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VAPORIX Diagnostics Summary

Documentation
for facilitating the troubleshooting procedure
in vapour recovery systems at filling stations
equipped with an automatic monitoring system of the type
VAPORIX.

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Preface

The company FAFNIR GmbH and its employees have performed the inspections with utmost care. However, no responsibility shall be accepted for the applicability of the results and interpretations communicated in this summary. We do not claim that the documentation is complete and point out that the documentation refers to examples that may, however, be quite different in each individual case on site.

FAFNIR reserves the right to make additions and alterations to this document at any time without prior notice.

1 Introduction

On 17 May 2002, the regulation regarding the amendment of the legal immission-related requirements of the 21st BImSchV (German federal immission protection regulation) entered into force. It regulates, among other things, the inspection of the vapour recovery systems installed in the dispensers of filling stations by means of an automatic monitoring system. It was stipulated that the automatic monitoring system must check to determine that the recovery rate of the vapour recovery operates within a tolerance range of 85 % to 115 %. If this is not the case for 10 assessable refuelling operations in succession, an alarm is signalled. If no repair work is carried out within 72 hours after the alarm has been triggered, the respective dispenser point is deactivated. Refuelling operations with a flow rate above 25 l/min for a period of at least 20 seconds are defined as being assessable refuelling operations.

The construing and the more precise interpretations of these stipulations are included in the Information Sheet 1 "System tests for active vapour recovery systems and their monitoring systems in Germany" dated 17 June 2002 and in the VDI (Association of German Engineers) Directive 4205, Sheet 1 to 5.

The basis for the stipulations in the regulation and in the information sheet as well as in the VDI directive was provided by two extensive studies conducted by Deutsche Wissenschaftliche Gesellschaft für Erdöl, Erdgas and Kohle e. V. (DGMK) (German Scientific Society for Petroleum and Natural Gas and Coal). The first study (DGMK research report 550-02, May 2001) was a feasibity study of the in 2001 available systems for the detection of deviations in vapour recovery rate. The experiences have been taken into account by the BImSchV regulation and the VDI 4205 directive. In the second study (DGMK research report 550-04, April 2003), the additional boundary conditions, such as the generation of alarm signals and shutdown functions, were successfully tested.

Since 1 April 2003, new filling stations in Germany were only allowed to go into operation if they have been equipped with an automatic monitoring system.

In the following years vapour recovery systems and vapour recovery monitoring systems of similar configuration have been introduced in several European countries mainly in Switzerland, Austria, Sweden, Great Britain, France and Italy.

In the USA especially in California, also vapour recovery systems are in use since the 90th. In addition to the vacuum assisted systems using a vacuum pump like in Europe also the so called balance systems are in use exploiting the displacement effect of the fuel itself. A further speciality in California is the necessity of the surveillance of the vapour pressure in the storage tank and the data collection by an in-station-diagnostic (ISD) system. The ordinances require in addition the processing of the collected vapour in order to separate the Hydrocarbons from the air.

In many other countries of the world also vapour recovery systems and automatic monitoring systems are in the introduction stage like Australia, Taiwan, China and Korea and possibly Japan.

The boundary conditions and surveillance requirement are in part different in these countries. The common thing is that as a minimum a vapour recovery system and the control of the vapour recovery system by an automatic monitoring system is mandatory but there are different extension envisaged and integrated into the country specific regulations.

The diagnostic tools that the company FAFNIR makes available in the following documentation give an insight into the behaviour of the vapour system itself and not into the supplementary systems mentioned. The typical cases of error are shown with the associated measurement values and the remedial measures.

2 Adjustments of the vapour recovery system

2.1 Active vapour recovery systems and the k-factor

The vapour recovery systems considered here are the so called active vapour recovery systems using a vapour pump for the suction of vapour. In contrast the balance systems work without a pump and rely on the pressure increase in the vehicle tank due to the vapour displacement by the fuel during the refuelling operation. This pressure difference pushes the vapours back to the storage tank.

There are three types of active vapour recovery systems in use. The most popular one employs a vapour pump running at constant speed while the vapour flow speed is controlled by a proportional valve. The second type uses a frequency converter to change the rotational speed of the vapour pump. The third type uses also a vapour pump running at constant speed. The vapour flow speed is controlled by a mechanical valve inside of the nozzle opening the gas channel in dependence of the fuel flow speed.

For all these three configurations the pumping efficiency is dependent on the properties of the vapour recovered. Generally the efficiency decreases with increasing Hydrocarbon concentration. This effect is taken into account as an average value by a so called k-factor. A k-factor of 1.09 as an example indicates, that the vapour recovery system under consideration exhibits a decrease of 9% in recovery rate for a typical hydrocarbon/air mixture with respect to 100% air. The k-factor is determined during the certification procedure. It allows an adjustment of a vapour recovery system with air only. Using the k-factor the result of the dry adjustment as described below can be used also for the normal operation where the Hydrocarbon are pumped.

The huge advantage of the dry adjustment and dry test is that experienced service personnel can do the necessary adjustment and test very quickly and without being exposed to Hydrocarbon vapours.

2.2 Dry adjustment

For the dry adjustment, special equipment is necessary as is displayed in the following figure.

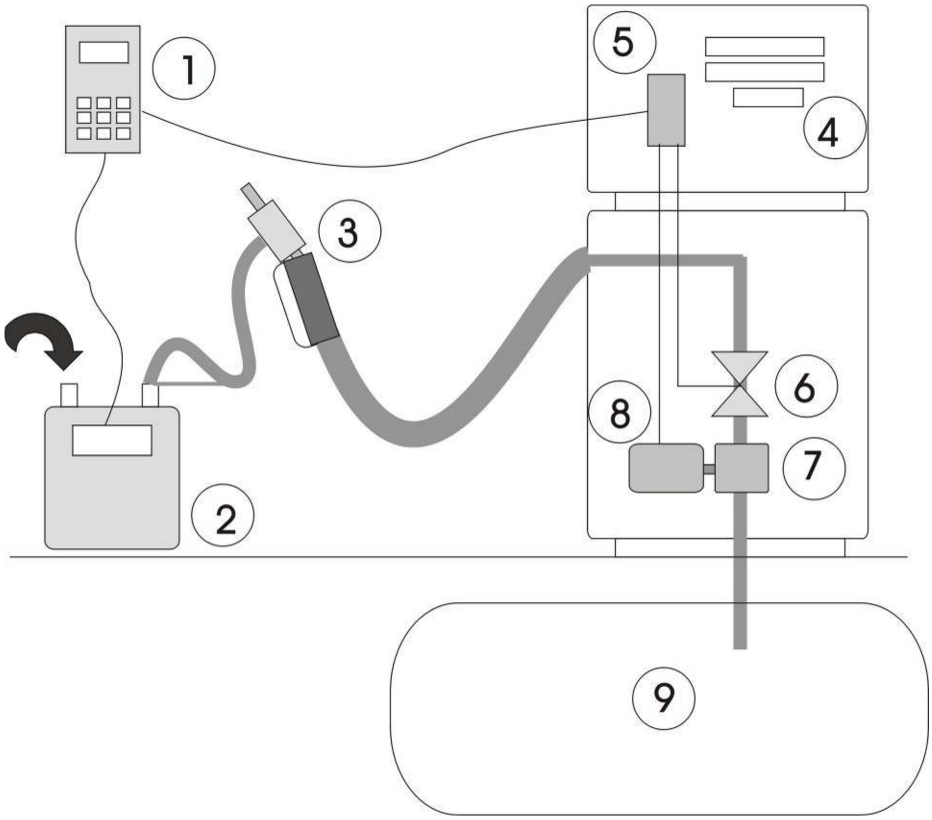

Figure 1: Typical on-site test arrangement

1) Hand held terminal provided by the VR system supplier
2) Gas (vapour) flow-rate meter
3) Dispenser nozzle and hose with meter adapter; the nozzle may have an integral proportional valve negating items 5 & 6
4) Dispenser
5) VR electronics – typically an add-on module connected to the host dispenser
6) Proportional gas flow valve
7) Vacuum pump (when this is variable speed the proportional valve is not used)
8) Vacuum pump motor
9) Underground storage tank

A gas flow-rate meter (2) is connected to the gas inlet of the nozzle by a flexible tube and an adapter. An electronic handheld (1) is connected to the vapour recovery electronic and to the gas flow-rate meter. Now the electronic in the handheld generates a pulse frequency simulating a certain fuel flow speed. The air flow generated by the vapour recovery system is measured and stored. This is done for a set of values in the range of about 10 l/min to 45 l/min. The deviations of the air flow speed with respect to the predefined values are determined and a correction set is calculated and transferred to the vapour recovery electronic.

In the normal operation, the vapour recovery electronic uses the correction values in order to adjust the vapour recovery rate close to 100%. To achieve this also for normal refuellings the k-factor must be taken into account.

2.3 Dry testing

The same equipment is used also for the dry test as is shown in figure 1 used for the dry adjustment. For the dry test a pulse frequency is generated in the handheld electronic (1) simulating a fuel flow speed. The measured vapour flow speed should be equal to the fuel flow speed multiplied by the k-factor value. With this procedure, the correctness of the adjustment of the vapour recovery system can be quickly tested without the necessity of using real fuel flow.

2.4 Wet testing

For the wet testing again the same equipment is used but with an additional container for fuel. A refuelling is performed into the container so there is a real fuel flow. The adapted gas flow-rate meter measures simultaneously the air flow. If the system is correctly adjusted the air flow speed must be somewhat higher than the fuel speed as given by the k-factor.

The wet test should be performed, if there is an indication that the value of impulses per litre that the dispenser electronic provides as an output for the vapour recovery electronic is not the same as configured in the vapour recovery electronic. This error would show up only in the wet test. For example if the dispenser would provide 50 impulses/l but the vapour recovery would expect 100 impulses per litre the vapour recovery system would generate only the half of the necessary gas flow speed. But a dry test would have given correct results.

Because the fuel must be poured back into the storage tank and because during the handling some of the hydrocarbon vapours are breathed in the wet test should be made only if absolutely necessary.

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3 Diagnostic tools

In order to be able to better assess the vapour recovery by the data provided by the automatic monitoring system VAPORIX, the company FAFNIR provides the program "VAPORIX-Diagnostics" for the purpose of reading out and representing the refuelling operations (refuelling history) stored in VAPORIX-Control. For that purpose, an RS232 cable is used to set up a connection between a notebook and VAPORIX-Control. Afterwards, the data for the both dispenser sides can be read out, stored in Excel tables and are represented automatically in tables (Table 1) and in diagrams (Figure 2).

Microsoft Excel - VAPORIX-Diagnose1

	A	B	C	D	E	F	G	H	I	J
1	History VAPORIX-Control									
2										
3	Side	A	Status	1						
4										
5	Sensor no.	Time	Date	Error counter	Fuel transfer counter	Recovery rate	Mean value of	Mean vapour	Vapour concentration status	Vapour
6						in %	Recovery rate in %	temp. in °C		in l/min
208	2287	09:30:24	12.10.2005	1	200	0	102,9	13,9	33	
209	2287	09:54:43	12.10.2005	1	201	0	102,9	14,6	53	
210	2287	10:10:45	12.10.2005	0	202	98	102,6	15,6	50	
211	2287	10:19:11	12.10.2005	0	203	107	102,9	16,4	45	
212	2287	10:29:07	12.10.2005	0	204	110	103,3	17,3	36	
213	2287	10:41:16	12.10.2005	0	205	96	102,9	18,2	60	
214	2287	10:57:27	12.10.2005	0	206	104	103	18,8	39	
215	2287	11:04:44	12.10.2005	0	207	105	103,1	18,6	54	
216	2287	11:12:06	12.10.2005	1	208	0	103,1	20,3	59	
217	2287	11:21:07	12.10.2005	0	209	100	102,9	19,3	63	
218	2287	11:28:12	12.10.2005	0	210	106	103,1	19,6	55	
219	2287	11:36:45	12.10.2005	1	211	0	103,1	21,3	40	
220	2287	12:41:41	12.10.2005	0	212	104	103,1	21,2	59	
221	2287	12:50:47	12.10.2005	0	213	102	103,1	21,2	52	
222	2287	13:03:56	12.10.2005	0	214	108	103,4	21,4	56	
223	2287	13:32:17	12.10.2005	0	215	100	103,2	20,6	47	
224	2287	13:40:58	12.10.2005	1	216	0	103,2	21,7	42	

Data Side A / Data Side B / Filling operations Side A / Filling operations Side B

Table 1: Table representation of the refuelling data of the dispenser side A read out with "VAPORIX-Diagnostics"; the assignments of the columns are given in the headline.

Each line in Table 1 corresponds to one as valid assessed refuelling operation. Up to 2,000 refuelling operations for both dispenser sides together can be stored. The sheets of the table can be switched between the data of dispenser side A and side B and between the graphical representation of the data also for both sides. Many phenomena can be discerned already by looking at the numbers in the table whereas in many cases it is very helpful to look at the data in the diagrams as shown in the figures of this compendium.

If the data are not immediately interpretable by looking at the tables or the graphs there are additional tools available that are accessable by the three tiny buttons discernable in the left upper part of the Table 1. The first button carries a FAFNIR flag the second button is designated by a drop of a liquid and the third button is designated by a thermometer.

If the data indicate that the number of impulses representing one litre of fuel is wrongly configured in the VAPORIX-Control, the configuration can be easily changed with a click on the (tiny) FAFNIR symbol. A pop-up window appears and the desired impulse/litre value can be typed in and can be transferred to the VAPORIX-Control by an additional click. An example of such an error is shown in chapter 5.6.

The liquid drop as a symbol activates a sorting function. The data in the table are sorted according to the magnitude of the fuel flow speed. Such a sorting reveals immediately errors in the adjustment characteristic of the vapour recovery system. A striking example is found in chapter 4.8.

The button with the thermometer symbol activates another sorting function. The data are arranged according to the vapour temperature. This can be useful if the efficiency of the vapour recovery system is strongly dependent on temperature.

In Figure 2 as an example the data of an refuelling point are shown where the vapour recovery system can savely be classified as well operating. The values of the recovery rate centre at about 100% with relatively low scatter. The limits for the adjustment of the recovery rate are 100±5 %. Because of the tolerances of the vapour recovery systems and of the automatic monitoring system, deviations of ± 10% are to be expected as typical. In the example shown in Figure 2, the fuel flow speed is approx. 35 l/min, and the vapour temperatures varies between 0 °C and 10 °C.

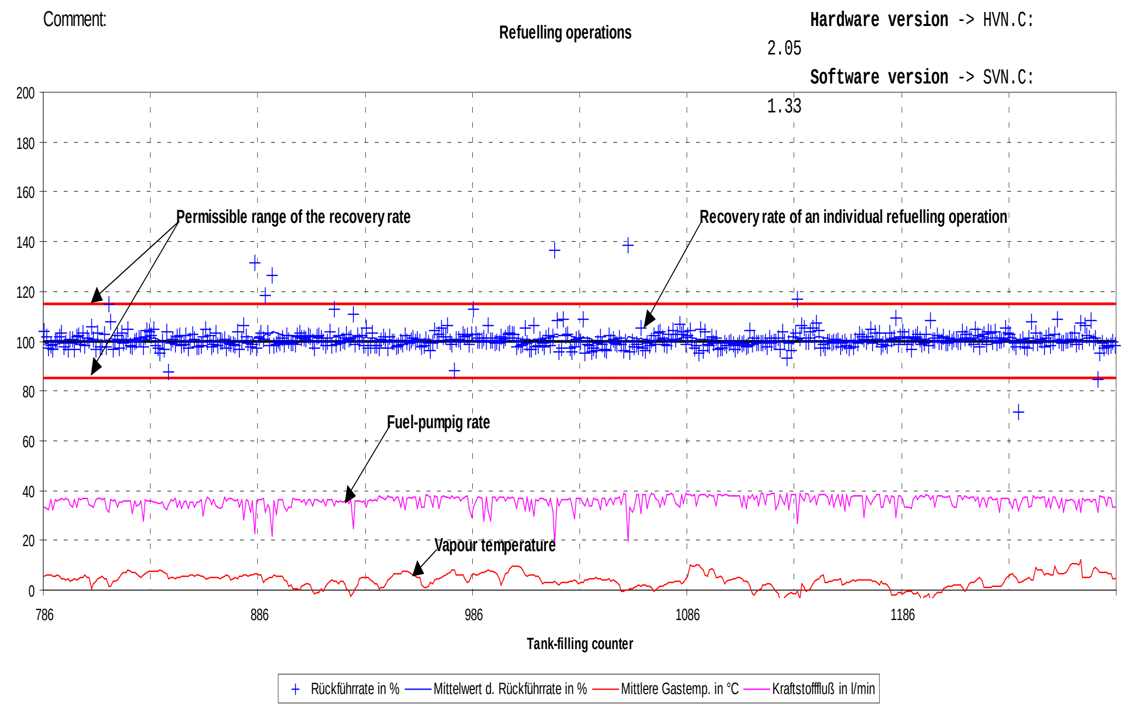


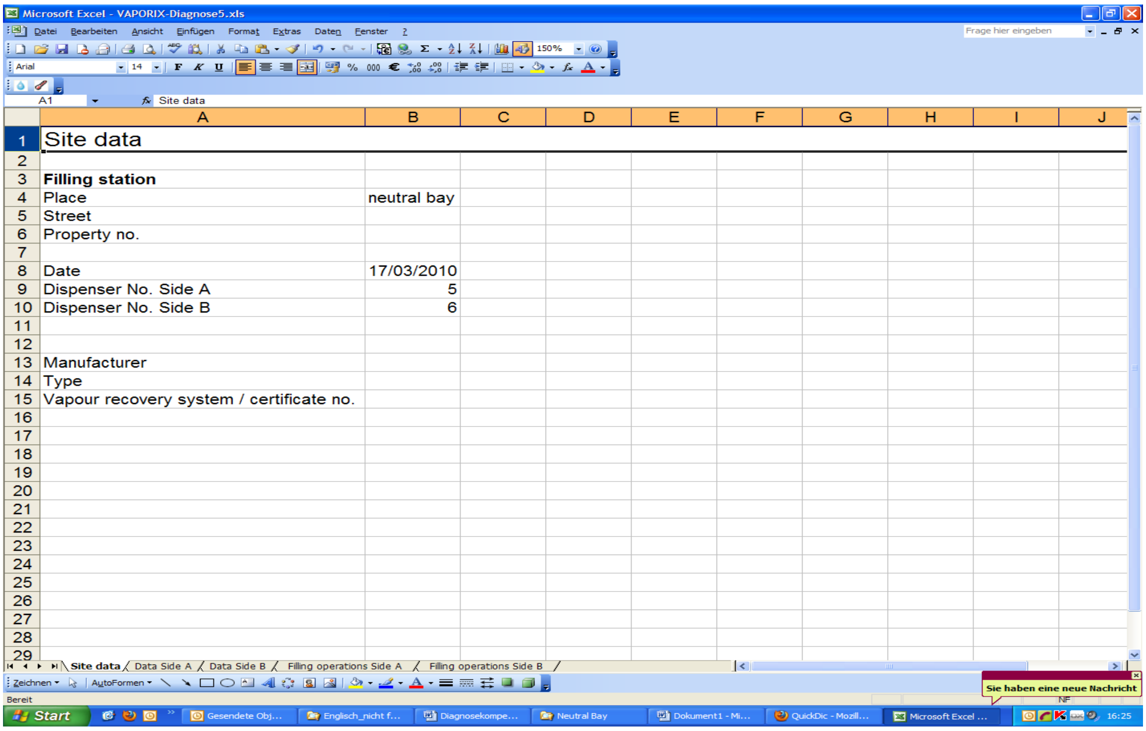
Figure 2: Graphical representation of the read-out refuelling operation data for one dispenser point. The meaning of the different graphs is indicated.

Various special cases are indicated in the refuelling history by defined numerical values:

- Sensor number = 0: indicates a reset of the error counter (VAPORIX dongle required)

- Sensor number = 999: sensor defective or no sensor exists
- Recovery rate = 200%: vapour flow without pulses, e.g. due to a adjustment procedure
- Recovery rate = 199%: maximum value of the recovery rate for existing fuel pulses, e.g. due to an incorrectly configured impulse value or by liquid in the recovery line

Further information, relevant to the interpretation of the data, should be entered in a separate sheet, as shown in Figure 3.



	A	B
1	Site data	
2		
3	**Filling station**	
4	Place	neutral bay
5	Street	
6	Property no.	
7		
8	Date	17/03/2010
9	Dispenser No. Side A	5
10	Dispenser No. Side B	6
11		
12		
13	Manufacturer	
14	Type	
15	Vapour recovery system / certificate no.	

Figure 3: Listing of important additional information for diagnostic purposes

In cases in which a **VAPORIX master** has been installed, the refuelling history can also be viewed without a notebook. To do so, a VAPORIX dongle must be plugged to the appropriate VAPORIX-Control.

For each refuelling point, the VAPORIX master also provides an alarm history, which contains the date and time for the alarms that have occurred.

For detailed information on the VAPORIX master, please refer to its operating instructions.

The rest of this document describes how the data gained by the VAPORIX diagnostics program can be used for error identification and how these errors can be recovered.

4 Faults in the vapour recovery system

4.1 Basic problems of vapour recovery

Cause

A HC gas-air mixture is pumped from the nozzle to the storage tank by a vapour pump. The goal is to suck the same gas volume at the nozzle inlet as liquid fuel volume is dispensed. The vapour has low thermal capacity and, on its way to the pump, adopts the temperature of the tubing very quickly. The related change of volume (approx. 3.5%/10°C) makes the pumped volume dependent on the type of recovery system and actual conditions that differ from the conditions during the adjustment process. So, due to this influences deviations from the ideal recovery rate must be expected.

For example if the vapour pump and the tubing heat up significantly during the day, then the vapour heats up and therefore expands during the flow. Assuming that the volume transported by the pump will remain nearly the same, then the volume sucked in at the nozzle become lower. As a result, the recovery rate is decreased with unchanged pumping capacity. Also the inverse effect will occur with the flowing gas cooled down inducing an increased vapour flow at the nozzle inlet. Another effect is to be expected on a busy station. There are only short pauses between refuelling operations and thus the vapour pump will heat up. This in turn reduces the pumping efficiency. Therefore the gas volume sucked in at the nozzle can decrease by several percent.

Impact and diagnosis

At highly frequented filling stations, the recovery rate declines substantially at certain times of the day.

Measures

The causes of the problem are of physical nature The extent of these unwanted variance is dependent on the type of the vapour recovery system. One way to reduce the problem is to adjust the vapour recovery during an average load. Then there are deviations to lower recovery rates at times with high frequency of refuellings and deviations to higher recovery rate at times with low frequency of refuellings like during the night. The VAPORIX history data can provide valuable help in determining the suitable time for adjustment. In most cases, however, it can be sufficient to adjust the vapour recovery system with a few minutes (5, better 10) of warm-up time.

Another measure is to install a module that corrects for such drift effects the **FAFNIR PCM module**. This module offers a correctively controlling of the vapour recovery system and would compensate also the variance in the cases of heating and cooling due to weather changes.

4.2 Total failure in the vapour recovery system

Causes

- Pump defective
- Thermal circuit breaker of the pump has tripped
- V-belt torn or jumped off

Impact and diagnosis

- Vapour recovery rate is very low or equal to zero as shown in Figure 4.

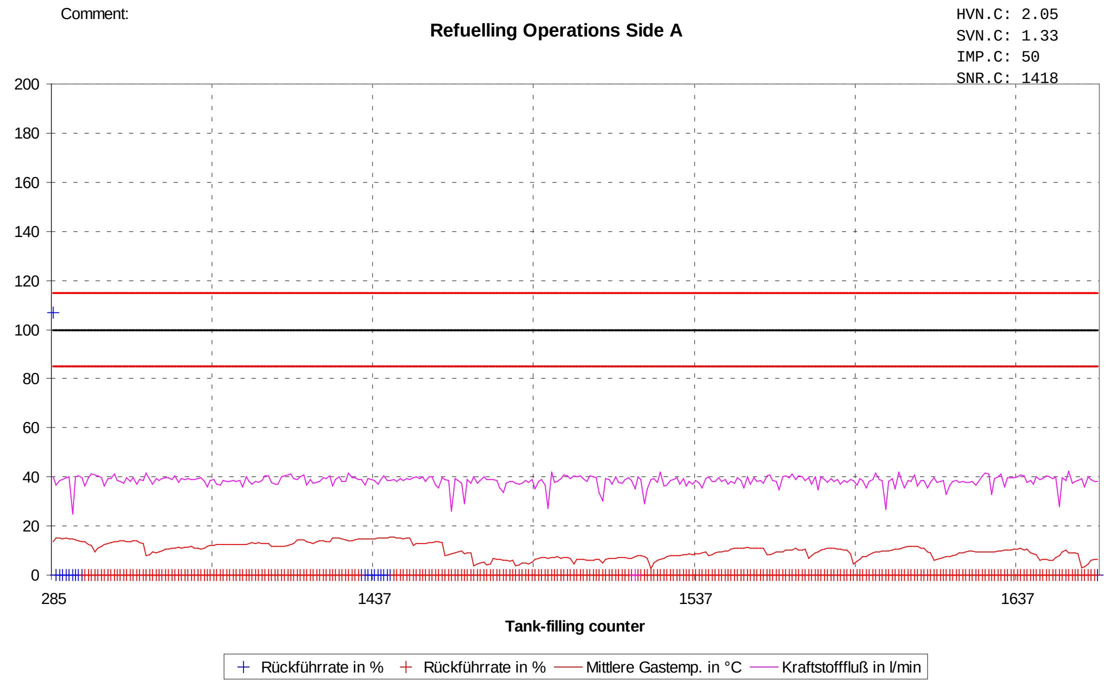


Figure 4: Total failure in the vapour recovery with 0% recovery rate. The colour of the crosses changes from blue to red as soon as the error counter reaches the value 10. At refuelling operation number 1433 a reset was exerted but without repairing the system. Therefore the colour of the crosses were blue for ten refuellings and then change to red again.

Measures

- Replacing the pump
- Switching the circuit breaker on again
- Renewing the drive belt

4.3 Extremely varying recovery rates caused by sticking proportional valve

Causes

- Metal chips or other dirt particles in the proportional valve
- Wear

Impact and diagnosis

In some cases, a balancing operation can still be carried out despite the fault. However, the adjustment curves created as a result are incorrect. The measured recovery rates vary considerably and can be much too high or much too low. In case the defect did not occur until after the adjustment procedure, the history data will be as shown in Figure 5.

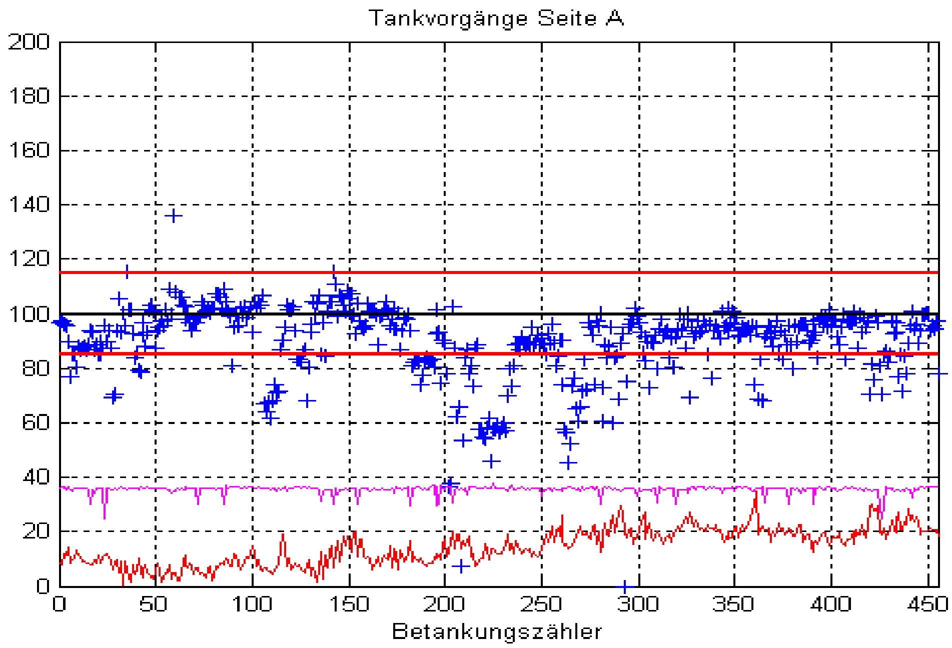


Figure 5: Dispenser point with sticking proportional valve. The x axis represents the refuelling counter, the blue crosses the recovery rate in percent, red line the gas temperature and the magenta line the average fuel flow speed.

Measures

- Cleaning the proportional valve
- Replacing the proportional valve

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4.4 Additional air flow caused by a leak in the pipe system

Causes

- Incorrectly tightened screw joints
- Crack in the vapour recovery pipe

Impact and diagnosis

Depending on whether the defect already existed during the dry adjustment procedure and whether the defect is located upstream or downstream from the sensor of the automatic monitoring system, a clear distinction must be made between 4 cases.

1) A leak (e.g. crack in the pipe or loose screw joint) occurs downstream from the sensor of the automatic monitoring system, in a time after the vapour recovery system was correctly adjusted without any leaks. In that case, the measurement value of the automatic monitoring system drops as shown in Figure 6. A dry measurement with a diaphragm flow meter at the nozzle would exhibit the same result.

2) With an existing leak downstream from the sensor of the automatic monitoring system, the vapour recovery is readjusted. The recovery rate is correct as long as the vapour pump is able to pump the additional volume sucked in through the leak. With high fuel flow rates, the recovery rate may possibly not be stable. A dry measurement with a diaphragm flow meter would provide the same result as the sensor.

3) A leak in the tubing between the nozzle and the sensor of the automatic monitoring system occurs after the vapour recovery system was adjusted previously without any leaks. The measurement values of the automatic monitoring system would still be within the permissible range, but the dry simulation would provide reduced values.

4) A leak in the area between the nozzle and the sensor of the automatic monitoring system already exists and the vapour recovery system is readjusted. The measurement values of the automatic monitoring system are then too high because of the additional air flow. The dry simulation would provide correct values.

Comment:

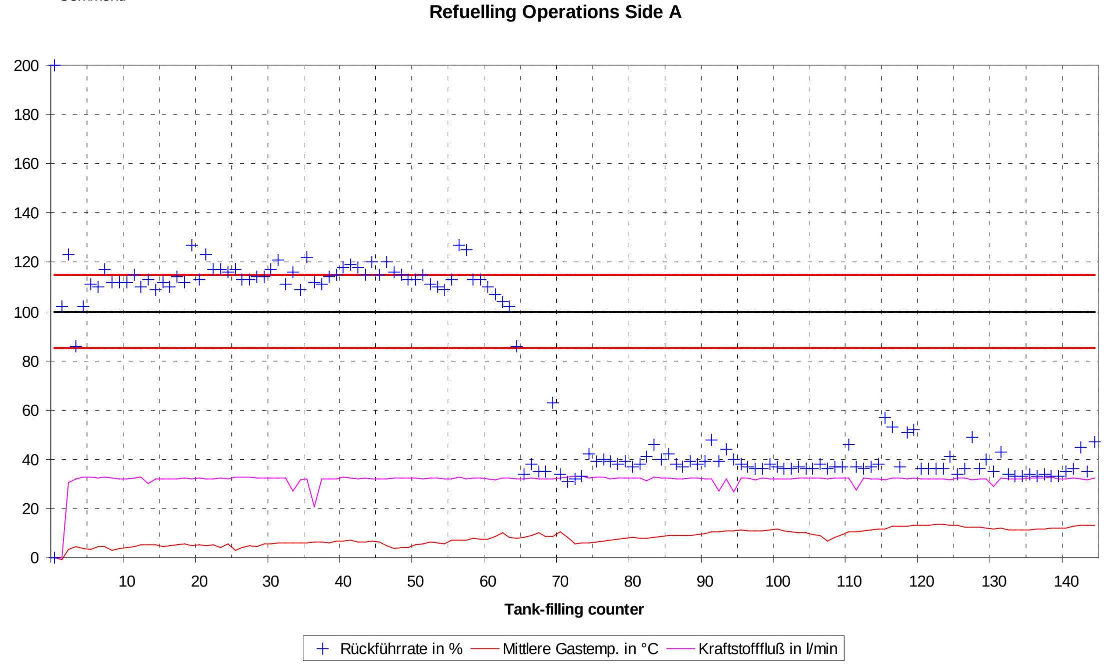

Figure 6: Example according to case 1. Refuelling history of a refuelling point, which during refuelling operation 65, a crack occurred in the flexible corrugated pipe between the sensor of the automatic monitoring system and the vapour pump. Due to the suction of additional air, the recovery rate fell to approx. 40 %.

Measures

- Leak test and sealing of the respective locations

4.5 Wrong recovery rate caused by incomplete opening of the nozzle in the case of an MPD (Multiple Product Dispenser)

Causes

- One Open/Close valve does not open completely

Impact and diagnosis

Depending on whether the defect already exists during the dry adjustment procedure and on which nozzle the adjustment procedure has been carried out, a distinction must be made between two general cases.

1. The defect did not already exist during the dry balancing operation of the vapour recovery or the balancing operation was carried out on a properly open nozzle. The recovery rates measured by the automatic monitoring system after the defect occurred are reduced for this hose. A dry simulation on defect nozzle would also show a reduced vapour flow. In Figure 7 is shown that the recovery rate is within the tolerance for the correct working hoses, but a reduced recovery rate is observed for the affected hose.

Figure 7: MPD with one incompletely opening Open/Close valve. Some of the refuelling operations exhibit a recovery rate of only 25%.

2. The dry adjustment procedure is carried out on the nozzle with the improper opened Open/Close valve The values of the dry simulation are, if the pumping performance of the vapour pump is sufficient, correct on the defective nozzle, but too high on the other nozzles. The recovery rates measured by the automatic monitoring system

would also be correct for the defective automatic nozzle but would be too high for the other hoses.

Measure

- Replacing the nozzle or the Open/Close valve

4.6 Parasitic air flow caused by an incorrectly closing of the Open/Close valve in the case of an MPD

Causes

- Open/Close valve defective

Impact and diagnosis

Depending on which nozzle the adjustment procedure has been carried out or whether the defect occurred before or after the adjustment, a distinction must be made between three cases:

1. The defect occurred on a correctly adjusted system. The recovery rates measured by the automatic monitoring system are hardly influenced by the defect since the automatic monitoring system cannot determine whether the volumetric flow pumped by the vapour pump is sucked in at one or several nozzles. During a dry simulation with a diaphragm flow meter, reduced recovery rates are measured on the intact nozzles and almost correct recovery rates on the defective nozzle. The defective Open/Close valve can sometimes be recognised by a whistling sound during the dry measurement.
2. The dry adjustment procedure is carried out on a defective nozzle. If the valve opens completely, the adjustment is correct and the statements made under item 1. will apply.
3. The dry adjustment procedure is carried out on an intact nozzle parallel to a defective one. In that case, the recovery rates measured by the automatic monitoring system are too high for all hoses since the diaphragm flow meter only registers the volumetric flow at one nozzle, whereas the automatic monitoring system registers the volumetric flow from two nozzles. The dry simulation provides correct recovery rates on the intact nozzles but too high recovery rates for the defective nozzle.

Measure

- Replacing the defective nozzle or the associated Open/Close valve

4.7 Fuel influx into the vapour recovery system

Causes

- O-rings or hoses leaky
- The fuel flow speed is too high
- Shutdown speed of the nozzle is too slow
- Unfavourably shaped fuel tank filler neck geometries of individual vehicle types
- The outlet pipe of the nozzle can be deformed as a result of falling down or a vehicle driving off

Impact and diagnosis

- Fuel intrudes the vapour recovery tubing. The vaporizing of the liquid is measured as excessive volumetric flow, frequently indicated by a recovery rate of 199% (see Figure 8)
- In many cases, fuel can be seen flowing out when the vapour recovery pipe is opened

Measures

- The system should not be readjusted as long as liquid is still in the tubing since otherwise – especially in the case of vapour recovery systems with a high k-factor – the recovery rate will be too high.
- Installation of new seals
- In the case of new dispensers or new seals, wait a few days until the sealing have swollen up.
- Replacing the hoses, if the cause cannot be found elsewhere
- Reduction of the fuel flow speed to values ≤ 40 l/min
- Replacing the nozzle by one with a more sensitive switch-off characteristic, if necessary, adjustment of the sensitivity
- Replacing the outlet pipe of the nozzles

Comment:

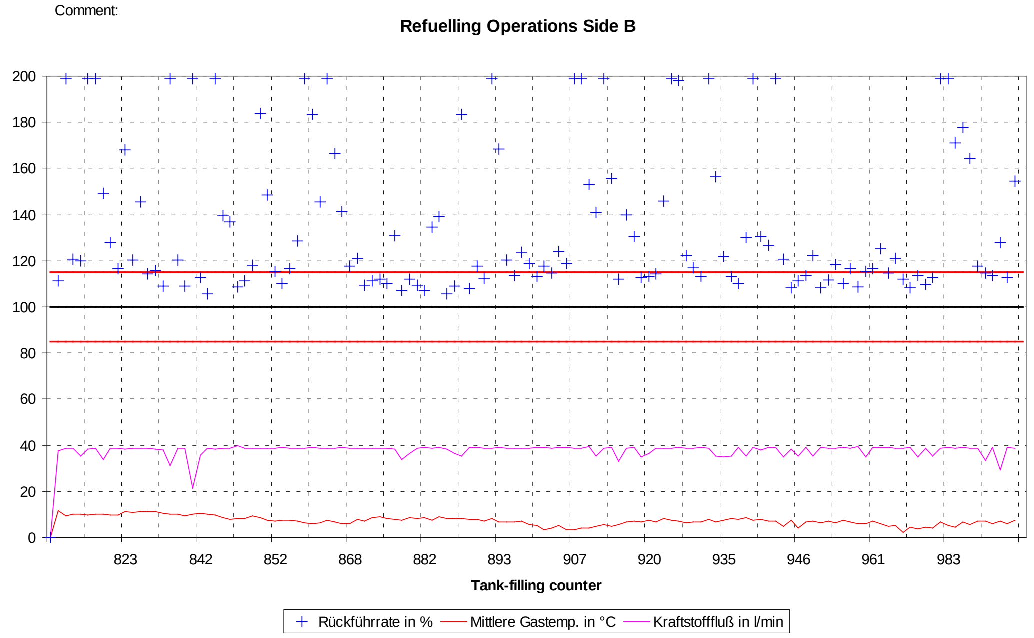

Figure 8: Occurrence of condensate in the recovery tubing. The recovery rate is frequently approximately up to 199%, which is the maximum value for the output in the case of existing pulses, as opposed to 200% in the case of non-existing pulses.

4.8 Incorrect recovery rates caused by incorrect transferring/saving of the adjustment data

Causes

- The data of the adjustment procedure are not correctly transferred or saved because of a fault in the adjustment equipment.

Impact and diagnosis

- Random values from before are then used for the control system. The recovery rates can be far apart depending on the fuel flow rate in each case (see Figure 9).
- A dry measurement reproduces the measurement values of the automatic monitoring system.
- Perform dry measurements with a diaphragm flow meter for different pump flow speeds.
- In order to detect possible causes sort the data with respect to the fuel flow speed. The result is shown in figure 10. It reveals immediately that the recovery rate is strongly dependent on the fuel flow speed. This indicates a faulty adjustment of the vapour recovery system.

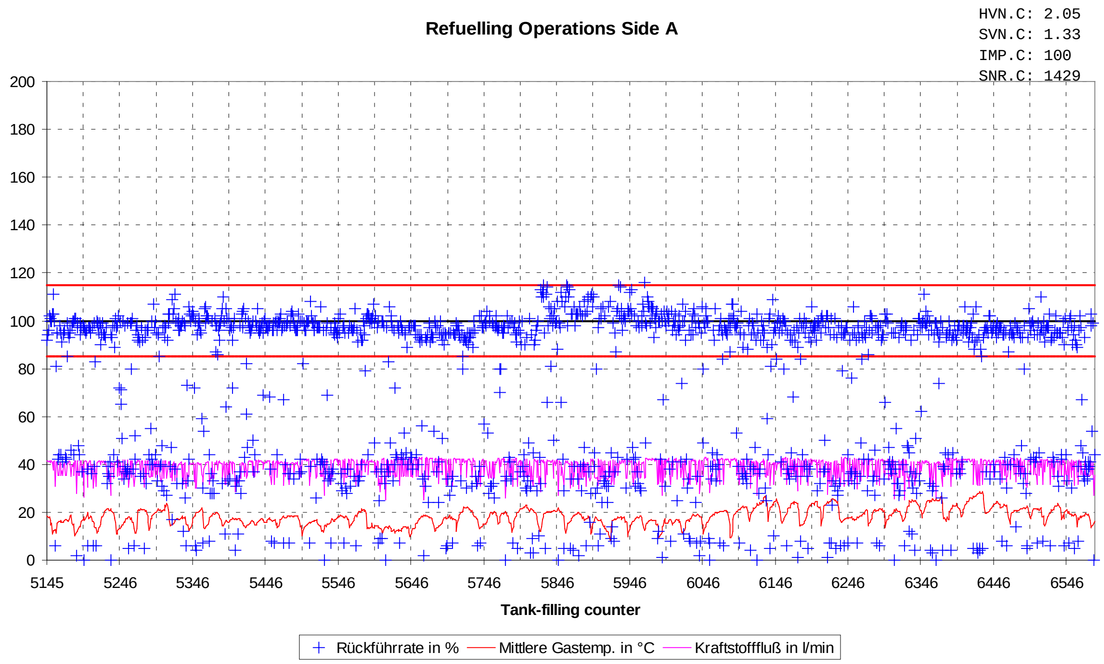

Figure 9: Data of dispenser point with frequently extremely reduced recovery rate. The exact cause cannot be detected in the standard data representation.

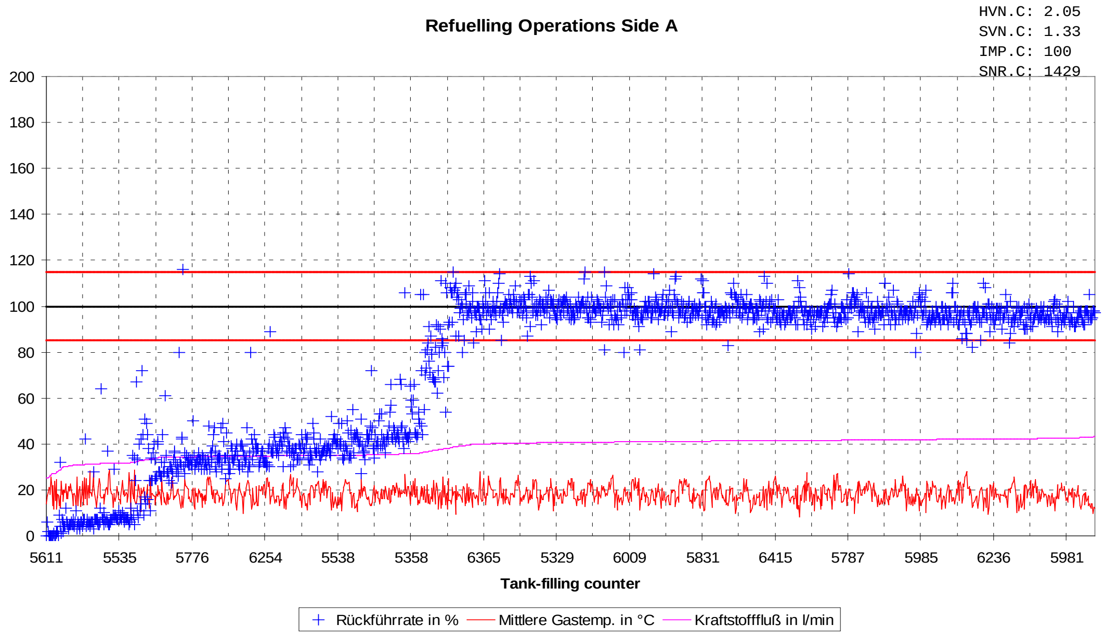

Figure 10: The same data set as in Figure 9 sorted according to the fuel flow speed (magenta curve). In the case of fuel flow speed below 40 l/min, the recovery rate declines substantially. The cause is a fault in the adjustment data.

Measures

- Repeating the adjustment procedure sometimes helps
- Software update of the faulty adjustment equipment

4.9 Slackening vapour pump efficiency

Cause:

- Due to the advanced wear of the vapour pump, the pumping performance decreases more and more.

Impact and diagnosis:

- The recovery rate drops more and more.
- Balancing operations provide only short-term improvement or no improvement at all.
- Dry measurements with a diaphragm flow meter show the same result.

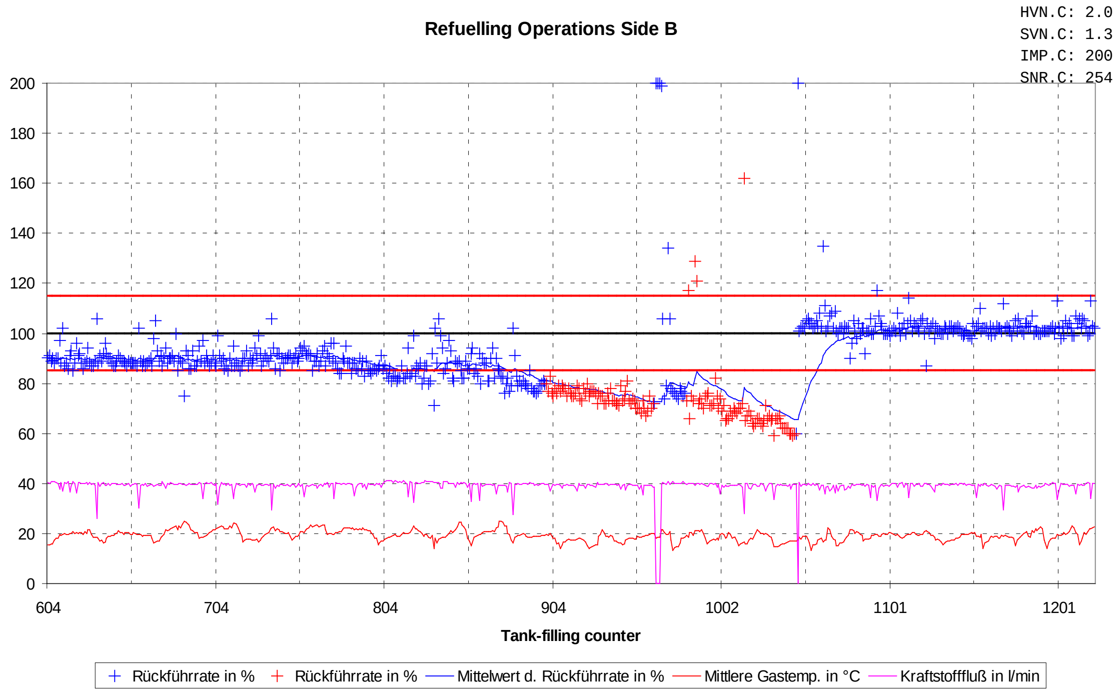

Figure 11: The recovery rate of the vapour recovery decreases more and more with time. The readjustment procedure at refuelling operation #965 only provides slight improvement. Replacing the pump during refuelling operation #1046 finally eliminates the cause.

Measure:

- Repair or replace the vapour pump

4.10 Driving off with nozzle hooked in the fuel tank filler neck

Cause:

- When attempting to leave the filling station without removing the nozzle from the fuel tank filler neck of the vehicle, the nozzle and/or the hose might be damaged. In the example shown in Figure 12, only the nozzle was replaced/repaired but a tear in the hose remained undiscovered, and therefore VAPORIX triggered an alarm after the dispenser was put into service again.

Impact and diagnosis:

- The diagnosis can be made more difficult because no information about the previous repair work is available at the time of the VAPORIX alarm rectification. In Table 2, it can only be seen that the dispenser point was shutdown for about one day.
- The recovery rate shown in Figure 12 apparently increases suddenly in the case of a previously perfect dispenser point.

- The status bit for liquid recovery (10-0000) has been set.

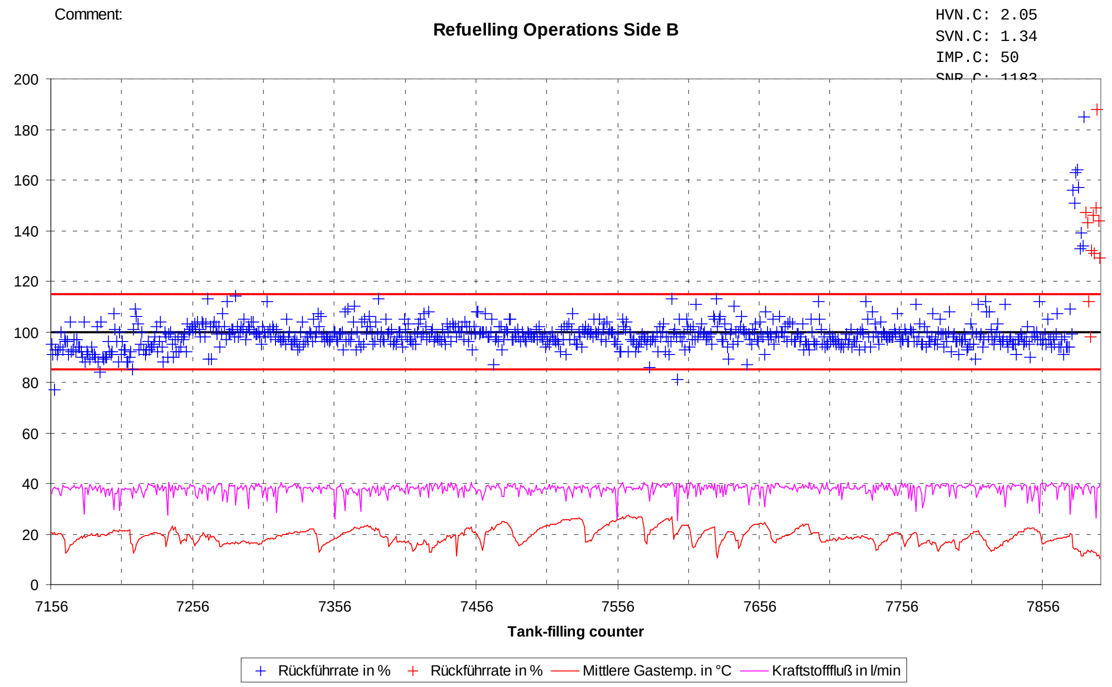

Figure 12: The recovery rate of the vapour recovery increases suddenly and apparently uncontrolled during refuelling operation #7877.

History VAPORIX-Control									
Side	B	**Status**	10-0000						
Sensor	**Time**	**Date**	**Errorcoun**	**Tank cc**	**Recov**	**Averag**	**Tempe**	**Vapou**	**Vapour t**
					in %	**Rückfü**	**in °C**		**in l/min**
2085	12:40:13	19.09.2004	0	7871	98	97,4	18,8	60	36,7
2085	13:15:18	19.09.2004	0	7872	94	97,2	18,8	59	36,9
2085	13:22:20	19.09.2004	0	7873	94	97	19	59	37
2085	13:33:58	19.09.2004	0	7874	94	96,8	19,2	52	36,5
2085	13:49:44	19.09.2004	0	7875	109	97,6	20,2	57	30,5
2085	13:55:47	19.09.2004	0	7876	99	97,7	19,8	58	39
2085	12:35:32	20.09.2004	1	7877	156	97,7	14,6	200	52,6
2085	13:16:57	20.09.2004	2	7878	151	97,7	14,1	200	58,1
2085	13:49:03	20.09.2004	3	7879	163	97,7	14,4	200	63,4
2085	14:33:24	20.09.2004	4	7880	164	97,7	14,1	200	62,2
2085	18:59:58	20.09.2004	5	7881	157	97,7	13,1	200	62,3

Sensor	Fuel flo
	in l/min
2085	37,6
2085	39,4
2085	39,5
2085	38,9
2085	27,9
2085	39,5
2085	33,8
2085	38,6
2085	38,9
2085	37,9
2085	39,7

Table 2: Refuelling operation #7877 was carried out after a shutdown period of almost 24 hours and provides recovery rates that are too high.

Measure:

- Replace all the adversely affected components.

5 Faults in operation and setup of the automatic monitoring system

5.1 Connection faults of VAPORIX-Flow

Causes

- Connecting cable has not been correctly attached onto the terminals.

Impact and diagnosis

In the rating plate of VAPORIX-Control, a two-colour LED is visible for each side and uses a flashing code to provide information on the status of the automatic monitoring system. After a sensor has been connected, VAPORIX-Control reads out the sensor parameters and tries to set the temperatures of the sensor elements. This operation is indicated by a flashing code – LED goes out only for a short time.

- If the flashing code has not changed into a constant, slow flashing even after one minute, either the connections have been mixed up or there is a defect in the VAPORIX-Flow/Control system.
- If the sensor parameters and therefore the sensor numbers cannot be read out, the serial numbers 999 are written in the history with zeros being output each time for temperature, vapour flow and vapour concentration (see Table 3).
- If the temperatures of the sensor elements cannot be set correctly, a negative sensor number is stored in the history (see Table 3).

History VAPORIX-Control										
Side	A									
Sensoı	**Time**	**Date**	**Errc**	**Tank-fı**	**Recov**	**Mean va**	**Average**	**Vapou**	**Vapour**	**Fuel flow**
					in %	**recovery**	**in °C**		**in l/min**	**in l/min**
6124	08:39:00	13.07.2004	0	13504	97	94,5	27,1	4	35	36,2
6124	08:43:13	13.07.2004	0	13505	96	94,6	26,8	3	34,6	36,2
6124	08:47:48	13.07.2004	0	13506	97	94,8	27,3	5	35,2	36,1
6124	08:52:58	13.07.2004	0	13507	96	94,8	27,1	3	34,8	36,2
6124	08:56:40	13.07.2004	0	13508	96	94,9	27,1	3	34,8	36,2
6124	09:02:15	13.07.2004	0	13509	97	95	27,6	4	35,1	36,2
6124	09:06:23	13.07.2004	0	13510	97	95,2	27,7	5	35,2	36,1
999	11:11:03	14.07.2004	1	13511	0	95,2	0	0	0	36,1
-6124	11:27:53	14.07.2004	2	13512	0	95,2	0	0	0	36,1
6124	11:48:53	14.07.2004	0	13513	97	95,3	23,7	4	35	36,2

Table 3: Refuelling operation #13511 was carried out with connection 8 not attached and refuelling operation #13512 with mixed-up connections 2 and 3.

Measure

- Attach the connecting cable correctly

5.2 Connection faults of the pulse inputs

Causes

- Connecting cable has not been correctly attached onto the terminals

Impact and diagnosis

- In the course of connecting the pulse inputs, the polarity was connected incorrectly and this is why the fuel flow speed cannot be determined by VAPORIX-Control.
- By flashing very quickly, the LED on VAPORIX-Control indicates vapour flow without pulses.
- Refuelling operations with vapour flow without pulses are included in the history data; the vapour pumping rate is indicated with 200%.

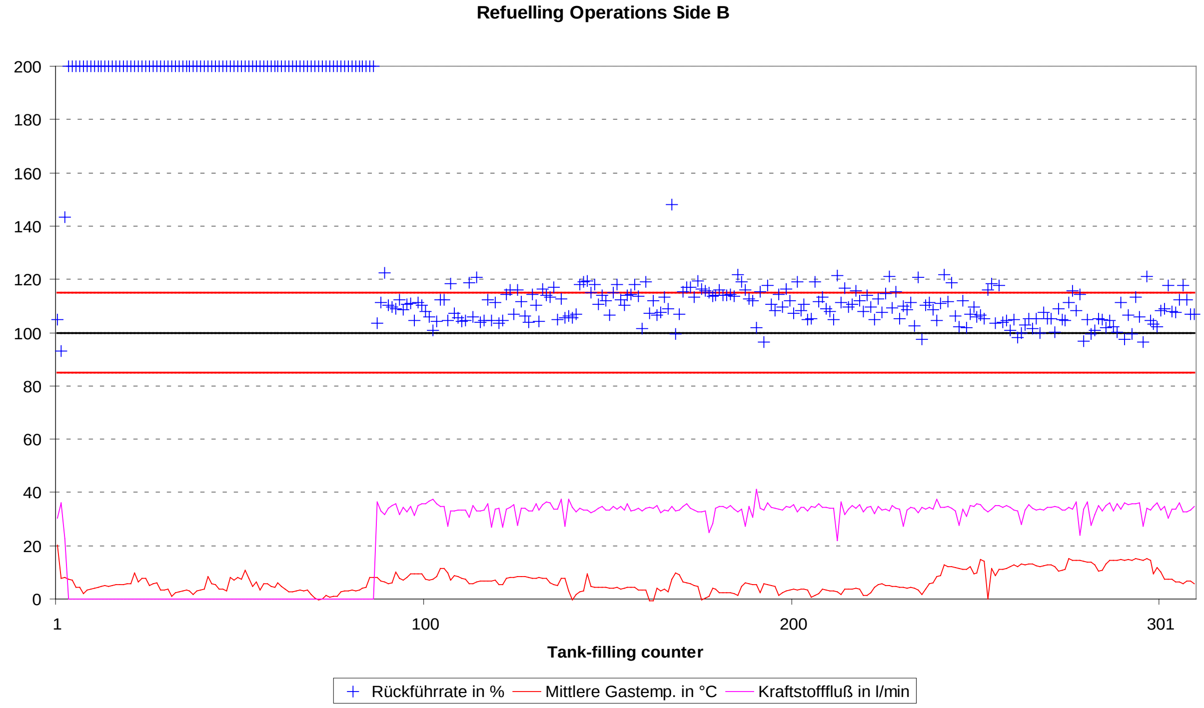

Figure 13: The connecting cable for the fuel pulses is not correctly attached on the VAPORIX-Control system, the output recovery rate is indicated to 200 % and the fuel flow speed is 0 l/min. During refuelling operation 87, the connection fault was rectified.

Measure

- Attach the cables correctly.

FAFNIR

5.3 Electromagnetic interference into the pulse cables

Causes

- Unfavourable cable installation in the vicinity of the high-voltage current interface of the dispenser

Impact and diagnosis

- Extreme interference couples into the pulse cables, which causes to an increased pulse rate at the inputs of the VAPORIX-Control. Accordingly, the evaluated fuel flow speed appeared too high and the recovery rate too low.

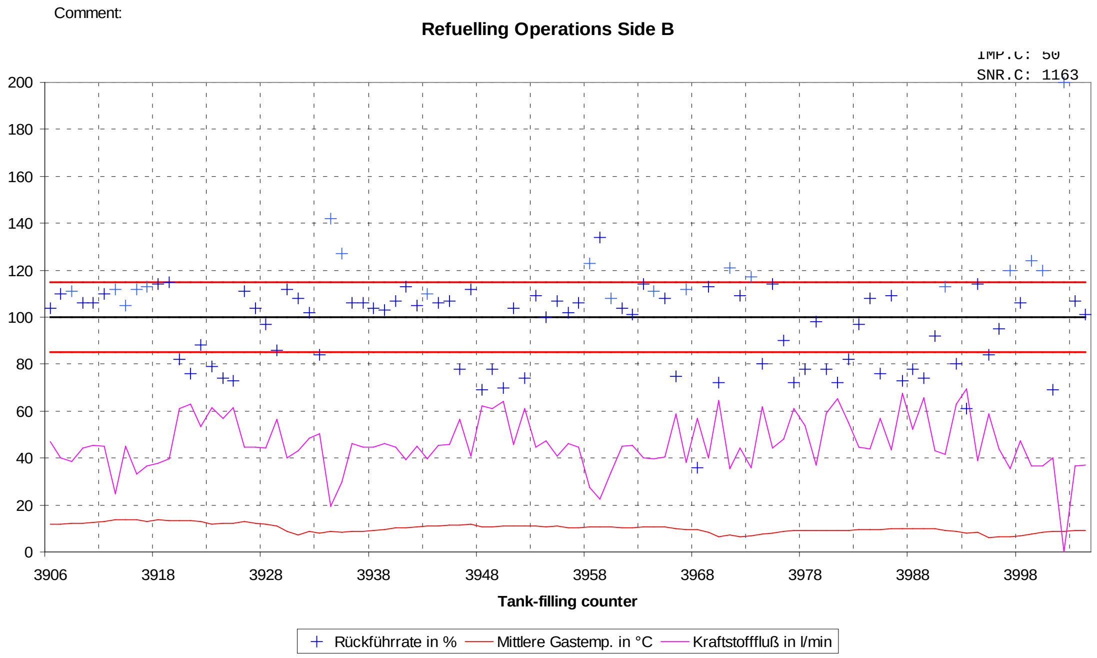

Figure 14: The output fuel pumping rate is partially above 60 l/min and exhibits an unusual scatter.

Measure

- Installation of the pulse cables sufficiently far away from the power cables

5.4 The sensor connection and the pulse inputs are connected to different sides of the dispenser

Causes

- The connecting cables of the VAPORIX-Flow system or the pulse cables have been plugged in on the wrong side.

Impact and diagnosis

- The pulse cable has been assigned to one dispenser side and the VAPORIX-Flow measures the vapour flow on the other side. The history data include refuelling operations with vapour flow without a fuel pumping rate and refuelling operations with fuel flow without a vapour pumping rate.

Measure

- Rectify the connections

5.5 Side mix-up error when connecting the vapour recovery control system to the dispenser computer

Causes

- Control cables of the gas recovery system plugged in incorrectly on the dispenser computer

Impact and diagnosis

- Although the vapour recovery system runs during each refuelling operation, it cannot normally create a vapour flow against the closed Open/Close valve of the other side. Less vapour flow can be indicated by the automatic monitoring system because of the pulsating vapour column. If a vehicle tank happens to be filled up at the same time on the opposite side, refuelling operations with an almost normal recovery rate will also be included in the history.

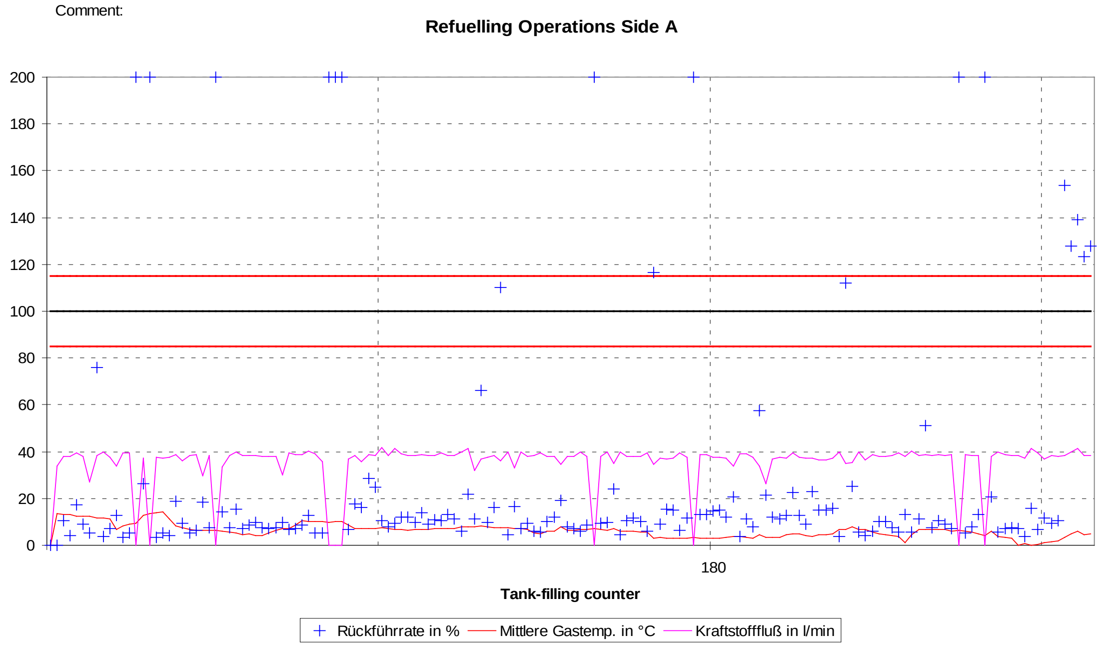

Figure 15: Refuelling operation on side A of an MPD with opposite-side control of the vapour recovery. The apparent recovery rate of approx. 10% is caused by pulsation of the vapour recovery system running on the other side.

History VAPORIX-Control										
Side	A									
Sensor no	**Time**	**Date**	**Error counter**	**Tank-filling counter**	**Recovery rate in %**	**Mean value of recovery rate in %**	**Average vapour ter in °C**	**Vapour coı**	**Vapour f in l/min**	**Fuel flow in l/min**
2147	13:22:15	04.11.2003	1	1		0	13,4	0	0	33,8
2147	18:51:43	04.11.2003	1	12	76,1	6,9	11,5	58	29,2	38,4
2147	13:14:13	08.11.2003	1	118	66	13,5	8,1	59	24,4	37
2147	16:22:04	08.11.2003	0	125	110,3	17	7,7	48	39,9	36,2
2147	05:40:16	10.11.2003	1	161	116,4	20,8	3	41	40,2	34,5
2147	16:59:43	10.11.2003	1	191	57,4	15,6	4,6	19	19,5	34
2147	15:45:05	11.11.2003	0	224	112,1	12,6	6,9	40	39	34,8
2147	12:39:37	12.11.2003	1	252	51,3	7,7	6,6	33	19,8	38,6
2147	10:40:45	13.11.2003	1	286	127,9	27,2	4,8	48	51	39,8
2147	10:45:57	13.11.2003	1	287	139,2	34,2	5,9	47	57,7	41,5
2147	11:37:58	13.11.2003	1	290	123,2	35,9	4,5	42	47,1	38,2
2147	11:57:07	13.11.2003	1	291	127,8	41,6	4,9	38	48,9	38,3
2147	12:02:40	13.11.2003	1	292	121	46,6	4,9	35	32	26,4

Table 4: The history entries from figure 15 with recovery rates greater than 50%. By comparing the date and time (e.g. 16:22 on 8.11.) with the entries of side B shown in Table 5 it can be seen that these recovery rates frequently occur during simultaneous refuelling operations on both sides. If the respective refuelling operation on the other side is missing, it took only a short period of time (< 20 sec) and was therefore not included in the history.

Historie VAPORIX-Control

Side	B	Datei	O:\VAPORIX\Felddaten\ScheidtB\SBArHHCu\Daten\Messaktion 13.11.2003\ZP78.TXT							
Sensor no.	**Time**	**Date**	**Error counter**	**Tank-filling counter**	**Recovery rate in %**	**Mean value of recovery rate in %**	**Average vapour ten in °C**	**Vapour cor**	**Vapour f in l/min**	**Fuel flow in l/min**
2150	13:26:33	04.11.2003	1	1	10,7	10,7	11,5	57	4,1	38,4
2150	13:42:20	04.11.2003	2	2	14,4	10,9	11,7	46	5,8	40,1
2150	14:19:11	04.11.2003	3	3	8	10,7	12,3	64	3,1	38,2
2150	14:37:37	04.11.2003	4	4	8,6	10,6	12,6	48	3,3	38,5
2150	15:06:19	04.11.2003	5	5	0	9,9	13,1	55	0	33
2150	15:13:01	04.11.2003	6	6	5,5	9,6	12,7	62	2,1	38,5
2150	15:34:33	04.11.2003	7	7	0	9	12,7	70	0	32,6
2150	15:54:42	04.11.2003	1	8	0	8,5	12,8	69	0	32,5
2150	16:26:52	04.11.2003	1	9	7,7	8,4	13,3	53	2,6	33,4
2150	16:58:14	04.11.2003	1	12	7,9	7,4	11,9	44	3,1	38,7
2150	17:12:39	04.11.2003	1	13	4,2	7,2	11,6	57	1,6	38,7
2150	17:36:08	04.11.2003	1	14	7,1	7,2	11,7	60	2,7	38,6
2150	17:44:55	04.11.2003	1	15	7,9	7,3	11,7	56	3	38,2
2150	17:59:49	04.11.2003	1	16	6	7,2	11,8	57	2,3	38,5

Table 5: Refuelling operations of the other dispenser side with recovery rates > 50 % for comparison with Table 4.

Measure

- Exchanging the control cables of the vapour recovery system

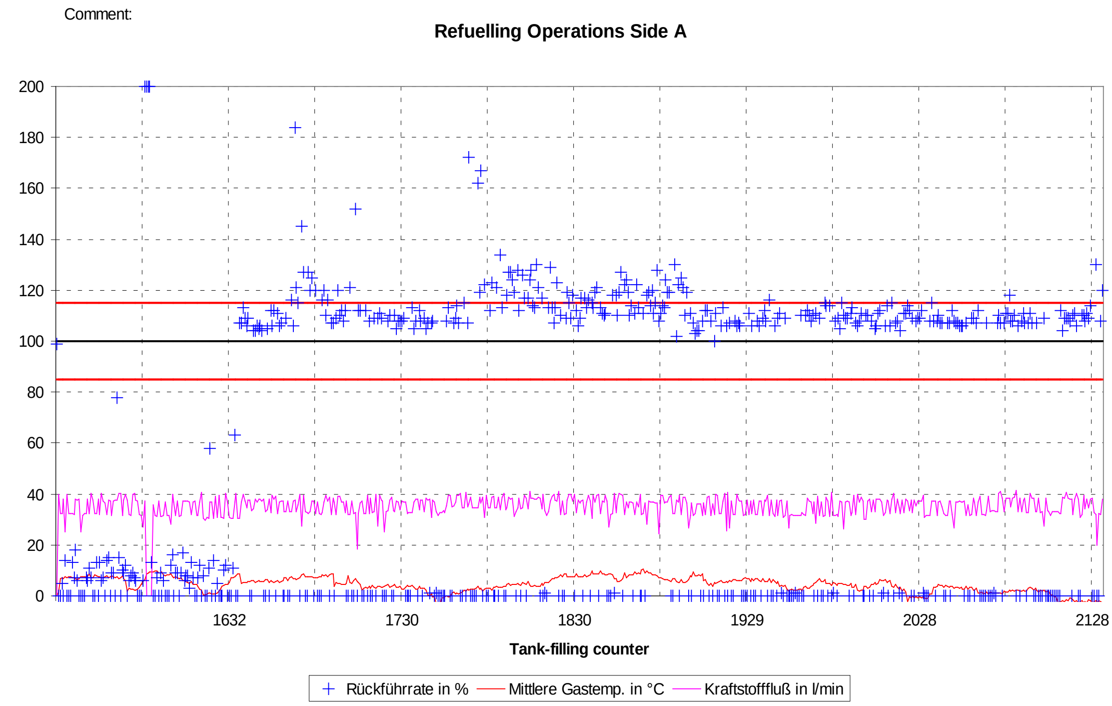

Figure 16: The same dispenser point as shown in after exchanging the cables of the vapour recovery system. During refuelling operation 1890, the system was adjusted. The pulses representing diesel refuellings are still present.

5.6 Wrong impulse rate configuration for the automatic monitoring system

Causes

- Wrong setting of the impulse rate

Impact and diagnosis

- If the impulse rate is set too high on the automatic monitoring system, the volumetric flow of fuel will be interpreted too low and the associated – correct volumetric flow of vapour – too high.
- If the impulse rate is set too low on the automatic monitoring system, the volumetric flow of fuel will be interpreted too high and the associated – correct volumetric flow of vapour – too low.
- A dry measurement with a bellows flow meter would provide correct values in both cases.

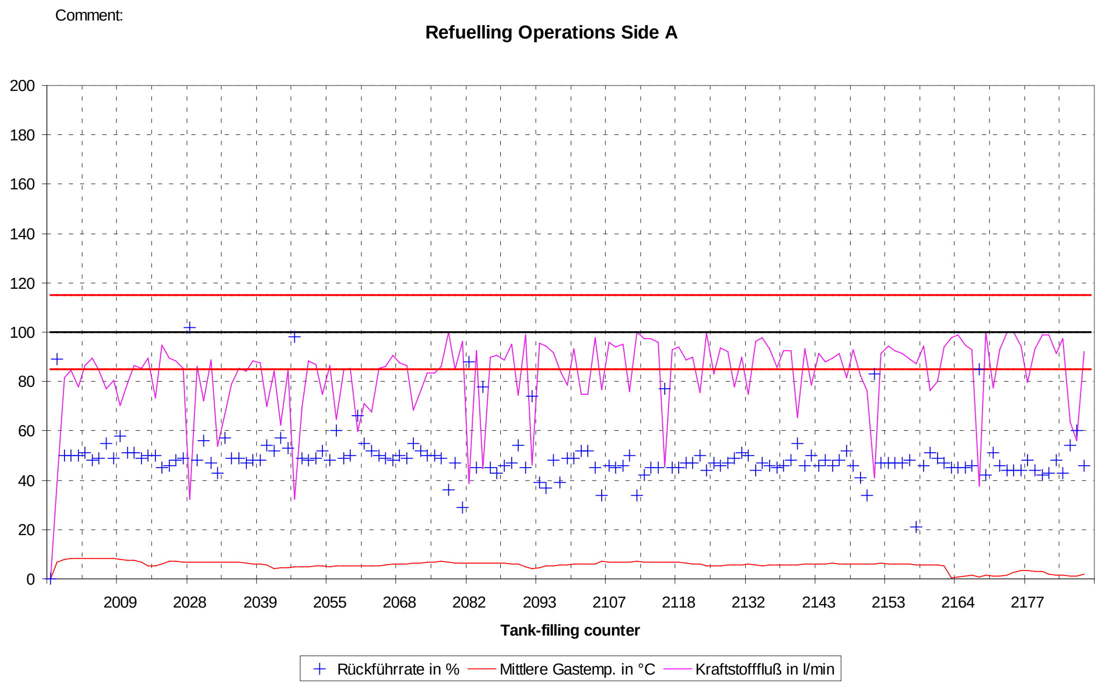

Figure 17: The fuel-pumping rate that is output by the automatic monitoring system goes up to 100 l/min, and the recovery rate is about 50%.

Measure

- Correcting the setting on the automatic monitoring system

5.7 Wrong impulse rate configuration for the vapour recovery control system

Causes

- Faulty configuration of the vapour recovery

Impact and diagnosis

- If the impulse rate is set too high in the vapour recovery control system, the volumetric flow of fuel will be interpreted too low and the vapour recovery system will not be pumping enough. A wet measurement with a diaphragm flow meter would also provide values that are too low. A dry measurement would provide apparently correct values.

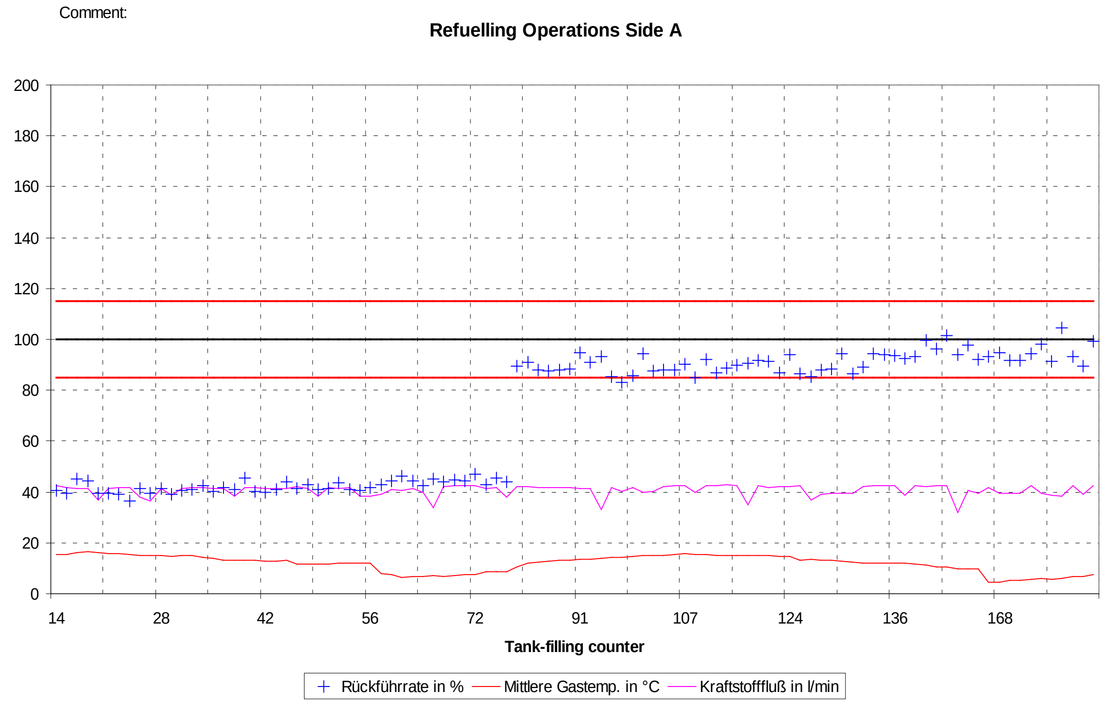

Figure 18: The refuelling operations 14…75 were carried out at an impulse rate set too high for the vapour recovery system. As a result, the vapour recovery ran with only half the pumping performance.

- If the impulse rate is set too high in the vapour recovery control system, the volumetric flow of fuel will be interpreted too low and the vapour recovery system will be pumping too much. A wet measurement with a diaphragm flow meter would provide the maximum pumping performance of the vapour pump. Here, too, a dry measurement would provide apparently correct values.

Measure

- Correcting the setting in the vapour recovery control system

5.8 Setting of a too high fuel flow speed

Causes

- Incorrect setting

Impact and diagnosis

- If the fuel pumping rate is set so high that the performance of the vapour recovery system is not sufficient in order to create the correct volumetric flow of vapour, the recovery rate will become too low.
- In addition, there is the risk that fuel will be sucked in by the high pumping speed at the end of the refuelling operation. This results in the apparently excessively high recovery rates as described in chapter 4.7 .

Measure

- Reduction of the fuel flow rate to the value specified in the TÜV (German Technical Control Board) certificate of the vapour recovery system.

5.9 Adjustment of systems with a high k-factor, if there is still fuel in the pipe

Causes

- Condensate recoveries based on the causes as described above.

Impact and diagnosis

- With a high k-factor, pumping performance reduced by the k-factor must be expected in the case of saturation caused by fuel in the return pipe. If the balancing operation is carried out and saved under these circumstances, a recovery rate increased by the k-factor will be generated during tank-filling operation. This recovery rate is then too high by the k-factor. Depending on the magnitude of the effect, a too high value is indicated by the automatic monitoring system.

Measure

- Operating the vapour recovery system with air (dry measurement) until the hydrocarbon concentration drops to an acceptable mark and renewed performance of a balancing operation.

5.10 Diesel pulses not inhibited

Causes

- Faulty configuration of the dispenser or missing interface for inhibiting the diesel pulses

Impact and diagnosis

- The diesel refuelling operations appear in the history data. If the vapour recovery is not running simultaneously, it is equal to zero, but if it is running, this can result in a small measurement value. The probability for the occurrence of these refuelling operations is approx. 30%. An alarm would be triggered only if 10 diesel tank-filling operations were to occur in succession.

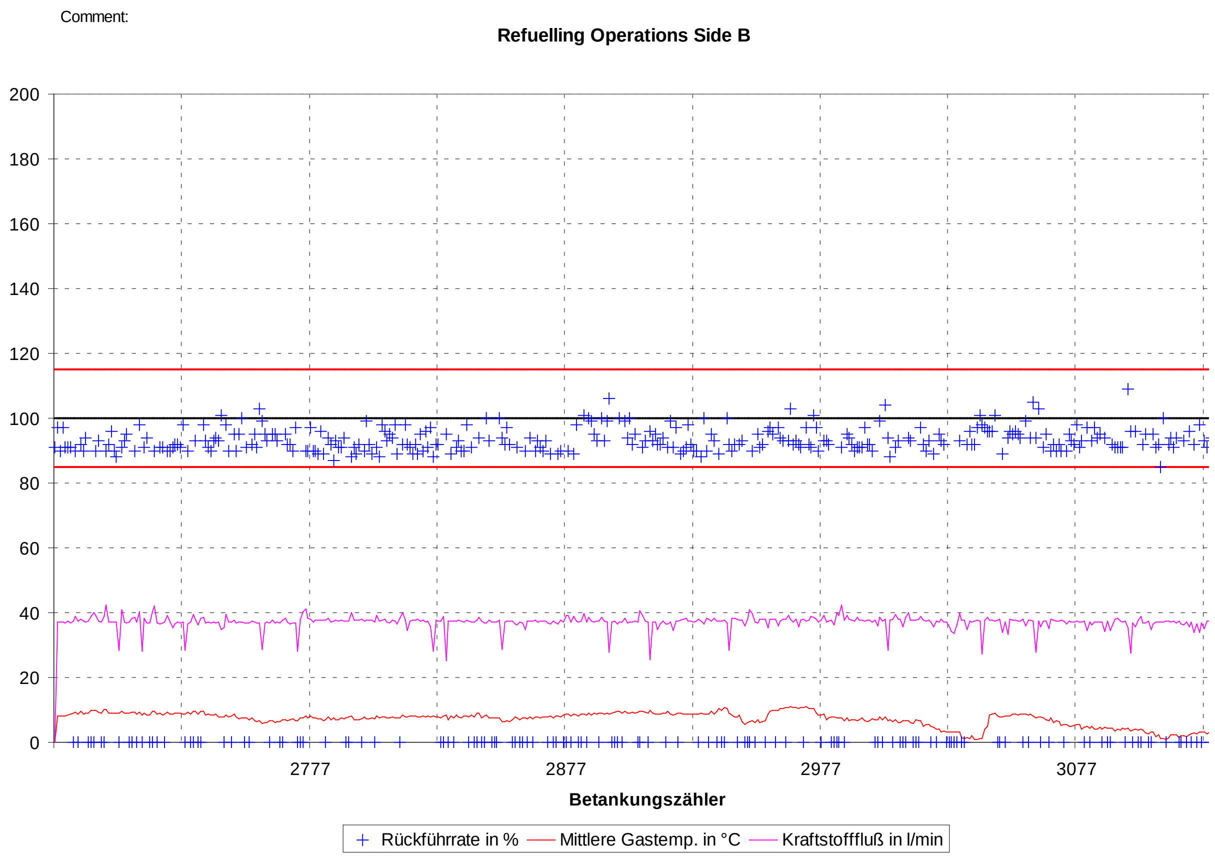

Figure 19: Diesel pulses are not hidden. In case more than 10 diesel tank-filling operations are carried out in succession, an alarm is triggered.

Measure

- Correct setting of the dispenser computer or installation of a suitable interface.

6 Measurement errors of the automatic monitoring system

6.1 Influence of recovered fuel

Causes

- As already described above

Impact and diagnosis

- The VAPORIX system is able to distinguish recovered liquid fuel from gaseous fuel. During regular operation, condensate recovery results in refuelling operations with a recovery rate of 199% but does not result in the activation of an alarm. In the event of permanent condensate recovery, a leak in the vapour recovery system exists.

Measure

- In the event of a leak, the leak must be repaired by replacing the defective components, e.g. the O-rings, the nozzle or the nozzle hose.

Examples

- See chapter 4.7

6.2 Pulsation influence

Causes

- Oscillating pumps, such as diaphragm and piston pumps, create an oscillating flow within the return pipe and the VAPORIX-Flow sensor. The recovery rate determined by the automatic monitoring system can be faulty.

Impact and diagnosis

- Compared with a dry measurement with a diaphragm flow meter, the automatic monitoring system measures frequently a too high recovery rate.

Measures

The measures to be taken depend on the type of vapour pump.

1. In the case of vane pumps with speed control or a proportional valve, the pulsation can be ruled out as a source of error.
2. In the case of diaphragm or piston pumps with proportional valve control, the pulsation is shielded to a large extent by the proportional valve. However, a minimum pipe volume of approx. 50 cm^3 between the sensor and vapour pump should be provided. A pipe diameter of 9 mm therefore requires a pipe length of approx. 80 cm.
3. In the case of double piston pumps with speed control, a minimum pipe volume of approx. 50 cm^3 between the vapour pump and sensor should also be provided.
4. In the case of diaphragm or piston pumps with speed control, the pulsation reaches the VAPORIX-Flow system in undamped form. This is why a pulsation damper should be installed between the sensor and pump. Approx. ten times the displacement volume of the pump or 200 cm^3 should therefore be used as a typical reference value. Pulsation dampers are available from FAFNIR.
5. In the case of diaphragm or piston pumps with a liquid-controlled valve in the nozzle, the pulsation of the pump running at full speed pulsation also has a direct effect on the VAPORIX-Flow system. Here the same measure should be provided, as described in item 4.

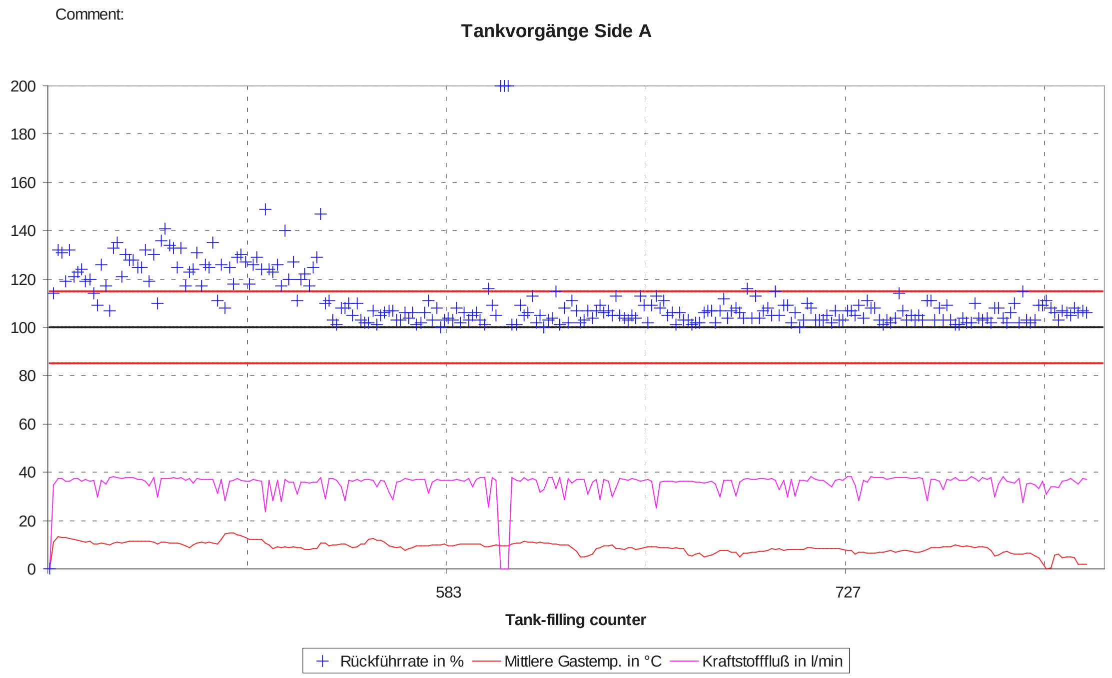

Figure 20: Speed-controlled vapour recovery system with diaphragm pump and too short pipe connection between VAPORIX-Flow and the pump. During refuelling operation 520, a pulsation damper was installed. The recovery rates and the spread of the measurement values decreased considerably.

Comment:

Figure 21: Case with a liquid-controlled valve in the nozzle. During refuelling operation 224, a pulsation damper was installed. Refuelling operations 871...954 were carried out again without a pulsation damper.

7 Faults in the connection and setup of the VAPORIX-Master

7.1 Mix-ups in the connecting cables

Causes

- Cable attached in wrong order

Impact and diagnosis

- Based on the assumption that the configuration is otherwise correct, the VAPORIX master is not able to set up a connection to VAPORIX-Control. The connection quality value at the master then drops from 100% to 0%.

Measure

- The respective cables must be replaced.

7.2 Interference

Causes

- If free wires for the wiring are used that run in the vicinity of power supply cables or in the vicinity of frequency converters.

Impact and diagnosis

- The interference can result in data corruption. The data arrives partly mutilated. The connection quality value at the master then drops to values below 100%. In order to be able to detect the respective cable, VAPORIX-Control must be connected to the VAPORIX master sequentially, if necessary. If appropriate, the connection can also be provided by means of a separate (open-air) cable for testing purposes. With this sequential trial-testing of the connection, it is not sufficient to only change the configuration on the VAPORIX master; instead, it is also necessary to physically remove, i.e. disconnect, the connected cable under suspicion.

Measures

- Use of another available cable. If necessary, the new cable must be drawn in.
- On a trial basis for the purpose of damping the interference, one 120 Ω resistor can be connected under the terminals of the affected VAPORIX-Control system and/or one 1 kΩ resistor can also be connected under the terminals of the VAPORIX master.

7.3 Setup and configuration faults

Causes

- Incorrect input data

Impact and diagnosis

- If, e.g., during the configuration an incorrect number was input, that VAPORIX-Control system will not be found by the VAPORIX master and the connection quality value at the master will drop from 100% to 0%.

Measure

- Input of the correct number of the VAPORIX-Control system.