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Aviation Safety, Eastern Region

Date: December 4, 2024

Subject: ERA23FA087, Fuel Burn Calculation

A calculation of in-flight fuel consumption was completed by the NTSB. The results are as follows:

Aircraft Registration: N74586

Make/ Model: Mooney M20B

Manufacturing Year: 1961

Engine: Lycoming O-360-A1D

Known Engine Mod: STC SA1156WE, Rayjay Turbocharger system

Fuel Tank Mod: STC SA2350CE, Wing bladders

A review of Automatic Dependent Surveillance-Broadcast data (ADS-B) flight data revealed a takeoff time of 09:25 Central Daylight Time (CDT) on December 13, 2022 with the airplane leveling off at 09:37 at an altitude of about 6000 ft mean sea level (MSL). Total time in the climb was 12 minutes. The airplane remained at 6000 ft MSL until 10:18 when the pilot reported a rough-running engine, for a total cruise time of 41 minutes.

At 10:18, the airplane began a descent from 6000 ft MSL, and ADS-B signal was lost at 10:25 at about 1400 ft MSL. Total recorded descent time as indicated by ADS-B was 7 minutes. The state of the engine was unknown during the descent, but estimated fuel consumption calculations only account for the time up to the pilot's initial call of a rough running engine, after 41 minutes of cruise flight.

The airplane had a Lycoming O-360-A1D, one of two model engines utilized in the M20B. A 1967 Mark 21 Model M20C Owner's Manual was found onboard the airplane, and a 1961 Mooney Mark 21 M20B Owner's Manual was also referenced for estimations. Although the M20B manual states that the airplane has an A1A engine, according to the manufacturer, there is no difference in performance from the A1A to A1D install. Per Lycoming Special Service Publication SSP-110-2, the only difference between the A1A and the A1D is retard breaker magnetos on the A1D.

The engine was equipped with a Rayjay Turbocharger Supplemental Type Certificate (STC), SA1156WE, in 1968. On page 8 of the Airplane Flight Manual Supplement for the STC, the only performance information provided states, "under turbocharged conditions, all performance is as good or better than that shown in the basic manual for corresponding altitudes." The cover page further describes that "for limitations, procedures and performance information not contained in this supplement, consult the basic Pilot's Operating Handbook."

The airplane was also modified with STC SA2350CE to install bladder type wing fuel cells in 1991. However, the M20B model Mooney is not listed on the STC's applicable model airplanes. While the STC should allow the airplane to carry 54.8 gallons of usable fuel and 2.5 gallons of unusable fuel, the total capacity of the wing bladder tanks on this model airplane is not represented in the STC and can therefore not be definitively determined.

On Page 26 of the M20B Mark 21 Owner's Manual, section 3 under the "Cruise Charts", states that "during fifteen minutes of climb, the engine will consume 3.5 gallons of fuel" for a consumption rate of 0.23 gallons per minute. It also states that one half or 0.5 gallons of fuel should be assumed for taxi.

The following calculation used the provided fuel consumption rate of 10.1 gallons per hour (gph), or 0.168 gallons per minute (gpm), found in the "Normal Cruise Chart" of the M20B manual. It is an estimate only and does not consider variations in leaning, atmospheric conditions, or winds during climb and cruise flight.

Taxi: 0.50 Gallons

Takeoff and climb: (12 minutes) X (0.23 gpm) = 2.76 Gallons

Cruise at 6000 Ft: (41 minutes) X (0.168 gpm) = 6.89 Gallons

Total estimated fuel consumed from engine start to initial engine issues: **10.15 Gallons**

The Mark 21 M20C manual does not include expected taxi and climb fuel consumption numbers. For the following calculation 0.50 gallons will again be assumed

for taxi and 0.23 will again be used for climb consumption. The M20C manual provides cruise fuel consumption for multiple altitudes and engine settings. Cruise calculations were made given best-case and worst-case scenarios to provide an estimated maximum and minimum for 6000 ft. The maximum fuel burn calculation used 2600 RPM and maximum manifold pressure (MP), and minimum fuel burn calculation used 2300 RPM and minimum MP.

The following calculation used the interpolated value of 12.46 gph or 0.208 gpm for a maximum fuel burn.

Taxi: 0.50 Gallons

Takeoff and climb: (12 minutes) X (0.23 gpm) = 2.76 Gallons

Cruise at 6000 Ft: (41 minutes) X (0.208 gpm) = 8.53 Gallons

Total estimated fuel consumed from engine start to initial engine issues: 11.79 Gallons

The following calculation used the interpolated value of 9.18 gph or 0.153 gpm for a minimum fuel burn.

Taxi: 0.50 Gallons

Takeoff and climb: (12 minutes) X (0.23 gpm) = 2.76 Gallons

Cruise at 6000 Ft: (41 minutes) X (0.153 gpm) = 6.273 Gallons

Total estimated fuel consumed from engine start to initial engine issues: 9.533 Gallons

While it is likely that the actual fuel consumption fell somewhere in between these numbers, neither number comes close to the amount of fuel that could have been available if the fuel tanks had been filled to their full reported capacity of 27.4 gallons in each tank. Because the right fuel bladder was discovered intact with no sign of fuel blighting or drainage, the most likely reason for fuel starvation is that the airplane was not actually fueled between flights and the pilot did not check or did not notice during his preflight. The incorrect registration number on the fuel receipt that the pilot received before his flight further lends to the fuel state before the accident flight remaining unknown.

Appendices

Appendix 1: STC SA1156WE Airplane Flight Manual Supplement, pages 1 and 8

Appendix 2: STC SA2350CE Airplane Supplemental Flight Manual pages 3 and 4

Appendix 3: 1967 Mooney Mark 21 M20C Owner's Manual, pages 38 and 39

Appendix 4: Lycoming SSP-110-2 page 7

Appendix 5: 1961 Mooney Mark 21 M20B Owner's Manual pages 26 and 28

Appendix 1: STC SA1156WE Airplane Flight Manual Supplement

Roto-Master, Inc.
7101 Fair Avenue
North Hollywood, CA 91605
Supplement No. One

FAA APPROVED
AIRPLANE FLIGHT MANUAL SUPPLEMENT
TO
MOONEY M20A, B, C, D and G
PILOT'S OPERATING HANDBOOK
AND FAA APPROVED AIRPLANE
FLIGHT MANUAL

This supplement must be attached to the Pilot's Operating Handbook when the airplane is modified by the installation of a Roto-Master (Rajay) Turbocharger System in accordance with STC SA1156WE.

The information contained herein supplements, or supersedes the basic handbook only in those areas listed. For limitations, procedures and performance information not contained in this supplement, consult the basic Pilot's Operating Handbook.


Supervisor, Flight Test Section
FAA Aircraft Certification Office
N. W. Mountain Region
Hawthorne, CA. 90250

FAA APPROVED DATE: FEB 14, 1985

Roto-Master, Inc.
7101 Fair Avenue
North Hollywood, CA 91605
Supplement No. One

Mooney M20A, B, C, D and G
P.O.H. Supplement
STC No. SA1156WE

- With turbocharger control left in the selected position, manipulate the throttles in a normal manner to continue the approach and landing.
- In the event execution of a go-around is required, advance the throttle lever to obtain desired manifold pressure.

CAUTION - Do not exceed 28.5 inches MAP

Performance

Under turbocharged conditions, all performance is as good or better than that shown in the basic manual for corresponding altitudes.

FAA APPROVED DATE	<u>February 3, 1966</u>
REVISION	<u>August 2, 1979</u>
REVISION DATE	<u>FEB 14 1985</u>

Appendix 2: STC SA2350CE Airplane Supplemental Flight Manual

O&N Aircraft Modifications, Inc.
Seamans Airport, Factoryville, PA 18419

Flight Manual Supplement
Mooney M20C, D, E, G

I. GENERAL:

FUEL

Total Fuel Capacity: 57.3 U.S. Gallons
Usable Fuel Capacity: 54.8 U.S. Gallons

Minimum Fuel Octane Rating and Color

Grade	Color
100	Green
100LL	Blue

II. LIMITATIONS:

FUEL LIMITATIONS:

2 Standard Tanks: 28.65 U.S. Gallons Each
Total Fuel: 57.3 U.S. Gallons
Usable Fuel: 54.8 U.S. Gallons
Unusable Fuel: 2.5 U.S. Gallons

Fuel Grade (and color): 100 Minimum Grade Aviation Fuel (Green).
100LL (Low Lead) Aviation Fuel (Blue) with a lead content limited to
2 cc per gallon is also approved.

DECALS AND PLACARDS:

- INTERIOR

On Fuel Selector Valve below words **LEFT** and **RIGHT**

27.4 GAL.

- EXTERIOR

On Fuel Tank Caps:

FUEL - 100 (GREEN) OR
100LL (BLUE) MIN. OCT.
27.4 U.S. GAL

O&N Aircraft Modifications, Inc.
Seamans Airport, Factoryville, PA 18419

Flight Manual Supplement
Mooney M20C, D, E, G

III. EMERGENCY PROCEDURES:

No Change.

IV. NORMAL PROCEDURES:

No. Change.

V. PERFORMANCE:

Airplane range must be adjusted for increased fuel capacity with this installation.

VI. WEIGHT AND BALANCE:

PROBLEM FORM	WEIGHT	MOMENT
Current Aircraft Empty Weight		
Oil - 8 qt. @ 1.875 lbs./qt. (Sta. -11.5) [Sump Assumed Full for All Flights]		
*Pilot and Copilot Seats (#1 and #2)		
Left and Right Rear Seats (#3 and #4)		
Fuel (Max. Usable 54.8 Gal. [328.8 lbs.] @ Sta. 48.4)		
Baggage (Max 120 lbs. @ Sta. 95.5)		
Hat Rack (Max 10 lbs. @ Sta. 119.0)		
Loaded Aircraft Weight		
Total Moment		
*Obtain the moment/1000 value for each seat position [FWD, MID, or AFT] from the loading computation in the original flight manual		
Note 1: Refer to the original flight manual for basic CG moment envelope		

Appendix 3: 1967 Mooney Mark 21 M20C Owner's Manual

FIGURE 3A

CRUISE & RANGE DATA

WEIGHT=2200 LBS.: BEST POWER MIXTURE
52 GAL. USABLE FUEL; NO RESERVE FOR RANGE CALCULATIONS
STANDARD ATMOSPHERE

ALTITUDE 5000' MSL

R.P.M.	M.P. IN.HG.	B.H.P.	% B.H.P.	GAL. HOUR	LBS. HOUR	TRUE AIR SPEED	ENDUR. HR:MIN.	RANGE Statute MILES
2600	24.5	156	87	12.9	77.4	185	4:02	745
	24.0	152	84	12.5	75.0	182	4:10	757
	23.0	144	80	11.8	70.8	177	4:25	779
	22.0	136	76	11.1	66.6	170	4:41	795
2500	24.5	153	85	12.4	74.4	183	4:11	765
	24.0	149	83	12.1	72.6	180	4:18	774
	23.0	141	78	11.4	68.4	175	4:34	798
	22.0	133	74	10.7	64.2	168	4:52	816
2400	24.5	149	83	11.9	71.4	180	4:22	785
	24.0	145	81	11.5	69.0	178	4:31	803
	23.0	138	77	10.9	65.4	172	4:46	820
	22.0	130	72	10.2	61.2	166	5:05	844
2300	24.0	141	78	11.2	67.2	175	4:39	813
	23.0	133	74	10.5	63.0	168	4:57	831
	22.0	126	70	9.9	59.4	163	5:15	856
	21.0	118	66	9.3	55.8	157	5:35	877
1800*	16.9	69	38	5.9	35.6	113	8:49	996

* MAXIMUM RANGE
ACCURACY OF DATA IS $\pm 3\%$
EACH 100 LBS. CHANGE IN AIRPLANE WEIGHT
WILL AFFECT TAS BY 1.2 MPH.

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FIGURE 3B

CRUISE & RANGE DATA

WEIGHT=2200 LBS.: BEST POWER MIXTURE
52 GAL. USABLE FUEL; NO RESERVE FOR RANGE CALCULATIONS
STANDARD ATMOSPHERE

ALTITUDE 7500' MSL

R.P.M.	M.P. IN.HG.	B.H.P.	% B.H.P.	GAL. HOUR	LBS. HOUR	TRUE AIR SPEED	ENDUR. HR:MIN.	RANGE Statute MILES
2600	22.5	145	81	11.8	70.8	184	4:25	811
	22.0	140	78	11.5	69.0	180	4:31	813
	21.0	132	73	10.8	64.8	173	4:49	831
	20.0	124	69	10.2	61.2	167	5:06	852
2500	22.5	142	79	11.4	68.4	182	4:34	829
	22.0	137	76	11.0	66.0	177	4:43	836
	21.0	129	72	10.4	62.4	171	5:00	855
	20.0	121	67	9.8	58.8	164	5:19	870
2400	22.5	138	77	10.8	64.3	178	4:49	855
	22.0	134	74	10.6	63.6	175	4:55	859
	21.0	126	70	9.9	59.4	169	5:15	888
	20.0	118	66	9.3	55.8	161	5:35	900
2300	22.5	134	74	10.6	63.6	175	4:55	859
	22.0	130	72	10.2	61.2	172	5:06	877
	21.0	122	68	9.6	57.6	165	5:25	893
	20.0	114	63	9.0	54.0	158	5:46	912
1800*	16.8	72	40	6.0	36.0	117	8:40	1013

* MAXIMUM RANGE
ACCURACY OF DATA IS $\pm 3\%$
EACH 100 LBS. CHANGE IN AIRPLANE WEIGHT
WILL AFFECT TAS BY 1.2 MPH.

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Appendix 4: Lycoming SSP-110-2

PISTON – (4) FOUR CYLINDER SERIES						
Model	HP	T/O† RPM	Fuel	C.R. ■	Description	E S/N ▲ Suffix
O-340-A2A	170	2700	100/100LL	8.50:1	Same as –A1A but fixed pitch prop.	-30
O-340-B1A	160	2700	80	7.15:1	Low compression –A1A	-30
O-360-A1A	180	2700	100/100LL	8.50:1	Dynafocal mounts	-36
O-360-A1AD	180	2700	100/100LL	8.50:1	Same as –A1A but with D4LN-3000 impulse coupling Magnetos	-36
O-360-A1C	180	2700	100/100LL	8.50:1	Similar to –A1A but has horizontal induction housing, Bendix PSH-5BD pressure carburetor and Retard Breaker Magnetos	-36
O-360-A1D	180	2700	100/100LL	8.50:1	Same as –A1A except for Retard Breaker Magnetos	-36
O-360-A1F	180	2700	100/100LL	8.50:1	Same as –A1A with -1200 series Magnetos	-36
O-360-A1F6	180	2700	100/100LL	8.50:1	Same as –A1F but has (1) sixth and (1) eighth order counterweights	-36
O-360-A1F6D	180	2700	100/100LL	8.50:1	Same as –A1F6 but with D4LN-3000 impulse coupling dual Magneto	-36
O-360-A1G	180	2700	100/100LL	8.50:1	Similar to –A1F but has horizontal carburetor and induction housing	-36
O-360-A1G6	180	2700	100/100LL	8.50:1	Same as –A1G but has (1) sixth and (1) eighth order counterweights	-36
O-360-A1G6D	180	2700	100/100LL	8.50:1	Same as –A1G6 but with D4LN-3000 impulse coupling dual Magneto	-36
O-360-A1H	180	2700	100/100LL	8.50:1	Same as –A1G but with prop. governor drive on left front of crankcase and -21, -204 Magnetos	-36
O-360-A1H6	180	2700	100/100LL	8.50:1	Same as –A1H but has (1) sixth and (1) eighth order counterweights	-36
O-360-A1LD	180	2700	100/100LL	8.50:1	Similar to –A1A but with D4LN-3000 impulse coupling dual Magneto and has prop. governor drive on left front of crankcase	-36
O-360-A1P	180	2700	100/100LL	8.50:1	Same as –C1G except dynafocal mounts	-36
O-360-A2A	180	2700	100/100LL	8.50:1	Same as –A1A but fixed pitch prop.	-36
O-360-A2D	180	2700	100/100LL	8.50:1	Same as –A2A except for Retard Breaker Magnetos	-36
O-360-A2E	180	2700	100/100LL	8.50:1	Same as –A2D with provision for AN fuel pump drive	-36
O-360-A2F	180	2700	100/100LL	8.50:1	Same as –A2A with -1200 series Magnetos	-36
O-360-A2G	180	2700	100/100LL	8.50:1	Same as –A1G but fixed pitch prop.	-36
O-360-A2H	180	2700	100/100LL	8.50:1	Same as –A2H but fixed pitch prop.	-36
O-360-A3A	180	2700	100/100LL	8.50:1	Same as –A2A but has 6 special long bushings in prop. flange	-36
O-360-A3AD	180	2700	100/100LL	8.50:1	Same as –A3A but with D4LN-3000 impulse coupling dual Magneto	-36

† Take-Off ■ Compression Ratio ▲ Engine Serial Number

Appendix 5: 1961 Mooney Mark 21 M20B Owner's Manual

LEVEL-OFF PROCEDURES (CONT'D)

3. Reduce the manifold pressure and RPM to desired cruise setting.
4. Learn the mixture for smooth operation (reference Lycoming's Operators Manual, page 32-33).
5. Retrim to maintain altitude.

CRUISE CHARTS

The following cruise charts are provided to enable you to choose the altitudes and power settings which will give the best performance. Please keep in mind the following information:

1. When the throttle is in the "full-in" position, the automatic enrichment valve in the carburetor is open. The power settings in the normal cruise and performance charts include the symbol "FT". It means full throttle but retarded sufficiently to close the automatic enrichment valve.
2. The indicated airspeed column in the normal cruise and performance charts contains a low and a high speed range because the airspeed will vary with temperature changes. In summer, it will read on the low side; in winter, it will read on the high side.
3. The "range" column in all three charts does not take into consideration the extra fuel used for take-off and climb-out. The average fuel consumption in a climb from sea level to 10,000 feet is 14.0 GPH. During fifteen minutes of climb, the engine will consume 3.5 gallons of fuel. Assuming that one-half gallon was used for taxiing, then forty-four gallons remain for cruise after level-off.

Referring to the "Fuel Consumption" column for your power setting, the remaining range in hours may be determined by dividing the fuel consumption per hour into forty-four gallons.

NORMAL CRUISE CHART

Altitude	Power RPM	Settings Manifold Pressure	% Power	Fuel Cons.	Indicated Airspeed** S. - W.	True Airspeed	Range (No Reserve)***
1,000	2300	23	70	9.8	152-163 mph	160 mph	5 Hrs. 00 Min.
2,000	2300	23	71	9.8	152-163 "	163 "	5 Hrs. 00 Min.
3,000	2300	23	71	9.8	152-162 "	165 "	5 Hrs. 00 Min.
4,000	2300	23	72	9.9	152-162 "	167 "	4 Hrs. 57 Min.
5,000	2300	23	73	10.0	151-160 "	170 "	4 Hrs. 54 Min.
6,000	2300	23	73	10.1	151-160 "	171 "	4 Hrs. 51 min.
7,000	2300	FT*	74	10.2	150-159 "	174 "	4 Hrs. 48 Min.
8,000	2300	FT	69	9.6	148-152 "	172 "	5 Hrs. 06 Min.
9,000	2300	FT	67	9.3	143-148 "	170 "	5 Hrs. 18 Min.
10,000	2300	FT	64	8.9	139-143 "	169 "	5 Hrs. 30 Min.
11,000	2300	FT	63	8.7	138-142 "	169 "	5 Hrs. 36 Min.
12,000	2300	FT	62	8.5	137-142 "	168 "	5 Hrs. 48 Min.

Above fuel consumption figures are based on rich mixture -- fuel consumption may be reduced by proper leaning.

* See "Cruise Procedures", Page 25

** See "Cruise Charts", Page 26

*** See Page 26

S. = Summer

W. = Winter