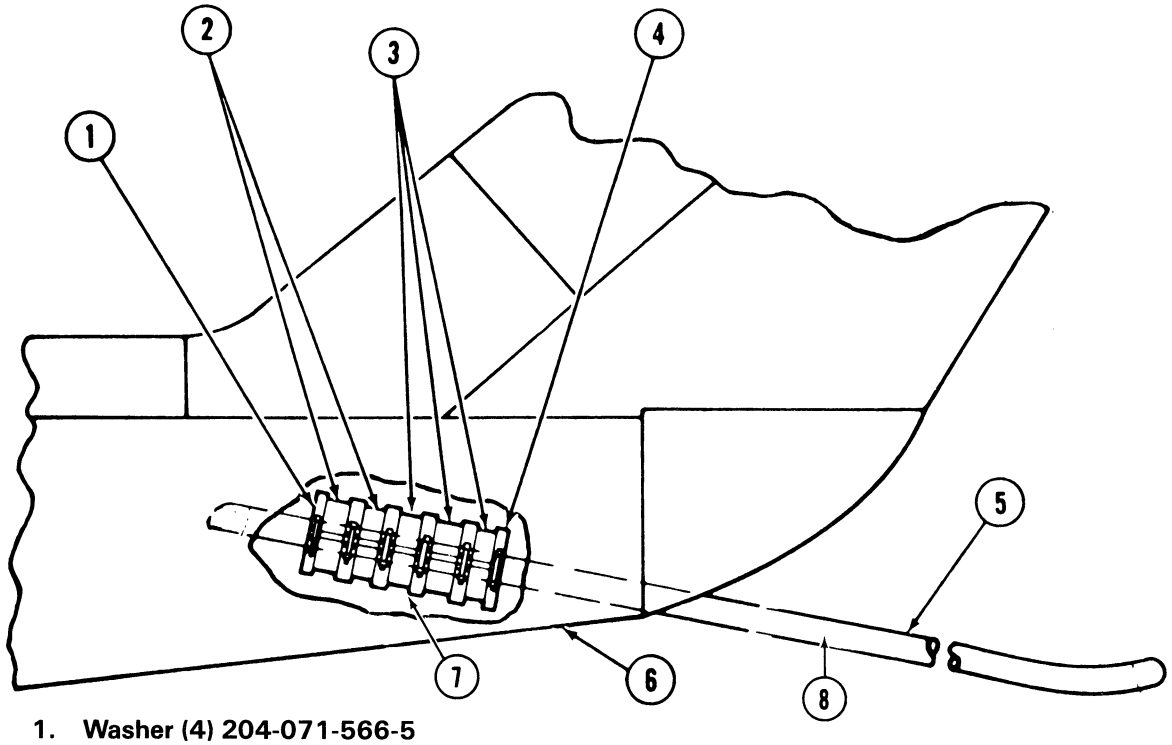


NOTE

Plus (+) indicates right lateral moment and minus (—) indicates left lateral moment for buttock line (BL) locations.

212-M-8-14

Figure 8-14. Nose ballast



1. Washer (4) 204-071-566-5
2. Ballast (2) 204-071-566-3 } Nominal weight each 6.3 pounds (2.86 kg)
3. Ballast (3) 204-071-566-1 }
4. Clamp (6) 204-040-811-1
5. Tail skid
6. Tailboom
7. Center of ballast location, approximately F.S. 441.0
8. Center of gravity for lead shot, approximately F.S. 457.0

212-M-8-15

Figure 8-15. Tail skid ballast

side of each tail skid access panel with actual weight of ballast added.

e. Install tail skid.

f. Add additional ballast, as required, not to exceed 50 pounds (22.68 kg) total ballast.

8-9. WEIGHT AND BALANCE SAMPLE PROBLEM.

The sample Actual Weight Record (figure 8-16) can be used as a guide to follow a helicopter from weighing to weight and balance check with intermediate steps to change Weight Empty configuration.

The "As Weighed" condition (paragraph 8-3) is shown in the block at top of Actual Weight Record. "Net" weight is 'Scale' weight less tare.

Center of gravity determination (paragraph 8-4) is shown directly below the 'As Weighed' block.

This helicopter is assumed to be dry so all Weight Empty fluids shall be added in determining Derived Weight. These fluids include hydraulic fluid and all transmission and gearbox oils together with unusable fuel and undrainable engine oil. This helicopter was originally weighed without seats. Therefore, seat weight shall be added. These items added to 'As Weighed' comprise "Derived Weight" and CG to be used in determining ballast required. The "Derived Weight" is 5954.2 lbs. (2700.8 kg) and the CG is F.S. 147.05. Using the formula in paragraph 8-5 , step 4:

$$\frac{5954.2\ (\text{Required CG} - 147.05)}{\text{Ballast Arm} - \text{Required CG}} = \text{Ballast}$$

Required CG is located by using figure 8-3 . Assume approximately 100 lbs. (45.36 kg) ballast and use a CG within Desired CG Range for new weight (5954+100). A reasonable ballast arm is -5. Thus:

$$\frac{5954.2\ (144.35-147.05)}{-5-144.35} = \text{Ballast}$$

$$\frac{5954.2(-2.7)}{-149.35} = 108 \text{ lbs.}$$

Figure 8-14 presents ballast weights and locations. The ballast selected should be placed as symmetrically as possible and amount used shall not be less than amount necessary to ensure satisfactory CG location.

In this case four 212-030-245-15 plates of 19 lbs. (8.62 kg) each and four 212-030-245-13 plates of 8 lbs. (3.63kg) each equals the 108 pounds (48.98kg) derived above. The moment for this ballast is -488 in.lbs. The Derived Weight and Moment plus Ballast Weight and Moment is Weight Empty Weight and Moment. The Weight Empty Moment divided by Weight Empty Weight is Weight Empty CG. This addition indicates the helicopter weighs 6062.2 with a 144.35 CG. A recheck on figure 8-3 indicates a satisfactory operating condition.

Further calculations on the Actual Weight Record will confirm operation is within flight limits.

Sample flight calculations demonstrating fuel burn, off-loading passengers, etc., are presented in Model BHT-212-FM A different Weight Empty and CG was used but the principle is the same.

The configuration of the helicopter will probably change several times due to addition of kits, engine change, etc. refer to the following examples:

BELL HELICOPTER TEXTRON
ACTUAL WEIGHT RECORD
MODEL 212

DATE WEIGHED 8-13-74 SERIAL NUMBER 30XXX

SCALE READINGS (LBS.) SKID		CONFIGURATION	SCALE	TARE	NET
FORWARD JACKPOINT, F.S.	61.69	B.L. - 30.0	480	95	385
FORWARD JACKPOINT, F.S.	61.69	B.L. + 30.0	2087	100	1987
AFT JACKPOINT, F.S.	211.58	B.L. ± 14.53	3495	199	3296
		TOTAL	6062	394	5668

*IN LATERAL CALCULATIONS
- IS LEFT
+ IS RIGHT

LONGITUDINAL C.G., AS WEIGHED

$$C.G. = \frac{61.69\ (2372) + 211.58\ (3296)}{\text{TOTAL WEIGHT}} = \frac{843696}{5668} = 148.85 \text{ IN.}$$

LATERAL C.G., AS WEIGHED*

$$C.G. = \frac{-30.0\ (385) + 30.0\ (1987) - 14.53\ (3296)}{\text{TOTAL WEIGHT}} = \frac{+169}{5668} = +0.03 \text{ IN.}$$

WEIGHT EMPTY DERIVATION	WEIGHT	LONGITUDINAL ARM	LONGITUDINAL MOMENT	LATERAL* ARM	LATERAL* MOMENT
AS WEIGHED	5668.0	148.85	843696	+0.03	+169
ADD: Unusable Fuel	+ 28.3	142.8	+4041	0	0
Undrainable Oil	+ 7.1	230.7	+1630	0	0
Combining G/B Oil	+ 13.7	220.2	+3017	0	0
Xmsn & G/B Oil	+ 27.3	172.9	+4721	0	0
Hydraulic Fluid	+ 15.6	129.4	+2018	-1.9	-30
Crew Seats	+ 73.6	54.0	+3974	0	0
Passenger Seats	+ 121.4	104.3	+12662	0	0
BALLAST	+108.0	-4.5	-488	0	0
WEIGHT EMPTY, SKID CONFIG.	6063.0	144.36	875271	+0.02	+139

MOST FORWARD C.G.

WEIGHT EMPTY	6063.0	144.36	875271	+0.02	+139
+ PILOT AND COPILOT	+ 340.0	47.0	+ 15980	0	0
+ PASSENGERS (4), CENTER SEAT, FACING AFT	+ 680.0	87.0	+ 59160	0	0
+ PASSENGERS (5), BACK SEAT, FACING FWD.	+ 850.0	117.0	+ 99450	0	0
+ OIL, ENGINE	+ 24.5	169.1	+ 4146	0	0
+ FUEL, MOST FORWARD	+ 472.0	127.6	+ 60227	0	0
	8429.5	132.2	1114234	+0.02	+139

MOST AFT C.G.

WEIGHT EMPTY	6063.0	144.36	875271	+0.02	+139
+ PILOT	+ 170.0	47.0	+ 7990	+ 22.0	+ 3740
+ OIL, ENGINE	+ 24.5	169.1	+ 4146	0	0
+ FUEL @ 6.5 #/GAL.	1409.2	153.3	216066	0	0
	7666.7	143.9	1103473	+0.51	+3879

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212-M-8-16

Figure 8-16. Actual weight record sample

Changes made as a result of configuration changes shall be documented and a current Weight Empty and CG shall be available at all times. The following demonstrates steps necessary when changes are made.

The following is the basic helicopter with dual controls, copilot instruments, and emergency floatation added:

	Weight	Longitudinal	Lateral		
Previous weight Empty	6063.0	144.36	875271	+ 0.02	+139
Add: Dual controls	+ 22.2	36.10	+ 801	-22.50	-500
Copilot instruments	+ 20.1	10.80	+ 218	-15.10	-304
Emergency flotation	+579.0	89.00	+51531	+ 0.90	+521
Derived Weight	6684.3	138.80	927821	-0.02	-144

A check on figure 8-3 shows the CG to be too far forward indicating a need for removal of nose ballast. The ballast computation formula may be used or trial and error is acceptable.

In this case, removal of previously added 108 lbs. (48,98 kg) is acceptable.

Weight Empty	-108.0		+488		-
	6576.3	141.16	928309	-0.02	-144

A recheck on figure 8-3 verifies this CG at indicated weight to be acceptable.

The above sample data has not covered lateral CG. The method of calculating lateral CG is shown on the Actual Weight Record. Maximum asymmetric limits are shown in BHT-212-FM and will not be approached unless extreme lateral payload position is encountered.

If it is necessary to load in this manner, a lateral check should be made.