INVESTIGATION OF A METHOD FOR REPAIRING THE HOT GAS SYSTEM BRANCH II OF THE SYMPHONIE-SATELLITE MV2 IN ORBIT

FINAL REPORT

by

H. BRAUN

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1. **Summary**

1.1 **Process**

Anomalies have occurred in the Symphonie Satellite MV2 on the hot gas system branch since May 1976, which in part have led to the failure of all engines, that is, engines no. H2, H4, H5.

**Analysis of the Process**

A detailed analysis of the phenomena has led to the conclusion that the fuel supply for the engines has been interrupted by some kind of blockage at one point of the conveyance system. Also the analysis performed has led to the conclusion that out of the two supply systems for oxidizer and fuel, the oxidizer system is blocked. This conclusion resulted from the fact that after turnoff of the engines, a thrust was delivered after a certain time without opening any fuel valves.

This phenomenon can be explained by the fact that during the previous regular activations of the engines, only fuel flowed out, which is frozen solid because of the fact that there is no combustion heat in the combustion chamber, and at a later time it was thermally decomposed by the oxidizer which was supplied in drops. From the process described here we can conclude that the oxidizer branch is blocked.

1.2. **Possibilities of Repair**

It is known that for certain pre-conditions, so called metal salts are formed in the oxidizer which first are present in the dissolved state. These metal salts can precipitate at the high speed of the solution medium, that is, through the narrow passages of the conveyance system in a jelly-like solid form (gel). This leads to further constriction of the narrow passage and
leads to complete blockage. It is natural to look upon this phenomenon as the cause of blockage of the oxidizer branch of the MV2.

An evacuation of the oxidizer branch is the only method of repairing the device in orbit. Therefore, we first carried out laboratory experiments where we observed the behavior of artificially produced jellies in a vacuum (1 Torr). It was found that the solid volume of the jelly is reduced, which is to be attributed to a sublimation. This gives us a first indication that there is a possibility of repairing the oxidizer branch in orbit. In order to estimate the effectiveness of the vacuum on the removal of jellies under these boundary conditions which prevail for the conveyance system, we performed further analyses to determine which simulations would be possible on the ground.

**Simulation Methods on the Ground**

In several discussions with representatives of the individual institutes such as CIFAS, GESOG, CNES we defined the simulation method on the ground. We fix the following:

The raw material for the jellies is manufactured artificially by mixing water, Kaltron and Iron Nickel nitrate to $\text{N}_2\text{O}_4$. The following composition has been specified 98 % $\text{N}_2\text{O}_4$, 1 % $\text{H}_2\text{O}$ and 1 % Kaltron 113 and 20 mg 50/50 Fe-Ni Nitrate. Water and Kaltron were added because one cannot exclude that these media have remained in the bellows tanks which are difficult to clean. A non-contaminated fuel MMH together with this contaminated oxidizer was used to operate a 10 N-engine under hot run conditions using an original replica of the conveyance system up to the systems valve. The test configuration was selected in this way because the critical passages in the com-
ponents after the system valve such as the filter, diaphragm and engine exist in it. The simulation of the blockage was carried out in conjunction with a hot run, because only in this way can one simulate the flow conditions in the conveyance system which exist in orbit.

We can assume that the operational conditions for the simulation method created in this way agree for the most part with the oxidizer branch in orbit. However, as far as the simulation of the contaminated fuel is concerned, we have to refer to estimates only. This uncertainty is only of secondary importance for the simulation tests on the ground, because we're not interested in examining the possible blockage, but instead we wish to investigate the possibility of removing an existing blockage using a vacuum.

1.4. Test Configuration

An original hot gas system (see appendices) was built from the system valve up to the engine. Filters, diaphragms and pipelines were newly constructed according to the available data sheet of the Symphonie project. The ten N-engine already had an operating time of 2148 seconds. Since jelly formation is accelerated at narrow passages by low fuel temperature, the entire conveyance system was installed in a basin filled with ice water. This way we satisfied the condition that already after a short operating time we could expect a blockage of the conveyance system. At the critical passages of the conveyance system such as the filter, diaphragm, engine valve with filter and the injection system of the engine, we installed measurement connections for measuring differential pressure, in order to be able to record a change in the cross sectional passage area brought about by the beginning of the blockage (see schematic diagram of the test configuration). In order to be able to evacuate the conveyance system after the hot run in the blocked state, we
manufactured an adaptor with which the expansion nozzle of the engine.

In the second test series we wish to examine whether the removal of the blockage is possible for those components which lie far away from the evacuation point, by extending the duration of the evacuation,
EVACUATE CONVEYANCE SYSTEM

\[ 4 \times 10^{-3} \text{Torr at } 23 - 26 \, ^\circ\text{C for } 72 \text{H} \]

HOTRUN 1.3
WITH CONTAMINATED \( \text{N}_2 \text{O}_4 \) BLOCKED AFTER 400 SECONDS

HOTRUN 2.1
REFERENCE TEST WITH NON-CONTAMINATED \( \text{N}_2 \text{O}_4 \) 1400 SECONDS

HOTRUN 2.2
WITH CONTAMINATED \( \text{N}_2 \text{O}_4 \), BLOCKED AFTER 360 SECONDS.

CONVEYANCE SYSTEM EVACUATION

\[ 5 \times 10^{-3} \text{Torr at } 28 - 29 \, ^\circ\text{C for } 285 \text{ Hours} \]

HOTRUN 2.3
WITH CONTAMINATED \( \text{N}_2 \text{O}_4 \), \( \text{N}_2 \text{O}_4 \) - TANK EMPTY, NO CRITICAL BLOCKAGE AFTER 1285 SECONDS

TANK IS REFILLED WITH CONTAMINATED \( \text{N}_2 \text{O}_4 \) FOR 1000 SEC OPERATING TIME

HOTRUN 2.4 WITH CONTAMINATED \( \text{N}_2 \text{O}_4 \) BLOCKED AFTER 99 SECONDS.
1.6 Test Results

Except for the hot run 2.3, a blockage was achieved with contaminated N$_2$O$_4$ after an operating time of about 400 seconds, which made it necessary to break off the hot run. The oxidizer throughput progressively was reduced, and at the same time the fuel throughput was increased because of a reduction in the combustion chamber pressure. The hot run was then terminated because due to the extreme displacement of the mixing ratio and the reduction in the total throughput, the combustion in the engine became extremely unstable and liquid unburned fuel came out of the engine.

The manner in which the blockage comes about can best be seen by investigating the variation of the flow number (FN). The flow number is a measure for the penetration cross section. It can be seen that cross section reduction per unit time in the filter is the greatest. From this we can conclude that the flow speed in the filter is very high and therefore a strong jelly formation occurs. In this way, already most of output products of the gels are held back by the filter. Therefore in the following narrow passages the cross-section reduction is much slower than in the filter. The cross-section reduction in the narrow passages which are switched into the filter indicates that these are really jellies and not solid particles which produce the blockage. This is because the fineness of the filter is selected so that particles which can still pass the filter are so small that they cannot bring about any blockage in the following narrow passages. The most important result of the tests is the fact that by evacuation, the blockage of the narrow passages can be reversed again. It is of interest in this connection that the removal of a blockage, that is the removal of the jellies, depends on the time over which the vacuum acts. For example, Test 2.3 shows that the blockage also can be removed completely at the point which is farthest away from the evacuation point, that is, the filter.
1.7 Final Conclusion

Ground tests have shown that a removal or at least a reduction of the blockage of the oxidizer branch is possible by evacuation. If one follows the test results further, we have to conclude that the greatest blockage occurs in the filter. This then results in a restriction in the capability to perform repairs to the oxidizer branch in orbit. This is because the filter installed ahead of the system valve cannot be subjected to a vacuum.
2. GRAPHS OF TESTS RESULTS

- Test Series 1, Tests 1 - 3 (1 Sheet)
- Test Series 2, Tests 1 - 4 (2 Sheets)
**FN-CHARACTERISTICS**

**HOT RUN 2.1**

**FN.onSubmit**

**FN.ModelForm**

**FN.ModelForm**

**DURING ALL TESTS: N₂O₄ STORAGE TEMP 8 ± 10 °C**
**FEED SYS. TEMP 4 ± 2 °C**

**NOMINAL ENGINE OPERATING CONDITIONS:**
**T = 40 N, f = 4.64**
**WITHOUT CONTAMINATED N₂O₄**

**WITH CONTAMINATED N₂O₄**

**WITH CONTAMINATED N₂O₄**

**T₁₀ - Tₓ: MEASURING TAILED**
**BY CLOGGING R MEASUREMENTPORT**
3. GROUND TESTS FOR INVESTIGATING THE MV-2 ANOMALIE
TN-RT35-7/77
Distribution:
RX 26  -  H. Schwanda
RT 353 -  H. Braun
RT 35  -  H. Munding
RT 351 -  H. Lammers
        -  F. Kail

MBB Report:  TN - RT 35-75/77
Author:      Munding, German
Subdivision: UR / RT 35
Title:       Ground Tests for Investigating the MV₂ Anomalie
Date:        November 4, 1977

Reference:
Appendix I, TN RT 353-1/77 of November 3, 1977
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Definition of the tests according to the protocol of October 13 1977 with the experts at Lampoldshausen. 
- Point 3 of the discussion protocol.

1. INITIAL CRITERIA

1.1 What Kind of Contamination is Present?

- Reaction product between contaminated $N_2O_4$ and the tank materials $V_2A$ and Titanium.

- Impurities in the $N_2O_4$ can be caused by humidity or residual amounts of freon (Simulation liquid). Both components favor the formation of salts (Fe - and Ni-nitrate) $NO_3^- + Me^+ \rightarrow Me NO_3$

1.2 What quantitative amounts of corrosion products leads to a blockage of the conveyance system?

1.3 At which point of the conveyance system did blockage occur?

2. TEST CONFIGURATION

The following experience and knowledge has to be applied for the design of the test configuration and execution:

2.1 The blockage does not occur suddenly but gradually and progressively.

2.2 The higher the temperature of the $N_2O_4$, the more Fe and Ni-nitrates can be held in solution without precipitation in the form of solids.
2.3. The higher the flow speed of the fuel, the greater will be the tendency for the Fe and Ni-Nitrates to precipitate as solids out of the solution.

From the initial criteria, experience and knowledge we can derive boundary conditions for the test configuration and execution.

In order to have a direct means of comparison with processes in the original system, it is simulated as much as possible in the test configuration as allowed by the blockage criteria.

3. DEFINITION OF THE CONTAMINATED $N_2O_4$

In the definition of the contaminated $N_2O_4$ solution we assume that the water content as well as the freon content cannot cause the blockage directly, but only indirectly by the increased formation of Fe and Ni-Nitrate. However since the formation of Fe and Ni-Nitrates is a long time process because of the water content and the freon content and the experiments have to lead to a result as fast as possible, the amount of Ni and Fe Nitrate is added directly to the $N_2O_4$

$N_2O_4$ solutions are produced which have a constant degree water and freon contamination, but their Fe and Ni nitrate amounts are increased until blockage occurs. Since the blockage already occurred at the beginning of the mission, the Fe and Ni nitrate amount can be selected so high that blockage already is present for a flow amount of 3 kg solution.
5. **DESIGN CRITERIA FOR TEST CONFIGURATION**

5.1 Instead of folding bellows containers we used tank filling containers. The reason: The $N_2O_4$ container has to be filled with $N_2O_4$ with different nitrate content for each test. The folding bellows tank is not suitable for these tests, because complete cleaning cannot be guaranteed and therefore the defined salt content cannot be determined with certainty.

5.2 In order to reduce costs, instead of He, $N_2$ is used to pressurize the fuels. The influence of dissolved gas in the fuel on the formation of blockage products is assumed to be small compared with the effect of the mixed amounts of Fe and Ni-nitrate.

5.3 The operation of the engine is done at a constant tank pressure in contrast to blow-down operation in the original hot gas system. Reason: a possible reduction in the throughput due to the beginning of blockage can be controlled much more poorly for blow-down operation.

5.4 The test configuration has flow meters in order to be able to adjust the nominal throughput amounts $m_{\text{gas}}$ (total) and the mixing ratio $r$ without difficult adjustment procedures. This is done by simply changing the tank pressures at the beginning of each test.

5.5 In the $N_2O_4$ supply system in which the blockage is expected the pressure losses in the filter, in the diaphragm and in the injection system of the engine are checked by measuring $\Delta P$. 

20
5.6 The entire fuel conveyance system except for the fuel containers is surrounded with ice water in order to guarantee a constant fuel temperature, especially for \( \text{N}_2\text{O}_4 \) from one test to another. It is small enough so that any blockage that occurs can be accelerated. The fuel conveyance system is submerged in a pan.

5.7 The conveyance system from the Nupro blockage valve up to the engine corresponds to the original conveyance system in length, armatures, such as filters and adjustment diaphragm and also with respect to flow cross section. The pipelines which lead through the flange are an exception to this.

5.8 Between the engine and the conveyance system there is a flange which is suitable for serving as a covering flange of the recipient. In this way after blockage has occurred in the engine, it can be evacuated without separating the conveyance system. During the blockage test, the flange at the same time serves as a sealing flange with respect to the water pan. The flange has to be installed so that the engine with the conveyance system can be disassembled from the water pan without being taken apart. The connections of the flange conveyance lines which have thick walls and are made with 3 - 4 mm 1W are made by means of bolts with respect to the conveyance system on the one hand and the engine on the other hand (ANR-DIN bolts) connections.

5.9 The conveyance system up to the separation points at the Nupro valves is mounted on a plate in order to be able to transport it together with the engine to the vacuum pump.
6. WORKING PLAN

6.1 Cleaning of the containers and cleaning of all of the components of the conveyance system.

We have to distinguish between parts which have already been contaminated with fuels and newly produced parts. The latter are cleaned according to TN RT 353-1/77, (see Appendix 1), Item 3.2 including and up to Item 3.3. For already contaminated parts, for example the HG-Symphonis tank filling container, cleaning is also performed according to TN RT 353-1/77, Item 3.3. For cleaning purposes the flange is removed from the tank and the inner wall is sprayed with a spray nozzle having a hard jet. The tank is placed with the flange opening toward the bottom. The container is closed and evacuated with simultaneous heating from the outside (20 minutes). After this the insulation is flooded with \(N_2\) (penetration of air is avoided). Empty weight of the container is determined with the final equipment installed.

6.2 Filling of the \(N_2O_4\) Container

Distilled \(N_2O_4\) is filled in through \(2 \mu\) Millipore-Filters and the filling is controlled by weighing. Then it is ventilated and the containers are first opened, in order to avoid the entry of air, if overpressure already exists in the container. \(N_2O_4\) containers are then finally connected to the test configuration.

6.3 Filling of MMH Containers

MMH is filled in cleaned Symphonis hot gas tank-filling containers. MMH is filled in through \(2 \mu\) Millipore-filters. Otherwise the same procedure is used as for the
7. PRODUCTION OF THE CONVEYANCE SYSTEM

7.1 All of the components of the conveyance system
   - Aeroquip-hoses
   - Nupro valves
   - flow meters
   - pipelines
   - screw connections
   - pressure transducers
are cleaned according to TN RT 353-1/77 except for the engine with the valve. The conveyance system is assembled under clean conditions.

7.2 The adjustment diaphragm is not adjusted with original fuel but with water instead, and the equivalent amount is calculated according to

\[
\frac{m_{Ox}}{m_{H_2O}} = \sqrt{\frac{Ox}{H_2O}}
\]

for equal \( \Delta p \).

7.3 All of the connections are made using DIN-Screw connections, and the capillary tubes are welded into the nipples.

7.4 A "constant" power supply can be used for the engine valve and a rocking switch may be used for control.

8. AMOUNTS OF FUEL TO BE FILLED

- Content of the fuel-filling container 7.5 liters
- The \( N_2O_4 \) container is filled with the amount required for a single test.
- The MMH-container is filled until the amount is suf-
ficient for all tests.
- Tank filling amount for MMH-container 7 lit \( \triangle 6300 \text{ gr} \)
- Useful amount 6.5 lit \( \triangle 5850 \text{ gr} \)

Assumed number of tests: 3

MMH-amount per test: 
\( N_2O_4 \) amount required for this 1950 gr 
Total amount 5148 gr

The required testing time is calculated from
\[
\frac{5148}{3.54} = 1454 \text{ s} \triangle 24 \text{ min}
\]

Summary:

Amounts to be filled; 
MMH 6300 gr
\( N_2O_4 \) 3500 gr

Test time to be expected per test: 24 min

9. TEST SEQUENCE

- Filling of the fuel amounts
- Calibration of transducers
- Hermeticity test for the entire conveyance system
- Functional test of the engine valve
- Filling of the pan with ice water
- Evacuation of the \( N_2O_4 \) conveyance system with closed tank valve and opened system valve
- pressurization of the \( N_2O_4 \) container at \( P_T \)

\[
\begin{align*}
P_E \ N_2O_4 &= 13.3 \\
\Delta P \ Bl &= 5.0 \\
\Delta P \ Rohr &= 0.5 \\
P_T &= 18.8 \text{ bar}
\end{align*}
\]

\[
\frac{24}{P_T}
\]
- Filling of the $N_2O_4$ conveyance system by opening tank valve.
- Taking of a cleanliness sample with a millipore-adaptor with a $2 \mu$ filter and a flow amount of 200 grams
- Qualitative check of the filter for particle amount, particle size and particle identification.
- Evacuation of the MMH conveyance system with a closed tank valve and open system valve
- Filling of the MMH conveyance system by opening the tank valve
- Manual recording of the fuel temperature in the tanks
- Manual recording of the tank pressures

\[ P_I = P_{Mano} - 0.3 \ (RV) \]

- Manual recording of the ice water temperature
- Equalization of the differential pressure transducers
- Manual recording of balanced readings
- Operation of the engine for 24 minutes
- Check of the mass throughputs using the flow meter readings. If necessary discontinue engine operation and make a throughput correction by changing the tank pressure, if there are deviations in

\[ \dot{m}_{N_2O_4\ Total} \] and \[ P_{Nom} \]

- Observations of differential pressures, injection pressure and flow meter readings in order to evaluate whether a possible reduction of the throughputs is caused by the beginning of blockage in the case where throughputs are reduced.
- Observation of the temperature loads on the engine, especially on the vacuum nozzle and interrupt test for any critical operational test.
- Let any blockage increase in the $N_2O_4$ system as long as the operating state of the engine does not become critical because of the displacement of the mixing ratio.
- After blockage of \( N_2O_4 \) has occurred
Conveyance system (reference value \[ \dot{m}_{N_2O_4} \leq 20 \% \dot{m}_{N_2O_4} \text{ Nominal} \]
Discontinue operation

- Determine the location of the blockage (filter, diaphragm injection system) from the changes in the differential pressures which have occurred or from the injection pressure.

- Close the tank valve (Ox/Br) (oxidizers/fuel) and the \( N_2O_4 \) system valve

- Rinse the MMH conveyance system with \( N_2 \) with an open engine valve by pressurization through the pressure relief valve of the MMH conveyance system and for closed MMH system valve.

- Remove ice water and take out the conveyance system together with the engine from the water tank.

- With a pre-vacuum, remove fuels from the engine and the conveyance system as much as possible by connecting a water spray pump to an adaptor (plate with a rubber sealing plate) to the vacuum nozzle of the engine.

- Install the engine with connected conveyance system to the recipient of the vacuum pump.

- Open the engine valve and evacuate the conveyance system for 48 hours: \( 10^{-2} \) Torr \( \) . Temperature of the engine valve should be checked. First record every 10 minutes. Close the engine valve when \( 95^\circ C \) is exceeded and open it again when temperature drops. Record vacuum pressure.

- Reinstall the conveyance system in the test assembly.
- Repeat the hot run test. Record the throughputs and pressures to check whether the degree of blockage has been reduced by the evacuation. The tank pressures in the previous step are maintained.

- If it is not successful to remove the blockage, the conveyance system is rinsed through a $2\mu$ filter with distilled water at a temperature of about 60°C. The rinsing water is captured in a clean container.

10. SPECIFICATION OF THE $N_2O_4$ FOR THE INDIVIDUAL TESTS

10.1 Test 1

Reference test for which no blockage is expected.

Distilled $N_2O_4$ with the following composition:

<table>
<thead>
<tr>
<th></th>
<th>Nominal values according to MIL-spec 26539C</th>
<th>Actual values</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_2O_4$</td>
<td>Weight wt%</td>
<td>99.5</td>
</tr>
<tr>
<td></td>
<td>Equivalent wt%</td>
<td>0.17</td>
</tr>
<tr>
<td>Solids</td>
<td>mg/l</td>
<td>≤ 10</td>
</tr>
</tbody>
</table>

The amount of solids is determined quantitatively by filtering through 1/μ-millipore filters of 200 g $N_2O_4$. Particle distribution on the filter is not determined, but on the other hand the dimension of the largest particles is determined.

10.2 Test 2

$N_2O_4$ of the following chemical composition is used:
98 wt % $N_2O_4$ (Purity c. nominal value of Test 1)
1 wt % $H_2O$ dest
1 wt % Kaltron MDS 113
20 mg/l (Nitrate mixture: 50 wt. % Fe-Nitrate)

Production of the Mixture. Both impurities
($H_2O$ and Freon) are mixed to the $N_2O_4$ by weighing. A 20 kg
balance is used (1 scale division = 5g).

Work sequence:

- Determination of the empty weight of the HG tank filling
  container $G_B$ = ..... kg

- Filling of the weighed Fe-Ni-Nitrate mixture. Weight ac-
  cording to Item 1 and weighed separately on an analysis
  balance.

- Fill the amount of water or freon determined according
to Point 2 and which has been weighed separately on an
analysis balance.

- Add the amount of the distilled $N_2O_4$ determined ac-
  cording to Point 2.

- Mix the components by shaking the previously closed con-
  tainer.

1. Determination of the FE-Ni-Nitrate amount for 3500 g $N_2O_4$

Amount of Nitrate $A_N = \chi \text{ mg/l} \cdot V_{N_2O_4}$

$\chi = 20 \text{ mg/l}$

Total amount $N_2O_4 = 3500 \text{ g} \quad (\rho = 1.446 \text{ g/cm}^3)$

$V_{N_2O_4} = 2.420 \text{ l}$

For 3500 g $N_2O_4$ the amount of nitrate is calculated
as follows: 

$$A_N = 20 \cdot 2.42$$

$$A_N = 48.4 \text{ mg}$$

The Fe-Ni-Nitrate mixture for 3500 g $N_2O_4$ consists of 24.2 mg Fe-Nitrate and 24.2 mg Ni-Nitrate.

2. Determination of the weight proportions of water and freon.

Total amount of contaminated $N_2O_4 = 3500$ g.

Wt. fraction $A = N_2O_4$ dest.
Wt. fraction $B = H_2O$ dest.
Wt. fraction $C = \text{Kaltron MDS 113}$

$$A + B + C = D$$

$$\begin{align*}
A &= 0.98 \cdot D \\
B &= 0.01 \cdot D \\
C &= 0.01 \cdot D \\
\end{align*}$$

$$G_{N_2O_4 \text{ dest.}} = 3430 \text{ g}$^* + 5 \text{ g}$$

$$G_{H_2O \text{ dest.}} = 35 \text{ g}$$

$$G_{\text{Kaltron}} = 35 \text{ g}$$

$$D = 3500 \text{ g}$$

* $+ 5$g balance air.

10.3. Test 3

If no blockage occurs for Test 2, in test three the Fe-Ni-Nitrate amount is increased to 40 mg/l.

The contaminated $N_2O_4$ for this test has the follow-
ing chemical composition:

98 wt % $\text{N}_2\text{O}_4$ (Purity c. nominal value of Test 1)
1 wt % $\text{H}_2\text{O}$ dest.
1 wt.% Kaltron MDS 113
40 mg/l (Nitrate mixture: 50 wt % Fe-Nitrate
50 wt % Ni-Nitrate)

Operating sequence just like for the production of the mixture as discussed in Test 2.

For $3500\ \text{g N}_2\text{O}_4$ the amount of nitrate is calculated from

$$A_N = 40 \cdot 2.42$$

$$A_N = 96.8\ \text{mg}$$

i.e. the nitrate mixture consists of 48.4 mg Fe-Nitrate and 48.4 Ni-Nitrate.
4. Test Configuration
4. Test Configuration
5. MANUFACTURING DOCUMENTS FOR TEST CONFIGURATION

- Work plan

- Work plan AP - Cleaning of the 10 N-TWK Engine SYS 2451 (Unit Nr. 35) after the first hot run when investigating the HG-anomalie

- Work plan MV2- Anomalie (2nd Test)

- Work plan AP - Cleaning of the 10 N-TWK (engine) after the second hot run.
Work Plan

1. Documents which apply:
   
   TN - RT 35 - 7/77  
   TN - RT 353- 1/77

2. The points shown in the work plan have to be confirmed by the person performing the test.

3. Work sequence

3.1. Buildup of the test apparatus according to TN - RT 35 - 7/77

3.1.1. Equipment to be used or manufactured: Made available and manufactured RT 353

1. pressure loading device SK 13 380 (BT-Nr. 2)
2. HG-Balances SK 8740 (BT-Nr. 1/2)
1. Vacuum pump type D S6
2. Vacuum hoses with adaptor
2. HG-Containers ($N_2O_4$) SK 8720 (BT-Nr. 5/7)
2. Arti-return valves Models -Nr. 2320 R-2 PP-5 ($N_2O_4$)
2. HG-containers (MMH) SK 8730 (BT-Nr. 1/7)
2. HG-container lines ($N_2O_4$) SK 8692 KK4 - 13
   KU5 - 14
1. HG-tank filling lines ($N_2O_4$) SK 8694 KU6 - $N_2$ (BT-Nr. 2)
2. HG-container lines (MMH) SK 8693 KU4 - 13
   KU5 - 14 (BT-Nr. 2)
1 GSP. Drive line (MMH) SK 15470 (BT-Nr. 1)
1 Filter for $N_2O_4$ SK 2480 - 22
1 Filter for MMH SK 16120
2 HG Pipe lines 1/8" x 0.01" x 1000 lg.
   for $N_2O_4$ and MMH-side
4 manual valves: NUPRO SS - 4H
2 Turbines Model LF 6-00
1 10 N-TWK SYS 2451 BT-Nr. 35
   with MBB-Valve SK 4550 BT-Nr. 44
1 TWK-Holder (for engine)
1 Suction device for TWK
2 pressure transducers CEP TYPE 4-351-002
2 pressure transducers CEC TYPE 4-326-L226
2 diaphragms $N_2O_4$ and MMH

3.1.2. Cleaning of all of the equipment mentioned under 3.1.1

Etching and cleaning of all pipelines, connection pieces
and welding adaptors

3.1.3. Cleanliness Class 1 demonstration
Conveyance System Unit cleanliness better than
Class I according to SAE

Pipe 27.5/74.2 5.12.77
Hoses
Tanks

3.1.4 Air Tightness of individual components

3.1.5 Integration of individual components

3.1.6 Air tightness test
Work Plan

3.1.7. Test Preparation
Mechanic
Measurement

3.1.8. Analyses
MON 0,3
MMH

3.1.9. Hot runs

3.1.10. Materials and Other Materials
Isopropl alcohol
Fuel: 15 kg N₂O₄
15 kg MMH

3.1.11. Monitoring during the evacuation

3.1.12. Conveyance system is rinsed with N₂ and is evacuated

3.1.13. Disassembly of individual components

3.1.14. Cleaning of Conveyance System
Hoses
Tanks

3.1.15. TWK (engine)
Disassembly
Cleaning
Assembly
Functional test according to AP-SYS 2451 (35) of 1/25/78.

3.1.16. Evaluation of Results
AP Cleaning of 10 N-TWK
(engine)

Name: SYS 2451 (Unit Nr. 35)
After 1st hot run for investigation of HG-anomalie

Distributor: LA

Author:

Hammerlin1 RT 353 25.1.78
(Name) (Abs.) (Datum)

37
<table>
<thead>
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<th>Page Number</th>
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<th>Date</th>
<th>Name/Division of Engineer</th>
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<td>1/25/78</td>
<td>Hammerlindl</td>
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</table>
WORK PLAN

Investigating the HG-Anomalie

Cleaning of 10 N-TWK SYS 2451(35)

1. Engine SYS 2451 is loosened at the separation point between the valve unit SK 4550 and the engine SK 8920. The screw safeties of Positions 13, 14 and 17 are removed by heating to 200-250 °C, using a soldering iron.

2. Valve unit SK 4550 is installed in spray device SK 11470/1.01. Valve is opened with a constant 24 V and is rinsed with completely salt-free water in the opposite direction according to TN RC 234-43/71.

3. Salt-free water is sprayed with \( \frac{5}{\mu} \) of cleaned \( N_2 \).


5. Isoprophenyl-alcohol is rinsed with \( \frac{5}{\mu} \) of cleaned nitrogen.

6. SK 8920 is installed on engine and then is equipped with spray device SK 11 340, and is rinsed with completely salt-free water according to TN RC 234-43/71.

7. Salt-free water is rinsed with \( N_2 \).


9. Isoprophenyl-alcohol is rinsed with \( N_2 \).

10. Engine SYS 2451 is assembled according to SYS 2451 Pos. 15 and HV SYS 2451 but without screw safety.

11. Air tightness test using \( \frac{5}{\mu} \) of purified \( N_2 \) in 40/80 gasoline. Test Pressure: 5 bar (Over pressure)

12. Engine is installed in receptacle for hot run anomalie II.
<table>
<thead>
<tr>
<th>Order</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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**WORK PLAN**

**MV2-Aномалия**

**Arbeit folge plan**

**Aномалия (2. Version)**

<table>
<thead>
<tr>
<th>Pos.</th>
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<tbody>
<tr>
<td>1</td>
<td>Disassembly &amp; cleaning of conveyance system</td>
</tr>
<tr>
<td>2</td>
<td>Fördersonst &amp; Reinigung, cleaning of hoses</td>
</tr>
<tr>
<td>3</td>
<td>Reinigung Tank N₂O₄, cleaning of tank N₂O₄</td>
</tr>
<tr>
<td>4</td>
<td>Disassembly &amp; removal of valve</td>
</tr>
<tr>
<td>5</td>
<td>Fertigung flasche N₂O₄, Functional test</td>
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(Illigible)
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<tr>
<th>ORDER</th>
<th>1</th>
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<th>4</th>
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<tbody>
<tr>
<td></td>
<td>Fertigungsdruck</td>
<td>Reibewiderstand</td>
<td>Dichtkeit, nachweis</td>
<td>Vakuumanlage</td>
<td>Integration</td>
<td>Dichtkeitsprüfung</td>
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</table>

According to the next demonstration for conveyance system, hoses, tank:

- Air tightness demonstration
- Vacuum insulation
- Instruction
- Air tightness test

Approval: no
<table>
<thead>
<tr>
<th>Order</th>
<th>1</th>
<th>2</th>
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**Approval**

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**Test Preparation**

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<th>Vermerklzeichnung</th>
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<tr>
<td>13</td>
<td>Analyse N2O4</td>
<td>JFVER</td>
</tr>
<tr>
<td>14</td>
<td>Heißlabor</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Werkstoff</td>
<td>Treibstoff</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15g N2O4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15g MH</td>
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</tbody>
</table>

**Monitoring during evacuation**

<table>
<thead>
<tr>
<th>No Überwachung kein Evakuieren</th>
<th></th>
</tr>
</thead>
</table>
AP Cleaning 10 N-TWK (engine)
after second run

SYS 2451 (Unit Nr. 35)
after second hot run when investigating
the HG-anomalie

Distributor: LA

Author: [Signature]

Examine: [Signature]
Investigation of HG-Anomaly
Cleaning 10N-TWK SYS 2451 (35)

CHANGE REGISTER

<table>
<thead>
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<th>Page No.</th>
<th>Reason for Change</th>
<th>Date</th>
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<td>1.25.78</td>
<td>Hammerlinl</td>
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</table>
WORK PLAN

Investigation of HG-Anomalie
Cleaning of 10 N-TWK SYS 2451 (35)

1. Engine SYS 2451 is loosened at the separation point between the valve unit SK 4550 and the engine SK 8920. The screw safeties of Positions 13, 14 and 17 are removed by heating to 200-250°C using a soldering iron.

2. Valve unit SK 4550 is installed in spray device SK 11470/1.01. Valve is opened with a constant 24 V and is rinsed with completely salt-free water in the opposite direction according to TN RC 234-43/71.

3. Salt-free water is sprayed with 5µl of cleaned N₂.


5. Isopropyl-alcohol is rinsed with 5µl of cleaned nitrogen.

6. SK 8920 is installed on engine and then is equipped with spray device SK 11 340, and is rinsed with completely salt-free water according to TN RC 234-43/71.

7. Salt-free water is rinsed with N₂.


9. Isopropyl-alcohol is rinsed with N₂.

10. Engine SYS 2451 is assembled according to SYS 2451 Pos. 15 and HV SYS 2451 but without screw safety.

11. Air tightness test using 5µl of purified N₂ in 40/80 gasoline. Test Pressure: 5 bar (over pressure).

12. Store engine.
6. TEST INSTRUCTION/ TEST REPORT FOR TEST SERIES 1
TASK DEFINITION

MBB Report: TN-RT353-5/77

Author: H. Czaika

Division: RT 354

Title: TEST INSTRUCTIONS
Ground tests for investigating the MV2 anomaly

First Test Series

Date: 12/7/77

Extended as a test report, test results recorded on 11/1/78.
1. **Study**

In order to investigate the MV2 anomaly (TN RT 353-7/77) we carried out hot runs with the 10 N-Engine (under atmospheric conditions).

In this report we specify the required work steps for preparing and executing the hot run tests.

**Test 1:** Reference test for which no blockage is expected.

**Test 2:** Hot run test for which $N_2O_4$ is used with the chemical composition mentioned under Item 2.3.2.2.

**Test 3:** Is only performed if in test 2 no blockage of the $N_2O_4$ conveyance system occurs. In this hot run the Fe-Ni-Nitrate fraction in the $N_2O_4$ is increased.

2. **Data on the Test Item and the Test Configuration for the Hot Run.**

2.1. **Test item:**
- 10 N-Engine SYS 2451 Number 35.
- with valve Number 44.
- Original fuel lines (line cross section and length) with filters and diaphragm according to the HG-System H4 (Sketch Page 8) with the conveyance line between the manual valve Ox 4 (BR 4) fuel and the engine.

2.2. **Test Configuration:**

The test configuration (Sketch Page 8) is built up according
to TN RT 35-77.
All of the components of the conveyance system and the fuel containers are cleaned according to TN-RT 353-1/77 and cleanliness is demonstrated using the millipore-method (without QS-documentation).

2.3. Fuels and fuel amounts

2.3.1. MMH: (Demonstration not required)
Amount of fuel to be filled: 6300 g
(for an expected testing time of 3 x 24 minutes)

2.3.2. Detailed $N_2O_4$ with the following chemical composition

2.3.2.1. Hot Run 1

<table>
<thead>
<tr>
<th>Nominal Values according to MIL-Spec.</th>
<th>Actual Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_2O_4$ wt. %</td>
<td>≥ 99.5</td>
</tr>
<tr>
<td>$H_2O$ equivalent wt. %</td>
<td>≤ 0.17</td>
</tr>
<tr>
<td>Solids mg/l</td>
<td>≤ 10</td>
</tr>
</tbody>
</table>

The solid fraction is determined quantitatively by filtering through $1\mu$m millipore filters of 200 g $N_2O_4$. Particle distribution on the filter is not determined. (see Test Sequence).

The amount of fuel to be filled: 3500 g
Number of particles, nominal value: Purity better than Class 2 according to SAE, signed: December 17, 1977

2.3.2.2. Hot Run 2

Distilled $N_2O_4$ with the following chemical composition:
(see data in TN-RT 353-7/77)

98 wt.% $N_2O_4$ dest. (Purity see item 2.3.2.1)
1 wt. - % $H_2O$ dest.
1 wt. - % Kaltron MDS 113
20 mg/l Nitrate mixture: 50 wt.% Fe-Nitrate
50 wt.% Ni-Nitrate

*(see preceding page) $HNO_3$ wt. % 0.64
$H_2O$ free wt. % 0.02
$HNO_3$ + free $H_2O$ result in an $H_2O$
equivalent of 0.11 wt. %.

Responsible for item 2.3.2.2. - RT351 - Mrs. Keil 22

Total amount of contaminated $N_2O_4$: 3500 g

$N_2O_4$ dest. = 3430 g (+ 5 g balance air)
$H_2O$ dest. = 35 g
Kaltron 113 MDS = 35 g
Fe-Nitrate = 24.2 mg
Ni-Nitrate = 24.2 mg

2.3.2.3. Hot run 3 (is performed because no blockage occurred
in Hot run 2)

Distilled $N_2O_4$ with chemical composition shown under
Item 2.3.2.2., but the Fe-Ni-Nitrate is increased to
40 mg/l

For 3500 g $N_2O_4$ we find
Fe-Nitrate: 48.4 mg
Ni-Nitrate: 48.4 mg

2.3.3. Filling of the $N_2O_4$ and the MMH containers

2.3.3.1. MMH-Container:

MMH is filled through a Millipore filter and
filling is controlled by weighing. Ventilation opening
on the container is first opened, if over-pressure exists in the container, in order to avoid penetration of air.

2.3.3.2. Filling of $N_2O_4$ Container

Filling of distilled $N_2O_4$ using $\frac{3}{4}$ Millipore filters, where filling is controlled by weighing. Ventilation of the container is only opened if over-pressure already exists in the container in order to avoid penetration of air. When producing the mixture for Test 2 and Test 3, the impurities (H$_2$O and freon) are mixed by weighing (2 $\mu$m filter). A 0.0 kg balance is used (1 scale division = 5 g).

Sequence:

- Determination of the empty weight of the $N_2O_4$ container (residual $N_2O_4$ is emptied out) GB = kg
- Filling of the Fe-Ni-Nitrate mixture which was weighed separately on an analysis balance.
- Filling of Kaltro- 113 MDS or the amount of water which has been weighed separately on an analysis balance.
- Weighing of the distilled $N_2O_4$
- Mixing of components by shaking the closed container.
- Before filling the $N_2O_4$ into the container for hot run 3, the container is cleaned according to TN-RT 353-1/77.

2.4. Measurement point plan
<table>
<thead>
<tr>
<th>Measurement point</th>
<th>Range</th>
<th>Recording#</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta p_1$ (F1)</td>
<td>0 - 6 atm</td>
<td>V, D, A</td>
<td>ged. 100 $\mu$F</td>
</tr>
<tr>
<td>$\Delta p_2$ (B1)</td>
<td>0 - 6 atm</td>
<td>V, D, A</td>
<td>ged. 100 $\mu$F</td>
</tr>
<tr>
<td>$P_L$</td>
<td>0 - 20 bar</td>
<td>V, D, A</td>
<td>ged. 100 $\mu$F</td>
</tr>
<tr>
<td>$P_C$</td>
<td>0 - 9 bar</td>
<td>V, D, A</td>
<td>ged. 100 $\mu$F</td>
</tr>
<tr>
<td>$\dot{m}_o$</td>
<td>Hz</td>
<td>D, A</td>
<td></td>
</tr>
<tr>
<td>$\dot{m}_b$</td>
<td>Hz</td>
<td>D, A</td>
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</tr>
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<tr>
<td>Time</td>
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</tr>
<tr>
<td>Pressure mark</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

# V = Visicorder; D = pressure; A = Reading

Pressure measurement transducers

$\Delta p_1$ CEC TYP 4 - 351 - 002
$\Delta p_2$ CEC TYP 4 - 351 - 002
$P_L$, $P_C$ CEC 4 - 326 - L 226

Turbine flow meter

COX 6-00 $N_2O_4$ Turb.Nr. 7191
COX 6-00 MMH Turb.Nr. 15732

Calibration of pressure transducers using $2\mu$-Filter (nom)
ORIGINAL PAGE IS OF POOR QUALITY
3. **Test Sequence**

3.1. **Preparations**

- filling of fuels (Point 2.3.3)
- calibration and installation of transducers
- functional test of engine valve
- air tightness test for the entire conveyance system by connecting through HV-OX3 (BR3) using GN2 = 10 bar (Filter \( \frac{1}{5} \mu m \))
- Filling of the pan with ice water
- pressurization of the \( N_2O_4 \) container at \( P_T \) (HV-OX2 "closed")

Pressure balance:

\[ P_{E \ N_2O_4} = 13,30 \text{ bar} \]

\[ \Delta p \text{ Blende} = 5,0 \text{ bar} \]

\[ \Delta p \text{ FÖS} = 0,5 \text{ bar} \]

\[ P_T = 17,80 \text{ atm} \]

- * for hot run 2 + 3 adjust values from hot run 1.
- Evacuation of the \( N_2O_4 \) conveyance system using HV-OX3 (\( \leq 1 \text{ Torr} \)) HV-OX4 "On"
- Filling of the \( N_2O_4 \) conveyance system by opening of the hand valve Ox 2
- Removal of a cleanliness sample with Millipore adaptor with a \( \frac{1}{5} \mu m \) filter and a flux of 200 g at the hand valve Ox 3.
- Qualitative check of the filter for particle amount, particle size and particle identification.
- Pressurization of the MMH-container with \( P_T \) (HV-BR 2"Closed")
Pressure balance $P_E^{\text{MMH}} = 14.10 \text{ bar}$

$\Delta p$ diaphragm $= 4.5 \text{ bar}$

$\sigma FOS = 0.3 \text{ bar}$

$P_T^* = 17.9 \text{ atg}$

(* For hot run 2 + 3 adjust values from hot run 1)

- evacuation of the MMH-conveyance system through HV-BR 3
  ($\leq 1 \text{ Torr}$)
  - HV-BR 4 "Open"
- Filling of the MMH-conveyance system by opening hand valve BR 2.

3.2. Nominal operating conditions for engine

$\dot{m}_{\text{ges}} = 3.54 \text{ g/s}$

$P_E^{\text{O}} = 13.3 \text{ bar}$

$P_E^{\text{3}} = 14.1 \text{ bar}$

$P_C = 8.7 \text{ bar}$

3.3. Hot run 1 (reference test for which no blockage is expected)

Test No. 02-2550/1 on December 16, 1977.

3.3.1. Manual Recording:

Temperatures in the tank

$T_{N_2O_4} = 12 \degree C$

$T_{\text{MMH}} = 9 \degree C$

$T_{H_2O} = 55 \degree C$
3.3.2. Ignition of Engines

- 2 seconds before Ignition, turn on engine Visicorder 1 cm/s
- upon ignition start engine time and print out in time intervals of 2 minutes (2x)
- check the mass throughputs: if necessary interrupt engine operation (stop the time), if deviations in $\dot{m}_{ges \, nom}$ and $r \, nom$ are found. Throughput correction by changing the tank pressures.
- Observation of differential pressures.
- Observation of temperature load on engine, especially on the vacuum nozzle.
Discontinue test for critical operating state.

3.3.3. Engine shut down at test time

$\tau_{ges} = 1440 \, s \quad$ Nominal time $= 1400 \, s$
- Visicorder "Off"
Manual Recording:

Engine temperature in the tank
\[ N_2O_4 \quad 10 \quad ^\circ C \]
\[ MMH \quad 10 \quad ^\circ C \]

Ice Water
\[ H_2O \quad 4,5 \quad ^\circ C \]
\[ N_2O_4 \quad 7,760 \quad kg \]
\[ MMH \quad 11,780 \quad kg \]

Balance Reading

Tank pressurization setting
\[ N_2O_4 \quad 17,80 \quad atg \]
\[ MMH \quad 17,85 \quad atg \]

- Reduction of \( P_{T-O} \) and \( P_{T-B} \)
- Close hand valves 0X 2 and BR 2
- OX 4 and BR 4
- Empty \( N_2O_4 \) container

Hot Run 2 (Test with contaminated \( N_2O_4 \) according to Item 2.3.2.2.)
Test Number 02-2950/2
December 16, 1977

3.4.1. Manual Recording:

Engine temperature in the tank
\[ N_2O_4 \quad 12 \quad ^\circ C \]
\[ MMH \quad 10 \quad ^\circ C \]
\[ H_2O \quad 0.6 \quad ^\circ C \]

Balance reading
\[ N_2O_4 \quad 17,85 \quad kg \]
\[ MMH \quad 17,85 \quad kg \]

Adjusted tank pressurization
\( N_2O_4 \quad 17.8 \quad atg \)
\( MMH \quad 17.85 \quad atg \)
3.4.2. Engine ignition

- Equalization of differential pressure measurement transducers

Check hand valves

| Ox 1 / BR 1 | "on" |
| Ox 2 / BR 2 | "on" |
| Ox 3 / BR 3 | "off" |
| Ox 4 / BR 4 | "on" |

3.4.2. Engine ignition

- 2 seconds for ignition turn-on visicorder 1 cm/s
- upon engine ignition start time and print out values in intervals of 1 minute (2x). Shorten intervals for throughput changes.
- Observe temperature load-on engine, especially on vacuum nozzle. Discontinue test for critical operating condition.
- Observe differential pressure, injection pressures and flux readings in order to evaluate possible throughput changes and whether these cause the beginning of blockage.
- Let blockages which can occur in the \( N_2O_4 \) conveyance system increase as long as the operating state of the engine is not critical because of the displacement of the mixture ratio.

3.4.3. Engine shut-down

3.4.3.1. After blockage of the \( N_2O_4 \) conveyance system has occurred

Nominal value:

\[ \dot{m}_{N_2O_4} = 0.44 \text{ g/s} \]

Imp/s

\[(\text{accordingly } 20\% \cdot \dot{m}_{N_2O_4} \text{ Nom.)} \]

3.4.3.2. After an operating time of

\[ t = 1440 \text{ s} \]
- Visicorder "OFF"

Recording:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Nominal value</th>
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<tbody>
<tr>
<td>Engine Temperature in the tank</td>
<td>$N_2O_4$: 10</td>
</tr>
<tr>
<td>Ice water temperature</td>
<td>$H_2O$: 1</td>
</tr>
<tr>
<td>Balance reading</td>
<td>$N_2O_4$: 49.34</td>
</tr>
<tr>
<td>Pressurization adjusted values</td>
<td>$N_2O_4$: 17.5 atg</td>
</tr>
<tr>
<td>Test time</td>
<td>MMH : 17.95 atg</td>
</tr>
</tbody>
</table>

- Reduction in $P_{TO}$ and $P_{TB}$
- Close hand valves Ox 2 and BR 2
  Ox 4 and BR 4
- If blockage occurs during the hot run:
  further sequence according to Item 3.4.4.
- If no blockage has occurred during the hot run,
  further sequence according to Item 3.5.

3.4.4. Blockage in the $N_2O_4$-conveyance system:

- From the changes in the differential pressures
  or injection pressure, determine the blockage
  location (filter, diaphragm, injection system).
- Rinse the MMH-conveyance system with $N_2$ with an
  open engine valve using the hand valve BR 3
  (observe BR fuel flux reading).
- Remove much of the fuels from the engine and
  the conveyance system (hand valves Ox 4 and
  BR 4 in the conveyance system are closed)
  by connecting a gas jet pump through an adapter.
to the vacuum nozzle of the engine (valve open).

- after this, connect the vacuum pump to the adapter

- open the engine valve and evacuate the conveyance system over 48 hours

\[ P_v \leq 10^{-2} \text{ Torr} \]

- temperature on the valve of the engine should be checked. At the beginning, make recordings at time intervals of ten minutes.
  - if 95°C is exceeded close the engine valve and open it again after the temperature as dropped and then record \( P_v \)
  - after the end of the evacuation time close the engine valve and close off the adapter in the vacuum pump.

3.4.4.1. Repetition of the hot run test 2 Test No. 01-2350/3
December 19, 1977
- Pressurization of \( \text{N}_2\text{O}_4 \) and MMH container.
  Adjustment values as under item 3.4.1.

- Evacuation of the \( \text{N}_2\text{O}_4 \) or MMH-conveyance system
  (hand valves in the conveyance system \( \text{HV-Ox 4} \) and \( \text{HV-BR 4} \) are closed) through \( \text{HV-Ox 3/BR 3} \)

  - fold the \( \text{N}_2\text{O}_4 \) conveyance system:
    Handvalve in the tank \( \text{HV-Ox 2} \) "OPEN"
    Handvalve in the conveyance system \( \text{HV-Ox 4} \) "OPEN"

  - fill the MMH-conveyance system:
    Handvalve in the tank \( \text{HV-BR 2} \) "OPEN"
    Handvalve in the conveyance system \( \text{HV-BR 4} \) "OPEN"

- Manual Recording
Nominal value

Fuel temperature in the tank
\[ T_{N_2O_4} = 9 \, ^\circ C \]
\[ T_{MMH} = 8 \, ^\circ C \]

Ice water
\[ T_{N_2O_4} = 3 \, ^\circ C \]
\[ N_2O_4: 10.185 \, kg \]
\[ MMH: 14.690 \, kg \]

Balance reading
Adjustment values for tank pressurization (see adjustment values of 3.4.1.)
\[ N_2O_4: 17.8 \, atg \]
\[ MMH: 17.95 \, atg \]

- Equalization of differential pressure transducers
- Check hand valves
  - Ox 1 / BR 1 "OPEN"
  - Ox 2 / BR 2 "OPEN"
  - Ox 3 / BR 3 "CLOSED"
  - Ox 4 / BR 4 "OPEN"

3.4.4.2. Ignition of Engine

- 2 seconds before engine ignition - Visicorder "ON"
  - 1 cm/s
- at engine ignition start time counting and print out values at 1 minute intervals (2x). Shorten time intervals if there are throughput changes.
- Observe the following: Temperature load on the engine, especially on the vacuum nozzle. Stop test for critical operating test.
- Observe differential pressures, injection pressures and flux readings in order to evaluate throughput changes which could occur, whether these are caused by a beginning blockage.
- allow (occurring) blockages in the $N_2O_4$ conveyance system to increase as long as the operating state of the engine is not critical because of displacement of the mixing ratio.

3.4.4.3. Engine Shutdown

3.4.4.3.1. - When the $N_2O_4$ conveyance system is blocked (same blockage as before evacuation)

3.4.4.3.2. - After an operating time corresponding to corresponding to the available $N_2O_4$

(Filled in $N_2O_4$ minus consumed $N_2O_4$ for the hot run 2 = remaining amount for repetition).

- Visicorder "OFF"

- Recording:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel temperature $N_2O_4$</td>
<td>$9$ °C</td>
</tr>
<tr>
<td>Ice water $H_2O$</td>
<td>$3$ °C</td>
</tr>
<tr>
<td>Balance reading $N_2O_4$</td>
<td>$9,450$ kg</td>
</tr>
<tr>
<td>Tank pressurization adjustment value $N_2O_4$</td>
<td>$17.8$ atg</td>
</tr>
<tr>
<td></td>
<td>$17.95$ atg</td>
</tr>
<tr>
<td>Test time</td>
<td>$445$ s</td>
</tr>
</tbody>
</table>
- Reduce $P_{TO}$ and $P_{TB}$

- Close handvalves Ox 2 and BR 2  
  Ox 4 and BR 4

- If the blockages are successfully removed, empty Ox and BR fuel conveyance systems.

- In the case of a failure, rinse MMH conveyance with GN 2 (20μm Filter) $N_2O_4$. Conveyance system is rinsed with a 2μm filter using distilled water at about 60°C. The rinsing water is captured in a clean container.

3.5. Hot Run 3 (Test with contaminated $N_2O_4$ according to Item 2.3.2.3.)

This hot run is carried out if no blockage has occurred during hot run 2. Hot run sequence is the same as for hot run 2 (item 3.4.1.).
Regarding ground test for investigating MV2 anomaly according to

TN-RT-7/77.

we find the following flux values for the diaphragms:

\[
\frac{1}{\mu N_{Bc}} = 0.0579 \text{ mm}^2 \\
\frac{1}{\mu N_{B1}} = 0.0692 \text{ mm}^2
\]

Definition:

\[
\mu_N = \frac{\pi}{14.72 \sqrt{p}} \text{ mm}^2
\]

\[
\sqrt{p} = \frac{600}{\text{bar}}
\]

Order:

\[
\sigma = \left( \frac{1}{\mu N} \right)^2 \frac{1}{200.5} \text{ bar}
\]

Nominal throughputs:

\[
\frac{\sigma_{02}}{\sigma_{10}} = 28.35 \frac{N^2}{g} = 2 \times 1.105 \\
\frac{\sigma_{01}}{\sigma_{10}} = \frac{10}{28.35} = 0.0568 \times 2.46
\]

\[
= 3.54 \times 3/8
\]

Specifications:

\[
\frac{1}{\mu N_{Bc}} = \frac{1}{\mu N_{B1}} = \frac{3.54}{0.66} = 5.34 \text{ %}
\]

\[
\sigma_{01} = \left( \frac{1.54}{0.6693} \right)^2 \frac{1}{200.5} = 4.2 \text{ in bar} = 6.3 \text{ %}
\]

\[
\sigma_{01} = \left( \frac{2.10}{0.6693} \right)^2 \frac{1}{200.5} = 5 \text{ in bar} = 5.7 \text{ %}
\]
name: HG N₂O₄ container

Item No: 8720
Component No: 7
Fabrication No:

To:

Nominal value for cleanliness demonstration: Class
Soll für Reinheitsnachweis: Klasse nach SAE

Ist: 1977, Liefer SAE 2757, Luft. 28.11.77
Actual value greater than (illegible) SAE

Soll für Betriebsdrucknachweis:
Nominal value for operating pressure demonstration:
Ist: 25 l
Actual:

Soll für Dichtheitsnachweis: Nominal for air tightness demonstration:
Ist: 25 l
Nominal:

Medien für Reinheitsnachweis: Isopropanol
Media for cleanliness demonstration: Isopropanol

Medien für Betriebsdrucknachweis:
Media for operating pressure demonstration

Medien für Dichtheitsnachweis: N₂, Netz. Luft.
Media for air tightness demonstration: line N₂

Chemische Reinheit mit Drägerröhren: geprüft
Ist: Restmengen von ppm
Chemical purity with tubes: tested ppm
Nominal: Residual amounts of ppm

Die mit "QS" versehenen Sollwerte sind von der QS nachzuweisen.
The nominal values with "QS" have to be demonstrated by the QS.
<table>
<thead>
<tr>
<th>Order</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abt.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Name: HG MMH container

Benzennung: HG - MMH - Behöller

Item No. Sach-Nr.: 8730

Component No. Bautl.-Nr.: 1

Fabrication No. Fabt.-Nr.: 1

To: Rohr:

Nominal value for cleanliness demonstration: Class Soll für Reinheitsnachweis: Klasse nach SAE

IST: Femm W. A nach SAE 25. IV 77

Actual value greater than (illegible) SAE Soll für Betriebssdrucknachweis:

Nominal value for operating pressure demonstration: Soll für Dichtheitsnachweis: Nominal for air tightness

IST: 25 bar 27. I. 77 demonstration:

Nominal: 286 bar 27. I. 77

Medium für Reinheitsnachweis: Isopropanol (IPA)

Medium for cleanliness demonstration: Isopropanol

Medium für Betriebssdrucknachweis:

Medium for operating pressure demonstration:

Medium für Dichtheitsnachweis: N₂, Netz über Media for air tightness demonstration: line N₂

Chemische Reinheit mit Drägerrührchen Chemical purity with tubes... tested

Chemical purity with tubes... tested

Ist: Restmengen von Nominal: Residual ambhüte: Of: 

Die mit QS versuchten Sollwerte sind von der QS zuweisen. The nominal values with "QS" have to be demonstrated by the QS.

- Munding- - Braun-
QS - DEMONSTRATION
 QS - NACHWEISES

for: Ground tests for investigating the MV anomaly
für: Bodentests zur Untersuchung der MV-Anomalie

<table>
<thead>
<tr>
<th>Order</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Name: NaOH HG container
Dennung: NaOH HG - Behälterleistungen

Item No.
Sach-Nr.: 8692 K 4 - 13
Component No.
Dautl.-Nr.: K 5 - 14

Fabrication No.
Fabr.-Nr.: 2

To:
By:

Nominal value for cleanliness demonstration: Class
Soll für Reinheitsnachweis: Klasse........... nach SAE

Ist: Reinheitsclasse Luft nach SAE 2112/77
Actual value greater than (illegible) SAE
better than Class 1 according to SAE 11/28/77
Soll für Betriebsdrucknachweis: 256...
Nominal for operating pressure demonstration:
Ist:

Nominal:
Nominal for air tightness demonstration
Soll für Dichtheitsnachweis: 466...

Ist: 40,6 % RT 77,11,77
Nominal

Media für Reinheitsnachweis: Isopropanol
Media for cleanliness demonstration: Isopropanol

Medium für Betriebsdrucknachweis:
Media for operating pressure demonstration:

Medium für Dichtheitsnachweis: N2, Neiz. Com.
Media for air tightness demonstration: line N2

Chemische Reinheit mit Drügereinigungs-
Chemical purity with tubes...... tested .................. geprüft
Ist: Restmengen von .................. .................. ppm
Nominal: residual amounts of...

Die mit "QS" versehenen Sollwerte sind von der QS
nachzuweisen. The nominal values with "QS" have to be

demonstrated by the QS.

Munding- 67
Braun-
OS - NACHWEIS

for: Ground tests
QS DEMONSTRATION

Page

for investigating the "QS" anomaly

Order | 1 | 2 | 3 | 4 | 5 | 6 | 7
--- | --- | --- | --- | --- | --- | --- | ---
Abt. | | | | | | | |
Name | | | | | | | |

Benennung: \(N_2\) tank filling line

Item No. | 8294
Sach-Nr.: | Ku 6 - \(N_2\)
Component No. | |

Bauml.-Nr.: 2

Fabrication No.

To:

Bohr:

Nominal value for cleanliness demonstration:

Soll für Reinheitsnachweis: Klasse nach SAE
Test: \(1\) nach SAE RTDS 40646 28.11.73

SAE

better than class 1 according to SAE

Soll für Betriebsdrucknachweis: 25 bar
Nominal for operating pressure demonstration:

Ist:

Actual

Soll für Dichtheitsnachweis: 40" Nominal for air tightness test
Ist: 40" RTDS 40646 28.11.73

Actual

Medien für Reinheitsnachweis: \(N_2\) Netz Lwm
Media for cleanliness demonstration: line \(N_2\)

Media for operating pressure demonstration:

Medien für Dichtheitsnachweis: \(N_2\) Netz Lwm
Media for air tightness demonstration line \(N_2\)

Chemische Reinheit mit Dr-

Geprüft:

Chemical purity with tube: tested

Nominal: Residual amounts of

Die mit "QS" versehenen Sollwerte sind von der QS
nachzuweisen. The nominal values with "QS" have to be
demonstrated by the QS.

Mundig...

Braun...
QS - NACHWEIS

QS DEMONSTRATION

För: Demonstrations zur Untersuchung

Order: 2

Abbl.

Name:

Name: MMH-Hg container lines

Benennung: MMH-Hg - Behälter-Leitungen

Item No.

Sach-Nr.: 8693

Component No.

Bautl.-Nr.: 2

Fabrication No.

Fabt.-Nr.: 

To:

Rohr:

Nominal value for cleanliness demonstration:

Soll für Reinheitsnachweis: Klasse nach SAE

Ist: 1. genauer Kl. 1 nach SAE Lüfter in 24.1.77

Actual: better than class 1 according to SAE

Nominal value for operating pressure demonstration:

Soll für Betriebsdrucknachweis: 256

Nominal value for air tightness demonstration:

Soll für Dichtheitsnachweis: 466

Nominal:

Media für Reinheitsnachweis: Isopropanol (IPA)

Media für Betriebsdrucknachweis:

Media für Dichtheitsnachweis: N₂

Media für Air tightness demonstration: line N₂

Die mit "QS" versehenen Sollwerte sind von der QS nachgewiesen. Die nominal values with "QS" have to be demonstrated by the QS.

Chemische Reinheit mit Drägerröhren
gewartet.

Chemical purity with tubes tested

Ist: Restmengen von

Nominal: Residual amounts of

-Nunding-

69

-Draute-
Name: GSP Drive line Apog for MMH pressurization

Bemerkung: GSP - Betriebsleitung Apog

Item No. für MMH Bedrückung

Sach-Nr.: 14 470

Component No:

Deutl.-Nr.: 1.

Fabrication No:

Fabr.-Nr.: 

To:

Honor:

Nominal value for cleanliness demonstration: Class

Soll für Reinheitsnachweis: Klasse nach SAE

Ist: 0,001 und SAE R711/A, according to SAE

Actual: better than class 1 28.11.72

according to SAE

Soll für Betriebsdrucknachweis: 255

Nominal value for operating pressure demonstration

Ist:

Actual:

Soll für Dichtheitsnachweis: 406

Ist: 406

Media für Reinheitsnachweis: N₂, Netzlos

Media for cleanliness demonstration: Line N

Media für Betriebsdrucknachweis:

Media for operating pressure demonstration:

Media für Dichtheitsnachweis: N₂, Netz 240m

Media for air tightness demonstration

Chemische Reinheit mit Drügertüchern line N₂ Chemical purity with tubes tested................. Copfhef

ist: Restmengen von

Nominal: Residual amount........ppm

Die mit "QS" versehenen Sollwerte sind von der QS nachzuweisen. The nominal values with "QS" have to be demonstrated by the QS.

-Nunding-

-Drahn-
Name:  Test design on N₂O₄ side  

Order No.  
Sach.-Nr.:  
Component No.:  

Filter  M₉SK2480 - 23 BT  Gehäuse Nr. 26/21  
Housings 

Rohr:  
To:  
Hose:  Nupro - SS-UH  

Soll für Reinheitsnachweis: Klasse *  
Nominal value for cleanliness demonstration 
Ist:  
Actual: better than Class I  
according to SAE  

Soll für Betriebsdrucknachweis:  
Nominal value for operating pressure demonstration  
Ist:  
Actual  

Soll für Dichtheitsnachweis:  
Nominal for air tightness demonstration  
Ist:  
Actual  

Media für Reinheitsnachweis: *propor.*  
Media for cleanliness demonstration:  
Media für Betriebsdrucknachweis:  
Media for operating pressure demonstration:  
Media für Dichtheitsnachweis: *N₂, N₂O₃ - Lam.*  
Media for air tightness demonstration: Line N₂  

Chemische Reinheit mit Drägerzylindern  
Chemical purity with tubes...tested ...geprüft  
Ist: Rustmengen von  

Nominal: Residual amounts of  

Die mit "QS" versehenen Sollwerte sind von der QS  
nachzuweisen. The nominal values with "QS" have to  
be demonstrated by the QS.  

-Nending-  
-Drahn-
Test configuration on MMH side

Nominal value for cleanliness demonstration:

Soll für Reinheitsnachweis: Klasse ........................ SAE

Ist: .................................................................

Actual: better than Class 1 according to SAE

Nominal value for operating pressure demonstration:

Soll für Betriebsspannung: ..................................

Ist: .................................................................

Actual:

Nominal value for air tightness demonstration:

Soll für Dichtheitsnachweis: ..................................

Ist: .................................................................

Nominal:

Medien für Reinheitsnachweis: isopropyl

Media for cleanliness demonstration:

Medien für Betriebsspannung: ..................................

Media for operating pressure demonstration:

Medien für Dichtheitsnachweis: N₂, Ne, He, Ar

Media for air tightness demonstration: line N₂

Chemische Reinheit mit Drügerrührchen

Chemical purity with tubes ....... tested. ................. geprüft

Ist: Restmengen von

Nominal Residual amounts of: ............... ppm

Die mit "QS" versehenen Sollwerte sind von der QS nachzuweisen. The nominal values with "QS" have to be demonstrated by the QS.

-Nunding-

-Braun-
The temperature on the engine is measured using a measurement bridge through the resistance of the coil.

Die Temperatur am Triebwerk wird mit einer Messbrücke über den Widerstand der Spule gemessen.

R\(_{\text{max}}\) = 331 Ohm  \(\Delta\) 95°C

Temperature an der Ox-Blende, Soll 28°C
Temperature on the OX-diaphragm Nominal 28°C
Betriebsspannung für Triebwerk 27 Volt DC
operating voltage for Engine 27 Volts DC

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>16.12</td>
<td>251</td>
<td>15°C</td>
<td></td>
<td>Region der Kochung</td>
<td>Bemerkung</td>
<td>Heitzburg</td>
</tr>
<tr>
<td></td>
<td>255</td>
<td>18°C</td>
<td>2 x 10^-2</td>
<td>Beginnings of evacuation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16°C</td>
<td></td>
<td></td>
<td>Evakuierung, evacuation not complete, suction line contaminated from engine to recipient with a brown liquid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.12</td>
<td>254</td>
<td>24°C</td>
<td>47</td>
<td>Region der Kochung</td>
<td>Bemerkung</td>
<td>Heitzburg</td>
</tr>
<tr>
<td>17.00</td>
<td>254</td>
<td>24°C</td>
<td>6 x 10^-2</td>
<td>Region der Kochung</td>
<td>Bemerkung</td>
<td>Heitzburg</td>
</tr>
<tr>
<td>18.15</td>
<td>30°C</td>
<td>27.5°C</td>
<td>3 x 10^-2</td>
<td>Engine valve open</td>
<td>Bemerkung</td>
<td>Heitzburg</td>
</tr>
<tr>
<td>21.30</td>
<td>34°C</td>
<td>28.5°C</td>
<td>3 x 10^-3</td>
<td>Engine valve open</td>
<td>Bemerkung</td>
<td>Heitzburg</td>
</tr>
<tr>
<td>21.12</td>
<td>238°C</td>
<td>26°C</td>
<td>4 x 10^-3</td>
<td>Engine valve open</td>
<td>Bemerkung</td>
<td>Heitzburg</td>
</tr>
</tbody>
</table>

1. Heating (light bulb) 4 cm closer
2. Similar temperature measured
<table>
<thead>
<tr>
<th>Monitoringschreibung</th>
<th>Widerstand</th>
<th>Temperatur</th>
<th>Oxidiertes Diaphragm</th>
<th>Vakuum</th>
<th>Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dat. Uhrzeit</td>
<td>Ohm</td>
<td>[°C]</td>
<td></td>
<td>Torr</td>
<td></td>
</tr>
<tr>
<td>17.12 10:10</td>
<td>300</td>
<td>26.7</td>
<td>5x10^-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.12 12:00</td>
<td>300</td>
<td>28.7</td>
<td>4x10^-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.12 16:16</td>
<td>300</td>
<td>26.0/26.8</td>
<td>4x10^-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.12 20:16</td>
<td>300</td>
<td>24.1/26.7</td>
<td>4x10^-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.12 22:45</td>
<td>296</td>
<td>22.1/26.3</td>
<td>4x10^-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.12 01:00</td>
<td>297</td>
<td>21/24</td>
<td>6x10^-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.12 19:26</td>
<td>257</td>
<td>28</td>
<td>4x10^-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.12 20:45</td>
<td>295</td>
<td>25.3</td>
<td>4x10^-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.12 21:10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ORIGINAL PAGE IS OF POOR QUALITY**
7. TEST INSTRUCTION/TEST REPORT FOR TEST SERIES 2
Project Definition:

Definition:

Author: H. Czaika

Division: RT 354

Title: Test Instructions

Ground Tests for Investigating the MV2 anomaly

Second test series

Date: 1/18/78

Summary: Extension of test report:

Experimental values recorded on February 13, 1978

Change:

3.5.1. was added, page 23.
1. Summary

In order to investigate the MV2 anomaly (TN RT 353-7/77) hot runs with the 10 N-Engine were carried out (in the atmosphere).

In the present document we specify the required steps for preparing and carrying out the hot run tests.

Test 1: Reference test for which no blockage is expected
Test 2: Hot run test for which $N_2O_4$ is used with the chemical composition specified in item 2.3.2.2.
Test 3: Is only used if during Test 2 no blockage in the $N_2O_4$ conveyance system occurs. In this hot run the Fe-Ni-Nitrate component in the $N_2O_4$ is increased.

2. Data on the Test Specimen and Test Installations for the Hot Run.

2.1. Test Specimen:

- 10 N-Engine SYS 2451 Bt. Nr. 35
  with valve Bt. Nr. 44

- Original fuel conveyance lines (line cross section and length) with the filter and the diaphragm according to the HG system engine H4 (Sketch Page 8) in the conveyance line between hand valve OX 4 (BR 4) and the engine.

2.2. Test Configuration:

The test configuration (sketch page 8) is done according to TN RT 35-7/77. All of the components of the conveyance system and the fuel containers are cleaned according to TN-RT 353-2/77 and the cleanliness is demonstrated using
the Millipore method (without QS documentation).

2.3. Fuels and Fuel Amounts

2.3.1. MMH: (Demonstration not required)

Amount of fuel to be filled: 6300 g
(for an expected test time of 3 x 24 min)

2.3.2. Distilled $\text{N}_2\text{O}_4$ with the following chemical composition

2.3.2.1. Hotline 1

Nominal value  Actual values

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{N}_2\text{O}_4$ wt %</td>
<td>≥ 99.5</td>
<td>99.34</td>
</tr>
<tr>
<td>H$_2$O Equival.  wt %</td>
<td>≤ 0.17</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Solids

| mg/l | ≤ 10 |

The solid fraction is determined quantitatively through 1/μm Millipore filters using 200 g $\text{N}_2\text{O}_4$. Particle distribution on the filter is not determined (see test sequence).

The amount of fuel to be filled: 3500 g
Number of particles, actual value: Cleanliness Class 2
according to SAE January 20 1978
signature: Muller

2.3.2.2. Hot run 2

Distilled $\text{N}_2\text{O}_4$ with the following chemical composition is used: (see data of TN-RT 353-7/77)

* $\text{HNO}_3$ wt %: 98 wt. % x dest. (Purity see item 2.3.2.1.)

0.64 wt. % $\text{H}_2\text{O}$ dest

$\text{H}_2\text{O}$ free 1 wt. % Kaltron MDS 113

wt. %: 0.02 20 mg/l Nitrate mixture: 50 wt. % Fe-nitrate

$\text{HNO}_3$ +free $\text{H}_2\text{O}$ gives an $\text{H}_2\text{O}$ equivalent 50 wt. % Ni-nitrate

of 0.11 wt. %. Responsible for Item 2.3.2.2. RT351 Mrs. Keil 78
Total amount of impurities $N_2O_4$: 3500 g
$N_2O_4$ dest. = 3430 g (+ balance air)
$H_2O$ dest. = 35 g
Kaltro 113 MDS.: = 35 g

Fe-Nitrate = 24.2 mg.
Ni-Nitrate = 24.2 mg.

2.3.2.3. Hot Run 3 (is performed if no blockage is found during
Hot Run 2.

Distilled $N_2O_4$ with the chemical composition as under
Item 2.3.2.2., but the Fe-Ni-Nitrate fraction is increased
to 40 mg/l
For 3500 g $N_2O_4$ we find:

Fe-Nitrate = 48.4 mg.
Ni-Nitrate = 48.4 mg.

2.3.3. Filling of the $N_2O_4$ and MMH-containers.

2.3.3.1. MMH-Container:
Fill the MMH using a 1/4" Millipore Filter and filling
is controlled by weighing. Ventilation on the container
is only opened if over pressure exists in it in order to
avoid entry of air.

2.3.3.2. Filling of the $N_2O_4$ container

Filling of distilled $N_2O_4$ through a 2\(\mu\) Millipore
filter and filling is checked by weighing. Ventilation
of container only when over pressure exists in it in
order to avoid penetration of air. When producing the
mixture for Test 2 and Test 3, impurities ($H_2O$ and freon)
are mixed by weighing (Filter 2\(\mu\)). A 20 kg bal-
ance is used for this (1 scale division = 5g).
Sequence:
- Determination of the empty weight GB of the $\text{N}_2\text{O}_4$ container (residual $\text{N}_2\text{O}_4$ is emptied) $\text{GB} = \text{kg}$
- Filling of the Fe-Ni-Nitrate mixture weighed separately on an analysis balance.
- Filling of the Kaltron 113 MDS or the amount of water separately on an analysis balance.
- Weighing of the distilled $\text{N}_2\text{O}_4$
- Mixing of components by shaking the closed container
- Before filling in the $\text{N}_2\text{O}_4$ into the container for hot run 3 the container is cleaned according to TN-RT 353-1/77

2.4. Measurement location plan

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Range</th>
<th>Recording*</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta p_1$ (Fl)</td>
<td>0 - 7 bar</td>
<td>V, D, A</td>
<td>ged. 100 $\mu$F</td>
</tr>
<tr>
<td>$\Delta p_2$ (B1)</td>
<td>0 - 13 bar</td>
<td>V, D, A</td>
<td>ged. 100 $\mu$F</td>
</tr>
<tr>
<td>$P_L$</td>
<td>0 - 20 bar</td>
<td>V, D, A</td>
<td>ged. 100 $\mu$F</td>
</tr>
<tr>
<td>$P_C$</td>
<td>0 - 9 bar</td>
<td>V, D, A</td>
<td></td>
</tr>
<tr>
<td>$m_O$</td>
<td>Hz</td>
<td>D, A</td>
<td></td>
</tr>
<tr>
<td>$m_B$</td>
<td>Hz</td>
<td>D, A</td>
<td></td>
</tr>
</tbody>
</table>

Valve signal Engine Time Pressure mark

* V-Visicorder, D-Printer, A-Reading.
3. Test Sequence

3.1. Preparations
- Addition of the fuels (Item 2.3.3.)
- Calibration and installation of transducers
- Functional test of engine valve
- Air tightness test of the entire conveyance system by applying a load through HV-0X3 (BR3) and GN2 = 10 bar (Filter 2μm)
- Filling of the basin with ice water
- Pressurization of the N₂O₄ container at Pₜ (HV-0X2 "CLOSED")

\[ P_{E \text{ N}_2\text{O}_4} = 13,30 \text{ bar} \]

Pressure balance

\[ \text{Diaphragm} = 5,0 \text{ bar} \]

\[ \Delta p \text{ FÖS} = 0,5 \text{ bar} \]

\[ 18,80 \text{ bar} \]

\[ P_{E} = 17,5 \text{ bar} \]

- For hot run 2 + 3, adjust values from hot run 1
- Evacuation of the N₂O₄ conveyance system by means of HV-0X3 \[(=0,1 \text{ Torr})\]
- Filling of the N₂O₄ conveyance system by opening hand valve Ox 2.
- removal of a cleanliness sample with a Millipore adapter with 1 μm Filter and a floor mount of 200 g on the manual valve OX3.
- qualitative check of the filter for particle amount, particle size and particle identification.
- pressurization of the MMH container at PT (HV-BR 2 "CLOSED")

<table>
<thead>
<tr>
<th>Pressure balance</th>
<th>( P_{E, MMH} )</th>
<th>14,10 bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>diaphragms</td>
<td>4,5 bar</td>
<td></td>
</tr>
<tr>
<td>( \Delta p , FOS )</td>
<td>0,3 bar</td>
<td></td>
</tr>
</tbody>
</table>

\[ P_T^* = 17,9 \text{ atg} \]

\* For hot runs 2 + 3 adjust values from hot run 1

- Evacuation of the MMH-conveyance system using (\( \leq 0.1 \text{ Torr} \)) HV-BR 4 "CLOSED"
- Filling of the MMH-conveyance system by opening handvalve BR2.

3.2. Nominal operating conditions for the engine

\[ \dot{m}_{\text{ges}} = 3,54 \text{ g/s} \]
\[ \dot{m}_{N_2O_4} = 2,20 \text{ g/s} \] (Turb.Nr. 7191)
\[ \dot{m}_{\text{MMH}} = 1,34 \text{ g/s} \] (Turb.Nr. 15732)
\[ P_{E-O} = 13,3 \text{ bar} \]
\[ P_{E-B} = 14,1 \text{ bar} \]
\[ P_C = 8,7 \text{ bar} \]
3.3. Hot Run 1 (Reference test for which no blockage is expected)
Test no. 02-2953/1 1/20/78

3.3.1. Manual recording:

<table>
<thead>
<tr>
<th>Nominal value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel temperature in the tank</td>
</tr>
<tr>
<td>$N_2O_4$ : $11$ °C</td>
</tr>
<tr>
<td>$MMH$ : $6$ °C</td>
</tr>
<tr>
<td>Ice water temperature</td>
</tr>
<tr>
<td>$N_2O_4$ : $2$ °C</td>
</tr>
<tr>
<td>$MMH$ : $2$ °C</td>
</tr>
<tr>
<td>Balance Reading</td>
</tr>
<tr>
<td>$N_2O_4$ : $10,965$ kg</td>
</tr>
<tr>
<td>$MMH$ : $13,679$ kg</td>
</tr>
<tr>
<td>Adjusted tank pressurization</td>
</tr>
<tr>
<td>$N_2O_4$ : $19.3$ atg</td>
</tr>
<tr>
<td>$MMH$ : $18.2$ atg</td>
</tr>
</tbody>
</table>

- Equalization of differential pressure measurement transducers.
- Check: Manual valve
  - Ox 1 / BR 1 "ON"
  - Ox 2 / BR 2 "ON"
  - Ox 3 / BR 3 "OFF"
  - Ox 4 / BR 4 "ON"

3.3.2. Engine Ignition:

- 2 seconds before engine ignition - Visicorder "ON" 2
- upon engine ignition start time and print out values at time intervals of 2 minutes (2x)
- check the mass throughputs: if necessary interrupt engine operation (stop the time), if deviations in $\dot{m}_{ges\ nom}$ and $\dot{m}_{r\ nom}$ are found. Throughput correction is made by changing the tank pressures.
- observation of differential pressures
- observation of temperature load on the engine, especially on the vacuum nozzle.

Interrupt test for critical operating state.
3.3.3. Engine shutdown for the test time

- Engine temperature in the tank
  - nominal value

- Ice water

- Balance reading

- Adjusted values of tank pressurization
  - reduction in $P_{T-O}$ and $P_{T-B}$
  - close hand valvesOX 2 and BR 2
  - empty $N_2O_4$ container

3.4. Hot run 2 (Test with contaminated $N_2O_4$ according to Item 2.3.2.2.)

Test No. 02-2953/2
January 20, 1978

3.4.1. Manual recording:

- Fuel temperature in the tank

- Ice water

- Balance reading

- Adjusted values of tank pressurization
  - see adjusted values for hot run 1
3.4.2. Engine Ignition

- 2 seconds before engine ignition - Visicorder "ON" 1
- start time upon engine ignition and print out values at 1 minute intervals (2x). Shorten intervals if there are throughput changes.
- Observe temperature load on engine especially on the vacuum nozzle.
  Discontinue test for critical operating conditions.
- Observation of differential pressures, injection pressures and flux readings in order to evaluate possible throughput changes and whether these are caused by the beginning of blockage.
- allow blockages in the $N_2O_4$ conveyance system to increase as long as the operating state of the engine is not critical because of the displacement of the mixing ratio.

3.4.3. Engine shutdown

3.4.3.1. After blockage of the $N_2O_4$ conveyance system has occurred Preference value

$$\dot{m}_{N_2O_4} = 0.44 \text{ g/s} \leq \text{Imp/s}$$
(according to 20% of $\dot{m}_{N_2O_4}$ Nom.)

3.4.3.2. After an operating time of

$$t = 1440 \text{ s}$$
- Visicorder "OFF"
Recording:

Fuel temperature in the tank

Ice water temperature

Balance reading

Adjusted tank pressurization

Test time

- Reduction in $P_{TO}$ and $P_{TB}$
- Close manual valves OX 2 and BR 2
  OX 4 and BR 4
- If blockage occurs during a hot run:
  further sequence according to item 3.4.4.
- If no blockage occurs during the hot run:
  continue sequence according to item 3.5.

3.4.4. Blockage in the $N_2O_4$ conveyance system

- From the changes in the differential pressures or
  the change in the injection pressure, determine
  the location of the blockage (filter, diaphragm,
  injection system)

- Close differential pressure can $d_P$ with $A_1, R, A$
  closed and close the connections using blind screw
  connections.
- Let ice water run out of the pan.
- Open HV-BR4 and evacuate MMH conveyance system
  through HV4-BR3 (P ≤ 0.1 Torr)
- Rinse the MMH conveyance system with \( N_2 \) with open engine valve through manual valve BR3 (flux reading BR is observed).
- Fuels are removed from the engine and the conveyance system for the most part. (Manual valves Ox4 and BR4 in the conveyance system are closed), by connecting a gas jet pump through an adapter over the vacuum nozzle of the engine (valve open).
- After this connect the adapter to a vacuum pump.
- Manometer \( P_{\text{vac}} \) is connected ahead of the filter.
- Open the engine valve and evacuate the conveyance system over 336 hours (\( P_{\text{vac}} 1 + P_{\text{vac}} 2 \) is recorded).

\[ P_v \leq 10^{-2} \text{ Torr} \]
- Surrounding temperature in the pan and the temperature on the filter are recorded.
- Temperature on the engine valve is checked. At the beginning record at intervals of 10 minutes.
  - if 95°C is exceeded close the engine valve and open it again after the temperature drops and then record \( P_v \).
  - After the end of the evacuation time close engine valve and close off adapter and vacuum pump (calibrate \( \Delta P_v, P_2, P_1, P_c \)).
  - Close manometer \( P_{\text{vac}} \) and connect pressure can \( \Delta P_1 \) pressure cans \( P_4, P_2, P_c \) are connected.

3.4.4.1. Repetition of hot run 2 Test No. 02-2955
February 2, 1978

- Pressurization of \( N_2 \), and MMH containers adjusted values as under 3.4.1.
- Evacuation of the HV-Ox 4 or MMH conveyance system (manual valves in the conveyance system 2 and HV-BR 4 are open) through HV-Ox 3/BR 3 (\( \leq 0.1 \) Torr)
- fill the $N_2O_4$ conveyance system:

Manual valve on the tank HV-Ox 2 "OPEN"
Manual valve on the conveyance system HV-Ox 4 "OPEN" (Check)

- fill the MMH conveyance system:

Manual valve on the tank HV-BR 2 "OPEN"
Manual valve on the conveyance HV-BR 4 "OPEN" (Check)

- Manual Recording:

<table>
<thead>
<tr>
<th></th>
<th>Nominal value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_2O_4$</td>
<td>12 °C</td>
</tr>
<tr>
<td>$MMH$</td>
<td>12 °C</td>
</tr>
<tr>
<td>$H_2O$</td>
<td>2 °C</td>
</tr>
</tbody>
</table>

Fuel temperature in the tank
Ice water
Balance reading

$N_2O_4$ : 10.234 kg
$MMH$ : 11.155 kg

Adjusted values of tank pressur-
ization (adjusted value Item 3.4.1.)

$N_2O_4$ : 17.3 atg
$MMH$ : 17.2 atg

- equalization of differential pressure transducers
- check: Manual valves
  - Ox 1 / BR 1 "ON"
  - Ox 2 / BR 2 "ON"
  - Ox 3 / BR 3 "OFF"
  - Ox 4 / BR 4 "ON"

3.4.4.2. Engine ignition

- 2 seconds before engine ignition - Visicorder "ON"
  - 1 cm/s
- start time at engine ignition and print over time
  intervals of 1 minute (2x). Shorten time intervals
  for throughput changes.
- Observe: temperature load on engine, especially on
the vacuum nozzle.
interrupt test for critical operating conditions.
- Observe differential pressures, injection pressure and flux reading in order to evaluate possible throughput changes and whether these are caused by a (beginning) blockage.
- Blockages which occur in the $N_2O_4$ conveyance system are allowed to increase as long as the engine operating state is not critical because of displacement of the mixing ratio.

3.4.4.3. Engine shutdown

3.4.4.3.1. - for blockage of the $N_2O_4$ conveyance system (same blockage as before evacuation)

3.4.4.3.2. - after an operating time according to the available $N_2O_4$

(Filled in $N_2O_4$ minus consumed $N_2O_4$ for hot run2 = remainder for repetition)
- Visicorder "OFF"
- Recording:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Nominal value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel temperature</td>
<td>$N_2O_4$: 4°C</td>
</tr>
<tr>
<td></td>
<td>$MMH$: 4°C</td>
</tr>
<tr>
<td>Ice water</td>
<td>$H_2O$: 2°C</td>
</tr>
<tr>
<td>Balance reading</td>
<td>$N_2O_4$: 7.64 kg</td>
</tr>
<tr>
<td></td>
<td>$MMH$: 3.19 kg</td>
</tr>
<tr>
<td>Temperature pressurization</td>
<td>$N_2O_4$: 17.3 atg</td>
</tr>
<tr>
<td>adjusted values</td>
<td>$MMH$: 18.2 atg</td>
</tr>
<tr>
<td>test time</td>
<td>$t$: 1949 s</td>
</tr>
</tbody>
</table>
- reduction in $P_{TO}$ and $P_{TB}$
- closed manual valve Ox 2 and BR 2
- Ox 4 and BR 4
- if blockage is successfully removed, empty Ox and BR conveyance systems.
- in the case of failure rinse MMH conveyance system with GN 2 (2μm Filter). $N_2O_4$
  conveyance system is rinsed through a2μm Filter using about 60°C warm distilled water. The
  rinse water is captured in a suitable clean container.

3.5. Hot Run 3 (test with contaminated $N_2O_4$ according to item 2.3.2.3)

This hot run is carried out if no blockage occurs for Hot Run 2.

Hot Run sequence the same as for Hot Run 2 (Item 3.4.1.)

3.5.1. Hot Run 3

When Hot Run 2 is repeated (item 3.4.4.1.) we found no blockage after about 1300 seconds (Ox-Tank empty)

After this an additional test Number 02-2956 was carried out with $N_2O_4$, using the composition of 3.3.3.2.

Surprisingly blockage occurred after 100 seconds on the filter (see graphed figures of test results).
Regarding ground tests for investigating the MV2 anomalies according to TN-RT 35-7/77.

**Tuning Diaphragms**

According to TN RE 31-65/74 (Tuning of: Tuning Bladder)

The following flow number result for the diaphragms:

\[ \frac{f}{\pi} = 0.0579 \text{ min} \]

\[ \frac{f}{\pi} = 0.0493 \text{ min} \]

\[ \text{Dissipation: } V = \frac{m}{\sqrt{V_{g}V_{ap}}} \text{ } \text{mm}^{2} \]

\[ \frac{V}{\text{bar}} \]

Nominal throughputs

\[ \text{Specified} \]

\[ \text{Vergaben} \]

\[ \text{Uns. in mm W, V} \]
Name: HG N₂O₄ Container
Item No: 8720
Component No:
Fabrication No:

To:

Nominal value for cleanliness demonstration: Class 1 according to SAE
Actual value: Date: 7/17/78 RC34
         (illegible)
Nominal value for operating pressure demonstration:
Actual:

Nominal value for air tightness demonstration:
Actual:

Media for cleanliness demonstration: Isoproponol

Media for operating pressure demonstration

Media for air tightness demonstration

N₂₂₂, LAM Supply Network

The nominal values with "QS" have to be demonstrated by the QS.

-Munding-         -Braun-
for Ground tests for investigating the MV₂ anomaly

Name: N₂O₄ Side Test Configuration

Item No.:

Component No.:

Fabrication No.:

Filter MQ SK 2480-22 BT Housing Nr. 20/21
Turbine Model LF 6-60 Serial No. 7191
To: HG tube 1/8" x 0.01" x 1000 mm long
Manual valve: Nupro SS 4H.

Nominal value for cleanliness demonstration Class 1 according to SAE
Actual value: Date: 7/17/78 RC34
          (illegible)
Nominal value for operating pressure demonstration:

Actual:

Nominal value for air tightness demonstration:

Actual:

Media for cleanliness demonstration: Isopropanol

Media for operating pressure demonstration

Media for air tightness demonstration N₂ LAM Supply Network

Chemical purity with tubes.....,tested
Nominal: Residual amounts of.....ppm
The nominal values with "QS" have to be demonstrated by the QS.

-Mundt:

-Braun-
for: Ground Tests for investigating the MV₂ anomaly

Name: MMH Side Test Configuration

Item No.: 

Component No.: 

Fabrication No.: 
Turbine: Model = LF 6-00 Serial No 15732 
To: HG tube 1/8" x 0.01" x 1000 mm long 
Manual valve: Nupro SS 4H.

Nominal value for cleanliness demonstration Class 1 according to SAE 
Actual Value: Date 7/17/78 RC34 
         (illegible)

Nominal value for operating pressure demonstration:
Actual:

Nominal value for air tightness demonstration:
Actual:

Media for cleanliness demonstration: Isopropanol
Media for operating pressure demonstration:
Media for air tightness demonstration: N₂ LAM Network...-

The nominal values with "QS" have to be demonstrated by the GS.

-Munding-

-Braun-
Name:  \( \text{N}_2\text{O}_2 \) \( \text{HG Tank filling line} \)

Item No.:  8694 Ku 6-\( \text{N}_2 \)

Component No.:  

Fabrication No.:  

Nominal value for cleanliness demonstration Class 1 according to SAE

Actual value Date 7.2.78 RC34

( Illegible )

Nominal value for operating pressure demonstration

Actual:

Nominal value for air tightness demonstration:  

Actual:  

Media for cleanliness demonstration:  \( \text{N}_2 \) line LAM

Media for operating pressure demonstration

Media for air tightness demonstration

Chemical purity with tubes........tested

Nominal: Residual amounts of .......ppm

The nominal values with "QS" have to be demonstrated by the QS.

- Munding -

- Braun -
Appendix B to
TN-RT 353 - 1/78
for: Ground tests for investigating the MV₂ anomaly

Author: Hersberg
Page 5 of 7

Name: GSP drive line A pug for MMH pressurization

Item No: 5470

Component No:

Fabrication No:

Nominal value for cleanliness demonstration: Class 1 according to SAE

Actual value: 7/12/78 RC34
(illegible)

Nominal value for operating pressure demonstration:

Actual:

Nominal value for air tightness demonstration:

Actual:

Media for cleanliness demonstration: N₂ LAM Supply Network

Media for operating pressure demonstration

Media for air tightness demonstration

Chemical purity with tubes tested

Nominal: Residual amounts of ppm

The nominal values with "QS" have to be demonstrated by the QS.

-Munding-

-Braun-
for ground tests for investigating the NV₂ anomaly

Name: MMH - HG Container line

Item No: 8693 Ku 514

Component No:

Fabrication No:

To:

Nominal value for cleanliness demonstration: Class 1 according to SAE

Actual Date: 7/02/78 RC34 (illegible)

Nominal value for operating pressure demonstration:

Actual:

Nominal value for air tightness demonstration:

Actual:

Media for cleanliness demonstration: Isopropanol

Media for operating pressure demonstration:

Media for air tightness examination:

Chemical purity with tubes......tested
Nominal: Residual amounts of .....ppm

The nominal values with "QS" have to be demonstrated by the QS.

-Munding-

-Braun-
for: ground tests for investigating the N\textsubscript{2}O\textsubscript{4} anomaly

Name: N\textsubscript{2}O\textsubscript{4} HO Container Line

Item No.: 8692 Ku 4 13

Component
No.: 2

Fabrication No.:  

To:

Nominal value for cleanliness demonstration: Class 1 according to SAE

Actual Date 7.12/78 RC34 (Illegible)

Nominal value for operating pressure demonstration:

Actual:

Nominal value for air tightness demonstration: Isopropanol

Actual:

Media for cleanliness demonstration:

Media for operating pressure demonstration:

Media for air tightness demonstration:

Chemical purity with tubes tested
Nominal: Residual amounts of ppm
The nominal values with "QS" have to be demonstrated by the QS.

-Munding-

-Braun-
The temperature on the engine is measured with a measurement bridge using the resistance of the coil.

\[ R_{\text{max}} = 331 \, \text{Ohm} \triangleq 95^\circ\text{C} \]

Temperature of the Ox-Diaphragm, nominally 28\(^\circ\)C

Operating voltage for Engine 27 Volt DC

Total evacuation time 336 hours (FS of 1.23.78)

<table>
<thead>
<tr>
<th>Monitoring Date</th>
<th>Temperature of the Diaphragm</th>
<th>Vacuum Resistance of the Surrounding Diaphragm Engine Coil[Ohm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>Time</td>
<td>(^\circ\text{C})</td>
</tr>
<tr>
<td>20.7</td>
<td>17 (25)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>17 (35)</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>18 (45)</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>21 (50)</td>
<td>26.5</td>
</tr>
<tr>
<td>21.7</td>
<td>7 (45)</td>
<td>27.5</td>
</tr>
<tr>
<td></td>
<td>12 (10)</td>
<td>27.5</td>
</tr>
<tr>
<td></td>
<td>16 (25)</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>20 (20)</td>
<td>29</td>
</tr>
<tr>
<td>22.1</td>
<td>6 (22)</td>
<td>23.5</td>
</tr>
<tr>
<td></td>
<td>13 (22)</td>
<td>23.5</td>
</tr>
<tr>
<td></td>
<td>19 (22)</td>
<td>29.5</td>
</tr>
</tbody>
</table>

- Engine open
- Lamp moved 4 cm back
- Lamp moved 4 cm back
## MV2-Anomaly Test Results

### Monitoring Temperature

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Temperature $^\circ$C</th>
<th>Vacuum [bar]</th>
<th>Vacuum [Torr]</th>
<th>Resistance of the</th>
<th>Remark</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.1</td>
<td>1950</td>
<td>27</td>
<td>0</td>
<td>$5 \times 10^{-3}$</td>
<td>302</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24.1</td>
<td>845</td>
<td>28.5</td>
<td>0</td>
<td>$5 \times 10^{-3}$</td>
<td>303</td>
<td></td>
<td></td>
</tr>
<tr>
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