



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
MANNED SPACECRAFT CENTER  
HOUSTON, TEXAS 77058

IN REPLY REFER TO: 70-FC41-128

June 29, 1970

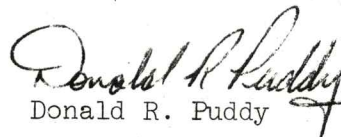
MEMORANDUM TO: Distribution

FROM : FC4/Assistant Chief, LM Systems Branch

SUBJECT : LSB Notes of Interest

Attached is a complete set of Notes of Interest generated by LSB that still contain valid data. Future Notes of Interest will be accompanied by an update in the index and will have the same baseline distribution as this memo.

Any questions or comments should be addressed to D. R. Puddy, extension 4626.

  
Donald R. Puddy

Enclosure

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
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TO: All ye knowledgeable ones desirous of tiny  
tidbits of tantalizing information

FROM: A studious researcher of sim-generated problems

SUBJECT: Them sticky marks and rods

7 Nov 1969

Recent developments have come to my attention and I thought I should make you all aware of them since Apollo 12 is just around the corner. In one of last Friday's descent runs those tricky sim people decided to stick the MARK X button "in" and as a result the crew was prevented from going to P66! Since the MARK and MARK REJECT buttons use the same processing in the computer as the RATE OF DESCENT switch, this is a perfectly legitimate failure and the systems people should have been prime for it since alarm 112 (mark or mark reject not being accepted) occurred some time prior to P63. In the future the crew will be monitoring for the 112 alarm and should they get it they may be interested in something I learned from the flight software people. P66 can be entered through the back door by first going to P67 (ATTD HOLD and MAN THROT), establishing the rate of descent desired via the TTCA, and then switching back to AUTO THROT. This will establish P66 guidance and hold the rate of descent just established. Any further changes in the rate of descent will require the same "in-and-out-of-P67" procedure.

Another little goodie concerns a RATE OF DESCENT switch that sticks (the possibility of which is not all that unlikely according to Grumman). If it occurs prior to selection of attitude hold the crew will again be locked out of P66. If it occurs subsequent to selection of attitude hold the computer will proceed directly to P66, process a one-foot-per-second change in the rate of descent P66 was entered with, lock the crew out of P64 and P65, and process no further ROD inputs. Again the "in-and-out-of-P67" procedure can be used to hold a manually established rate of descent, but of course P64 and P65 guidance is lost since P66 performs an attitude hold function only. There is no alarm 112 in this case so your only indication of something wrong is the sudden and undesirable appearance of P66 in the DSKY mode lights.

Stay tuned for further developments.

Bud Durand  
LM Systems Branch





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NOV 10 1969

IN REPLY REFER TO: 69-FC4-3

MEMORANDUM TO: FC/Chief, Flight Director's Office  
FROM : FC4/Assistant Chief, LM Systems Branch  
SUBJECT : Emergency liftoff procedures

1. Discussions among members of the Apollo 12 ascent team have indicated that the present checklist for emergency liftoff, while adequate, does not portray the actions that would be taken for an absolute minimum liftoff situation. The existing procedure was based on minimum time activation and alignment of both guidance systems, preconditioning the ascent batteries, and configuring all systems for staged operations. Simulations have indicated that manual ascents are feasible and should be considered as the normal mode of operation if time does not permit battery preconditioning or guidance system activation and alignment.
2. Using these new guidelines, we have prepared a procedure which should allow liftoff within three minutes (system configuration time only) and enable at least a computer driven FDAI reference. Listed below are the required chronological steps:

BATS 5 & 6 - ON tb - gray

BATS 1 thru 4 - OFF/RESET tb - gray

PRO

(RESTART LT - ON, STBY LT - OFF)

RSET, V96E

CB(11) IMU OPR - CLOSE

(NO ATT LT - OFF IN 90 SEC)

IF TIME ALLOWS:

V41N20 - LOAD DESIRED

X, Y, Z GMBL ANGLES

CB(11) AGS - CLOSE

AGS STATUS - OPERATE

400 + 4E LUNAR ALIGN

400 + 0E ATT HOLD

MODE CONT (BOTH) ATT HOLD

Configure CBs Per EMER LIFT OFF Status Charts



S-BAND ANT - SLEW

P = +120°

Y = -30°

TRACK MODE - AUTO

MASTER ARM - ON

ASC He SELECT - BOTH

ASC He PRESS - FIRE

GO TO APS START CARD

3. Modifying the present 15 minute procedure to place the ascent batteries on line, take the descents off, and then activate and align the guidance systems may also eliminate glitching the computer systems.

4: We recommend that these changes be made to the Apollo 12 checklists or at least that the technical information be relayed to the crew. Inputs from the ground during real time, except to recommend an emergency liftoff within a certain time frame, should be eliminated.

  
Donald R. Puddy

cc:

FC/G. D. Griffin

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FC4/W. L. Peters

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FC4:DRPuddy:mg

1/30/70

Note of Interest - PQGS (See also "PQGS" dated 2/27/70)

1. Apollo 11 and 12 data has indicated that the DPS Propellant Quantity Gaging System low level light came on some 20 to 30 seconds early. This is confirmed both by the smoothing of the PQGS data and by calculating where the light should have been activated according to the trajectory data. The data also shows that the PQGS measurements oscillated (see figure 1) two to three percent from one second to the next. These oscillations make it almost impossible to declare the low level invalid because they jump into the acceptable range.

2. Data indicates that the early low level and PQGS oscillations are being caused by slosh in the propellant tanks or inside the PQGS tube. In order to discuss this problem, a meeting was called by Colonel McDivitt and Mr. Owen Morris. The various aspects of this problem were discussed and the following conclusions were reached:

a. For Apollo 13, no extra time should be added to the low level because no one knows for sure what is causing the apparent premature low level or whether it will occur on Apollo 13 as it did on Apollo 11 and 12.

b. Increasing the sample rate on Apollo 13 and 14 on the PQGS measurements to 100 samples per second should allow post mission teams to determine what is happening.

c. If slosh is the problem, it was noted that the anti-vortex baffles would prevent an early uncovering of the zero G can. The low level is at 9.4 inches and the anti-vortex baffles are about three inches high.

Colonel McDivitt did feel that the Apollo 13 procedures should be looked into to see if there was any way to minimize the problem. He also felt that a larger effort should be spent to try and understand the problem.

3. The following action items were given to Owen Morris in conjunction with the above:

a. More work should be done to try and determine whether slosh could cause this problem and what sort of mechanical means could be used to correct it; i.e., screens, baffles in the PQGS.

b. Work should continue to see if electronic filtering could correct the low level coming on early by having it look at a certain number of inputs before latching.

c. The accuracy of the PQGS should be looked into again in light of the recent data and the effect on the mission.

d. Ground controllers should look into whether the PQGS could be smoothed so as to better validate the low level.

4. Since the meeting, the following things have occurred or come to light:

a. The 100 sample/sec PQGS data will be averaged every second at the RSDP and sent back to MCC for real-time use. If the frequency of the oscillations is greater than 2 or 3 cycles per second, the data should appear smooth. Determination of whether the data is smooth or not will have to be made in real-time.

b. We had a discussion with Al Bean and Al said he did not notice any fluctuations in the gages during Apollo 12, but he never looked at them for a long time; he did glance at them occasionally. He did say that he was surprised that they seemed to work so well. This may indicate that there is only a ground problem, but since Al said it could have been fluctuating but he did not notice it, we have no way of knowing for sure.

5. The ground procedures and mission rules are being scrutinized to determine if any improvement could be made if the smoothed data is in fact smooth. The current procedure is shown in Figure 2 and the proposed procedure is shown in Figure 3. The advantages and disadvantages of each procedure are shown below:

a. Current procedure:

(1) Advantage. If anything goes wrong, the crew always reads 2% on his gage which simplifies the procedure from a ground standpoint.

(2) Disadvantages.

(a) The crew could abort as much as 60 seconds early (3%) if low level was invalid and if the crew display oscillates as much as the ground telemetry.

(b) The crew must look at their gage more which takes time away from other things.

b. Proposed procedure:

(1) Advantages:

(a) If the low level light comes on when the lowest PQGS is greater than 7%, that much hover time can be saved; i.e., 20 seconds/1 percent PQGS.

(b) The crew hears callouts just like the low level was valid unless there is some other failure which invalidates the time; i.e., propellant leaks, MR, etc.



(2) Disadvantages:

- (a) It changes an existing procedure which has worked well for two missions.
- (b) It complicates the ground procedures.
- (c) This procedure will work only if the ground data is smooth which won't be known until powered descent is started. In the event the data wasn't smooth, the old procedure would have to be used. Of course, the crew wouldn't know what procedure we were using, so it wouldn't be any impact on them.

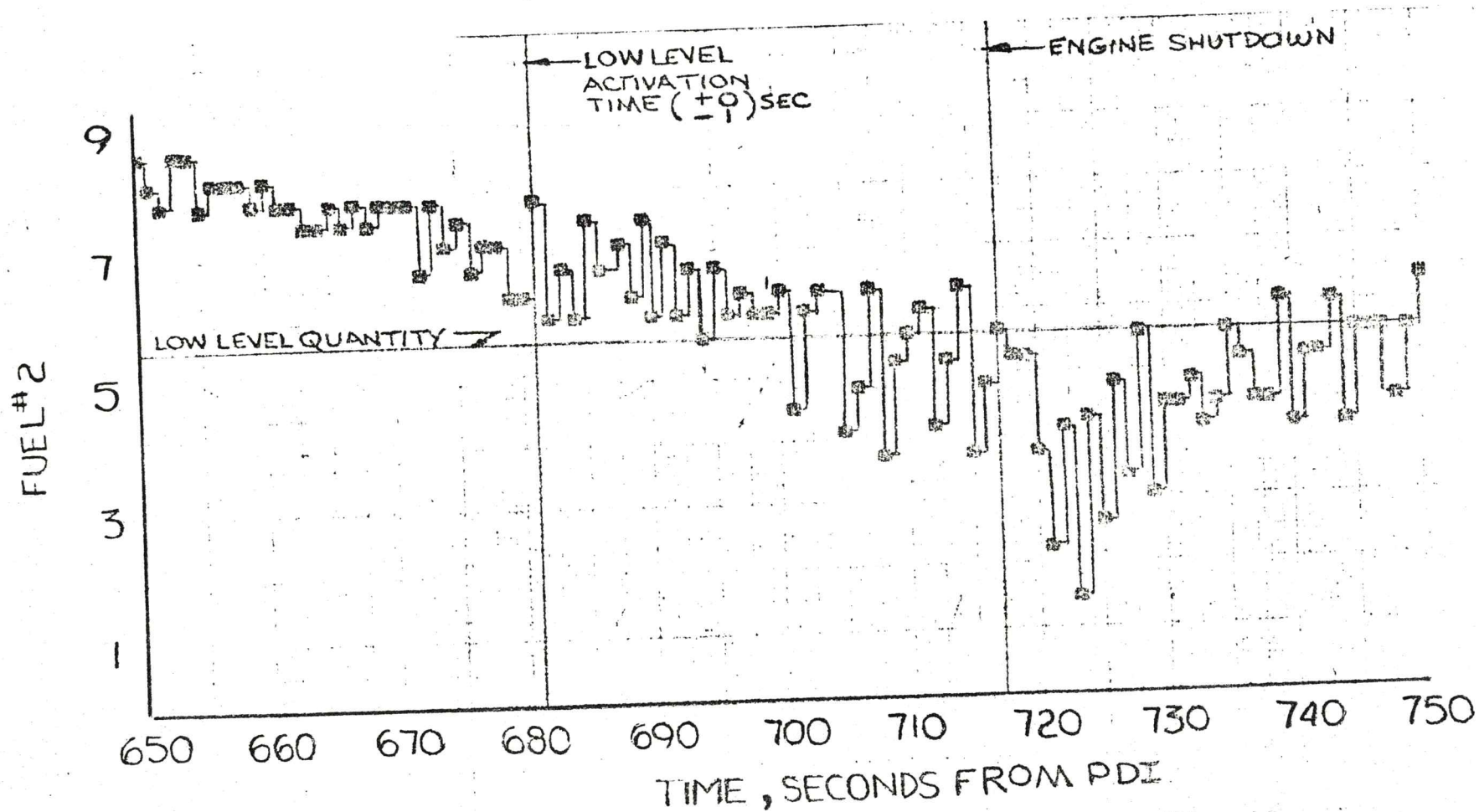
6. No decision has been reached to date on what procedure should be used and no decision will be reached until further study is made.

*Robert S. Nance*  
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GAC/Bethpage/J. Salek

LM-6 PQGS READINGS  
FOR FUEL 2  
(FIGURE 1)



February 19, 1970

Note of Interest -- Bang-Bang Method for APS Helium Leaks

The procedure to use should an APS helium leak between the quad check valves and ASC helium regulator 1 and 2 shutoff valves occur has been in a constant state of change since IM-5 (schematic, enclosure 1). The discussion has concerned the exposing of a leak in the above mentioned area to a constant supply of helium. The object when a leak is present is to expel propellants. A certain amount of helium is required to expel propellants, and the remainder may be lost through a leak. The helium leak rate on the helium which may be lost can vary depending on the time the leak is exposed to the helium source. The smaller the leak exposure time, the larger the leak rate can be for a given amount of helium. The amount of time the leak is exposed to helium can be reduced by closing the ASC shutoff valves and using the tanks in a blowdown mode. Using the Conservation of Mass principal, the following equations can be written which shows graphically why the time the leak is exposed ( $t_{\text{time leak exposed}}$ ) needs to be restricted.

$$M_{\text{in}} = M_{\text{out}}$$

$$M_{\text{leaving source tanks}} = M_{\text{out}} \begin{matrix} (1) \text{ to expel propellant} \\ (2) \text{ thru leak} \end{matrix}$$

$$M_{\text{leaving source tanks}} = (\dot{m}_{\text{leak}})(t_{\text{time leak exposed}}) + (\dot{m}_{\text{to expel prplnt}})(t_{\text{time to expel prplnt}})$$

Enclosure 2 shows the procedures for IM-5 (method 1), IM-6 and IM-7 (method 2), plus the new approach known as the bang-bang method (method 3) which is being proposed for IM-7 and subsequent. Each of the three procedures listed in enclosure 2 was subjected to a study to show the maximum allowable leak rate that each method could stand and still provide for propellant depletion. The results were:

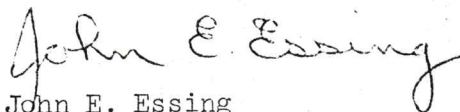
Method 1 - 0.02 lbs mass of He/sec  
Method 2 - 0.03 lbs mass of He/sec  
Method 3 - 0.04 lbs mass of He/sec

The assumptions used in the study are described in enclosure 3, and a plot of time into powered descent versus ullage pressure for each method is shown in enclosure 4.

The data clearly indicates that method 3 which is the bang-bang procedure allows the highest leak rate while still being able to deplete propellants. Method 3 showed that the maximum leak rate increased by placing the APS in a blowdown mode on three occasions during the burn. Since this was a hand calculated study, conditions could not be optimized; therefore, larger leak rates could be found to be acceptable simply by placing the system in a blowdown mode more often. A computer study which



could refine the assumptions made and optimize all parameters involved will be the only way to determine the proper procedure exactly.



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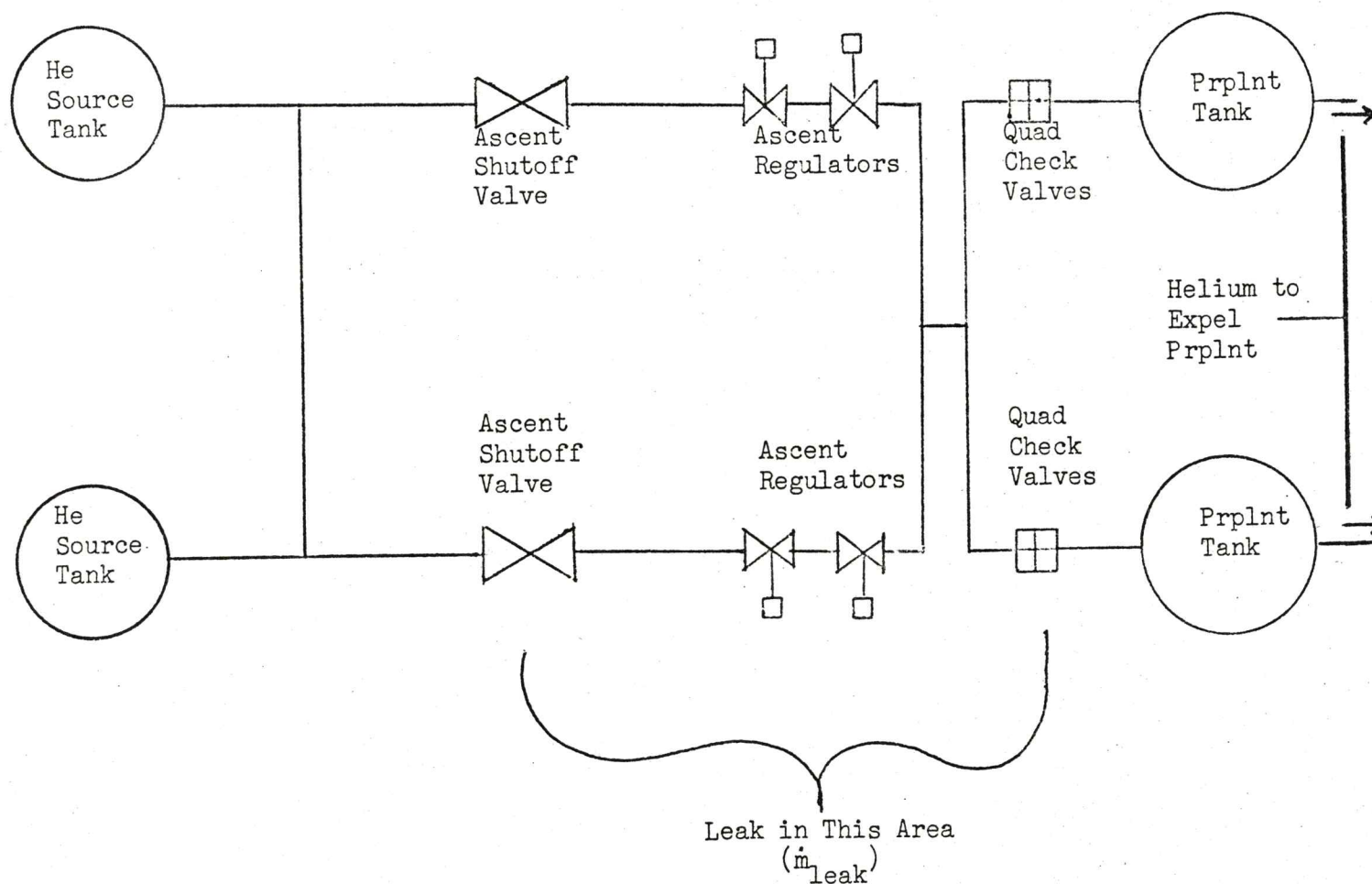
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Enclosure 1

#### Method 1 (IM-5 procedure)

If leak occurs prior to liftoff between quad check valves and shutoff valves:

- (1) Pressurize with one bottle immediately prior to ignition.
- (2) Use second helium bottle when APS goes in blowdown.

#### Method 2 (IM-6 and IM-7 procedure)

If leak occurs prior to liftoff between quad check valves and shutoff valves:

- (1) Pressurize with one bottle immediately prior to ignition.
- (2) Use second helium bottle when APS ullage pressure greater than or equal to 125 psia or after 280 sec into the ascent burn.

#### Method 3 (Bang-Bang procedure)

If leak occurs prior to liftoff between quad check valves and shutoff valves:

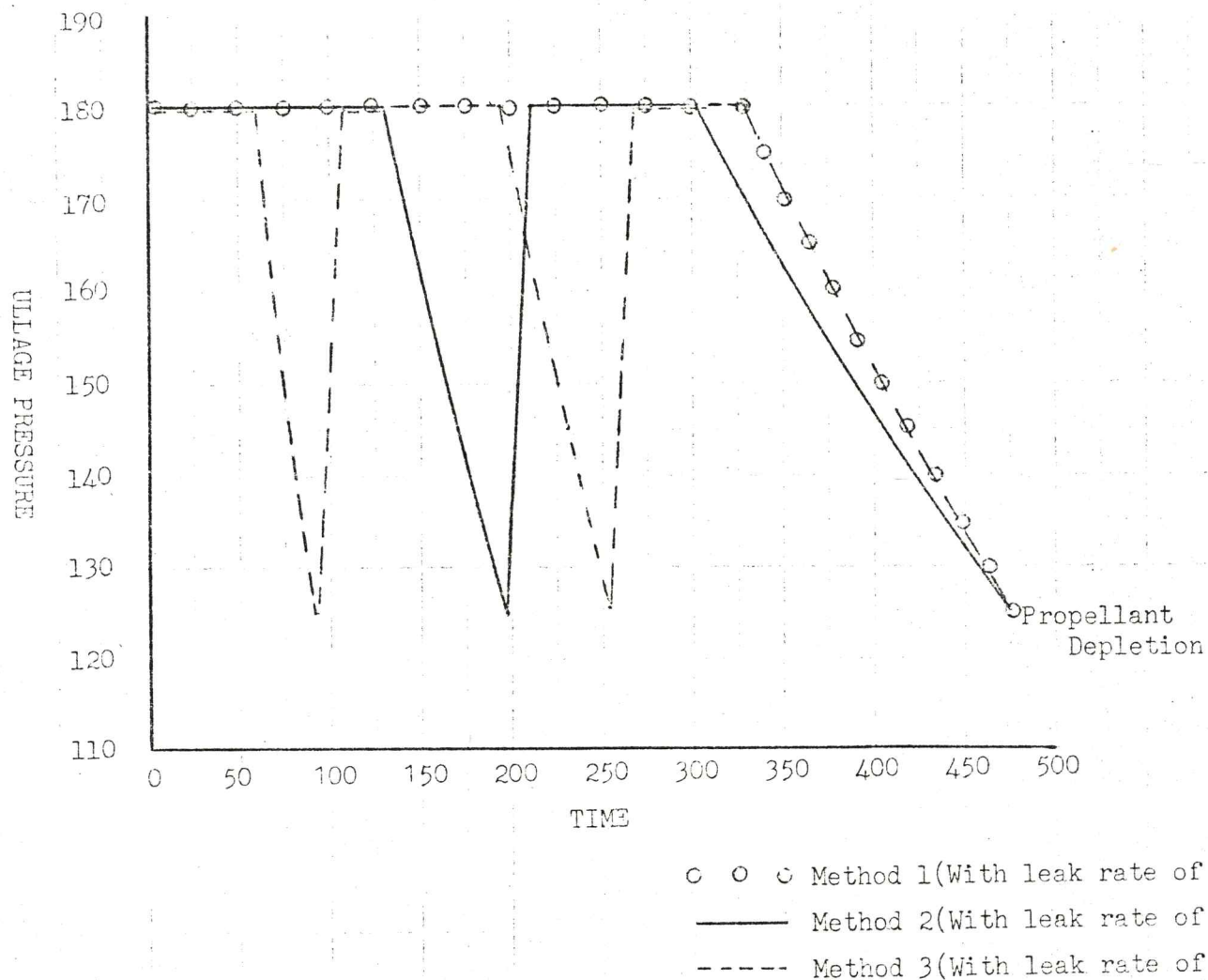
- (1) Pressurize with one bottle immediately prior to ignition.
- (2) After 60 seconds into burn, close ASC shutoff valves and go into blowdown until ullage pressure is 125 psia. Repressurize and repeat procedure until propellants are depleted. Second helium bottle should be used when required.



Assumptions made in study

- (1) All helium is used from each tank.
- (2) Helium usage (and propellant usage) is same whether system is in normal burn mode or blowdown mode. This causes  $I_{sp}$  to be fixed.
- (3) Engine helium usage is 0.0205 lb/sec.
- (4) Minimum ullage pressure for safe engine operation is 125 psia.
- (5) Time to repressurize system at any time into the mission from an ullage pressure of 125 psia is 15 seconds.
- (6) The leak is downstream of the regulator so leak rate is constant during normal operation. (Pressure feeding leak is around 180 psia at all times when the leak is being fed.)

Enclosure 4



See correction to the Note Of Interest on "Redundant Ascent Engine On," dated 4/3/70

20 February 1970

#### Note of Interest - Redundant Ascent Engine On

1. The Apollo 13 mission rule on loss of redundant ascent engine on capability during PDI presently requires an abort if DPS insertion capability exists. This is based on the risk of continuing PDI past DPS insertion capability with only one path to ignite the APS, and the fact that this risk is unwarranted. Extended lunar stay would be NO GO with the crew being one failure away from a catastrophic condition (i.e., failure in manual APS on circuit).
2. If the loss of redundancy occurs after DPS insertion capability, PDI is to be continued through landing even though extended lunar stay is NO GO. The rationale is that the APS must be used regardless of loss of redundancy and it is safer to land, regroup, and lift-off from the lunar surface than attempt an abort stage during the final minutes of PDI.
3. Utilizing certain design features of the auto eng on logics, a work-around procedure is available for certain "Eng on Cmd" failures, previously considered as loss of ascent eng on redundancy and cause for abort or an early lift off. When the LGC (or AEA) commands an "eng on" to the CES circuitry, the CES sends an "on" command to both the descent and ascent eng on logic. Which engine ignites depends on which engine is armed. Both the descent and ascent engine on/off logic are designed such that once an "on" command has been received, the auto "on" command from the computer or logic input CES circuitry can be lost and the logic will hold the engine on. Therefore, both the descent and ascent eng on/off logics are holding an eng on during PDI, and will continue to do so even if the ENG ARM circuit breaker (4CB37, panel 16) fails, or any other failure occurs, resulting in the loss of the auto on to the logics. The eng on/off logics for both engines will continue to hold the "on" command as long as their respective circuits are powered and not reset. For the ascent engine, the power source is from the ATCA power supply, which requires the ATCA circuit breaker (4CB82, panel 16). The ABORT STAGE pb resets the ascent eng on/off logic, and therefore, should not be used during the nominal procedures for lunar lift off.
4. Since the Abort Stage pb resets the ascent eng on/off logic, redundancy should be considered lost for these failures only for an abort during PDI requiring use of the APS. In order to achieve an Abort Stage during PDI and still maintain the redundancy for the cases listed above, MASTER ARM, APS pressurization, and EPS battery switchover must be performed manually as well as placing the ENG ARM switch to "ASC" and calling up the appropriate LGC program via the DSKY or switching to AGS. This is a lengthy procedure during an Abort from PDI, especially during the final minutes. Therefore, if an APS abort is required after a loss of the auto on cmd, it is recommended that the Abort Stage pb plus Start pb be used. Based on the work-around procedure, however, the above failures should be considered as NOT having lost ascent engine on redundancy. Therefore, PDI should only be aborted prior to loss of DPS insertion capability for confirmed failures of the manual Start override circuitry or auto on circuitry resulting in a loss of the "on" command from the ascent eng on/off logic.



5. Assuming the auto on failure during PDI, the following procedures should be performed for LM powerdown after landing and lunar liftoff:

a. Lunar surface powerdown:

- (1) CB (16) stab/cont: ENG ARM - OPEN (Prior to selecting P68 if not already open).
- (2) CB (16) Stab/Cont: ATCA - LEAVE ENERGIZED

If the ATCA circuit breaker is pulled during the nominal power down sequence, the "on" command held in the ascent eng on/off logic is lost and cannot be restored. Therefore, liftoff at next best opportunity is required. There is sufficient battery power on Apollo 13 to handle this additional load.

b. Lunar liftoff:

- (1) Pressurize APS nominally per checklist.
- (2) MASTER ARM - on at nominal time in checklist (staging will not occur if not performed).
- (3) DO NOT activate Abort Stage pb at any time (nominally, T -30 sec).
- (4) ENG ARM sw - ASC at TIG = 0 (eng will ignite and staging will occur).
- (5) Backup auto start via START pb.
- (6) Manual shutdown based on DSKY/DEDA shutdown criteria (auto off command will not reach ascent eng on/off logic).

*Larry W. Strimple*  
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GNC Section, LSB

*Hal JEH*  
HAL/JEH

23 February 1970

Note of Interest - Loss of Manual Throttle

The loss of both TTCA's or the manual throttle logic will cause the throttle to fall into the non-throttleable range when the LGC commands full throttle. This could occur anytime during the first seven minutes or so of powered descent, resulting in an abort case (the present M/R calls for an abort prior to higate) when max non-throttleable time is exceeded. In order to prevent an abort, the DECA power CB (4CB69 PNL 11 STAB/CONT) could be pulled which forces the throttle to FTP hydraulically due to the fail safe design of the throttle when DECA power is lost (see DRW 10.23 Zone G5). At throttle down, which could be relayed from MCC or read from commanded throttle on DSKY, the crew could push in the DECA Power breaker and continue to land with the auto throttle in control (Note: The auto throttle commands can compensate for loss of the manual throttle bias at thrust levels of 63% and below). To abort, the same procedures could be used to obtain max throttle capability. However, during the period that the DECA Power breaker is pulled, there are two operational modes in which redundancy is temporarily lost:

1. The crew loses the ability to monitor the Eng Gimbal warning light.
2. There is only one method of holding on the DPS ENG (i.e., the "Des Eng Cmd Ovr" Sw PNL 3 ISI9).

These two apparent disadvantages may be circumvented since the gimbal circuit can be monitored from the ground and the single route of holding on the DPS engine is not critical prior to throttle down. Therefore, the method of pulling the DECA Power breaker is a feasible procedure for the continuation of PDI if all manual throttle is lost.

*Ed Marzano*  
Ed Marzano

*HAL/NEH*  
HAL/NEH

23 February 1970

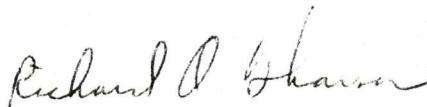
Note of Interest - LM Attitude Control Modes during PDI

1. Of the many LM attitude control modes, four are acceptable for performing undocked powered maneuvers. In order of priority, these are: PGNS Auto, AGS Auto, PGNS Rate Cmd, and AGS Rate Cmd. However, for PDI, AGS Auto is not considered a valid control mode except for an abort case. The remaining modes, PGNS minimum impulse, AGS pulse, AGS direct (3-axis), and hardover are deemed unacceptable for powered maneuvers.
2. For PDI, a philosophy has been adopted which states that any failure that leaves only one acceptable control mode such that one more failure would require use of an unacceptable control mode, an abort will be requested to insure crew safety. Based on this philosophy, there are a number of failure modes which may occur that will allow for continuation of the mission. A number of examples follow: (Enclosure 1 defines the control modes, their components/interfaces, and disabling failures.)
3. The present mission rules require PGNS Auto/Rate Cmd and AGS Rate Cmd for initiation and continuation of PDI. If a failure occurs in the PGNS auto mode such that PGNS rate cmd is uneffected (e.g., mode control switch failure), the two remaining control modes, PGNS Rate Cmd and AGS Rate Cmd, share no point of commonality except jet drivers for which one failure has no effect on crew safety. The same logic is true for a loss of PGNS Rate Cmd independent of PGNS Auto. In these cases continuation of the mission would be the recommended course of action. It should be pointed out that loss of either mode may cause a change in the crew landing procedures. For example, loss of PGNS Auto would cause the crew to manually fly the FDAI error needles until touchdown. This would not allow automatic velocity nulling using auto-P66. Loss of PGNS Rate Cmd would necessitate flying in PGNS Auto or switching to AGS Rate Cmd for manual-P66 capability and switching back to PGNS for Auto-P66 velocity nulling.
4. A failure which causes loss of both PGNS Auto/Rate Cmd would leave only AGS Rate Cmd as an acceptable control mode. A subsequent failure (CES AC fail, which disables all three RGA's and loss of AGS Auto) would result in an abort utilizing one or more of the unacceptable control modes. Thus a failure common to both PGNS Auto/Rate Cmd would require an abort.
5. The loss of AGS Rate Cmd would leave the crew dependent on PGNS Auto/Rate Cmd. This is undesirable since a single failure could remove total PGNS capability; however, consideration for continuing the mission with loss of AGS Rate Cmd would be given if the failure is independent of AGS Auto since this would be a valid mode for an abort if required. The partial loss of AGS Rate Cmd (loss of one RGA) is considered an acceptable mode with the crew using AGS direct (secondary coils) in the effected axis. Based on this, a one-axis failure on AGS Rate Cmd will allow continuation of the mission.



6. Loss of AGS Auto would not constitute loss of AGS Rate Cmd in all cases since the crew may have rate dampening capability (no attitude hold). Thus, this failure may not be cause for abort unless AGS Rate Cmd is also disabled. In addition, loss of any of the unacceptable modes of control (secondary coils, etc.) also is an allowable event until only one acceptable control mode exists at which time an abort must be performed.

7. The statements above reflect the intent and interpretation of the current 3-axis control mission rules. It should be pointed out that inherent in these rulings is the availability of PGNS guidance steering for either automatic steering or for providing steering information to the crew (FDAI error needles). The loss of this capability above hi-gate is cause for an abort. However, below hi-gate manual landing at the crew's option may be attempted with loss of guidance steering. The rationale for this decision is that the problem may be recoverable upon landing and that time for ground evaluation during this time frame is minimal. Thus, in accordance with this statement, landing may be attempted after hi-gate (at the crew's option) with a violation of the 3-axis control philosophy stated earlier, since the failure of guidance steering may be common with PGNS Auto/Rate Cmd. Of course, an obvious unrecoverable failure would be cause for an abort and would be so recommended during this time frame.



Richard A. Thorson

Enclosure



HAL/JEH



<u>Control Mode</u>	<u>Components/Interfaces</u>	<u>Ruling</u>
PGNS Auto	Operational ISS	Loss of mode <sup>1</sup>
	Operational LGC	Loss of mode <sup>1</sup>
	Valid Navigation	Loss of mode
	Primary Pre-amps	Loss of mode <sup>2</sup>
	CES-LGC Interface	Loss of mode <sup>2</sup>
PGNS Rate Cmd	Operational ISS	Loss of mode <sup>1</sup>
	Operational LGC	Loss of mode <sup>1</sup>
	Primary Pre-amps	Loss of mode <sup>2</sup>
	ACA	c/m with loss of one
	ACA-LGC Interface	Loss of mode
	CES-LGC interface	Loss of mode <sup>2</sup>
AGS Rate Cmd	Operational AEA	c/m <sup>3</sup>
	Operational ASA	c/m <sup>3</sup>
	3 RGA's	c/m with loss of one <sup>4</sup>
	ACA	c/m with loss of one
	Abort pre-amps	Loss of mode <sup>2</sup>
	ATCA	Loss of mode
	CES-AEA interface	Loss of mode <sup>2</sup>
AGS Auto	Operational AEA	Loss of mode
	Operational ASA	Loss of mode
	3 RGA's	c/m with loss of one <sup>4</sup>
	Abort pre-amps	Loss of mode <sup>2</sup>
	ATCA	Loss of mode
	CES-AEA Interface	Loss of mode <sup>2</sup>

1. A permanent loss of either the ISS or LGC will disable both PGNS Auto and Rate Cmd. A temporary loss of the ISS or LGC will disable only PGNS Auto (cause a loss of guidance steering) leaving PGNS Rate Cmd as an acceptable mode.

2. Although these components and interfaces are common to each mode, there are specific failures associated with each that may disable only one of the two modes.

3. Loss of the AEA or ASA functions would cause a loss of the attitude hold function of AGS Rate Cmd. This would only effect AGS Rate Cmd if erroneous outputs were introduced to the ATCA. A zero output would permit retention of AGS Rate Cmd as an acceptable control mode.

4. Loss of one RGA would disable rate dampening in the effected axis only. By using AGS direct in this axis, AGS Auto/Rate Cmd remains an acceptable mode.

February 27, 1970

Addendum to PQGS Note of Interest

Reference Note of Interest - PQGS (For copy of this reference contact R. S. Nance, extension 4717.)

1. The purpose of this addendum is to update everyone on the status of the PQGS problem with oscillating data and the recommended procedures for Apollo 13.

2. Since the PQGS Note of Interest was put out, the following new developments have occurred:

a. Post touchdown PQGS data from IM-5 revealed the PQGS measurements settled out after a few minutes except for a very few one and two-PCM count changes (one PCM count equals approximately 0.4% PQGS reading).

b. Grumman has done some crude initial slosh testing that shows that slosh could be amplified by the PQGS. This may be due to the high velocity of the fluid as it passes the three openings at the bottom of the tank (see enclosure 1). This propellant flow could cause a pressure drop inside the PQGS and make the level pulse down. This is only considered a possibility now but more sophisticated testing is under way.

c. Grumman made a movie of what the IM-6 fuel 2 ground data would have looked like on the onboard gage. Even though we already have seen this data on graphs, the movie really impressed just how much the PQGS onboard gage could fluctuate.

d. Marlo Cassetti's people have done some statistical analysis of the ground PQGS data and have come up with one sigma variation from the mean of 0.6% and a three-sigma variation of  $\pm 1.8\%$ . Due to the lack of high sample rate data, these numbers are relatively crude. Enclosure 2 shows these numbers are rather conservative. By just looking at this enclosure, one can see for any given instant the variation could be considerably less than 1.8%.

3. The current decision point for validating the low level on the upper end of the range is 7.1% on the lowest valid PQGS reading (5.6% nominal low level + 1.3% PQGS accuracy + 0.2% possible error due to sampling data once every 5 seconds at MCC). This conveniently corresponds to a PCM

count which is 7.134%. This means that if the proposed (alternate) ground procedure (figure 3 of this addendum) were used, at least 1.5% of the propellant would be lost if the low level is invalid. This is due to starting the 93-second time callouts at 7.1% instead of 5.6%. This means that the abort/no abort decision point could come at 2.5% actual propellant remaining (1% abort pad + 1.5% lost because of starting time callouts at 7.1% instead of 5.6%). The current procedures call for using 2% on the lowest valid gage if the low level is declared invalid.

Because of the fluctuations of the PQGS ( $\pm 1.8\%$ ), the abort decision point using this method could come at 3.8% actual propellant remaining (2% abort pad + 1.8% fluctuation). This means the difference between these two methods could be as much as 1.3% (3.8% minus 2.5%) which is equivalent to 26 seconds of hover time. One, however, must not lose sight that the 1.8% fluctuations are a 3-sigma situation and the one-sigma fluctuations are only 0.6% which would make the abort/no abort decision point 2.6% (2.0% + 0.6%). This says that the 2% method could be just as good as the alternate procedure; in fact, there is a 67% probability that this will be true. None the less, the possibility does exist that the current procedure could make us reach the abort/no abort decision point as much as 26 seconds early, so we recommend that the alternate procedure be implemented since it could help the situation and it would not endanger crew safety. This recommendation is made with the following provisions:

a. Flight controllers must simulate these procedures until they have confidence in them. This will only be possible if the simulation people can mod the current programs to make the simulator data look like real world data, and there is no guarantee that this can be done. If the procedures cannot be simulated, the Apollo 12 procedures will be used.

b. The smoothness of the data must be validated in real-time.

It must be noted that the recommended procedure in no way changes crew procedures and does not change current procedures if the low level is valid.



4. No matter what procedure is adopted, the crew must be advised of how much the PQGS fluctuates. Whenever the crew is told to use 2% on their gage, they must realize that this means once they see 4%, they must monitor the gage continuously until they see 2% for the first time. That point is their abort/no abort decision point.

*Robert S. Nance, Jr.*

Robert S. Nance, Jr.

IM Propulsion Section, LSB

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FA/R. G. Rose

PT/D. Arabian

EA/P. Deans



March 2, 1970

Second Addendum to PQGS Note of Interest

On February 27, 1970, a meeting was held with Jim McDivitt, Owen Morris, Phil Deans, Don Arabian, and other interested parties and it was decided that FCD's recommendation was the best we could do for Apollo 13 and still remain conservative in approach.

*Robert S. Nance*

Robert S. Nance  
IM Propulsion Section, LSB

# PROPELLANT SLOSH CHARACTERISTICS

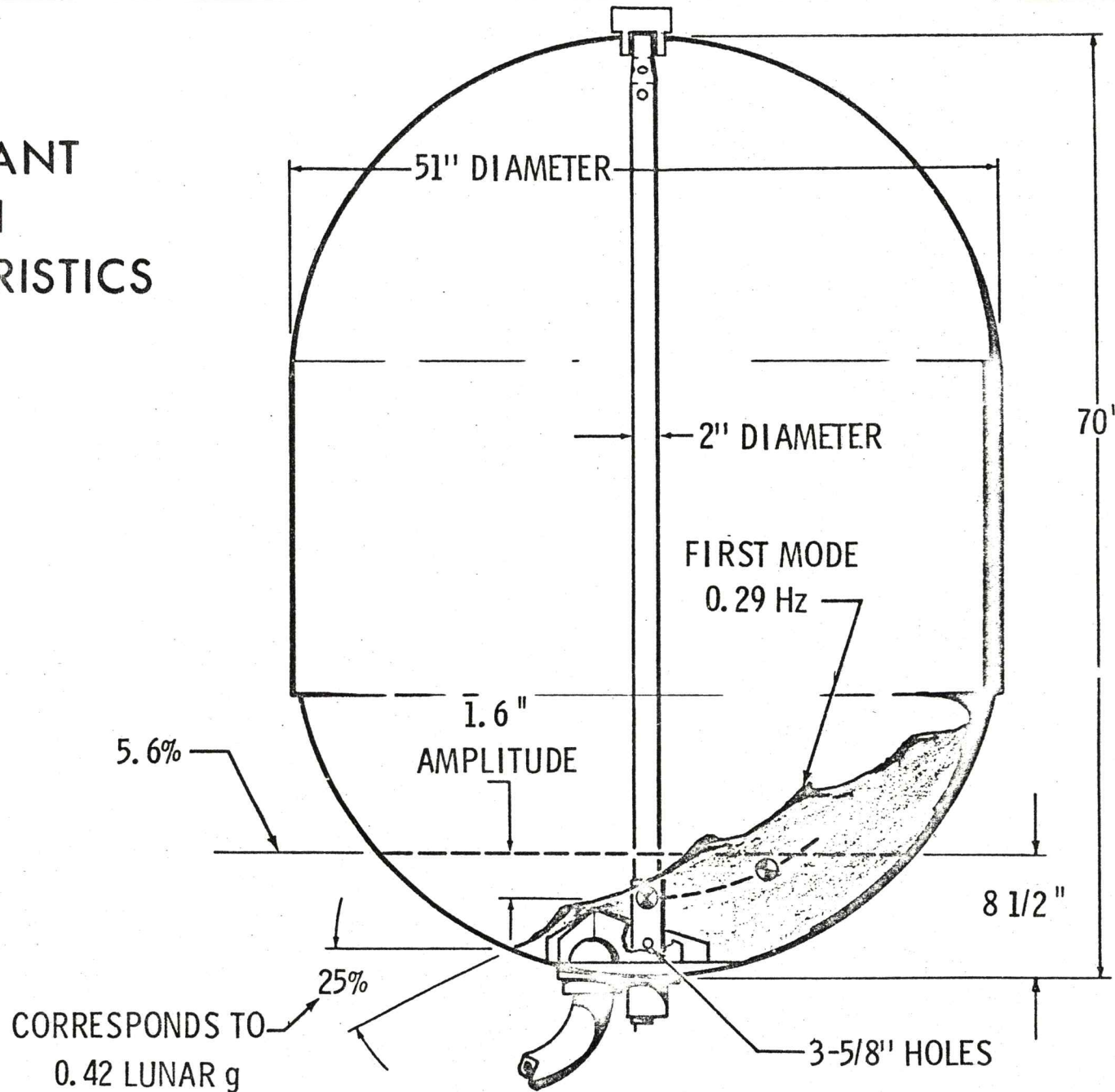
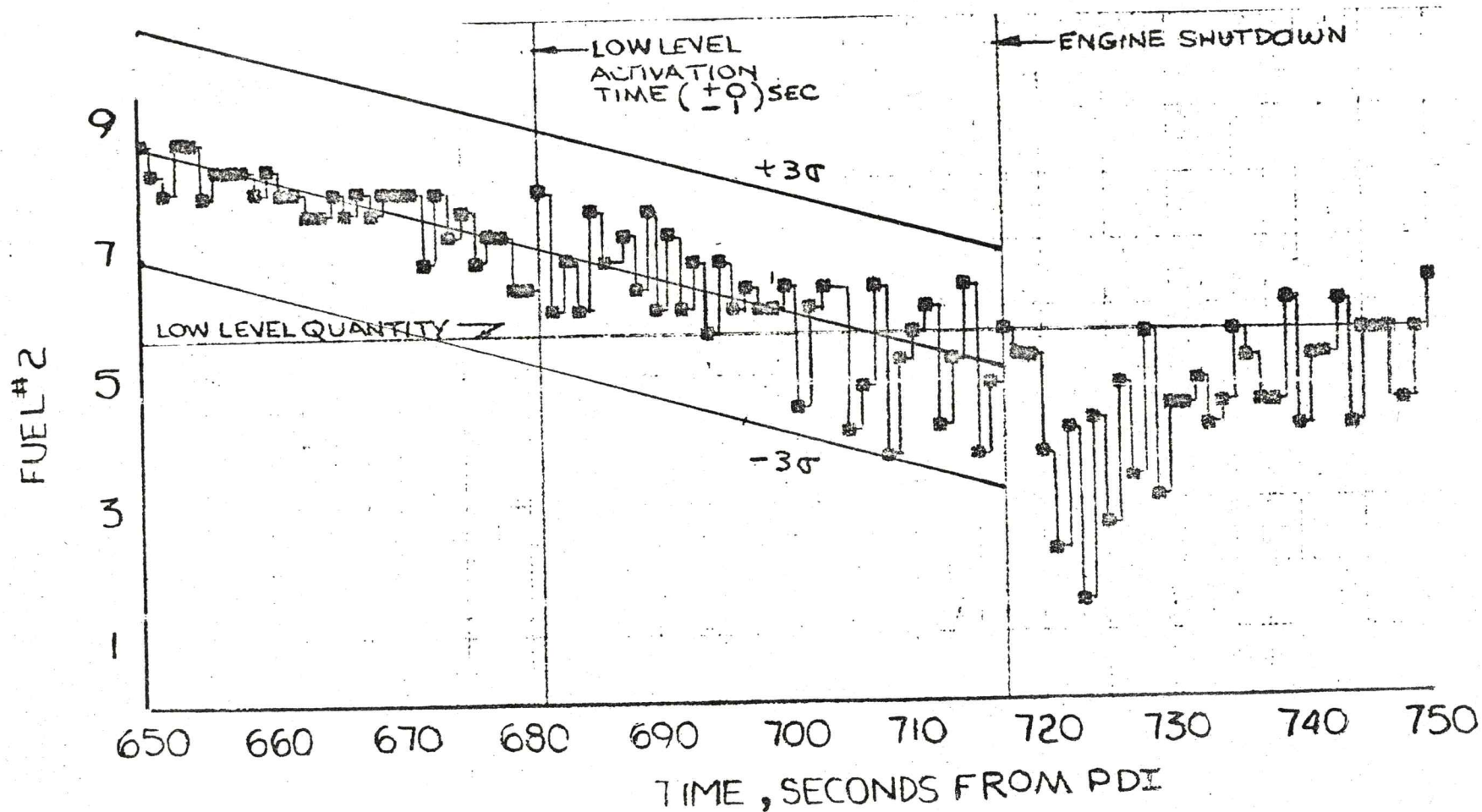
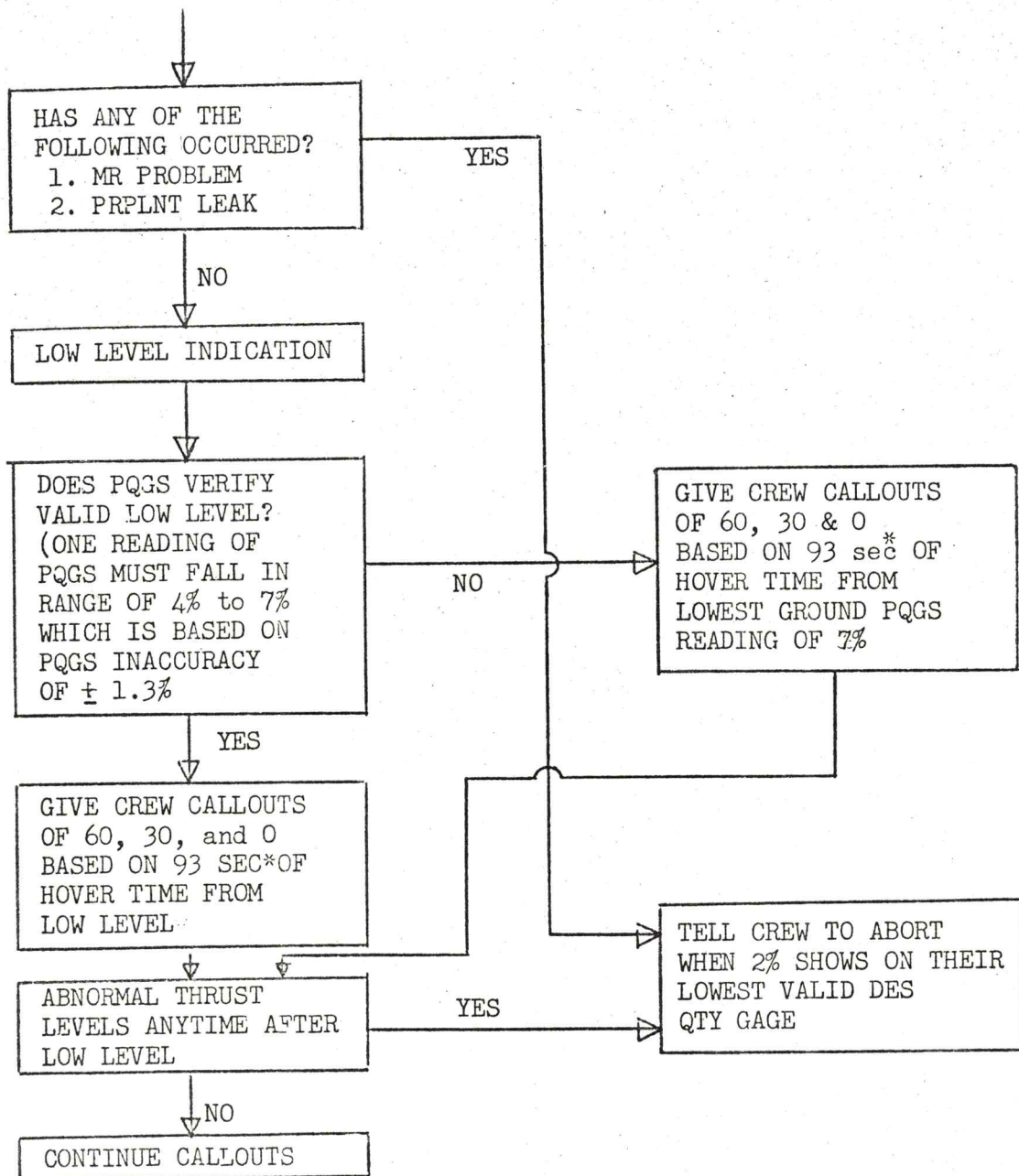


FIGURE 1

LM-6 PQGS READINGS  
FOR FUEL 2  
(FIGURE 2)



ALTERNATE GROUND PROCEDURE  
(FIGURE 3)



\* THIS GIVES 20 SEC  
OF HOVER TIME OR  
APPROX. 6 SEC AT  
FTP AFTER ZERO CALL  
REACHES CREW

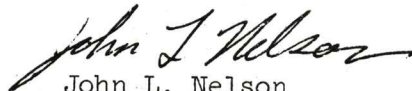


27 February 1970

Note of Interest - Pipa Bias Measurements on the Lunar Surface

1. During the Apollo 13 mission, pipa bias calculations will be made after touchdown for comparison with pre-PDI bias measurements. Pipa bias measurements will also be made during launch prep with the intention of giving FIDO a PGNS Delta V error estimation. No attempt will be made to update pipa bias from the surface measurements, since no real-time experience has been gained with the procedure. Based on successful measurement of pipa bias on Apollo 13, it is anticipated that a mission rule change will be proposed for Apollo 14, stating that pipa bias will be updated during launch prep if the delta bias exceeds  $\pm$  TBD cm/sec<sup>2</sup>.

2. The method used to measure pipa bias on the lunar surface is to calculate the amount of lunar gravity expected in each of the IM stable member axes using MPAD's value of lunar gravity, gimbal angles at the time of the measurements and the Guidance Officer's determination of local vertical attitude. This calculated value is differenced with the measured value of lunar gravity, obtained from pipa information, to determine pipa bias. The technique described above was applied to Apollo 11 and 12 data. The biases calculated on the surface correlated very well with inflight bias measurements. The pipa bias shifts experienced during Apollo 12 between PDI and Insertion would have been detected during launch prep had the above method been used. Refer any questions concerning lunar surface pipa bias calculations to John Nelson, extension 4717.



John L. Nelson  
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March 9, 1970

Note of Interest -- RCS Heater CB Anomaly LM-7/Apollo 13

Reports from the Cape indicate a problem with an RCS heater circuit breaker (4CB222 RCS system A/B-2 panel 16). The circuit breaker on the average of 25 percent of the time fails to stay latched when activated.

This circuit breaker (4CB222) powers one heater on each of the four thrusters on quad one. There are two heaters for each thruster in the quad. The other set of heaters for quad one are powered through circuit breaker 4CB218 (RCS system A/B-1 panel 11) which has automatic control only.

The decision has been made to push the circuit breaker (4CB222) in for launch. The circuit breaker will have a guard placed over it which will allow the circuit breaker to pop due to an over current condition and allow it to stay in nominally.

The following procedure will be used to insure a safe operating thruster temperature. On the backside of the moon, during normal activation, the crew will close the heater circuit breakers and put all RCS heater switches to auto. Since the circuit breaker for quad one (4CB222) is already pushed in, the set of heater associated with it will be activated when the RCS heater switch for quad one is placed in the auto position.

Approximately 15 minutes later at AOS, the ground receives data. At this time, the quad temperature should be up to a nominal reading if both sets of heaters are working properly. One heater on each thruster will maintain the thruster temperature but requires a longer time initially to warm the thruster up to a safe operating temperature. If the quad temperature is low at this time, we know that only one set of heaters are working. With only one set of heaters on quad one, we would have to wait 25 minutes after the quad temperature reached 120° F to insure a safe engine operating temperature.

This could possible delay the hot fire test 5 to 10 minutes. This would be only a minimum change to the checkout prior to PDI. A change has been submitted to the checklist to reflect changing the circuit breaker position.

*Glenn W. Watkins*

Glenn W. Watkins  
LM Systems Branch/Propulsion Section

## NOTE OF INTEREST: VALID/INVALID LOW LEVEL AND THE CREW

For LM-7, the ground is processing data from the DPS propellant gauging system at a much higher sample rate. It is hoped that by having the higher sample rates that the data will be processed to be smoother than on previous missions. This will aid the ground in determining a valid or an invalid low level. The ground's criteria for a valid low level is that at least one propellant quantity must fall in the range of 7.1 percent to 4.5 percent when the low level comes on.

INVALID LOW LEVEL CASES1. Early Low Level

If the low level comes on earlier than 7.1 percent, say 8 percent, the ground will call the low level invalid. A call will be made when the lowest gauge reads 7.1 percent. This establishes the new "low level" point. Nominal call outs are then made to the crew from that point. Ninety-three seconds after 7.1 percent the crew would hear their "Bingo" call. In past missions, the crew would have been told to go on 2 percent on their lowest gauge.

2. Late Low Level

A stop watch will be started as soon as the lowest gauge reads 7.1 percent. The propellant quantities will be closely monitored to see if the low level appears between 7.1 percent and 4.5 percent on the lowest gauge. If the low level comes on late, say 4.3 percent, it would be declared invalid. Call outs would then be based on the stop watch started at 7.1 percent. The crew in this case would not hear a "60 sec" call out since we would be past the "60 sec" call before we would know that the low level was invalid. The crew would only hear a "30 sec" call and "Bingo" for this



case. Again for this case the crew would have been told to go on 2 percent for past missions.

### TWO PERCENT CASES

During PDI, if the low level is declared invalid and the ground special processing is determined not to be smoothing the data, the crew will be told to go on 2 percent quantity on their propellant gauge.

If the DPS low level is declared valid, the crew of course, hears their normal call outs. Several cases will be discussed where the low level would be declared invalid. The ground procedures will be different from the past missions, but call outs to the crew would remain the same.

Other events can also cause the crew to revert to 2 percent on their gauge as an abort/no abort decision point. In general, anything that can cause an abnormal usage in propellant invalidates the normal call outs past low level and causes the crew to go to 2 percent. The normal call outs past low level are based upon operating in an automatic throttle mode which established a throttle setting and a propellant flow rate as a baseline. If the throttle is taken over manually, the engine flow rate is no longer predictable and the crew must rely on the 2 percent reading. A propellant leak also invalidates the normal call outs past low level, since an abnormal usage of propellant results.

It is very important for the crew to realize what a call on 2 percent on his gauge means. It is felt that the crew will not see the descent quantities decrease in a smooth fashion, but will see the quantities fluctuate



particularly in the lower quantity regions. Grumman made a movie of the LM-6 fuel 2 ground data as it would look on the onboard gauge, which showed the data didn't decrease smoothly but did fluctuate. A statistical analysis study has shown that the gauge can fluctuate a three sigma variation of  $\pm 1.8$  percent.

If the decision is ever made to go on a 2 percent reading, the crew will have to monitor the propellant quantities almost continually after the lowest quantity reads 4 percent. Once the gauge drops to 2 percent for the first time, the crew faces their "Bingo" or abort/no abort decision point. Recognition of the first time the gauge drops to 2 percent is even more critical with the fluctuations present in the propellant quantity gauging system. This insures an adequate abort pad of 1 percent of actual propellant (20 sec of hover).

*Glenn W. Watkins*

Glenn W. Watkins  
LM Propulsion Section, LSB

April 3, 1970

Note of Interest - Correction to the Note of Interest on "Redundant Ascent Engine On"

1. As stated in the Note of Interest - "Redundant Ascent Engine On", dated February 20, 1970, an "auto on" command is trapped in both the Descent and Ascent auto engine on logic after an auto PDI ignition. Therefore, even with the loss of the ENG ARM circuit breaker or the auto engine on command to the logics, the "auto on" from each logic will still be issued to the respective engine circuitry.
2. Due to this phenomenon, it was rationalized that Ascent engine on redundancy still existed if special procedures were performed during lunar surface power down and lunar liftoff. These procedures were an attempt to prevent the trapped "auto on" from being reset, which would occur if the ATCA was powered down during lunar surface activities or the Abort Stage button was pushed during nominal liftoff sequence. Engine ignition was to occur when the ENG ARM switch was placed to ASC, after insuring APS pressurization and MASTER ARM - ON.
3. Every fact stated above is true, except for one overlooked point - the ENG ARM switch also resets the trapped "auto on" signal. Therefore, no auto ignition will occur, as previously thought, when the engine is armed via the switch, and only manual start capability exists. Both methods of arming the Ascent engine resets the auto on logic; i.e., ENG ARM switch and Abort Stage button. Thus, any attempted method of starting the APS will result in the loss of the "auto on" signal trapped since PDI ignition.
4. From the above discussion, it is obvious that the proposed work-around procedures will not provide the desired Ascent engine on redundancy. Once again, the loss of the ENG ARM circuit breaker is cause for abort during DPS Insertion capability and no-go for lunar stay after DPS Insertion capability.
5. Please pass the salt and pepper.

*Larry W. Strimple*  
Larry W. Strimple

FC42:IWStrimple:drd

April 8, 1970

Note of Interest - IM-7 SHe Heat Leak Anomaly

1. Attachments 1 and 2 show cross sectional views of the IM super-critical helium (SHe) tank. Since so much is being said about SHe tank problems lately, I felt a note of interest showing diagram of the tank would be helpful.
2. During CDDT, the initial SHe pressure rise rate during tank fill was about 3 times normal before it leveled off to the 7.8 lbs/hr. Also, when the tank was vented down after CDDT, the pressure schedule was different from previous tanks. This could have been due either to different loading procedure (which was not the case), or to a breakdown of the vacuum insulation in the annulus between the inner vessel and outer tank (see Section BB). This annulus is evacuated to  $10^{-6}$  mm Hg during manufacture at Garrett. In the case of the tank presently on IM-7, it was manufactured three years ago and checked for vacuum at Bethpage one year ago (it passed).
3. The problem appears to be a very small amount of gas, either air or nitrogen, trapped in the annulus (vendor didn't purge it all out), or a very small leak over the year which has allowed the gas to vent in. It is most probably the latter case, but no one knows. This gas causes a "thermal short" while vaporized, destroying the insulation qualities so important to insure the burst discs do not blow before the DPS is required.
4. Because of the CDDT anomaly,<sup>a</sup> Discrepancy Report (DR) was written, a special test was devised, and conducted over the weekend of April 3 at KSC. The 18-hour test consisted of loading the SHe tank and running an accelerated IM-7 duty cycle on the SHe. The test was as follows:
  - a. SHe tank was filled with SHe
  - b. Pressure was artificially forced to 900 psia by flowing warm helium through the manifold.
  - c. GSE equipment was pulled off.
  - d. SHe pressure was allowed to build up to 1344 psi on its own (10-hour period).
  - e. Tank was vented down.

The initial rise rate during fill averaged 28 psi/hr. The average use rate during the 10-hour period was a steady 14.2 - 14.4 psi/hr.

5. Based on the results of the test and the CDDT data, it has been concluded that the high heat leak due to foreign gas thawing occurs at a tank pressure somewhere between 640 psia and 900 psia. Taking the

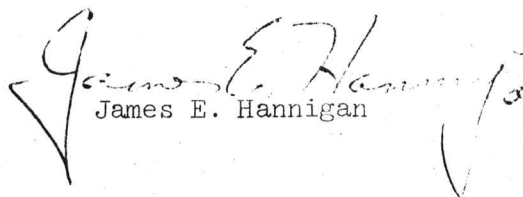


at 14.4 psi/hr. This puts us about 44 hours GET, at the earliest, when we will expect the rise rate to change from 6.4 psi/hr to the higher value. We expect the "higher value" to be 14.4 minus about 1.5 (due to lg stratification), or about 13 psi/hr. We are, however, using 15 psi/hr in our planning. We had TRW to run the various cases for nominal PDI, LOI backup, and TEI backup, and I have the data attached (Attachment 3). It all looks good. We are nowhere near the burst disc lower limit of 1887 psia.

6. We are preparing our procedures for various contingency cases. First of all, we are planning to have the crew turn on the cabin readout of SHe pressure at the 59-hour IM Familiarization (see Attachment 4 for procedure). If the reading is within some expected range, we will log it and egress the IM. If, however, the cabin reading is zero, or very high (like 1200 or so), we will ask for a telemetry readout (see Attachment 5 for procedure). If the SHe pressure is projected to be 1700 or 1750 psia at PDI, we will close the helium regulator shutoff valves for the 10% throttle portion of powered descent burn (where the heat input is very high to the SHe tank). Then the one valve will be opened after throttle up and we proceed normally. (We exercised this yesterday during the sim, and it worked satisfactorily.) We also may have to vent the SHe earlier on the surface than when we do it now (just before ascent). This is no problem--we will just watch the pressure.

7. If the SHe pressure is clearly too high at 59 hours GET to permit PDI or LOI backup, we probably will perform some kind of venting procedure before LOI to get the pressure down in order not to blow the burst discs (if we do that, of course, the mission is over right then, since we don't have blowdown burn capability until about 37% propellant remaining). This procedure will involve firing the DPS for at least 2 seconds to blow the SHe squib, to close the DPS vent solenoids (Parker valves), blow the DPS vent squibs, +X ullage, open the DPS vent solenoids for a very short time. We probably will freeze up the fuel-to-helium heat exchanger (which is okay now--it is structurally beefed up), so we will need about 10 hours thereafter for it to thaw out. We also have a 40-sec. +X constraint due to plume deflector thermal limits (the CSM -X limits are close to 7 sec, I think, due to IM impingement). It won't take long with the vent valve open to vent out too much, so it will be a hairy operation. And, we are told if slugs of liquid propellant hit the Parker valves while helium is flowing, valve chatter will occur, creating the possibility of not being able to reclose them solidly. But, what have we got to lose?

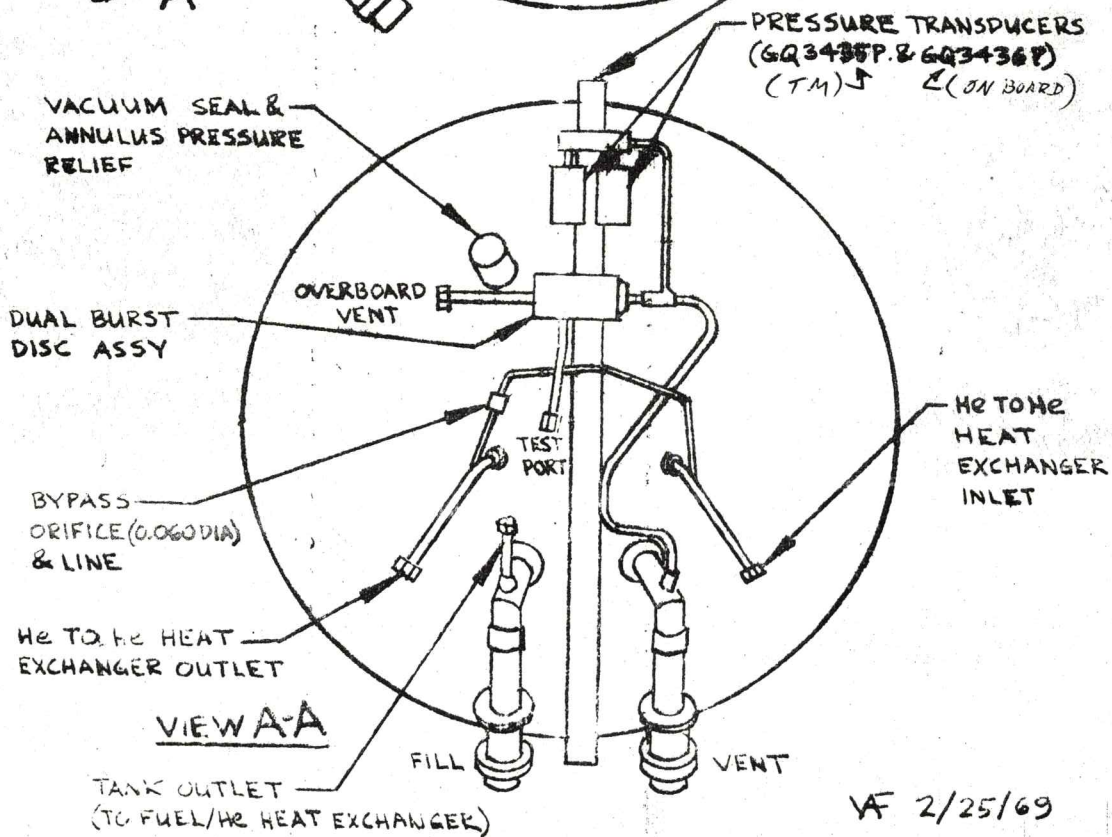
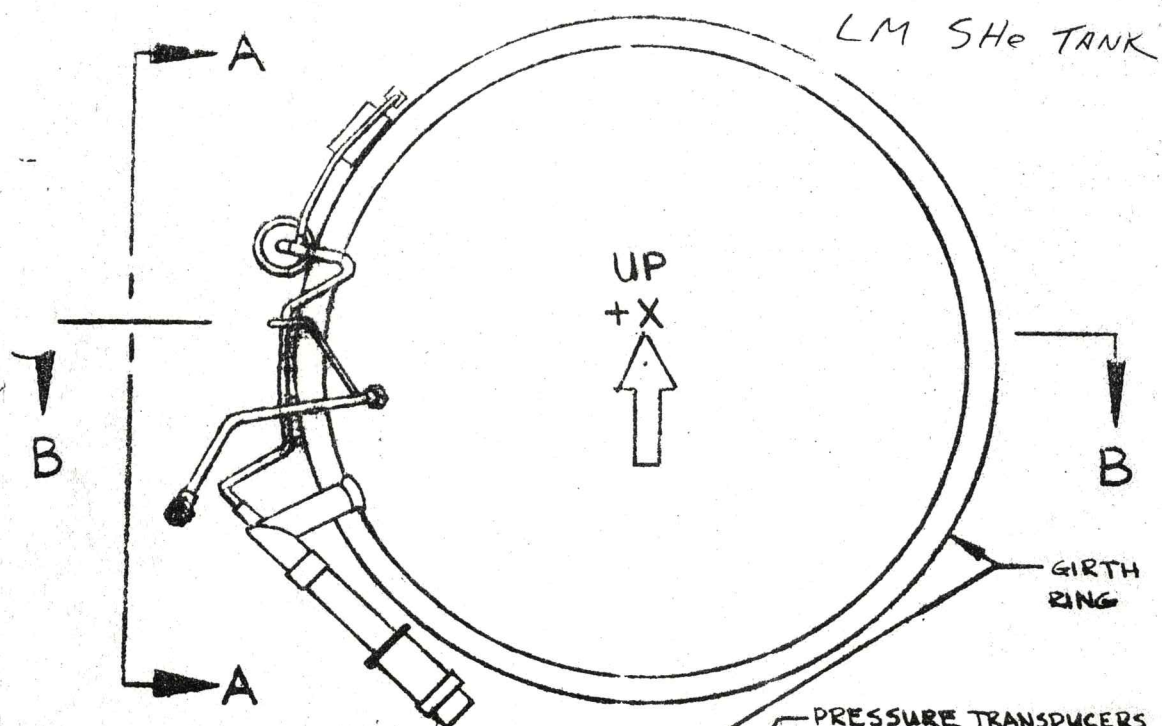
8. They will load SHe Thursday morning, April 9, and top it off on Friday morning. We will watch the rise rate closely and see if it duplicates the CDLP rate. If it is clearly higher, we will be in trouble.

  
James E. Hannigan

Attachments (5)

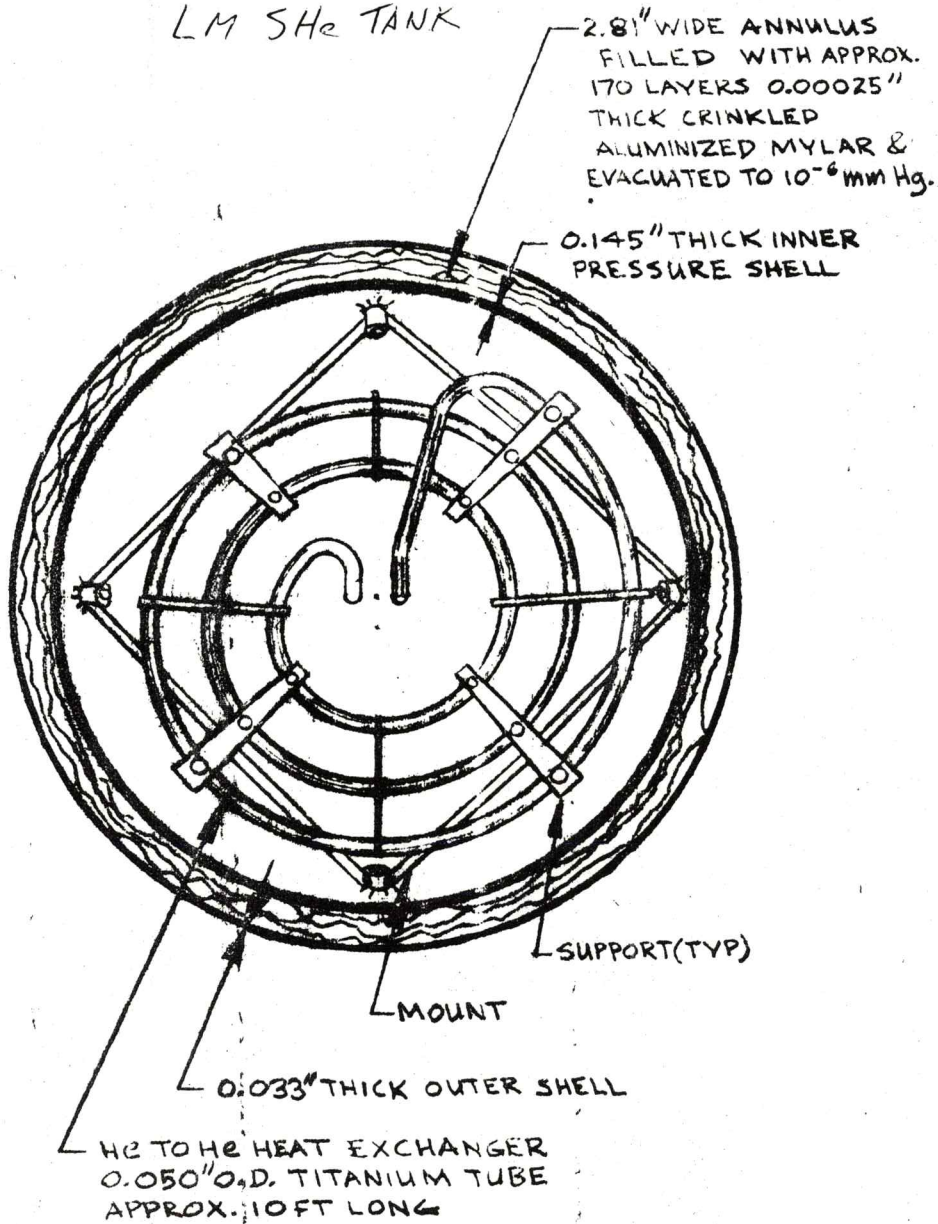
FC4:JEHannigan:dh





WF 2/25/69

# LM $\text{SH}_2$ TANK



SECTION BB

2/25/69

Attachment 2

TRW has completed the SHE computer run for LM-7 SHE anomaly. The results and assumptions are:

ground rise rate	7.9 psia/hr
nominal coast rise rate	6.4 psia/hr
anomaly rise rate	15.0 psia/hr

Nominal mission pressure profile

GET	pressure	event
00:00 GET	373 psia	launch
44:00 "	655 psia	annulus phase change
103:30 "	{ 1523 psia	PDI start
	{ 1588 psia	peak pressure
	{ 470 psia	end pressure

LOI abort case pressure profile

GET	Pressure	event
00:00	373	launch
44:00	655	annulus phase change
79:25	{ 1187	LOI start
	{ 1230	peak press.
	{ 987	end press
116:25	{ 1592	TEI start
	{ 1650	peak press
	{ 900	end press

At annulus phase change medium in annulus begins to change state and cause a transient short which causes a change pressure rise rate from 6.4 psia/hr to 15 psia/hr

## FOR CREW DISPLAY ONLY

- 1) ACT - 1
- 2) ACT - 11 , STEP 1
- 3) CB(11) AC BUS B : He PQGS PROP DISP - CLOSE  
: NUM LTG - CLOSE  
: BUS TIE INV 1 - CLOSE  
EPS : INV 1 - CLOSE
- CB(16) INST : SIG SENSOR - CLOSE
- 4) INV - 1
- 5) Hel MDN - SUPCRIT PRESS  
Monitor SUPCRIT PRESS \_\_\_\_\_
- 6) INV - OFF
- 7) ACT - 15 , STEPS 4 & 5

Attachment 4



FOR LO BIT RATE TM

- 1) ACT-1
- 2) ACT-11, STEP 1
- 3) CB(11) INST: SIG CONDR 1-CLOSE  
CB(16) INST: SIG SENSOR -CLOSE  
: PCM/TE -CLOSE  
: SIG CONDR 2-CLOSE  
COMM: PRIM SBD(2)-CLOSE  
: PHP-CLOSE
- 4) COMM CONFIGURATION  
EITHER S-BAND OR VHF-~~ESM~~ RECORD.  
SEE ED FENDALL'S MEMO.
- 5) ACT-15, STEPS 2, 4 & 5

Attachment 5

May 6, 1970

Note of Interest: Mini CCB

Subjects discussed which were applicable to LSB:

1. DPS PQGS CHANGES FOR APOLLO 14.
2. LUNAR DUMP VALVE CAPABILITY

Grumman proposed that the modified PQGS Probes be put in three of the four DPS tanks on LM-8. The modification consists of three plugs in each probe which decrease the size of the three holes that allow flow to the probe. It is hoped that this fix will damp the oscillations of the PQGS readings. The recommendation is backed up by a series of tests at Langley which indicate that this fix will improve the situation. The rationale for only three probes is derived from the fact that we did not receive any 100 sample per second data on Apollo 13 in the low PQGS range ( $< 10$  percent). The data from the unmodified probe will provide the basic for further modifications to the PQGS or low level sensor if they are required.

The unmodified probe will be the -Z oxidizer tank which even with the oscillating PQGS data should not get below the +Z oxidizer tank. This is due to the C.G. location which causes a 2.7 percent difference between the tanks.

Owen Morris directed Grumman to install the three modified probes on LM-8 and install modified probes on all four tanks for LM-9 and subsequent.

FCD was given the action item to review our special processing for the PQGS and come back with recommendations by June 5, 1970.

The other item of interest under discussion was the ability of the lunar dump valves to vent in zero gravity. Grumman presented their tests to date which indicated that if propellants reached the vent valves while a vent was being attempted the valve would be pulled shut. The tests also showed that the valves would resist being opened again or would

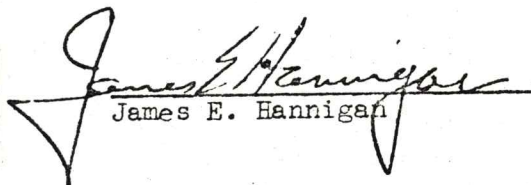
immediately close if they did open. It had been found, however, that a trim orifice above the valve would improve the situation by causing a lower pressure at the valve inlet. The only problem was experienced when low voltage (21 V.) was used and then the valve still wouldn't open. Other tests revealed that by reversing the valve (inlet vs outlet), a vent could be accomplished with propellants.

Grumman wants to do some more testing particularly with venting supercritical helium. LTA 5 will be used for some of the tests. So far as IM-8 is concerned, some decision will be made in the near future. Grumman felt that if the valve is reversed, the orifice should be added also since the line will already be cut.

*Robert S. Nance*

Robert S. Nance  
IM Propulsion Section, LSB

Approved:

  
James E. Hannigan

May 19, 1970

# Note of Interest: Invalid Attitude Errors on Apollo 13

A meeting was held by John Hannaway of G&C Division to discuss the LM attitude error problem that occurred on Apollo 13. In attendance were representatives from G&C, FSB, MIT and LSB. The following represents conclusions reached by the parties present.

The error needles on attitude errors noted prior to the MCC-7 burn were invalid in that they were not representative of the difference between the final desired attitude (FCDU) and the present attitude (ACDU). In fact, a study of the post-flight data revealed the calculated errors were given by:

$$ATT\ ERR = FCDU - ACDU + \text{Fixed Bias}$$

By imposing a fixed bias on the attitude error calculation, it was impossible for the crew to obtain valid readings from their error needles. This was true even when the final desired angles were equal to the actual angles (i.e., the vehicle was at the desired attitude).

The existence of a possible bias can be seen by the following set of equations used by the LGC in generating the error commands. Consider the first pass through the Attitude error display sub-routine.

$$AK_n = FCDU - ACDU_n \quad (n = 0, 1, 2, 3, \dots)$$

$$\Delta ERR_n = AK_n - E_n$$

$$E_{n+1} = AK_n$$

Where  $AK_n$  = The difference between the final desired CDU angles and the actual CDU angles at the time of computation.

$\Delta ERR_n$  = Incremental change in the total attitude error at the time of computation relating to the difference between FCDU and ACDU.

$E_n$  = The present value of the CDU error counter, initially set to zero by the DAP upon recognition of a CDU zero command.

$E_{n+1}$  = The new value of the CDU error counter, used to derive the  $\Delta ERR$  on the subsequent pass through the attitude error display sub-routine.

On the second and subsequent passes, the above sequence is exactly the same. All  $\Delta ERR$ 's are sent to the CDU error counter and algebraically summed continuously for display. It can easily be seen that if  $E_n$  is non-zero on the first pass through the sub-routine, a fixed bias will be established and maintained throughout the remainder of the attitude error computations.



The following example illustrates the problem seen on Apollo 13 as the ACDU's approach the FCDU as in an attitude maneuver:

$$\text{Let FCDU} = 180^\circ$$

$$\text{ACDU}_0 = 150^\circ$$

$$\text{ACDU}_1 = 165^\circ$$

$$\text{ACDU}_2 = 180^\circ$$

$$\text{ACDU}_3 = 180^\circ$$

$$E_0 = 10^\circ$$

$$\text{1st pass } AK_0 = \text{FCDU} - \text{ACDU}_0 = 180^\circ - 150^\circ = 30^\circ$$

$$\Delta\text{ERR}_0 = AK_0 - E_0 = 30^\circ - 10^\circ = 20^\circ$$

$$E_1 = AK_0 = 30^\circ$$

$$\text{Displayed attitude error} = \Delta\text{ERR}_0 = 20^\circ$$

$$\text{2nd pass } AK_1 = \text{FCDU} - \text{ACDU}_1 = 180^\circ - 165^\circ = 15^\circ$$

$$\Delta\text{ERR}_1 = AK_1 - E_1 = 15^\circ - 30^\circ = -15^\circ$$

$$E_2 = AK_1 = 15^\circ$$

$$\text{Displayed attitude error} = \Delta\text{ERR}_0 + \Delta\text{ERR}_1 = 20^\circ - 15^\circ = 5^\circ$$

$$\text{3rd pass } AK_2 = \text{FCDU} - \text{ACDU}_2 = 180 - 180^\circ = 0^\circ$$

$$\Delta\text{ERR}_2 = AK_2 - E_2 = 0^\circ - 15^\circ = -15^\circ$$

$$E_3 = AK_2 = 0^\circ$$

$$\text{Displayed attitude error} = \Delta\text{ERR}_0 + \Delta\text{ERR}_1 + \Delta\text{ERR}_2 = 20^\circ - 15^\circ - 15^\circ = -10^\circ$$

Thus, the total displayed error is  $-10^\circ$ .

It can be seen that in all passes, a constant bias of  $-10^\circ$  was introduced into the displayed attitude error by failing to zero the initial value of  $E_n$ . This in fact was the problem on Apollo 13. Ordinarily, the DAP sets  $E_n = 0$  whenever a CDU zero is issued by the LGC. However, in the Apollo 13 case, the LGC was powered up with the DAP turned off. The subsequent platform alignment and the associated CDU zero's were not sensed by the DAP and

the values of  $E_n$  (x, y & z) were not zeroed. In fact, the values of  $E_n$  were the last values computed (AK<sub>n</sub>) by the LGC following the PC+2 burn<sup>n</sup>. This was confirmed by an E-memory<sup>n</sup> dump prior to turning the DAP on for MCC-7.

It should be understood that there was no hardware or software anomaly associated with the attitude error problem. The apparent anomaly resulted from an unorthodox procedure utilizing the LGC and DAP independent of each other. Nominally, this would not occur, however, in future missions, care should be taken to ensure the proper initialization of the DAP whenever it is turned on.

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**JUN 16 1970**

SUBJECT: IM Ascent Propellant Quantity Gaging Techniques for Short Rendezvous

1. The nominal rendezvous plan for Apollo 14 and future missions consists of a one orbit type rendezvous. This plan requires a second APS engine burn, or RCS burn with APS interconnect, to be successful. To insure that this critical burn can be accomplished, the APS propellant capability must be known as accurately as possible. This discussion is a basic look at present APS propellant gaging methods and their capability to support this goal.

2. The APS propellant low level sensors are installed in each propellant tank and detect a specific height of propellant remaining in the tank. The height of the sensor is known and varies  $\pm 0.100$  inches, manufacturing tolerances. Considering these tolerances and  $\pm 3\sigma$  flow rates the variation in burn time remaining is approximately 1 1/2 seconds. This is at the time of actuating the sensor.

3. The RTCC calculation of APS burn time remaining is based on parameters telemetered from the spacecraft. As a result the accuracy of this program is 5 percent of the total burn time. At completion of the insertion burn, the accuracy of this calculation is approximately 23 seconds.

4. The IM CALC QTY RTCC Program is used to calculate APS propellant remaining. This calculation uses the LGC mass, as telemetered from the spacecraft. Variation in mass used to calculate propellant remaining, as a result, takes into consideration variations in propellant flow rates. The accuracy of this program is approximately 3 percent, or approximately 14 seconds of APS burn time after completion of the insertion burn.

5. From the above discussion, it is felt that the low level sensor is the most accurate method to gage the APS propellant remaining. If the insertion burn is completed without actuation of the low level sensor, a minimum of approximately 8 seconds of burn time remains. The other methods cannot provide this assurance.

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June 17, 1970

NOTE OF INTEREST: Open DPS Propulsion Items

A meeting was held on May 27, 1970, between the LM Propulsion Section, Descent Subsystem Manager and Grumman representatives concerning current problem areas on the descent propulsion system. The following topics were discussed: Supercritical Helium (SHe), Propellant Slosh and Engine Erosion. Supercritical helium and erosion will be discussed in this note of interest. Propellant slosh will be discussed in Robert Nance's trip report concerning slosh tests at Langley.

SUPERCritical HELIUM

The LM-7 SHe tank pre-mission had a higher than normal rise rate. After the second DPS burn on Apollo 13, the rise rate increased to approximately 33 psi/hr. Grumman feels that the cause of the high rise rate is that hydrogen is trapped in the vacuum annulus of the SHe tank. This trapped hydrogen increases the heat transfer thru the annulus thereby increasing the pressure rise rate. The titanium SHe tank in manufacturing appears to have an affinity for water vapor and absorbing moisture depending on the humidity of that day. The oxygen oxidizes before the tank is assembled, but the hydrogen outgasses after a period of time.

At the lower temperature and pressure region, the hydrogen is frozen. As SHe is being used, the temperature increases causing the hydrogen to sublimate. After sublimating, the heat transfer increases causing the pressure rise rate to increase. When 50 percent of the SHe is remaining, the hydrogen is completely in a gaseous state and at that point, the pressure rise rate on coast is at its highest. Less than 50 percent remaining, the pressure rise rate decreases because the bulk of the heat input is absorbed by the SHe tank itself instead of the SHe mass.

The LM-8 and 9 SHe tanks have been tested for a range of mass conditions with the worst case pressure rise rate occurring at the 50 percent point. This pressure rise rate is approximately 15 psi/hr, much lower than the LM-7 SHe tank in this region. Grumman has proposed that if each mission SHe tank can perform the worst case profile with some margin that the SHe tank be acceptable for that mission. Grumman has reviewed the LM-8 SHe tank for all of the alternate missions that they are aware of. The mode II LOI abort case appears to be the worst case, since two DPS burns are required with a long coast time between burns ( 15 to 37 hours). The LM-8 SHe tank was able to perform all of the above profiles considered. Grumman was given an action item to look at a LM rendezvous case after the CSM has performed the circularization burn. The propulsion section will coordinate with Flight Dynamics to see if all abort profiles were considered. Another criteria established for the SHe tank was that each tank be tested again as close to the mission as possible to see if the pressure rise rate characteristics had increased to insure the tank acceptable for the mission.



Grumman has generated a curve for each SHe tank showing the pressure rise rate as a function of propellant or SHe quantity. This curve is necessary for constructing a SHe profile for any alternate mission. The curve will be submitted for SODB approval.

#### SHe FRACTURE MECHANICS

A SHe fracture mechanics curve was presented as a function of SHe pressure and quantity. The fracture mechanics curve shows that for any quantity of SHe or propellant remaining greater than 25 percent, the burst disc will protect you against a tank failure. Below 25 percent mass and at a high pressure (below the burst disc), a fracture mechanics failure can occur. This of course, means the SHe tank would have to be vented prior to this point. If an abort required a long DPS burn as well as retention of the DPS stage for consumables, we could be in this unprotected region. Grumman has asked that the fracture mechanics curve be included into the SODB.

#### DPS EROSION

An erosion redline has been used in past missions that allows only a 30 percent increase in the DPS throat area. This is to protect against an engine burn thru. Grumman has re-evaluated the DPS erosion and concluded that the engine can erode to 35 percent safely without a burn thru. This allows a pad to take into account streaking. This redline number is used to compute the time allowable in the non-throttleable region. With this increase in the erosion redline, additional time in the non-throttleable region has been gained. A failure in the engine throttle loop (loss of manual thrust input 10 percent) would drop the engine in the non-throttleable region. We now have gained additional time to recover from that failure and still complete PDI.

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