



## DYNAMIC BALANCING PROCEDURE

FOR MAIN ROTOR BLADES ON 321 AND 330

### I N T R O D U C T I O N

The purpose of this document is to detail all the operations required to make individual main rotor blades dynamically and aerodynamically interchangeable.

This balancing operation comes after static balancing, which ensures that the centrifugal forces are equal.

In itself, the dynamic balancing operation consists in measuring moments and tracking in relation to a master blade.

- Dynamic balancing is achieved by chordwise displacement of balancing weights located at the blade tip.
- Aerodynamic balancing is achieved by adjusting tabs on the trailing edge in the blade tip area.

A parameter known as the pretracking number, resulting from the effective twist of the blade, is measured after balancing. This facilitates rigging operations on the aircraft, because the blade attachment fitting can be set to give the best possible track at the very first rotation.

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DOCUMENTS REFERRED TO

- Maintenance and overhaul instructions ..... GIR 3694
- Rotor head balancing manual : SA 321 direction .... GIR 3543
- Rotor head calibration manual : SA 330 direction .. GIR 3544
- Definition of requirements as a function of the  
  number of production blades to be manufactured..... GIR 3562

APPENDICES

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I - TEST CONDITIONS

I.1 - ATMOSPHERIC CONDITIONS

- For the relative humidity, refer to the electronic tracker specifications (limit 95 %).
- When necessary, it is occasionally possible to balance 330 blades in very fine rain (drizzle). The optical cell must be wiped clean before rotation.
- Maximum wind strength 25 knots for all blades (when there is strong gusting, this limit must be reduced to 20 knots).

I.2 - CONDITION OF BLADE BEFORE DYNAMIC BALANCING

- Blades must, in theory, have been statically balanced. For special checking, however, it is permissible to proceed with a maximum static moment deviation of 2 mkg between the reference blade and those to be checked.
- On 321 blades, the blade tip cover must have been statically balanced.
- 330 blade tip covers must have undergone the weight adjustment operation.
- Production-line dynamic balancing is done with a tip cover belonging to the blade ; as detailed on page 11, not all the screws are fitted.

IMPORTANT - Do not proceed if blade tip covers are not fitted.

### 1.3 - INSTRUCTIONS TO ENSURE VALIDITY OF TESTS

- Dynamic balancing must always be relative to a master blade.
- As required by § III.3.4.,  $dR/R$  values and static zero indication must be checked every day, and the calibration of  $M \theta$  moment recording instruments (with the dead weight), and dynamometric cells, as well as the dynamic zero indication \*\* (at the nominal balancing speed) must be checked every week.
- The balance of the rotor head (without blades) must be checked every month, as per GIR 3544\*, or after replacement of a rotating component of the pitch control system. Also, this check is related to, and must precede, checking of the rotor head with blades.
- Checking of the rotor head pretracking zero point, as per GIR 3544 \*, must be performed once every month and also whenever any pitch change control component is replaced. This check should also precede checking of the rotor head with blades.
- As described in GIR.3544\*, the rotor head must be completely calibrated every month, using master blades. This check confirms the good condition of the primary master blades.
- Checking and, if necessary, recalibration of the secondary blades, as detailed in GIR.3544 \*, must be carried out periodically; in principle, whenever 100 production blades have been balanced using each of the secondary master blades.

Should the rate of production be greater than 100 blades per master per month, these checks should be performed monthly. If, however, production is less than 100 blades per year, the period between checks must not be greater than 1 year.

\* GIR.3544 or 3543, depending on the type of blade to be balanced.

\*\* IMPORTANT - After resetting the static zero point, the dynamic zero point should be checked ; if it has varied by more than 20 units in differential, the settings must be readjusted as described in GIR.3544 (or 3543).

IMPORTANT

Any blade which has been modified or repaired since dynamic balancing must be tested on the rig.

However, it is permitted to dispense with dynamic rebalancing in the case of 321 blades only on which one or two of the 12 pockets at the root end have been replaced ; this is provided that the static balancing has led only to very minor adjustment (by about the degree of tolerance) and also that the blade has not been used in flight since its last dynamic balancing operation.

- It should be noted that such a blade (especially if it has carried out a large number of flying hours) may have poor flight characteristics if used with blades which have carried out a large number of flying hours without repairs or rebalancing.
- Any blade which has received repairs of any kind after flying must undergo dynamic rebalancing.
- The test rig technicians must record and report \* to the appropriate test engineer any trends they may observe from day to day, in addition to the results of the above checks and calibrations.

\* For test rigs with approved status or under licence, regularly send to Aerospatiale their calibration or adjustment sheets and any appropriate observations.

## II - TEST EQUIPMENT

### II.1 - BLADE BALANCING SYSTEM EQUIPMENT

- For test rig maintenance instructions, refer to GIR 3694.
- Blade adaptors : Three adaptors are required for each type of blade :
  - 321 - SL 61 B 1000.011
  - 330 - 8705.330.11.0000.00 Table 80
- Measuring equipment : Three moment recording instruments, MECI type (Leeds and Northrup Licence), capable of direct and differential measurements, are required. Accuracy :  $\pm 3\%$  of maximum indication.
- One tracking measurement instrument : 1 Chicago-Aerial cell + computer unit, model WMA/WMIA or model CA/470/A  
Measuring accuracy :  $\pm 2$  units - (1 unit = 1/16 inch).
- Tachometers :
  - 1 ROCHAR type or equivalent, accuracy  $\pm 0.1$  rpm
  - 1 ordinary type, dial display, accuracy  $\pm 1$  rpm (recommended for indicating trends).
- Trim tab (or trailing edge) bending tools :
  - For the 321 : two tools are required, one for bending, the other for straightening out ; part number : 69.06.1615.20.100.
  - For the 330 : The following set of tools is required :
    - 69.01.330.A.11.0012.00
    - 69.02.330.A.11.0012.00
    - 81.01.330.A.11.0012.00
- Weights : - one 30-pound calibration weight is used to calibrate the recording system with dead weight. Accuracy :  $\pm 0.03$  pound.
- For the 321 : - 1 torque wrench, calibrated from 2 to 20 mkg.

## II.2 - MASTER BLADES

To ensure quality control over long periods, a certain number of primary and secondary master blades, as specified in GIR 3562, are required.

### - Requirements for test rigs with approved or licence status :

The three primary master blades must mandatorily be returned to Aerospatiale every two years for revalidation.

Primary master blades are used only to check the pretracking zero point, to balance the rotor head and to check and if necessary rebalance the secondary master blades. The primary master blades must under no circumstances be used in the rain or in a dusty atmosphere.

The secondary master blades used for production line balancing have to be checked, and if necessary adjusted, by reference to the primary master blades. Any remaining differences are corrected by the application of correction factors (see GIR.3544 page 52).

Master blades must be kept in a special store, away from oil, grease, etc...)

They are carried, for short distances, on trolleys\* with the blades resting on their leading edge ; for longer distances, they should be placed in the proper containers for that type of blade.

They must also be kept very clean, and washed if necessary with a Teepol + water solution or an equivalent MIL C 25179A product. After washing, they should be rinsed with clean water.

This operation should be performed as soon as the blades are removed, and prior to storage. For refitting, it is sufficient to wipe them down with a clean dry cloth immediately before use.

\* Part number : 95.01.1615.20.100, trolleys fitted with blade supports  
95.01.321.11.0010.00

### II.3 - RIG BLADES

It is necessary to have a set of SA 321 test rig blades a set of SA 330 test rig blades in order to perform the sinking operations required after refitting a rotor head.

These blades are also used for any test that may jeopardize the balance of the master blades.

The balance of these blades need only be average.

### III - PREPARATION

#### III.1 - SINKING OPERATIONS AFTER FITTING ROTOR HEAD TO SHAFT

After placing the rotor head on the shaft, the main head nut is tightened as detailed in GIR.3694 § 4.3.17 (585 to 635 mkg).

After tightening the nut, a common reference mark is drawn on the main head nut and the outer ring :

- Fit the rig blades (kept for this purpose).
- Rotate for 5 hours, as follows :
  - 10 sequences lasting 30 minutes each, with full track and moment readings at the pitch settings for the type of blade used. (Eliminate track variations to within 1°). After each 30-minutes sequence, visually inspect the rotor head assembly.
- After the 5 hours, again apply 585-635 mkg of torque to the main head nut. If this is seen to tighten, (marks no longer in line : offset > 1 mm) resume rotation for 3 hours with the same sequences as above.

- The sinking operation will be considered finished when the head nut no longer tightens when the torque is applied. (Less than 1 mm between the marks).

### III.2 - PREPARATION OF BLADES AND RIG

- III.2.1 - Install the secondary master blade on the yellow sleeve and adjust the pretracking setting to the number for that blade.

Make sure the leading edge is clean. If it has been used for a previous balancing operation, clean it with a damp sponge.

Note : Dirt on the leading edge can cause an error of up to 40 units on the  $\eta\theta$  slope, for a pitch variation of  $8^\circ$ .

- III.2.2 - Install two blades for balancing on the two other sleeves, set the motor unit counter to 0 and make sure the leading edges are clean.

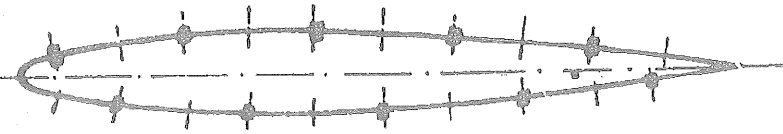
On 330 blades, check that the three tabs are in line with the chord of the blade profile (gluge on 0) and realign them if necessary.

Note \*- Not all the blade tip cover screws are fitted ; refer to sketch below for each type of blade.

Note\* Applies to Aerospatiale only. Licensees and approved maintenance shops should install all the screws.

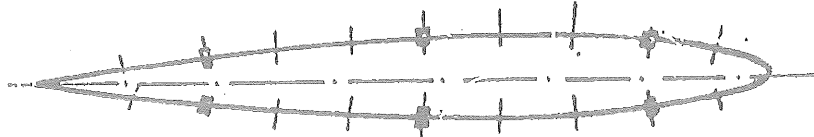
330

Upper surface

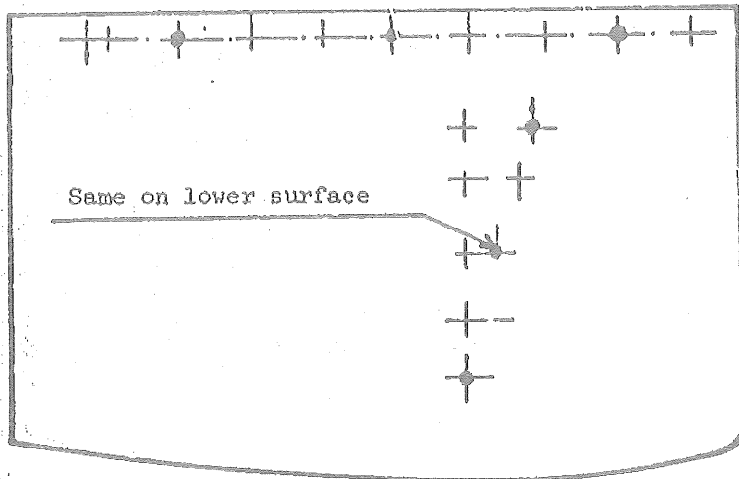


321

Upper surface



Same on lower surface



**Warning :** Blades with part numbers not shown in table II must never be installed without authorization from the competent person in the Engineering Department or from the Engineer supervising the test.

SA 330 trim tab alignment and blade tip cover screw fitting may be done alongside the rig.

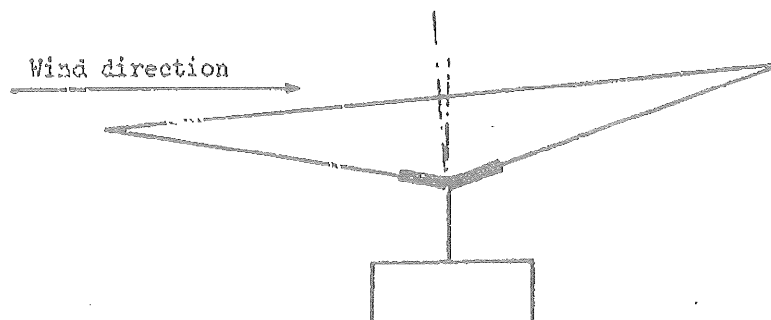
III.2.3 - Preparation of rig :

- At the start of every sequence of work, the whole area of the rig should be inspected and cleared of any objects liable to cause damage when the rig is turning. (Rags, cloths, etc...). Look for other safety hazards.
- Someone should be assigned to make a general visual inspection of the rotor, and to make sure that all rotating components are firmly secured. Check that all tools have been returned to the cubicle and that the blade tip cover screws are locked in position.
- Check wind speed, which must not be more than 25 knots in normal wind conditions ; if there are gusts, the maximum wind speed is 20 knots.

If the rig supervisor considers that the prevailing wind conditions constitute a hazard during handling or balancing of blades, stop the rig and remove the blades carefully.

- Check that the overspeed settings are correct for the type of blade installed  
SA 321 : 215 rpm  
SA 330 : 280 rpm
- Also check that the direction of rotation is correct for the type of blade installed on the rig.
- Check that the blade lifting apparatus is in the lowered position and that all existing safety systems are in working order :
  - now adjust collective pitch to within 1° on the dial
  - fit the cyclic pitch to 1° and work with the rotor disk leaning into the wind, using the longitudinal and lateral controls.

Make quite sure that the sum of these two values is equal to  $1^\circ$ .



When making these adjustments, allow for the phase offset between the control plane and the rotor disk.

### III.3 - RECORDING INSTRUMENTS : USE, - CHECKING AND CALIBRATING

#### III.3.1 - General :

The measuring equipment consists of three MECI recording instruments which record the pitch moments transmitted by dynamometric cells located in the pitch control train.

It is important to wait 15 minutes between starting the instruments and taking the first measurement.

The power supply to the recording instruments is only switched off when the rig stoppage is to last more than two days.

When taking calibration or zero adjustment measurements, be careful to actuate the graph-plotter drive system several times to eliminate frictions in the stylus drive mechanism.

A 5 cm plot is enough to supply a valid indication, once the styli have stabilized.

III.3.2 - Zero checking on recording instruments :

This check must be carried out twice a day and every time there is a large change in temperature.

- Disconnect the pitch change rods by removing the lower attachment pins, and allow them to hang freely ; support the bellcrank arms on blocks HES.604.932 (these blocks are placed on the upper flange) ; replace the pins in the yokes of the disconnected rods.
- Start the recording instrument graphdrives and obtain a plot of about 5 cm. Use the zero-adjusting potentiometer for setting to the static zeros obtained after rotor head adjustment as per GIR 3543.
- After this setting, reconnect the rods to the rotating swashplate.

III.3.3 - Deflection checking by dead-weight calibration :

This check must be carried out every week and every time the dR/R check is not satisfactory.

- Disconnect the pitch change rods as described above, leaving them to hang freely with the attachment pins in place. Record the zero value, without stopping the plotter.
- Hang the 30-pound weight on the attachment pin, making sure that no part of the rod or weight is in contact with the non-rotating swashplate.

The stylus should now move through 255 inch pounds, which is 25.5 small divisions in the direct mode (graph paper MECI B 30 847) and 51 small divisions in the differential mode (graph paper MECI B 30 848).

- If "direct" readings are taken on differential paper this represents 17 small divisions.
- If the deflection is not correct, reset by adjusting the "scale" potentiometer
- Remove 30 pound weight, check zero and adjust if necessary (it is normal to have to adjust the zero if the scale is changed appreciably).
- Again suspend the 30 pound weight and check that the result is correct.
- Remove the weight, note the zero value, stop the recording instrument and move on the calibration checking (dR/R).

#### III.3.4 - Checking of dR/R :

This check must be performed immediately after dead-weight calibration, and can be used daily thereafter to rapidly check that the instruments are correctly calibrated.

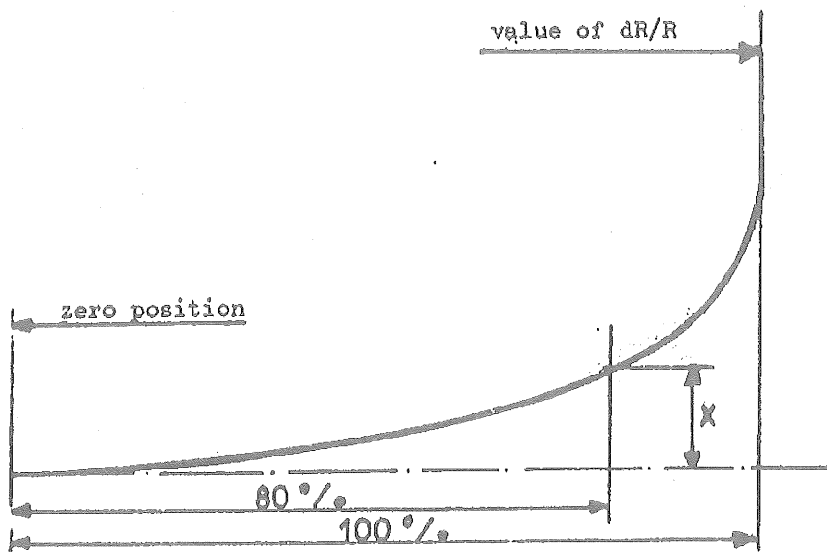
- Start the recording equipment, and obtain a plot of about 5 cm. Without stopping the plotter, switch on the calibration check and note the direct mode reading \* on the three recording instruments : refer to these for the daily checks and if there is a change of more than 3 units, repeat the deflection adjustment § III.3.3.

\* Typical reading : 450 in direct mode.

III.3.5 - Checking the time constant :

This check must be performed every week (with rods disconnected).

Using the plots obtained for checking  $dR/R$ , as per § III.3.4., measure the graph displacement for a given percentage of stylus displacement, specified as 80 %.



N.B. - The displacement indicated by dimension X must be within 5 % the same for the three recording instruments.

This value can be adjusted using the "damping" potentiometer.

III.3.6 - Amplifier gain adjustment (inactive band) :

Checking is required monthly because amplifier efficiency may diminish with time.

- If there are no blades on the sleeve, this can be done with the pitch rod connected ; if there are blades, the rods must be disconnected.
- Place the recording instrument in the direct mode, start the graph plotter, and turn the pinion of the stylus motor until this offers strong resistance. Then turn the pinion in the other direction, to obtain the following plot :



- Adjustment : starting from surge oscillations (maximum gain), reduce the gain until they disappear completely ; the inactive band X must be less than 2 units of moment.

III.3.7 - Sequence of standard operations :

III.3.7.1 - Daily operations :

- . Direct zero on E, Y and B, differential zero on R and B
- . check dR/R in direct mode on R, Y and B.

III.3.7.2 - Weekly operations :

Check and adjust deflection of the three recording instruments by dead weight calibration.

a) - Start with the blue instrument.

Use "direct" mode. Move the stylus to the paper 0. Suspend the weight and record simultaneously.

The displacement should be  $255 \pm 2.5$  units of moment ; adjust deflection if necessary. The blue direct mode plotter is thus adjusted.

b) - Adjust the red instrument in direct mode, with the same procedure.

c) - Finally, adjust the yellow instrument in direct mode and then place the red and blue switches on differential.

Move the yellow stylus to paper 0 and set the red and blue styli to + 100, by adjusting the differential zero.

Suspend the weight on yellow, and adjust the deflection to obtain  $255 \pm 2.5$  units. When this deflection is correct, again suspend the weight and check that the red and blue styli show  $255 \pm 2.5$  units in the opposite direction (this corresponds to differential reciprocity). If the reciprocity is not correct, try to achieve a compromise between direct adjustment of the yellow and the reciprocity readings obtained.

If the reciprocity is still incorrect, maintenance is probably required on the instruments (calibrated wires, etc...)

d) - Now check the  $\Delta R/R$  and the damping on the three instruments.

e) - Then reset the direct and differential static zeros on instruments, and then reconnect the pitch rods.

III.3.7.3 - Monthly operations : Check amplifier gain as per § III.3.6.

#### III.4 - BALANCING THE ROTOR HEAD

This consists in balancing the complete sleeve + pitch control linkage assembly so that the pitch moments transmitted by this assembly, when varying pitch, lag and coning angle, are kept within very narrow tolerances.

For details, refer to GIR 3543.

#### III.5 - PRETRACKING THE ROTOR HEAD AND MASTER BLADES

##### III.5.1. - Pretracking the rotor head :

This consists in calibrating the pitch change rods (linear actuators) so that setting the pitch change rods to the pretracking number for the blades will result in zero tracking in rotation for a given pitch angle.

To achieve this, it is usual to use master blades whose pretracking number is accurately known. Refer to GIR.3544 § B.III.1 for this procedure.

III.5.2 - Pretracking master blades :

The pretracking numbers on these blades were originally established by a number of accurate measurements.

However, with the passage of time and minor damage to the blades, changes may have occurred. These are apparent when there is difficulty in achieving the pretracking zero.

In such cases, the following procedure is used to check the numbers :

a) - Install the main master blade (or the best known one in terms of pretracking) on the blue sleeve. On the other two sleeves, fit master blades or any already balanced blades.

- Rotate the rotor at the nominal speed, with the cyclic pitch suited to the wind direction, and set the collective pitch to the correct angle for the type of blade ( $1^{\circ}$  for SA 330,  $5^{\circ}$  for SA 321).

- Eliminate the tracking difference between the red and the blue blades.

- Stop the rotor and adjust the blue actuator counter to the number on the master blade fitted, on the blue sleeve (by disconnecting the locking device).

b) - Remove the main master blade and replace it with one of the masters to be checked. Rotate the rotor as before and eliminate the tracking variation by adjusting the blue actuator only.

- Stop the rotor and read the pretracking number obtained by the above operation.

c) - Proceed in the same way for the other two master blades.

The blades now have correct numbers ; mark these, with the date of the operation, using an ink stamp.

d) - Since the rotor head pretracking zero has now been upset, re-establish it as described in GIR 3544.

### III.6 - READING AND ADJUSTING PRETRACKING COUNTERS

#### III.6.1 - Sikorsky actuators :

The actuators give direct readings for positive values; for negative values, read the complement relative to 0.

e.g. : 00105 → + 10.5 minutes    99955 → - 4.5 minutes

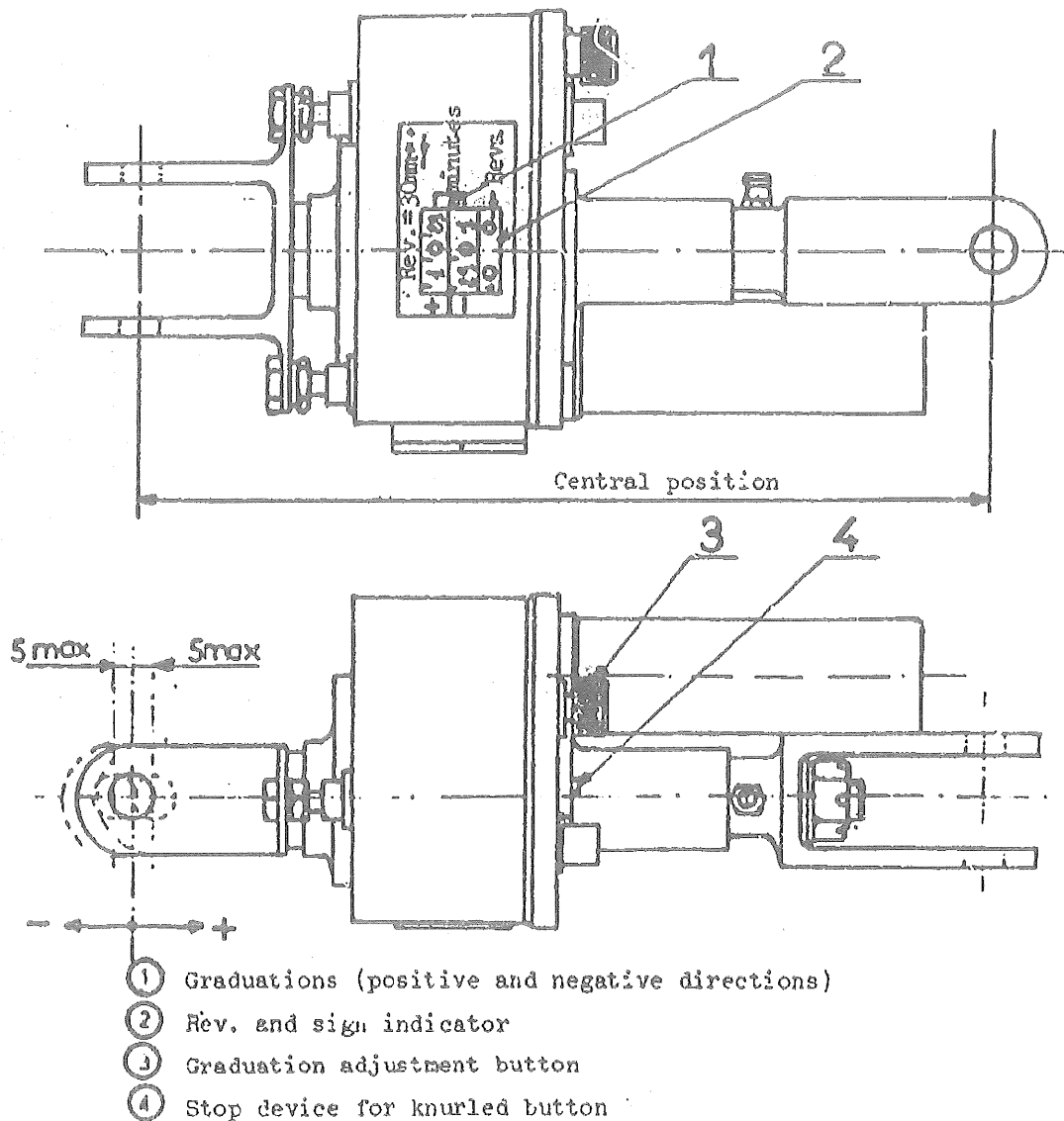
To adjust the setting, unscrew the counter locking device (2 screws), pull it clear of the cogs and manually turn the counter drive until the correct number shows.

Afterwards, replace the locking device.

### III.6.2 - Artus actuators - Description :

These give direct readings ; the + or - sign is read off the ring 2, which also counts revolutions based on 1 rev. = 30 minutes ; note the sign and read the corresponding graduation on the ring 1.

To adjust the graduations, loosen the lock screw for stop 4, push in the knurled button 3 and turn the scale to the required value. After this, put all items back to their original position.



### III.7 - TAB BENDING TOOLS

#### III.7.1 - SA 330 :

No special adjustment is required for use. Fit the locking plate to the tab pocket, tighten the two side screws onto the trailing edge and bend the tab using bending pliers. Check result with gauge.

#### III.7.2 - 321 :

The tools used to bend the trailing edge of the pockets have to be set to change the  $\Theta$  moment by about 150 units (in the area of pockets 2, 3 and 4). To achieve this, it is necessary to adjust the four dimensions below, as represented in the sketch on page 24.

$$X = 3 \text{ mm} \quad Y = 14 \text{ mm} \quad Z = 0$$

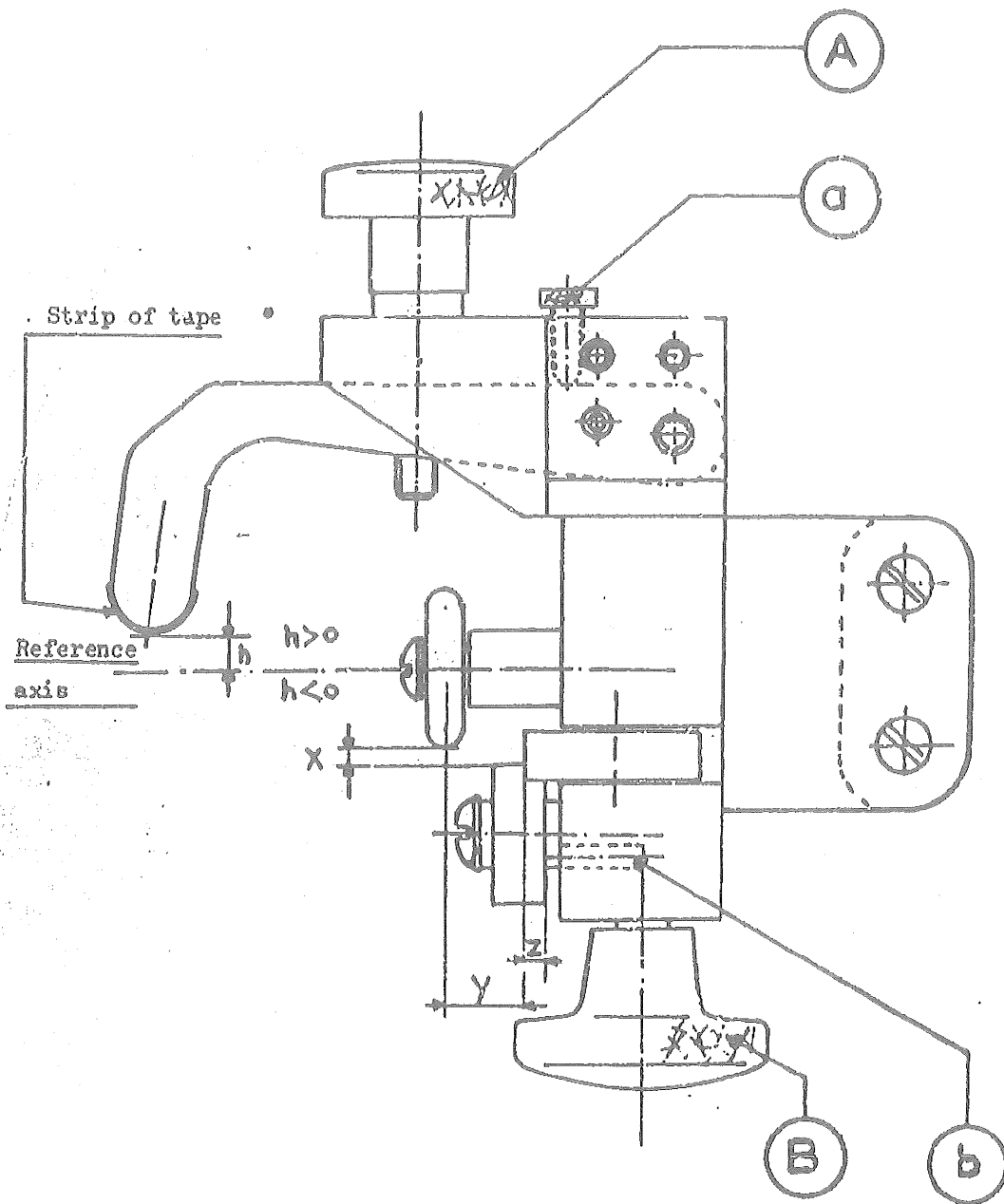
h on bending tool = + 4 mm/reference axis (above)

h on straightening tool = -3 mm/reference axis (below)

- Dimensions Y and Z are obtained by adding washers.
- Dimension X is obtained by turning the knurled knob B, which is locked by the screw b when the required value is reached.
- Dimension h is obtained by adjusting the angle of the pad support arm until in contact with screw a. When the required dimension is reached, lock using the knurled knob A.

Note : To avoid damage to the paintwork on the pockets, the pad must be covered with a strip of tape, which must be changed whenever it becomes worn.

Final adjustment of the tool is achieved by practice in observing the results obtained.



TAB BENDING TOOL for SA 321 ROTOR BLADE  
ADJUSTMENT DIMENSIONS

\* This strip of tape is a consumable item. : Pt No = TESAFLEX SCOTCH 33  
 or equivalent Colour : BLACK

aerospatiale DIVISION HELICOPTERES	EDITIONS				N° GIR 3675	Page 24

IV - TEST PROCEDURE

IV.1 - TAB ADJUSTMENT - Rotation at nominal speed, low pitch

IV.1.1- Set cyclic pitch to  $1^\circ$ , so as to lean the rotor disk into the wind.

Rotate the rotor at the nominal speed for the type of blade being balanced.

Set collective pitch to  $1^\circ$ .

IV.1.2 - Data recording

Remove the track difference between the blades to be balanced and the master blade, by adjusting the actuators.

**IMPORTANT** - Never touch the yellow master blade actuator during production line balancing.

Record the  $\Theta$ -moments: direct for yellow, differential for red and blue. If the value recorded is beyond the range of the differential mode (recording instrument end stop), switch to direct mode, multiply the readings by 3 and convert the difference algebraically by reference to the master blade.

**IMPORTANT NOTE** - With all measurements, allowance must be made for sleeve corrections - See page 31 § IV.5.2.

IV.1.3 - Adjustment :

If the reading is more than 100 units different from M it must be adjusted by bending the trailing edge.

A positive differential value will require the trailing edge to be bent downwards.

A negative differential value will require the trailing edge to be bent upwards.

IV.1.4 - Operating procedure :

- SA 321 :

There are two tools, one for bending upwards, the other for straightening out.

The trailing edge may be bent only from the second pocket onward and in the direction of the blade root. It is absolutely forbidden to bend the trailing edge downwards.

Approximate efficiency : (With tool set as per §III.7.2)

Pockets 2, 3 and 4 : 150 units of M

Pockets 5, 6 and 7 : 100 units of M

**NEVER BEND MORE THAN SIX POCKETS**

- SA 330 :

Make quite sure at the outset that the three tabs are aligned at 0 (check with measuring gauge) P/N : 81.01.330.A. A.11.002.00.

When adjusting operate as follows, in proportion to the moment to be corrected :

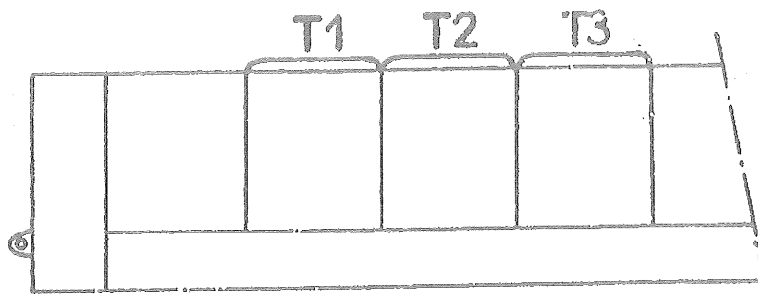
Gauge divisions

$M_{\theta}$  efficiency per division on gauge

T.1	T.2	T.3	
0	0	1	1st Stage
0	1	2	2nd Stage
1	2	3	3rd Stage.
1	3	4	4th Stage
150	100	80	
- 3	- 5	- 9	Do not exceed these values.
+ 2	+ 3	+ 6	

Intermediate combinations are possible

POSITION OF TABS



IV.2 - ADJUSTMENT OF WEIGHTS - Rotation at nominal speed with pitch variation

IV.2.1 - Rotate rotor at nominal speed with collective pitch at  $1^{\circ}$ .

IV.2.2 - Initial check :

Eliminate track difference at  $1^{\circ}$  and then record moments in direct mode for yellow and differential mode for red and blue. Read tracking of red and blue blades.

Increase pitch by  $2^{\circ}$  increments as shown in Fig I - Each time record  $M_{\theta}$  and T.

For each blade, determine the difference between  $M_{\theta}$  at high pitch and  $M_{\theta}$  at low pitch. This difference is called the slope ( $\Delta M_{\theta}$ ).

Do the same for the track.

i.e. :  $\Delta M_{\theta} = M_{\theta}$  at high pitch -  $M_{\theta}$  at low pitch

$\Delta T = T$  at high pitch -  $T$  at low pitch

IV.2.3. - Adjustments : (values based on differential) :

Slope with Positive Moment \* Move weights towards

Slope with Positive Track leading edge

Slope with Negative Moment Move weights towards

Slope with Negative Track trailing edge

IV.2.4 - Operating procedure :

- SA 321 :

There are two types of dynamic balancing weights attached to a rail. Each position has a numbered mark. Refer to Fig IV, page 37, for efficiency data.

\* A positive Moment slope corresponds to an increase in nose-up moment with an increase in pitch.

N.B.- Interpret measurements as algebraic values.

- SA 330 :

There are 5 types of weights which can be moved from one stud to another. The maximum (dimensional) capacity of a stud is 6 large (166 g) weights + 1 washer.

Be careful to leave at least 1 1/2 threads beyond the Nylostop self-locking nut ; a washer must always be left beneath each nut.

For efficiency data, refer to Fig IV, page 37.

For acceptance tolerances refer to Fig II.

#### IV.3 - COMPROMISE BETWEEN M $\theta$ SLOPE AND TRACK SLOPE

Since the parameters of M $\theta$  slope and track slope are linked to the same principle of adjustment (displacement of weights), it is often necessary to adjust the M $\theta$  slope to an extreme value in order to bring the track slope within tolerance.

#### IV.4 - COORDINATION OF TABS AND WEIGHTS IN ACHIEVING TOLERANCE LEVELS OF MOMENT AT ALL PITCH SETTINGS

The final tolerance levels require that M $\theta$  be within  $\pm 25$  units of the master, so that for a positive slope there must be a negative M $\theta$  at low pitch, and vice versa.

Example : SA 321 blade - Measured M $\theta$  slope : + 22

If the low pitch M $\theta$  is + 20, it is clear that the high pitch Moment will be + 42, and thus beyond the tolerance of  $\pm 25$  at all pitch settings. It is therefore necessary to adjust the low pitch moment to a value between + 3 and -27.

Example : 330 blade - Measured  $M_{\theta}$  slope : - 32

If the  $M_{\theta}$  at low pitch is - 23, it can be seen that the high pitch Moment would be -55, and thus beyond the tolerance of  $\pm 25$  at all pitch settings.

In this case, therefore, the low pitch  $M_{\theta}$  has to be set to a value between + 7 and + 25.

The low pitch  $M_{\theta}$  is adjusted using the tabs, as described in §§ IV. 1.3 and IV. 1.4

#### IV.5 - FINAL READINGS FOR ACCEPTANCE - FIXING THE PRETRACKING NUMBER

##### IV.5.1 - Final readings :

When all the above operations have been carried out, it is necessary to take at least two readings so that the assessment of the blade's characteristics can be based on a mean figure.

(The number of readings should be increased if the variations are large).

Proceed as follows :

- eliminate track difference at  $\theta = 1^{\circ}$
- record  $M_{\theta}$  and take track readings at the pitch angles specified for the type of blade being balanced.
- return to low pitch at  $1^{\circ}$  and take a repeat series of readings.
- when this is finished, do not stop the rotor but move on to the pretracking procedure.

IV.5.2 - Pretracking :

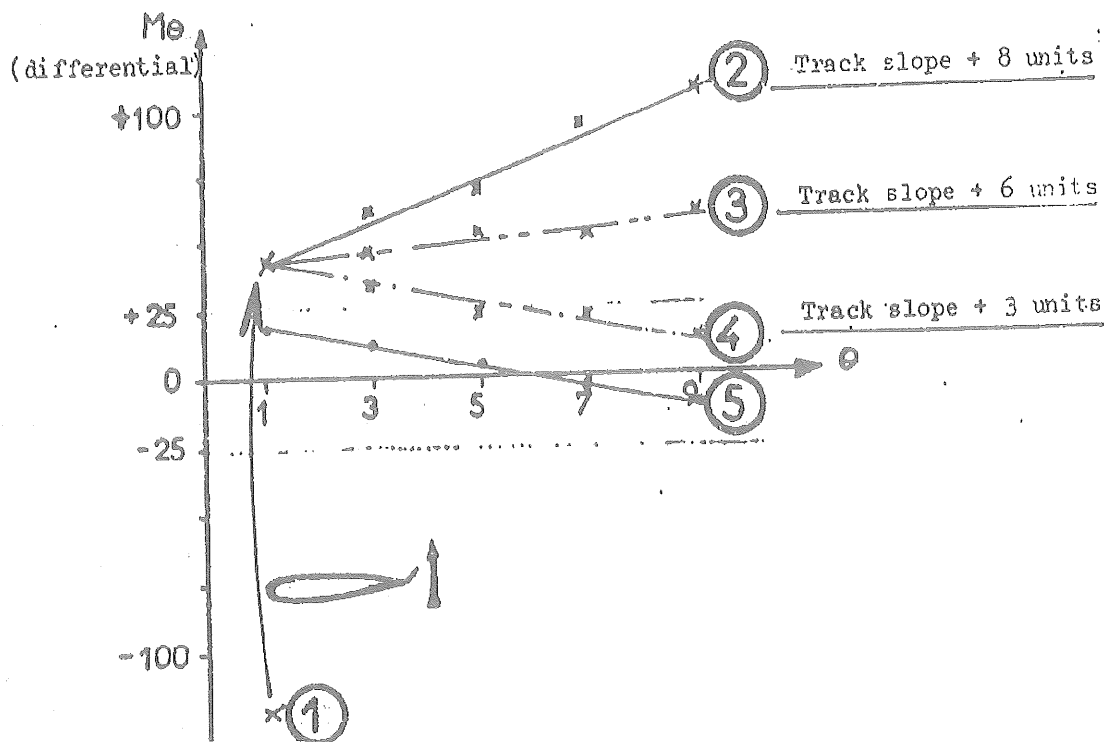
- When the last reading has been taken, set the collective pitch to the pretracking angle, i.e.  $5^{\circ}$  for the SA 321 and  $1^{\circ}$  for the SA 330.
- Eliminate track differences relative to the master by adjusting the Red and Blue actuators.
- Actuate the collective pitch control several times, return to the pretracking pitch and adjust the track if necessary.
- This operation may be considered complete when no track adjustment is required.
- Return to  $1^{\circ}$  pitch if necessary, stop the rotor and read the Red and Blue pretracking numbers off the corresponding actuators ; record these on the balancing sheet.

**I M P O R T A N T   W A R N I N G**

In all the measurements described above, allowance must be made for the sleeve corrections established in accordance with GIR 3544.

To avoid endless calculations, proceed as follows :

- For stages IV 1, 2, 3, 4 it is necessary to refer to the "Target values" which are precisely the correction figures with the opposite sign. In this way, it is easy to see what action is required to improve the blade adjustment.
- For stage IV.5 it will be necessary to establish the mean of the readings and add to it algebraically the sleeve correction figures, in order to obtain the true value.



Rotation no.	Assessment of result	Action
1	$M\theta$ difference at $1^\circ$ more than 100 units	Adjust $M\theta$ close to master by bending tab upwards
2	$\Delta M\theta$ and $\Delta T$ positive and beyond tolerance	Displace weights towards leading edge
3	$\Delta M\theta$ correct $\Delta T$ positive and beyond tolerance	Compromise betw. $\Delta M\theta$ and $\Delta T$ Weights tow. leading edge, B.A
4	$\Delta M\theta$ correct, $\Delta T$ correct Requirement of $\pm 25$ units at all pitch angles not met	Reduce $M\theta$ to $1^\circ$ by locally straightening tabs
5	Correct result : $\Delta M\theta$ 25 units, $\pm 25$ units at every pitch angle $\Delta T \pm 4$ units.	Proceed with pretracking
Remove set of blades for final operation		

FIGURE 1

TEST RIG PARAMETERS

Blade	Type of adaptor	Nr Rotor (rpm)	i, Blade root*	Collective pitch range used
330	8705 - 330.11.0000.00 - figure 80	2 5 5	4, 2°	1, 3, 5, 7.
321	SL 61 B 1000.011	1 9 5	4, 2°	1, 3, 5, 7, 9

\* Corresponds to zero pitch angle at 0.75 R.

+  
+  
**FIGURE II**

ROTOR BALANCING TOLERANCES

Blade type	MØ at all pitch settings	Moment slope	Track slope	Petrack angle
Units	1 = one inch pound		inch	Minutes
3 3 0	$\pm 25$	$\pm 36/6^\circ$	$\pm 4/6^\circ$	$\pm 20$
3 2 1	$\pm 25$	$\pm 25/8^\circ$	$\pm 6/8^\circ$	$\pm 20$
Special SA 321 case Blades with double protective tape balan- ced against master blade without tape *	$-20 \pm 25$	$+80 \pm 25$	$+ 6 \pm 6$	$\pm 20$
* <u>Example :</u> Correction	- 6	+ 8	+ 3	
Target value ; normal conditions	+ 6	- 8	- 3	
Target value for double tape blade against master	- 14	+ 72	+ 3	

F I G U R E III

DYNAMIC BALANCING MASTER BLADES

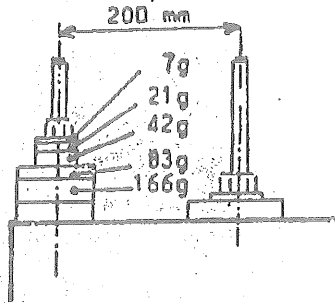
	Master blades to be used	Type of blades to be balanced	Remarks
SA 330 BLADES	87.02.330-11.0012.00 87.03.330-11.0012.00	11.0012 .12 to .19	On layer of tape on leading edge
	See NOTE 1	11.0012 .25, .27 to .33 .36 to .44	Two layers of tape on leading edge
	87.01.330-11.0012.47 87.02.330-11.0012.47	11.0012 .45 to .55	Thick stainless steel leading edge protection
SA 321 BLADES	87.02.321-11.0020.00 87.03.321-11.0020.00	11.0020 .00 to .10	No protection during balancing
	See NOTE 2		
	87.02.321-11.0020.11 87.03.321-11.0020.11	11.0020 .11 to .15	Two layers of tape on leading edge during balancing
	See NOTE 2		
	87.01.321-11.0030.03 87.02.321-11.0030.03	11.0030 .00 and 01 11.0030 .02 and 03	Blade with extended chord (540 mm)

NOTE 1 - Blades with single and double layers of tape can be balanced, without distinction, against the same master blade. For reasons of uniformity, however, it is advisable to equip the master with the same protection as the majority of the blades to be balanced.

NOTE 2 - It is permissible to balance blades with double layers of tape against a master blade with no protection, on condition that the correction values shown in figure II are applied.

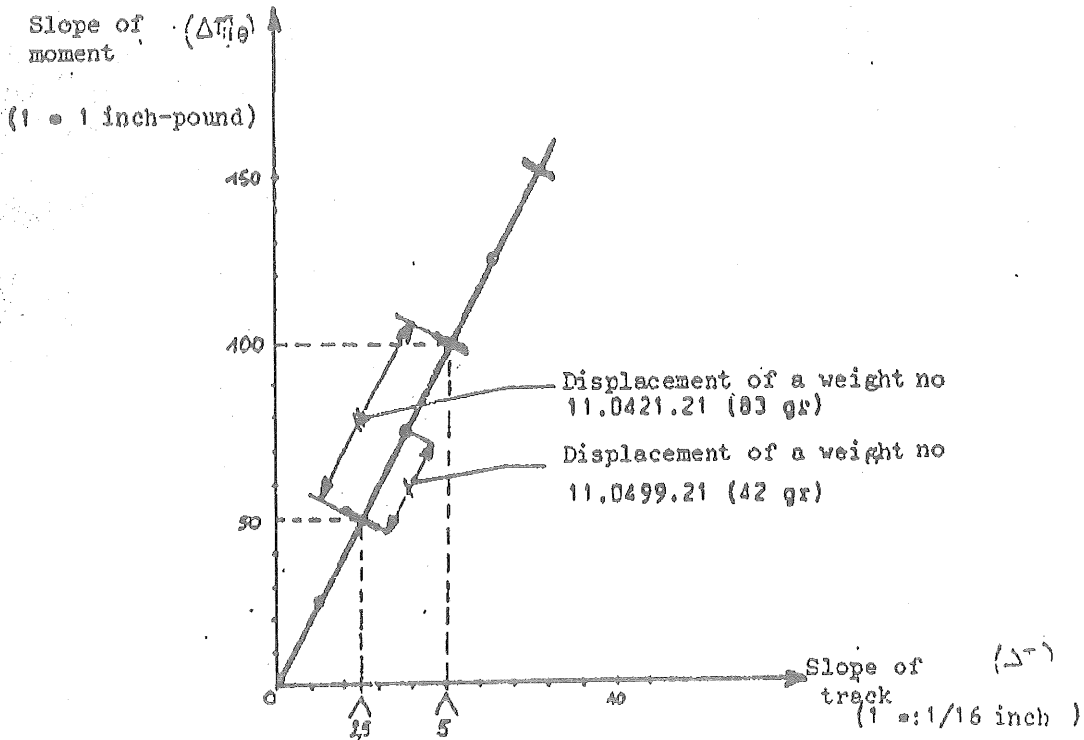
FIGURE IV

DISPLACEMENT OF DYNAMIC BALANCING WEIGHTS

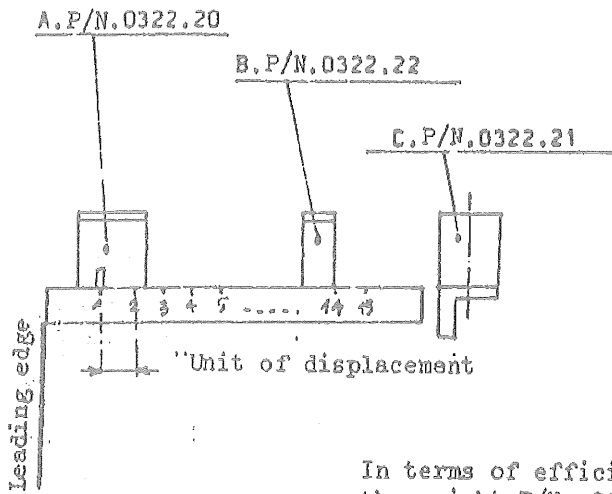


WEIGHT, P/N	WEIGHT (in grammes)
11.0421.20	166
11.0421.21	83
11.0499.20	42
11.0499.21	21
Washer L.2311	7

SA 330 BLADES

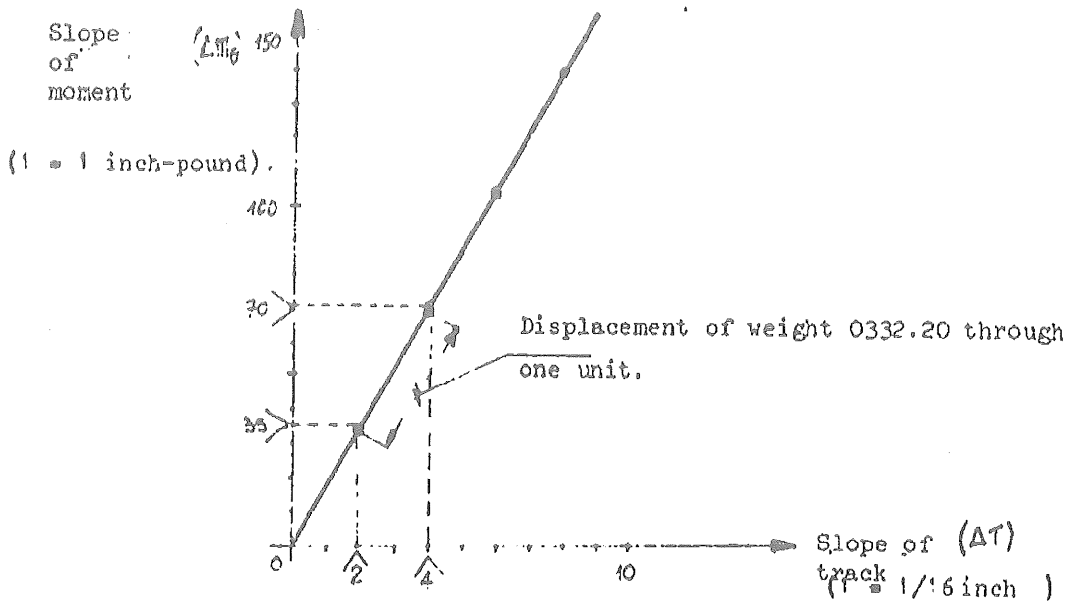


NOTE - This curve is an indication based on statistical observation.



In terms of efficiency, one unit of displacement of the weight P/N .20 equals two units for P/N .22.

SA 321 BLADES



NOTE - This curve is an indication based on statistical observation.

TROUBLE - SHOOTING CHART

Symptom and means of detection	Probable cause	Remedial action
Excessive variation, from one test to another, of the readings of the $\theta$ moment (M $\theta$ )	Instrument fault. Faulty thrust bearings (Rollway) or spindle radial bearings	
Excessive leakage from spindle bearing lubrication system	Worn seal in spindle/sleeve assy. Faulty installation of oil seal ring or lip seal in spindle/sleeve assy.	Replace seal. Install correctly.
Tracking variation greater than 6 units/8° due to rotor head (detected by checking rotor head using master blades)	Too much cyclic. Pitch range exceeding 8° or pitch too high	Keep cyclic at value read at 0.5° max. Check correspondence between cockpit pitch setting and actual blade angle.
	Pitch control linkage stiffness not the same for the three arms. Play or binding in pitch control linkage bearings. Excessive play in the electric tracking control jacks Faulty radial bearings in spindle.	Switch or replace torque tubes to confirm difference of stiffness. Check for bearing play or binding and replace if necessary. Eliminate play. Replace.

TROUBLE - SHOOTING CHART (Cont'd)

Symptom and means of detection	Probable cause	Remedial action
Break in consistency of $\theta$ moments in relation to blade pitch setting	Bearings in pitch control linkage, e.g. torque tube bearings, do not turn freely or have hard points.	Replace faulty bearings.
Abnormal M $\theta$ readings on recording instruments. (Wide fluctuation, deflection, etc...)	Rotor head out of balance. Instrument faults. Dirt on slip-ring bushes Zero shift Fault in dynamometric cell Poor connections Time constants in M $\theta$ recording instruments are not the same. Poor calibration of M $\theta$ recording instruments	Rebalance rotor head.  Clean Adjust zero Replace Check wiring Check time constants.
Excessive zero shift.	Heat-sensitive capacitor on time constant circuit.  Misadjustment due to poor insulation caused by water or humidity.	Replace capacitor or maintain constant ambient temperature at capacitor.  Remove humidity or improve sealing.

TROUBLE - SHOOTING CHART (Cont'd)

Symptom and means of detection:	Probable cause	Remedial action
<p>Mθ recording instrument cannot be steadied on scale.</p>	<p>Discontinuity or earth fault due to :                      - faulty dynamometric cell                      - poor connections                      - earth fault due to water or humidity</p>	<p>Replace cell.                      Check wiring                      Remove humidity or improve sealing</p>
<p>Impossible to bring the dead point within the acceptable limit, i.e. 1/4 % of the total scale (2 units of withinon direct recording instrument, 1 unit of on differential recording instrument).</p>	<p>Too little amplifier gain.                      Faulty amplifier.</p>	<p>Adjust amplifier gain                      Replace amplifier</p>
<p>Failure of electronic tracking equipment</p>	<p>Broken wires or poor insulation.                      Faulty wiring between time signal transmitter and electro-optical sensor</p>	<p>Check. Repair or replace cables.</p>
<p>Pitch change light does not go out.</p>	<p>Signal transmitter gap too big.                      Blades beyond reach of electro-optical sensor                      Crossed wires from signal transmitter</p>	<p>Adjust gap to <math>0.02 \pm 0.005</math> inch.                      Make sure blades pass between 3 and 12 feet above sensor.                      Make sure pin A on transmitter is connected to pin A on phasing unit and pin B to pin B.                      Fit sensor with light shield.</p>
	<p>Direct sunlight on cell of electro-optical sensor                      Faulty electro-optical sensor                      Faulty phasing unit</p>	<p>Replace                      Replace</p>



C.E.H/B - DYNAMIC BALANCING OF BLADES OF TYPE SA 330

Sheet no. \_\_\_\_\_

DATE \_\_\_\_\_  
DURATION \_\_\_\_\_  
TIME VERT. MOT. \_\_\_\_\_

BLADE No. {  
 YELLOW (Reference) \_\_\_\_\_ Charge \_\_\_\_\_  
 BLUE \_\_\_\_\_ Operation \_\_\_\_\_ Charge \_\_\_\_\_  
 RED \_\_\_\_\_ Operation \_\_\_\_\_ Charge \_\_\_\_\_

Temp. \_\_\_\_\_  
Press \_\_\_\_\_  
WIND \_\_\_\_\_

BLADE	ADJUSTMENTS (Inch-pounds)			SLOPE			TRACKING (Inches)					ADJUSTMENTS			WEIGHT POSITIONS				
	1°	3°	5°	7°	9°	1°	3°	5°	7°	9°	WEIGHT TAB	BLADE	BEF. ADJUSTMT.	AFT. ADJUSTMT.					
Y														A	B	C	A	B	C
B														B					
R														R					
Y																			
B														B					
R														R					
Y																			
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