APOLLO ENGINEERING MEMORANDUM A-M # 15868

AC ELECTRONICS
RECEIVED
MAY 17 1967
MILA

5 May 1967

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SUBJECT: PIP TROUBLESHOOTING PROCEDURES FOR THE ISS LEVEL OF TESTING

The purpose of this memorandum is to provide PIPA troubleshooting guide lines which may be used to minimize the incidence of unverified failures at the ISS level of testing. The attached flowgrams illustrate the symptom, the diagnostic testing that should be performed, and the conclusions that accrue based upon the results of the diagnostic testing.

The list of PIPA problems commonly encountered during ISS testing and the appropriate troubleshooting procedures are as follows:

| | |
|---|---|
| FIGURE 1 | Abrupt Changes In Null and/or One g Bias |
| FIGURE 2 | Abrupt Changes In Null and/or One g Bias, Accompanied By A Variable Spread Between Null Bias and One g Bias |
| FIGURE 3 | PIPA IA Axis Requires Continuous Adjustment In Attitude In The Horizontal Plane To Achieve A PIPA Null |
| FIGURE 4 | Large Shift In PIPA Misalignment |
| FIGURE 5 | Large Abrupt Shift In PIPA Scale Factor |
| FIGURE 6 | Saturated G/S Output Signal |
| FIGURE 7 | Large Component Of G/S Quadrature |
| FIGURE 8 | No G/S Output |

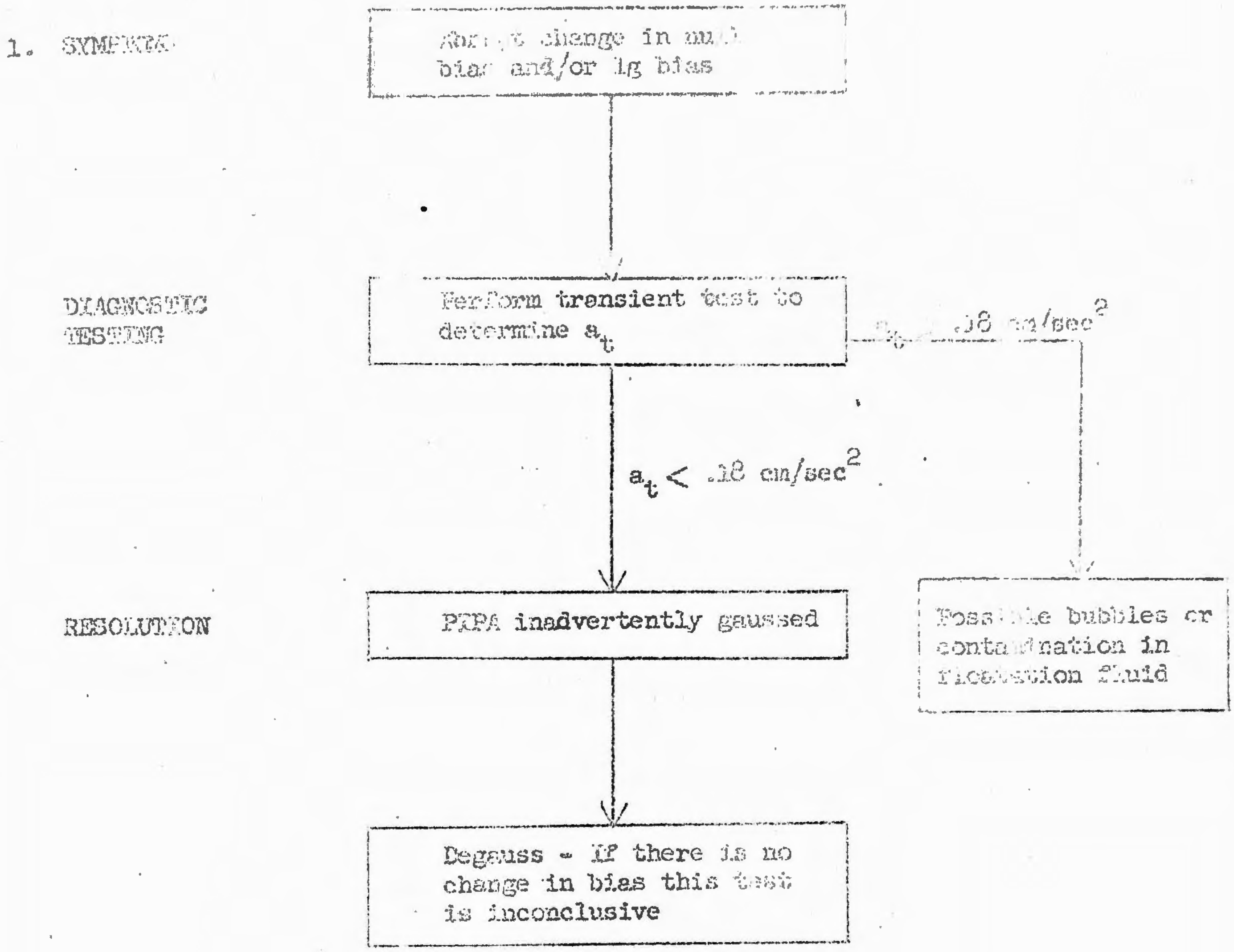

FIGURE 1

For definition of PIPA bias - Appendix B

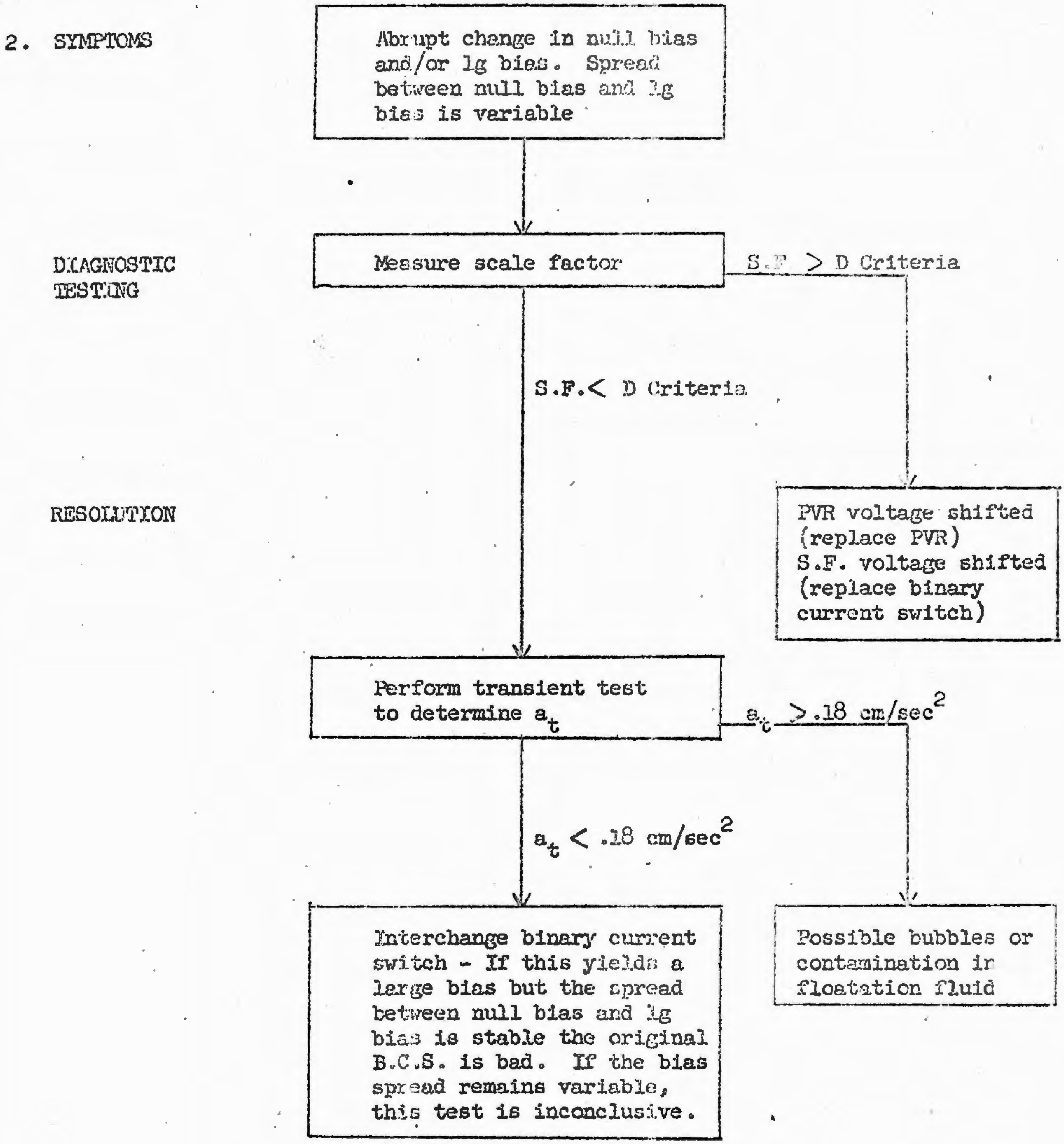
2. SYMPTOMS
DIAGNOSTIC TESTING
RESOLUTION
Abrupt change in null bias and/or 1g bias. Spread between null bias and 1g bias is variable
Measure scale factor
S.F. > D Criteria
S.F. < D Criteria
PVR voltage shifted (replace PVR) S.F. voltage shifted (replace binary current switch)
Perform transient test to determine $a_t$
$a_t$ > .18 cm/sec$^2$
$a_t$ < .18 cm/sec$^2$
Interchange binary current switch - If this yields a large bias but the spread between null bias and 1g bias is stable the original B.C.S. is bad. If the bias spread remains variable, this test is inconclusive.
Possible bubbles or contamination in floatation fluid

FIGURE 2

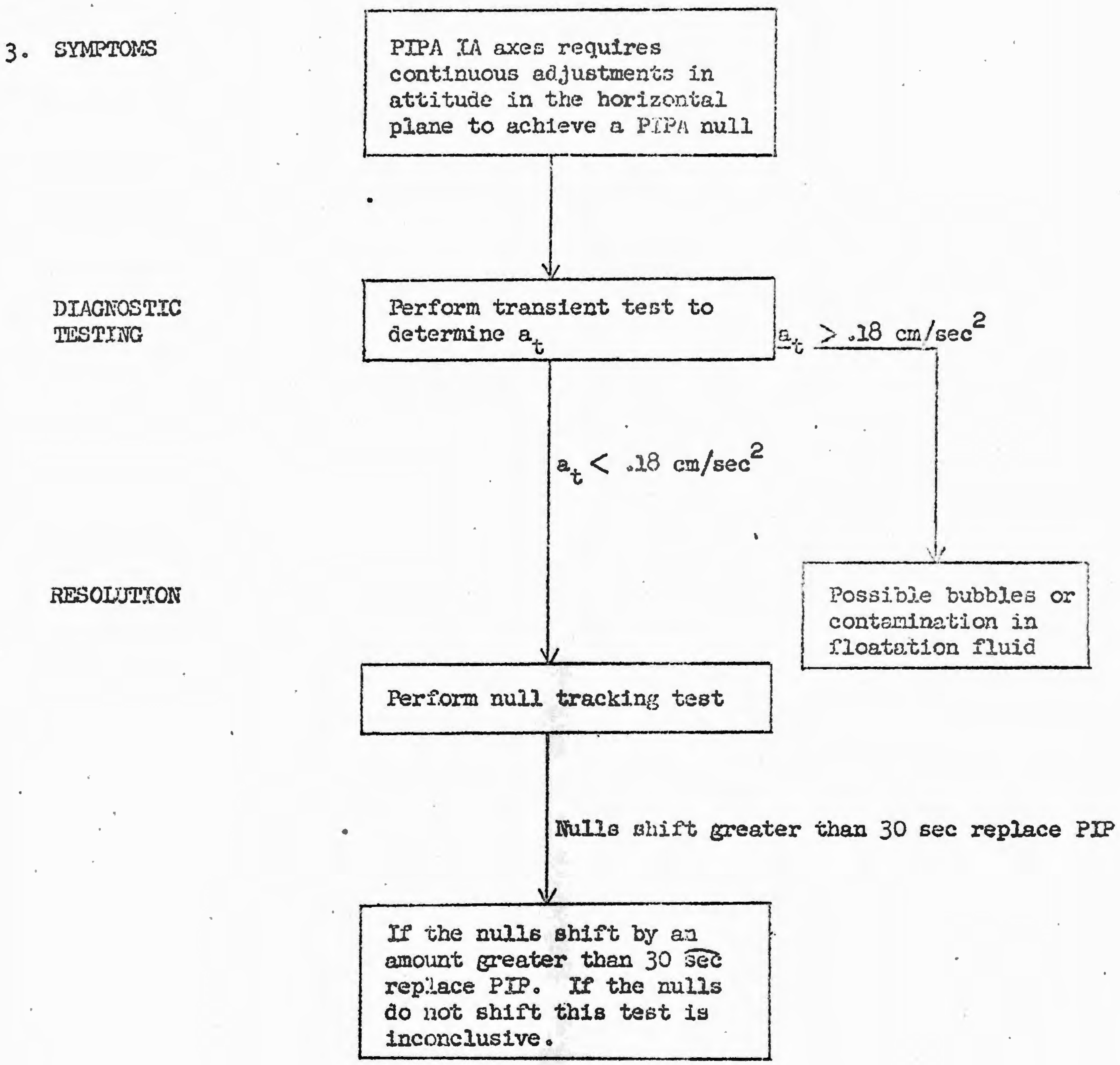
3. SYMPTOMS
PIPA IA axes requires continuous adjustments in attitude in the horizontal plane to achieve a PIPA null
DIAGNOSTIC TESTING
Perform transient test to determine $a_t$
$a_t > .18$ cm/sec$^2$
$a_t < .18$ cm/sec$^2$
Possible bubbles or contamination in floatation fluid
RESOLUTION
Perform null tracking test
Nulls shift greater than 30 sec replace PIP
If the nulls shift by an amount greater than 30 $\widehat{\text{sec}}$ replace PIP. If the nulls do not shift this test is inconclusive.

FIGURE 3

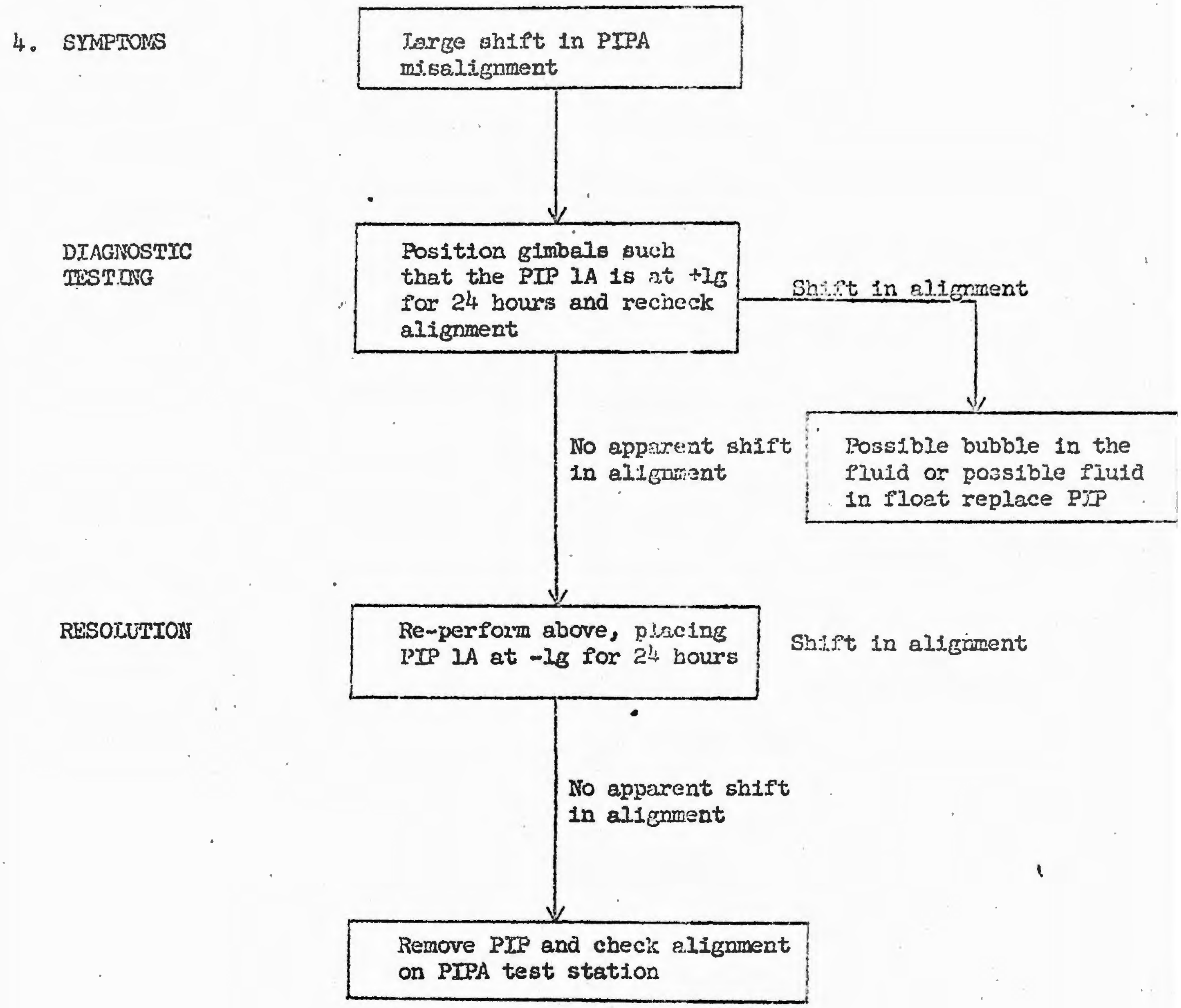
4. SYMPTOMS
Large shift in PIPA misalignment
DIAGNOSTIC TESTING
Position gimbals such that the PIP 1A is at +1g for 24 hours and recheck alignment
Shift in alignment
Possible bubble in the fluid or possible fluid in float replace PIP
No apparent shift in alignment
RESOLUTION
Re-perform above, placing PIP 1A at -1g for 24 hours
Shift in alignment
No apparent shift in alignment
Remove PIP and check alignment on PIPA test station

FIGURE 4

5. SYMPTOMS

DIAGNOSTIC TESTING AND RESOLUTION

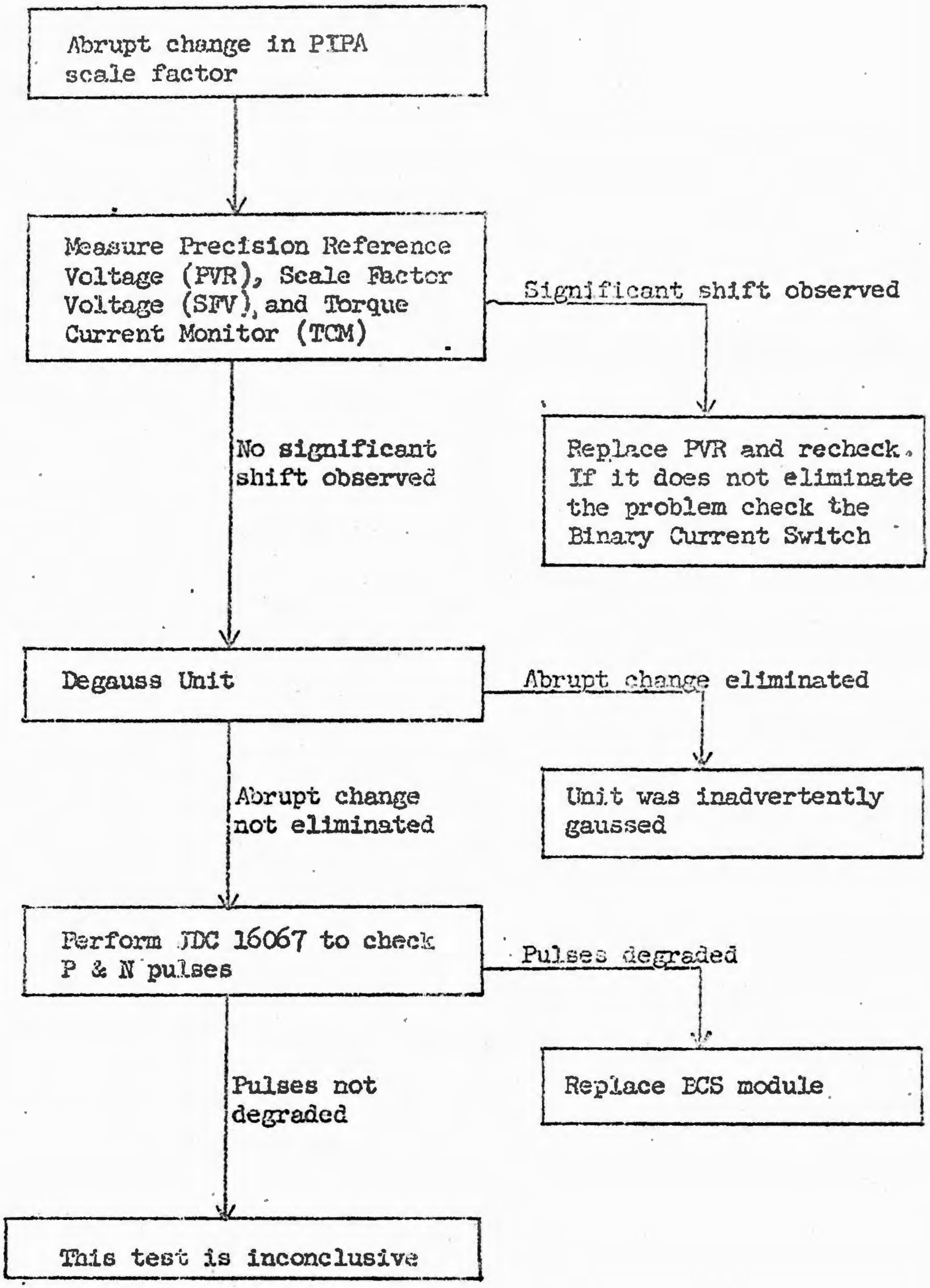

FIGURE 5

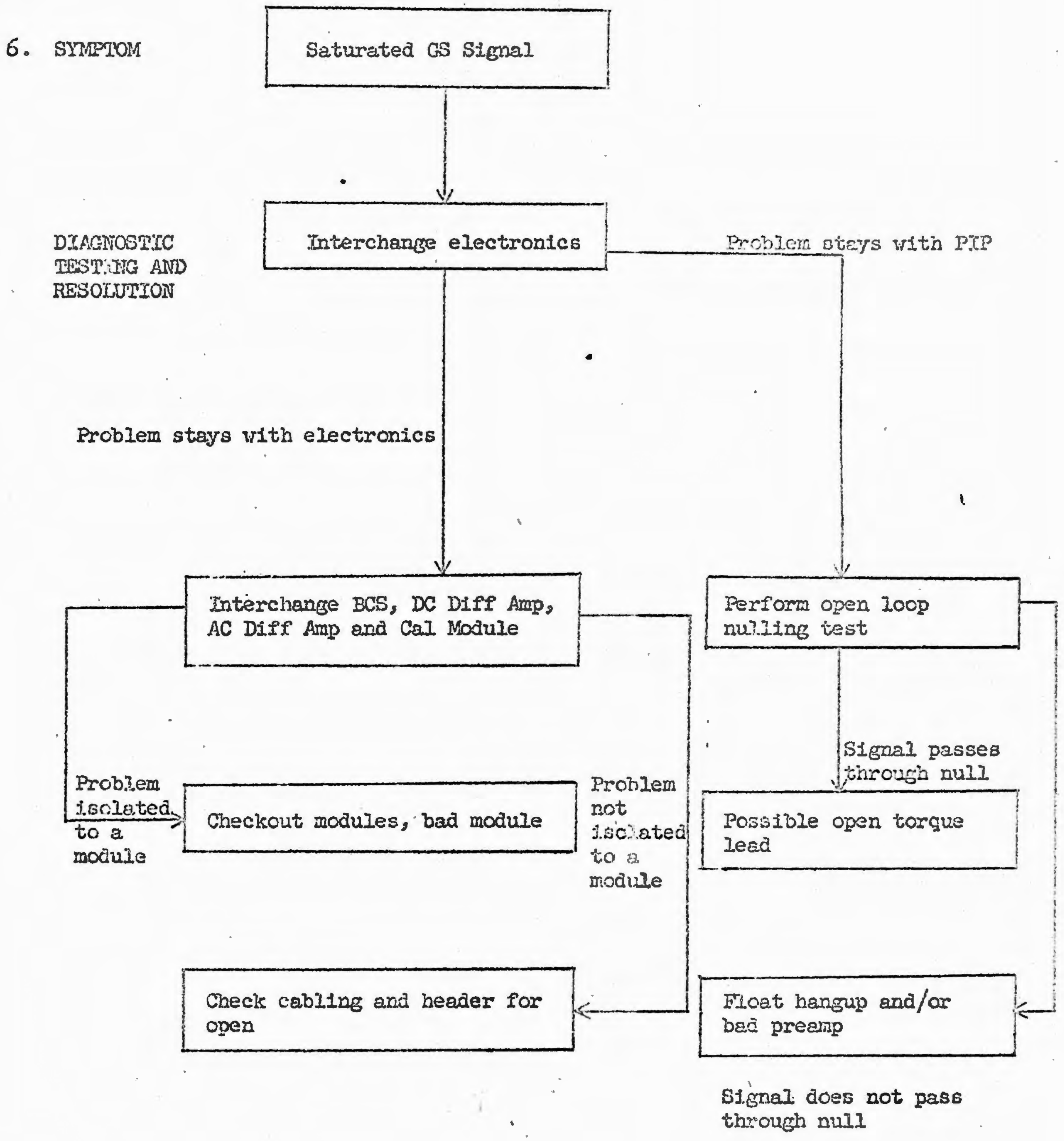
6. SYMPTOM
Saturated GS Signal
DIAGNOSTIC TESTING AND RESOLUTION
Interchange electronics
Problem stays with PIP
Problem stays with electronics
Interchange BCS, DC Diff Amp, AC Diff Amp and Cal Module
Perform open loop nulling test
Signal passes through null
Problem isolated to a module
Checkout modules, bad module
Problem not isolated to a module
Possible open torque lead
Check cabling and header for open
Float hangup and/or bad preamp
Signal does not pass through null

FIGURE 6

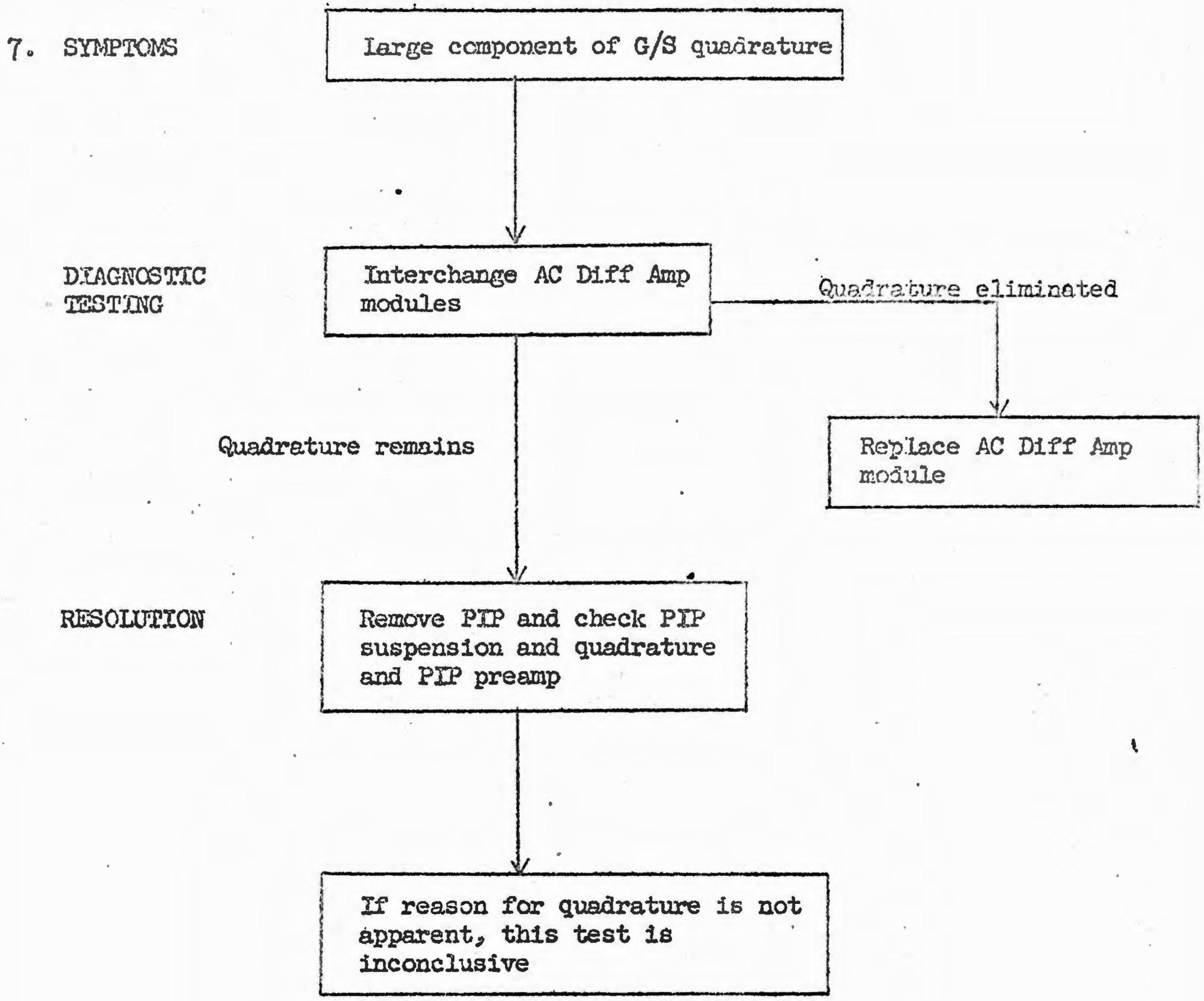
7. SYMPTOMS
Large component of G/S quadrature
DIAGNOSTIC TESTING
Interchange AC Diff Amp modules
Quadrature eliminated
Replace AC Diff Amp module
Quadrature remains
RESOLUTION
Remove PIP and check PIP suspension and quadrature and PIP preamp
If reason for quadrature is not apparent, this test is inconclusive

FIGURE 7

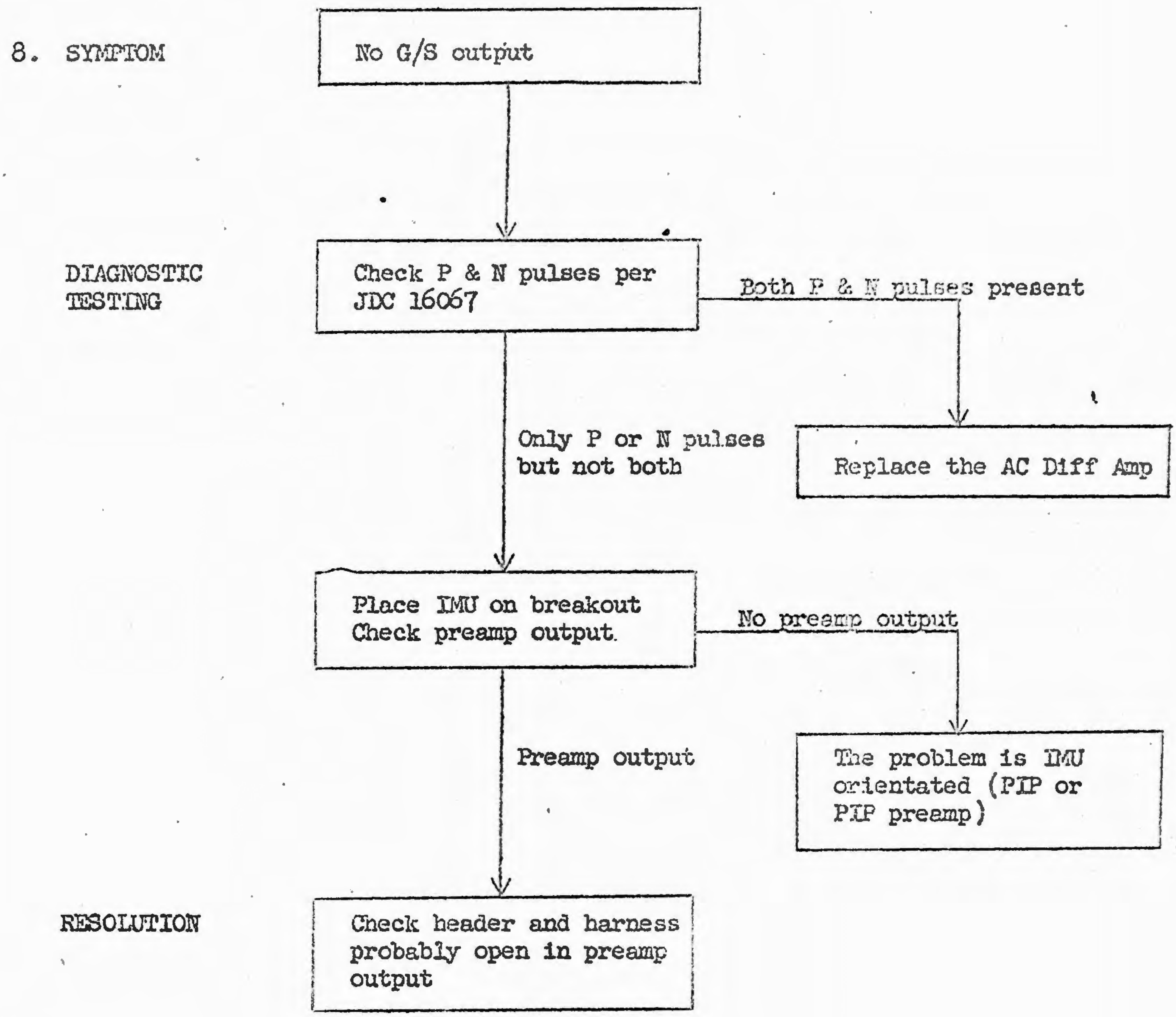

FIGURE 8

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# APPENDIX A

## PIPA SCALE FACTOR

The PIPA scale factor is defined as the velocity increment represented by one $\Delta V$ pulse. This factor is evaluated by placing the PIPA IA axis in a 1G field and measuring the time required to accumulate a predetermined number of $\Delta V$ pulses. The indicated acceleration of a PIPA in a 1G field is as shown in equation A1 below.

EQUATION A1

$$a_+ = g = \left[ \frac{SF_+ \ \Delta V}{\frac{N_{T+}}{3200}} + b \right] \ \text{cm/sec}^2$$

$$a_- = -g = \left[ \frac{-SF_- \ \Delta V}{\frac{N_{T-}}{3200}} + b \right] \ \text{cm/sec}^2$$

where:

$SF_+$ is the scale factor in a +1g field in cm/sec/ $\Delta V$ pulse.

$SF_-$ is the scale factor in a -1g field in cm/sec/ $\Delta V$ pulse.

$\Delta V$ is the preset number of $\Delta V$ pulses.

$\frac{N_{T+}}{3200}$ is the lapsed time to accumulate a predetermined number of $\Delta V$'s with the PIPA IA axis in a +1g field. Lapsed time is measured with 3200 cps clock pulses.

$\frac{N_{T-}}{3200}$ is the lapsed time to accumulate a predetermined number of $\Delta V$'s with the PIPA IA axis in a -1g field. Lapsed time is measured with 3200 cps clock pulses.

b = PIPA bias at 1g.

The significance of PIPA bias at 1g as it effects scale factor measurements is illustrated in Figure A-1 and Equation A2.

A

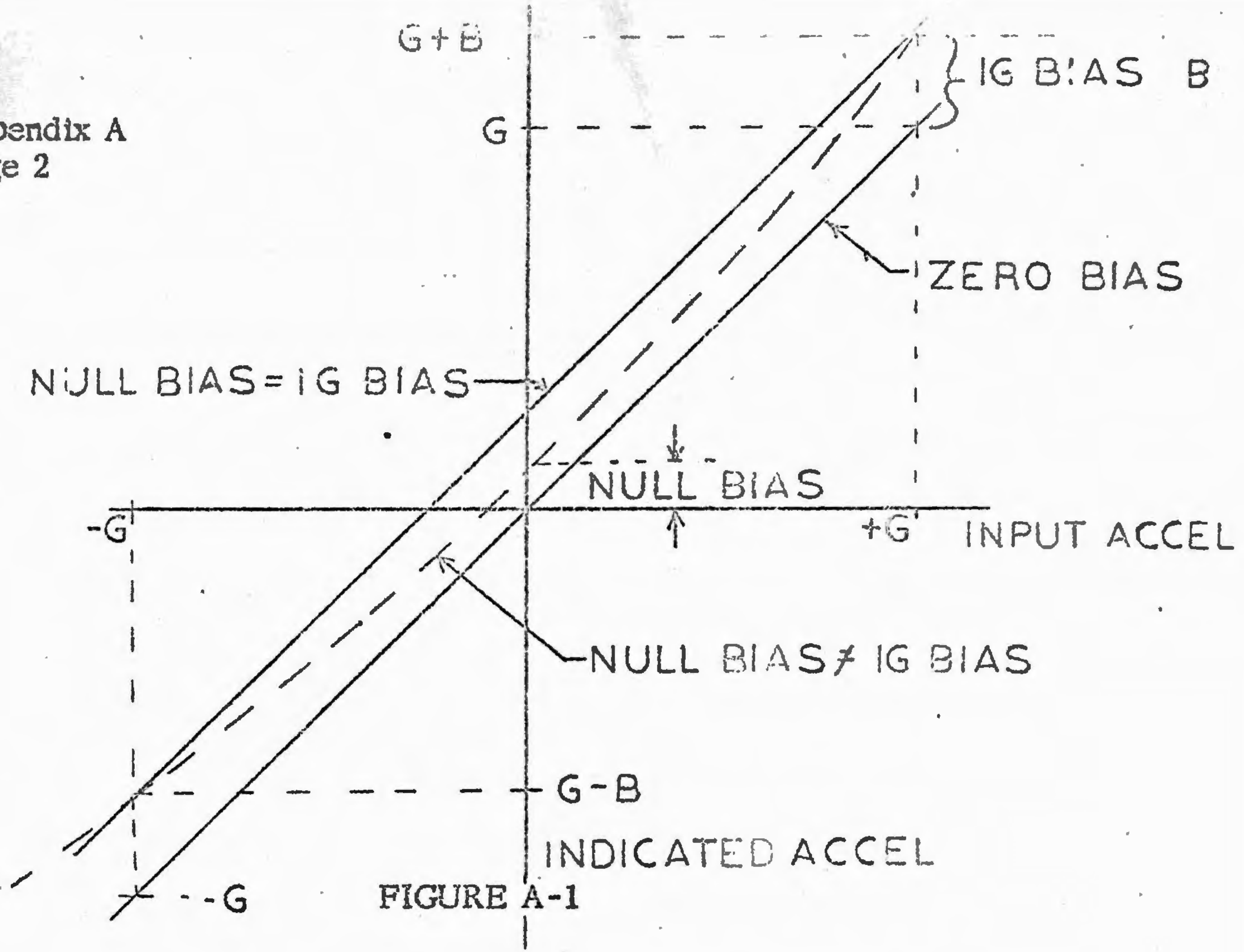

FIGURE A-1

PIPA scale factor is evaluated from equation A1 by solving for $SF_+$ and $SF_-$ and averaging the result. (Equation A2)

EQUATION A2

$$SF_+ = \frac{(g - b)N_{T+}}{3200\,\Delta V}$$

$$SF_- = \frac{(g + b)N_{T-}}{3200\,\Delta V}$$

$$SF_{avg} = \frac{SF_+ + SF_-}{2} = \frac{1}{2}\left[\frac{(g - b)N_{T+}}{3200\,\Delta V} + \frac{(g + b)N_{T-}}{3200\,\Delta V}\right]$$

$$\frac{SF_+ + SF_-}{2} = \frac{g}{3200\,\Delta V}\left[\frac{N_{T+} + N_{T-}}{2}\right] + \frac{b}{3200\,\Delta V}\left[\frac{N_{T-} - N_{T+}}{2}\right]$$

The error in evaluating scale factor due to 1g bias is negligible since a bias of 1 $cm/sec^2$ is equivalent to approximately 1 ppm.

In practice, the scale factor and 1g bias are both determined from the same test data. For CM PIPA's, with a preset of 30,000 $\Delta V$ pulses,

$$SF = \frac{g}{3200 \times 30,000} \left[ \frac{N_{T-} + N_{T+}}{2} \right]$$

$$= \frac{g}{96} \left[ \frac{N_{T-} + N_{T+}}{2} \right] \times 10^{-6} \text{ cm sec}^{-1} \text{ pulse}^{-1}$$

EQUATION A3

The procedure for determining the PIPA scale factor is outlined in JDC's 14201, 14203, and 14205 for the X, Y, and Z PIP's respectively.

For LEM PIPA's the preset count is 150,000 $\Delta V$ pulses, therefore

$$SF = \frac{g}{3200 \times 150,000} \left[ \frac{N_{T-} + N_{T+}}{2} \right]$$

$$= \frac{g}{480} \left[ \frac{N_{T-} + N_{T+}}{2} \right] \times 10^{-6} \text{ cm sec}^{-1} \text{ pulse}^{-1}$$

EQUATION A4

The procedure for determining the PIPA scale factor is outlined in JDC's 16201, 16203, and 16205 for the X, Y, and Z PIPA's respectively.

# APPENDIX B

## NULL BIAS AND DOWN ANGLE

### Null Bias

Null bias is one-half of the apparent deviation in PRA axis position from the attitude required to achieve a PRA up null to a PRA down null. It is caused by an unbalance in torques applied to the float via the T+ and T- torque generator coils.

Assume that during a single 3:3 torquing cycle, the net torque unbalance is $\Delta M$. Then when obtaining a PRA up null the PRA must be moved an angle $\alpha$ from vertical (assuming no PIP misalignment) to balance the unbalance torque $\Delta M$, and when obtaining a PRA down null, the PRA must be moved $-\alpha$ from vertical to again balance $\Delta M$. (Figure B-1)

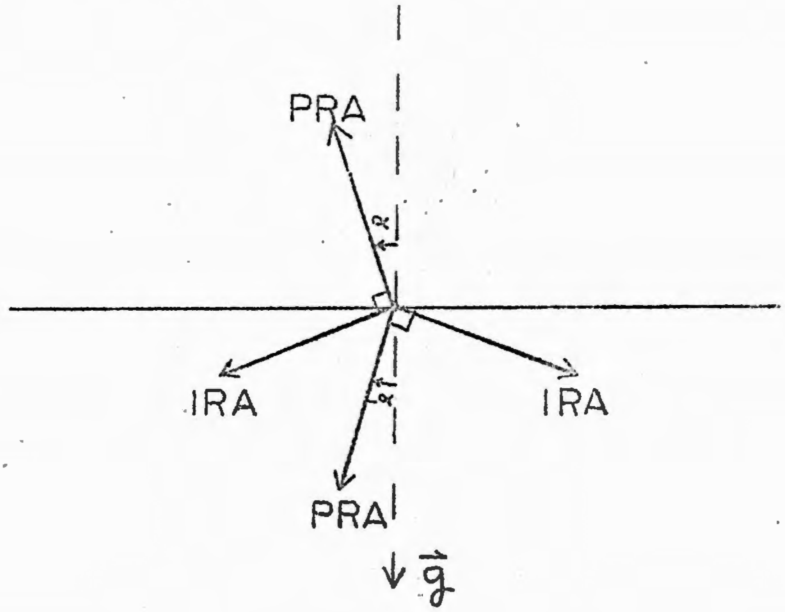

FIGURE B-1

The PRA up and down positions are thus separated by $180^\circ - 2\alpha$. The null bias angle is defined as $\alpha$, and is related to net torque unbalance as follows:

$$\alpha = \frac{\Delta M}{mgl} \qquad \text{B.1}$$

The down angle is the actual angle at which true local vertical is defined by a particular PIPA.

$$A_D = \text{PRA down null position} - \alpha \qquad \text{B.2}$$

The down angle is used to determine PIP orientation for measuring 1g bias and scale factor.

The procedures that describe the null bias test at ISS are JDC's 16200, 16202, and 16204 for the X, Y, and Z PIPA's respectively.

## 1g Bias

1g bias is defined as one-half the difference in acceleration sensed at $A_D - 90^o$ and $A_D + 90^o$ (IA up and IA down). Assuming the PIPA scale factor is independent of attitude

$$A_B = \frac{a_{IA\ down} - a_{IA\ up}}{2} \qquad \text{B. 3}$$

The acceleration sensed at $A_D - 90^o$ and $A_D + 90^o$ is determined by counting 3200 cps clock pulses until a preset number of $\triangle$ V's is accumulated. If $N_{T-}$ is the number of clock pulses counted at IA up and $N_{T+}$ is the number counted at IA down, then

$$a_{IA\ up} = \frac{V\ up}{t\ up} = SF \times \text{no. } \triangle V\text{'s} \times \left[\frac{3200}{N_{T-}}\right] \qquad \text{B. 4}$$

$$a_{IA\ down} = \frac{V\ down}{t\ down} = SF \times \text{no. } \triangle V\text{'s} \times \left[\frac{3200}{N_{T+}}\right]$$

and

$$A_B = \frac{a_{IA\ down} - a_{IA\ up}}{2}$$

$$= \frac{SF \times \text{no. } \triangle V\text{'s} \times 3200}{2} \left[\frac{1}{N_{T+}} - \frac{1}{N_{T-}}\right] \qquad \text{B. 5}$$

$$= \frac{SF \times \text{no. } \triangle V\text{'s} \times 3200}{2} \left[\frac{N_{T-} - N_{T+}}{N_{T+} N_{T-}}\right]$$

The product $N_{T+}N_{T-}$ is found by determining the nominal number of clock pulses N as follows:

$$SF = \frac{g \times t}{(\text{no. of } \triangle V\text{'s})} = \frac{gN}{(\text{no. } \triangle V\text{'s})(x)(3200)}$$

and

$$N = \frac{SF}{g} (\text{no. } \triangle V\text{'s} \times 3200) \qquad \text{B. 6}$$

Then

$$N_{T+}N_{T-} = N^2 = \frac{SF}{g}^{\,2} \ (\text{no. } \Delta V\text{'s} \times 3200)^2$$

and

$$A_B = \frac{g^2}{2 \times SF} \left[\frac{1}{\text{no. } \Delta \text{ V's} \times 3200}\right] \left[N_{T-} - N_{T+}\right] \qquad \text{B.7}$$

For CM PIPA's, SF = 5.85 cm $\sec^{-1}$ $\text{pulse}^{-1}$ and the preset number of V's = 30,000.

Thus,

$$A_B = \frac{(980)^2}{2 \times 5.85} \left[\frac{1}{(30,000 \times 3200)}\right] \left[N_{T-} - N_{T+}\right]$$

$$= 0.856\,(N_{T-} - N_{T+}) \times 10^{-3} \text{ cm sec}^{-2} \qquad \text{B.8}$$

For LEM PIPA's, SF = 1.00 cm $\sec^{-1}$ $\text{pulse}^{-1}$ and the preset number of V's = 150,000.

Thus,

$$A_B = \frac{(980)^2}{2 \times 1} \left[\frac{1}{150,000 \times 3200}\right] \left[N_{T-} - N_{T+}\right]$$

$$= (N_{T-} - N_{T+}) \times 10^{-3} \text{ cm sec}^{-2} \qquad \text{B.9}$$

The times $t_{up}$ and $t_{down}$ will be different due to the net torque unbalance $\Delta$ M. At $A_D - 90°$, the torque unbalance will add to the torque produced by gravity and will result in a decrease $\Delta$ t in the time required to count a preset number of $\Delta$V's. Similarly, at $A_D + 90°$, $\Delta$ M will result in an increase of $\Delta$ t. Thus,

$$A_B = \frac{SF \times \text{no. } \triangle V\text{'s} \times 3200}{2}\left[\frac{1}{N + \triangle N} - \frac{1}{N - \triangle N}\right]$$

$$= SF \times \text{no. } \triangle V\text{'s} \times 3200 \left[\frac{\triangle N}{N^2}\right] \qquad \text{B. 10}$$

$$= \frac{g^2}{SF}\left[\frac{1}{3200 \times \text{no. } \triangle V\text{'s}}\right] \triangle N$$

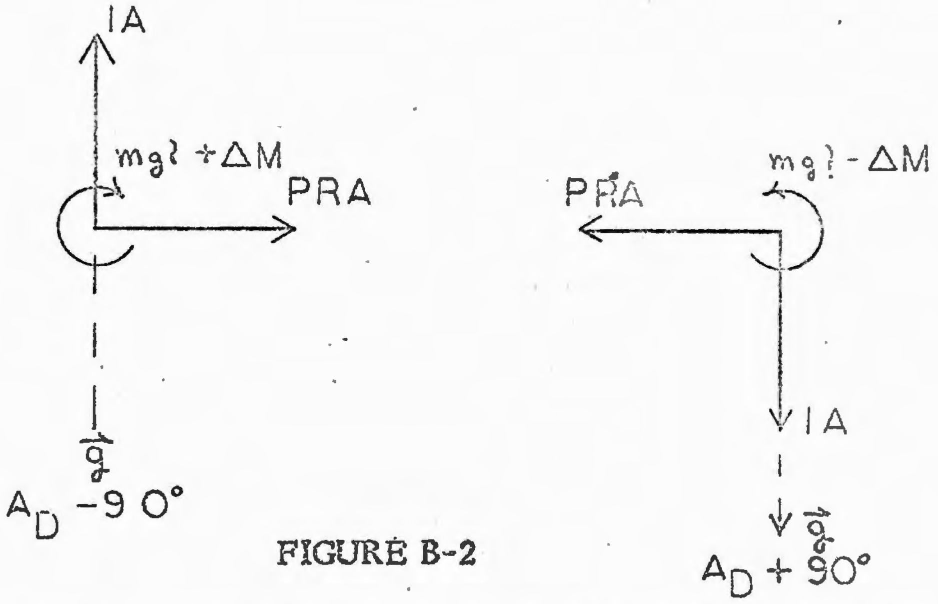

FIGURE B-2

The incremental change in clock pulse count $\triangle N$ is found as follows:

$$\triangle t = \frac{V}{g^2} \triangle g = \frac{SF \times \text{no. } \triangle V\text{'s.}}{g^2} \times \frac{\triangle M}{ml}$$

and

$$\triangle N = \left[\frac{3200 \times SF \times \text{no. } \triangle V\text{'s}}{g^2}\right] \times \frac{\triangle M}{ml}$$

$$= \left[\frac{3200 \times SF \times \text{no. } \triangle V\text{'s}}{g^2}\right] g \propto \quad \text{from equation B. 1} \qquad \text{B. 11}$$

The 1g bias is then

$$A_B = \left[ \cancel{\frac{g^2}{SF \times 3200 \times no.\ \triangle V's}} \right] \times \left[ \cancel{\frac{3200 \times SF \times no.\ \triangle V's}{g^2}} \right] \quad g\propto$$

and

$$A_B = g\propto \qquad \text{B.12}$$

This is the same as the null bias angle when it is converted to equivalent cm/sec$^2$:

$$A_B = g \times \text{null bias} = g\propto \qquad \text{B.13}$$

# APPENDIX C

## PEAK TRANSIENT TEST

The purpose of the Peak Transient Test is to determine the stability with which a PIPA can measure a constant acceleration input. The PIP is rotated about its OA from a PRA down null to an attitude that is equivalent to 1/2 g. In effect the PIP is subjected to step input accelerations of 1/2 g magnitude that varys from -1g to +1g. Assuming a constant PIPA scale factor the variability in five (5) acceleration measurements at a fixed attitude of the PIPA IA axis is a reliable indicator of floatation anomalies.

The acceleration by the PIPA is evaluated by measuring the time required to accumulate a predetermined number of $\Delta$ V pulses. The time to accumulate the preset number of $\Delta$ V pulses is recorded from five (5) consecutive runs at a fixed IA attitude.

The maximum acceleration measured by the PIPA is:

$$\text{C-1} \qquad a_{max} = \frac{SF \times \Delta V}{\frac{T_{min}}{3200}}$$

where

$a_{max}$ = measured acceleration in cm/sec$^2$

SF = scale factor in cm/sec/$\Delta$ V pulse

$\Delta$V = preset pulses, 75,000 for LEM; 15,000 for CM

$T_{min}$ = minimum of 5 time recordings as measured by a 3200 pulse per second clock

$T_{max}$ = maximum of 5 time recordings as measured by a 3200 pulse per second clock

The minimum acceleration measured by the PIPA at the same IA attitude is:

$$\text{C-2} \qquad a_{min} = \frac{SF \times \Delta V}{\frac{T_{max}}{3200}}$$

The maximum short term variability in measured acceleration is:

$$\text{C-3} \qquad a_T = a_{max} - a_{min} = SF \times 3200 \left[ \frac{1}{T_{min}} - \frac{1}{T_{max}} \right] \Delta V$$

$$a_T = SF \times 3200 \left[ \frac{T_{max} - T_{min}}{T_{max} T_{min}} \right] \Delta V$$

The explicit equations for LEM and CM PIPA's are as shown in equation C-4.

$$\text{C-4} \qquad a_T = C \left[ \frac{T_{max} - T_{min}}{T_{max} T_{min}} \right]$$

where

$C = 1.404 \times 10^8$ for CSM at 1/2 g
$C = 2.808 \times 10^8$ for CSM at 1 g
$C = 1.20 \times 10^8$ for LEM at 1/2 g
$C = 2.40 \times 10^8$ for LEM at 1 g

The complete "Peak Transient Test" involves evaluating $a_T$ at eight (8) cardinal positions of the IA axis as shown in Figure C-1. The PIP is rotated from 1A to $1A_8$ in 1/2 g steps.

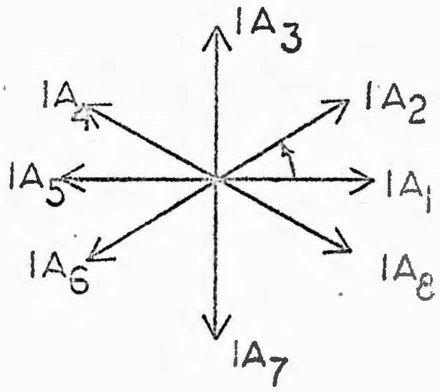

FIGURE C-1

The preset △ V count for each IA attitude is selected such that the accumulated time for each cardinal position is approximately the same.

The procedure for performing the Peak Transient Test in a G&N configuration is as follows:

1. Set up counter and printer per the applicable JDC (16201 for the X PIP, 16203 for the Y PIP, and 16205 for the Z PIP).
2. Obtain a stable 3:3 null at the first null position per applicable JDC. (JDC 16200 for the X PIP, JDC 16202 for the Y PIP, and JDC 16204 for the Z PIP.)

3. Set counter preset to 37,500 for LEM and 7500 for C/M.

4. Rotate the table rotary axis +30° from the null obtained in step 2 and reset the counter. Obtain 5 counter printouts.

5. Set counter preset to 75,000 for LEM and 15,000 for C/M.

6. Rotate the table rotary axis to +90° from the null obtained in step 2 and reset the counter. Obtain 5 counter printouts.

7. Repeat step 3.

8. Rotate the table rotary axis to +150° from null obtained in step 2 and reset the counter. Obtain 5 counter printouts.

9. Obtain a stable 3:3 null at the second null position per the applicable JDC. (Reference step 2.)

10. Repeat steps 3 through 8 using the null obtained in step 9 as a reference.

11. The transient $a_t$ shall be calculated at each position in accordance with the following:

$$a_t = SF \left[ \frac{X(T_{max} - T_{min})}{(T_{max})(T_{min})} \right] \quad 3200$$

12. Repeat steps 1 through 11 three times.

# APPENDIX D

## NULL TRACKING TEST

The open and closed loop null tracking tests are used to detect floatation problems. These tests are generally performed to add credence to the results of a peak transient test which indicated problems with floatation.

### Closed Loop Null Tracking

The closed loop null tracking test is performed by tumbling the PIPA about its OA axis and measuring the IA left and right nulls that occur as a result of this agitation.

The procedure for performing the closed loop null tracking test in the ISS configuration is as follows:

1. Obtain a stable 3:3 null at the first position per the applicable JDC (16200 for the X PIP, JDC 16202 for the Y PIP, and JDC 16204 for the Z PIP).
2. Rotate the rotary table +90° from the null obtained. Hold the system in this orientation for 5 minutes.
3. Repeat step 1, tracking and recording the null value at 1 minute intervals on the oscillograph tape for 15 minutes.
4. Repeat step 2 but rotate -90° from null.
5. Repeat steps 1 through 4 for the second null position.

### Open Loop Null Tracking

The open loop null tracking test is a float freedom and phasing check. The PIP is rotated about the OA axis to an angle +2° from a PRA down null. The G/S output is then monitored to determine if the error signal changes phase. If it does not the PIP is rotated to -2° from a PRA down null and the G/S output is monitored. The error signal should change phase which would indicate proper operation of the PIP preamp and that the float is not hung up.

The procedure for performing the null tracking test in the ISS configuration is as follows:

1. Set the table at the first position +2° per applicable JDC (16200 for X PIP, JDC 16202 for Y PIP, and JDC 16204 for the Z PIP).
2. Press PIPA Loop Inhibit button.
3. Monitor the G/S Error Signal to determine if it passes through null (monitor for 5 minutes).
4. Rotate the rotary table -2° from the first position and repeat step 3.

# APPENDIX E

When a system's problem has been isolated to the electronics of one particular PIPA loop the problem can be further isolated to the IMU or to the PIP electronics by interchanging the PIP electronics. This is accomplished by the following procedure:

1. Downmode the system.
2. Breakout connector J2 on the IMU Breakout Box.
3. On the Breakout Box connect the following wires:

   X PIP T+ IMU side to Y PIP T+ PSA side
   X PIP T- IMU side to Y PIP T- PSA side
   X PIP T+ IMU side to Y PIP T+ PSA side
   X PIP S$\overline{G}$ Hi IMU side to Y PIP S$\overline{G}$ Hi PSA side
   X PIP SG Lo IMU side to Y PIP SG Lo PSA side
   X PIP T+ PSA side to Y PIP T+ IMU side
   X PIP T- PSA side to Y PIP T- IMU side
   X PIP T+ PSA side to Y PIP T+ IMU side
   X PIP S$\overline{G}$ Hi PSA side to Y PIP S$\overline{G}$ Hi IMU side
   X PIP SG Lo PSA side to Y PIP SG Lo IMU side

4. Place system in Operate.
5. The X PIP output will be indicated on the Y PIPA electronics output.
6. The X and Y PIP's are used as an example, any two PIP's can be interchanged.