MODEL 100

HOW TO USE THE

DOUGLAS

SKY RULE

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DOUGLAS AIRCRAFT COMPANY, INC.

TESTING DIVISION

DESIGNED BY

DOUGLAS AIRCRAFT COMPANY, INC.

SANTA MONICA, CALIFORNIA

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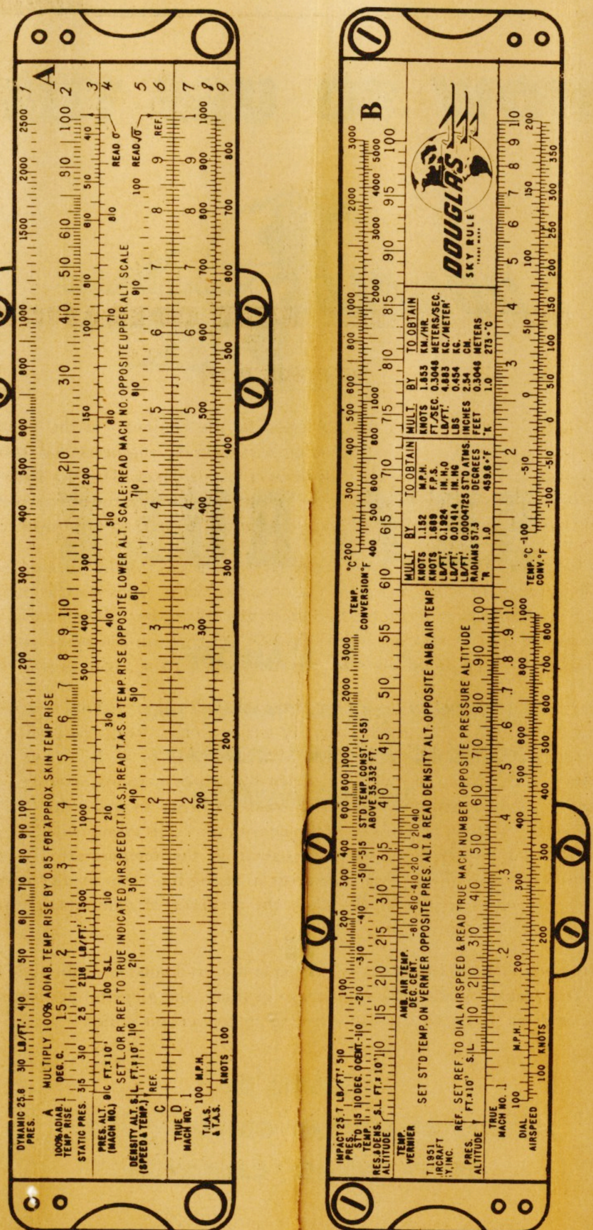

DOUGLAS SKY RULE OPERATION

INTRODUCTION

Douglas Sky Rule was designed and perfected by the engineers of the Douglas Aircraft Company, Inc., for the purpose of providing aeronautical engineers and test pilots with useful information pertaining to the performance of airplanes. The Sky Rule is especially useful for personnel who need "on the spot" answers without reference to voluminous text books and charts. The arrangement of scales on the Sky Rule is shown below:

It should be noted that the upper and lower stator bars and the slide on each side of the Sky Rule were arranged to work together in solving problems. Consequently, the slide should never be reversed from one side of the rule to the other. For identification purposes, the "C" scale on the slide should coincide with the "D" scale on the lower stator bar of side "A". In addition, all scales on side "A" are numbered on the right hand side of the rule.

All scales included on the Sky Rule were calculated and engraved with a degree of accuracy which exceeds the reading accuracy of the rule with two exceptions. First, the probable error in determining true Mach number from "dial airspeed" is ± 1.0% and the maximum possible error is ± 3.0%. This error is caused by approximations necessary to correct for compressibility and normal shock effects. Second, in order to make the "100% adiabatic temperature rise" scale a simple two-cycle logarithmic scale (similar to "A" scale on conventional slide rules), the value of the constant in the temperature rise equation was changed from 0.995 to 1.000. This introduces a negligible error in the temperature rise determination. However, it does not affect the accuracy of determining squares, square roots and relative density.

The airspeed scales incorporated on the Sky Rule are graduated in "miles per hour" and in "knots". This feature enables the operator to evaluate the airplane performance in either miles per hour or in knots, without referring to conversion tables.

SUMMARY OF OPERATIONS

Operation	Location of Scales	Description of Operation
Multiplication and division	Side "A" Scales "C" & "D" (#6 & #7)	Multiplication: Set "Ref." over one of factors on "D" scale. Locate other factor on "C" scale, and below it read product on "D" scale. Division: Set divisor on "C" scale opposite number to be divided on "D" scale. Read result on "D" scale under "Ref."
Square roots and squares	Side "A" "D" scale (#7) "A" scale (#2)	Square Roots: Set hairline over number on "A" scale (#2). Read square root of that number below on "D" scale. Squares: Set hairline over number on "D" scale. Read square of that number above on "A" scale (#2).
True indicated airspeed vs. true Mach number	Side "A" Airspeed scales #8 & #9 Press. alt. scale #4 Mach No. scale #7	To Obtain M: Set L. or R. "Ref." over TIAS. Move hairline to pressure altitude and read M below on scale #7. To Obtain TIAS: Set hairline over M and adjust pressure altitude in line with this setting. Read TIAS below "Ref." on scale #8 or #9.
True indicated airspeed vs. true airspeed	Side "A" Airspeed scales #8 & #9 Dens. alt. scale #5	To Obtain TAS: Set L. or R. "Ref." over TIAS. Move hairline to density altitude and read TAS directly below on scale #8 or #9. To Obtain TIAS: Set hairline over TAS and adjust density altitude in line with this setting. Read TIAS below "Ref." on scale #8 or #9.
Square root of relative density ($\sigma^{1/2}$) and relative density (σ) vs. altitude	Side "A" $\sigma^{1/2}$ scale #7 σ scale #2 Dens. alt. scale #5	To Obtain $\sigma^{1/2}$ and σ: Set density altitude to L. index on "D" scale (#7). Read $\sigma^{1/2}$ under R. "Ref." on "D" scale. Read σ over applicable marker on scale #2.
Indicated speed of sound (a_i) and speed of sound (a) vs. altitude	Side "A" Press. alt. scale #4 Dens. alt. scale #5 "a" & "a_i" scale "D" (#7)	To Obtain "a_i": Set pressure altitude to L. index on "D" scale (#7). Read indicated speed of sound (a_i) under R. "Ref." on "D" scale. To Obtain "a": Determine "a_i" as explained above. Set "a_i" on "D" scale (#7) and adjust L. or R. "Ref." over this number. Read speed of sound (a) on "D" scale (#7) opposite desired density altitude (scale #5).
True indicated airspeed and true airspeed vs. temperature rise	Side "A" Airspeed scales #8 & #9 Dens. alt. scale #5 Temp. rise scale #2	To Obtain Temperature Rise from TIAS: Set L. or R. "Ref." over TIAS. Move hairline to density altitude and read "100% Adiabatic Temp. Rise" directly above on scale #2. To Obtain Temperature Rise from TAS: Read temperature rise directly above true airspeed on scale #2.

SUMMARY OF OPERATIONS *(Continued)*

Operation	Location of Scales	Description of Operation
True indicated airspeed vs. dynamic pressure	Side "A" Airspeed scales #8 & #9 Dyn. press. scale #1	To Obtain Dynamic Pressure: Read dynamic pressure directly above true indicated airspeed on scale #1.
Pressure altitude vs. density alt.	Side "B" Alt. scale & std. temp. scale on upper stator bar Temp. vernier on movable slide	To Obtain Standard Temperature: Read standard air temperature directly above pressure altitude on upper stator bar. To Obtain Density Altitude: Set hairline over pressure altitude. Determine standard temperature for this pressure altitude as explained above. Adjust standard temperature on temperature vernier under hairline. Move hairline to ambient air temperature on vernier and read density altitude directly above this air temperature setting.
Dial airspeed vs. true Mach number	Side "B" "M" and airspeed scales on lower stator bar Press. alt. scale on slide	To Obtain True M: Set L. "Ref." over dial airspeed. Move hairline to pressure altitude and read M directly below on Mach No. scale. To Obtain Dial Airspeed: Set pressure altitude over true Mach number. Read dial airspeed below "Ref." on airspeed scale. To Obtain TIAS: Obtain TIAS on side "A" for known values of pressure altitude and true Mach number (scales #4 and #7, side "A").
Dial airspeed vs. impact pressure	Side "B" Airspeed scale on lower stator bar Impact press. scale on upper stator bar	To Obtain Impact Pressure: Read impact pressure directly above dial airspeed on impact pressure scale.
Conversion scales: Deg. Centigrade vs. Deg. Fahrenheit	a) −100°C to 200°C Side "B" Lower stator bar b) +200°C to +3000°C Side "B" Upper stator bar	Convert directly from one system to the other.
Conversion scale: Feet of alt. vs. static press., lb/ft^2	Side "A" Scales #3 & #4	Convert directly from one system to the other.
Conversion scale: Miles per hour vs. knots	a) Side "A" Scales #8 & #9 b) Side "B" Lower stator bar	Convert directly from one system to the other.

DEFINITION OF TERMS

True Indicated Airspeed (TIAS), also known as Equivalent Airspeed—Dial airspeed reading, corrected for instrument, position and compressibility errors.

True Airspeed (TAS)—Airplane speed relative to air $= TIAS/\sigma^{1/2}$

Dial Airspeed—Observed airspeed indicator dial reading. Instrument and position errors were assumed to be equal to zero in constructing "dial airspeed" scale on Sky Rule.

Speed of Sound (a) Speed of propagation of small pressure waves in a given fluid. For standard air, speed of sound varies linearly from 761 mph at sea level to 662 mph at 35,332 feet, and remains constant from that altitude to above 100,000 feet.

Indicated Speed of Sound (a_i)—This speed is constant for a given pressure altitude and is equal to $a \times \sigma^{1/2}$.

True Mach Number (M)—Ratio of true velocity of air to the velocity of sound. Note that true Mach number scales on Sky Rule are defined as follows:

$$M = \frac{TAS}{a} = \frac{TIAS}{a \times \sigma^{1/2}} = \frac{TIAS}{a_i}$$

Consequently, the combination of pressure altitude (but not density altitude) and indicated airspeed for that pressure altitude is used to define the Mach number.

Relative Density (σ)—Ratio of density of air at a given altitude to that at sea level at NACA standard conditions.

Dynamic Pressure (q)—Difference between total and static pressures assuming air to be an incompressible fluid, defined as:

$$q = \frac{1}{2} \rho_o (TIAS)^2 = \frac{(TIAS)^2}{391}$$

where "q" is in lb/ft² and "TIAS" in mph.

Impact Pressure (q_c)—Pressure acting at the forward stagnation point placed in an air current, such as the differential pressure existing between the pitot-static head orifices.

Pressure Altitude—Altitude corresponding to a given pressure in a standard atmosphere (Note: Density altitude is equal to pressure altitude corrected for the difference in temperatures existing between standard temperature and ambient temperature at that pressure level.)

Static Pressure—Pressure measured at rest in the undisturbed atmosphere.

Standard Temperature—Temperature of air existing in a standard atmosphere. This temperature is equal to +15°C at sea level. At altitude, standard temperature decreases at a constant rate to −55°C at 35,332 feet, and remains constant at −55°C to above 100,000 feet.

DEFINITION OF TERMS *(Continued)*

100% Adiabatic Temperature Rise—Full rise in temperature resulting from bringing the moving airstream to complete rest at a stagnation point. This temperature rise is defined by the following equation:

$$\Delta t = 0.2\,(M)^2\,(T_{ambient}) = 0.995\left(\frac{TAS}{100}\right)^2$$

where Δt is temperature rise in °C and TAS is true airspeed in mph. In order to make the temperature rise scale on Sky Rule a simple two-cycle logarithmic scale, value of the constant in the above equation was changed from 0.995 to 1.000 which introduces negligible error.

Skin Temperature Rise—Rise in the airplane skin temperature resulting from adiabatic compression of air coming to a partial rest at the airplane's surface. The explanatory note on Sky Rule says to use 85% of the 100% adiabatic temperature rise for determining average airplane skin temperature rise.

EXAMPLES

Multiplication and Division

Problems	Answers
15 x 3.7	55.5
280 x 0.34	95.2
753 x 89.1	67,000
83 ÷ 7	11.85
137 ÷ 513	0.267
17.3 ÷ 231	0.0749

Square Roots and Squares

Problems	Answers
$\sqrt{7.3}$	2.7
$\sqrt{73}$	8.54
$(1.73)^2$	2.99
$(44.5)^2$	1980

True Indicated Speed vs. True Mach Number

Problems		Answers
TIAS	Press. Alt.	M.N.
210 knots	S.L.	.318
"	26,000	.533
"	51,000	.958
"	94,000	2.67
"	65,000	1.338

EXAMPLES *(Continued)*

True Indicated Speed vs. True Mach Number *(Continued)*

Problems		Answers
M.N.	Press. Alt.	TIAS
0.82	S.L.	624 mph
"	30,000	340 mph
"	60,000	167 mph
2.52	S.L.	1920 mph
"	50,000	652 mph
"	80,000	318 mph
"	95,000	222 mph

True Indicated Speed vs. True Airspeed

Problems		Answers
TIAS	Dens. Alt.	TAS
320 knots	S.L.	320 knots
320 "	30,000	524 "
510 mph	20,000	699 mph
510 "	50,000	1305 "
TAS	Dens. Alt.	TIAS
800 mph	60,000	246 mph
800 "	25,000	535 "

Square Root of Relative Density ($\sigma^{1/2}$) and Relative Density (σ) vs. Altitude

Problems	Answers	
Density Altitude	$\sigma^{1/2}$	σ
20,000	.730	.533
40,000	.496	.246
70,000	.242	.0586

Indicated Speed of Sound (a_i) and Speed of Sound (a) vs. Altitude

Problems	Answers	
Altitude	a_i Use scale #4, Side "A"	a Use scale #5, Side "A"
S.L.	761	761
20,000	516	707
30,000	415	678
40,000	328	662

EXAMPLES *(Continued)*

True Indicated Airspeed and True Airspeed vs. Temperature Rise

Problems			Answers
TIAS	Density Altitude	TAS	100% Adiabatic Temp. Rise
150 kts	10,000 ft		4.05°C
300 "	20,000 ft		22.4° C
400 "	40,000 ft		86.0° C
		300 mph	9.0° C
		500 mph	25.0° C
		1000 mph	100.0° C
		1500 mph	225.0° C

True Indicated Airspeed vs. Dynamic Pressure

Problems	Answers
TIAS	Dynamic Pressure
150 mph	57.7 lb/ft^2
300 mph	230 lb/ft^2
500 mph	640 lb/ft^2

Pressure Altitude vs. Density Altitude

The following example illustrates this operation: Determine density altitude for 10,000 ft pressure altitude and ambient air temperature of +10°C.

1) Set hairline to 10,000 ft pressure altitude.

2) Directly above this setting read standard temperature of −4.8°C for this pressure altitude.

3) Adjust slide until it coincides with the hairline at −4.8°C on vernier.

4) Move hairline from −4.8° to +10°C on vernier and read the density altitude of 11,700 feet directly above this setting.

Problems		Answers	
Press. Alt.	Ambient Air Temp.	Std. Temp.	Density Alt.
5,000 ft	15°C	5°C	6,100 ft
"	5°C	5°C	5,000 ft
"	−10°C	5°C	3,200 ft
20,000 ft	−10°C	−24.7°C	21,700 ft
40,000 ft	−40°C	−55°C	41,400 ft
60,000 ft	−70°C	−55°C	58,500 ft

EXAMPLES *(Continued)*

Dial Airspeed vs. True Mach Number

Problems		Answers
Dial Airspeed	Press. Alt.	True Mach Number
250 mph	20,000 ft	0.481
400 knots	23,000 ft	0.893
400 knots	60,000 ft	1.89
True MN	Press. Alt.	Dial Airspeed
3.00	80,000 ft	479 mph
3.00	50,000 ft	885 mph
1.00	20,000 ft	552 mph

Dial Airspeed vs. Impact Pressure

Problems	Answers
200 mph	104 lb/ft^2
400 mph	438 lb/ft^2
600 mph	1070 lb/ft^2
800 mph	2140 lb/ft^2

HOW TO ADJUST YOUR SKY RULE

A perfect slide rule, when out of adjustment, often appears defective. Each rule is accurately adjusted before it leaves the factory. However, handling during shipment, dropping the rule, or even a series of slight jars while laying the rule down during use may loosen the adjusting screws and throw the rule out of alignment. Follow these simple directions for slide rule adjustment.

CURSOR-HAIRLINE ADJUSTMENT · Loosen the bottom two screws on both Cursor windows or spacer opposite tension spring. Press with left thumb to maintain constant contact with edge of rule; align hairline with left hand indices and tighten screws on that side. Turn rule over and check alignment of hairline on other Cursor window. If necessary, loosen all screws on this side and align with left hand indices as needed, and tighten screws carefully.

SLIDER TENSION ADJUSTMENT · Loosen adjustment screws on end brackets; regulate tension of slider, tighten the screws using care not to misalign the scales. The adjustment needed may be a fraction of a thousandth of an inch, and several tries may be necessary to get perfect slider action.

SCALE LINE-UP ADJUSTMENTS · (1) Move slider until indices of C and D scales coincide. (2) Move cursor to one end. (3) Place rule on flat surface with face uppermost. (4) Loosen end plate adjusting screws slightly. (5) Adjust upper portion of rule until last graduation on righthand side of Scale #2, side "A", coincides with arrow on slider.

REPLACEABLE ADJUSTING SCREWS · All Pickett All-Metal rules are equipped with Telescopic Adjusting Screws. In adjusting your rule, if you should strip the threads on one of the Adjusting Screws, simply "push out" the female portion of the screw and replace with a new screw obtainable from your dealer, or from the factory at a cost of $.06 each in stamps.

HOW TO KEEP YOUR SKY RULE IN CONDITION

Always hold your rule between thumb and forefinger at the ENDS of the rule. This will insure free, smooth movement of the slider. Holding rule at center tends to bind the slider.

LUBRICATION · *Do not use ordinary lubricating oil on your slide rule. It turns black and dirties your hands and work.* Your slide rule is treated with a light "silicone" lubricant at the factory. This oil, which works into the surface of the metal, is designed to lubricate your rule indefinitely.

If your rule should run dry, or if the slider begins to move hard or with a dry, rasping sound:

1. Lubricate with a light "Silicone" lubricant. Work in well by moving slider back and forth, then wipe off. OR—
2. If a light silicone is unobtainable, simply rub tongues and grooves with a very soft lead pencil. Move slider back and forth to work the graphite well into the metal, then wipe excess graphite off.

MAINTENANCE · The body of your rule is made of magnesium. The edges, not covered with plastic, may gradually darken (or oxidize) with age. This ageing, or darkening, is a common characteristic of metals like magnesium, German silver, silver, brass, copper, pewter, etc.

This normal ageing or darkening of the rule affects neither the accuracy of the scales nor ease of operation.

Extreme atmospheric exposure tends to warp and distort wood, and to rust steel, which is common knowledge. This is not true of magnesium. Such exposure may tend to deposit an oxidation film on the surface, causing the slider to stick or move hard.

If this happens to your rule, take out the Telescopic Adjusting Screws and remove both Top Rule Member and Slider without disassembling the Cursor. Clean the oxidized edges of the rule with a silver polish, Bon Ami, rubber ink eraser or other cleaning agent. Slide Top Rule Member and Slider back into position. Relubricate. Then make Scale Line-Up and Slider-Tension Adjustments.

WHY YOUR RULE OPERATES BETTER WITH CONSTANT USE · Being made of metal, the moving parts of your slide rule "lap in" with use. This process of wearing smooth means your slide rule will operate with increasing smoothness year after year.

CLEANING · Wash surface of the rule with non-abrasive soap and water when cleaning the scales. If Cursor window becomes dulled from long use, simply polish and brighten the window surfaces with a small rag and tooth powder.

Pickett ALL-METAL SLIDE RULES

PICKETT & ECKEL, INC.

Keeping pace with modern science

Manufactured by

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CHICAGO 3, ILLINOIS

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