The Maintenance System VÅRD FM MVIF - Maintenance of Materiel in the Swedish Armed Forces
Summary

VÅRD FM MVIF online

FÖRSVARETS MATERIELVERK

The Maintenance System VÅRD FM
MVIF - Maintenance of Materiel
in the Swedish Armed Forces

Summary

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1 The maintenance of materiel

This document describes the maintenance system of the Swedish Armed Forces for all materiel that needs to be kept in satisfactory operating condition. By carrying out systematic inspections, incipient failures are detected in time and as a consequence major defects can be avoided.

The maintenance system applies to all field equipment within the Swedish Armed Forces, apart from the materiel placed in permanent bases. Navy vessels, aircraft and helicopters have their own specific maintenance systems.

In dehumidified storage materiel can be kept in good condition for years. This lowers costs for maintenance as well as costs for repair of defects caused by humidity.

1.1 Personnel in the Swedish Armed Forces

The Swedish Armed Forces consist of conscripts as well as employed officers, soldiers, civilian personnel and mechanics. The maintenance system for materiel is developed for this type of Armed Forces.

Throughout a training year, the materiel is used during different periods of time. If the materiel is not needed between two training years, it is stored dehumidified in so-called mobilization storages. The storage period can vary between 1 and 16 years, depending on the type of materiel and how it is used. This is the main difference to other countries' standing armed forces, where materiel is used regularly during shorter or longer periods of time.

2 The purpose of the maintenance system Vård FM

The purpose of the maintenance system Vård FM is to ensure long-term functionality of materiel, so that military units have access to materiel ready to use at any time. Early detection of defects minimize maintenance as well as repair costs, and the risk of injury. The main technology of Vård FM is dehumidification of the materiel when it is not in use. By using dehumidification, the number of maintenance actions are reduced and the inspection intervals can be extended.

The environment in which the military units operate, how and where the materiel is stored between missions affect the condition of the materiel. Examples for different environments are educational periods in Sweden and missions abroad. Environments abroad can be extremely testing for both, materiel and personnel, especially in areas where materiel is exposed to high humidity, high temperatures, mud, block terrain, old ammunition, mold, ozone and ultraviolet radiation.

3 The principles of Vård FM

The main principles of Vård FM are:

- Vård FM is adapted to a limited war threat and readmission.
- Materiel maintenance is performed based on time of the year and usage.
- Maintenance intervals are based on times for educational operations in Sweden and have to be adjusted for an increased usage during missions abroad.
- One of the daily duties of the user of the materiel is to carry out materiel-specific controls.
- Basic controls are carried out by technicians/mechanics or other specially trained personnel. Statutory controls must be carried out by specially trained inspectors.
- Storage controls are carried out by technicians and specially trained storage personnel.
- Basic and safety controls must only be carried out in peacetime.
- The main part of all materiel used for educational purposes as well as foreign missions must be stored dehumidified in short-term storage.

Maintenance of materiel is carried out based on the following:

- Time of the year - which month.
- Mileage, km - e.g. vehicle.
- Runtime, hours - e.g. generator.
- Shots fired - e.g. heavy weapons.
- Long-term storage - usage interval is longer than 1 year.
- Short-term storage - usage interval is shorter than 1 year.

MVIF - Maintenance of Materiel in the Swedish Armed Forces.

The system comprises the following documents:

- Materiel maintenance schedules:
  - Daily inspection
  - Special inspection e.g. every month, every third month
  - Main inspection - e.g. 1, 2, 4 years
  - Materiel in storage
  - Lubrication
  - Anticorrosion treatment
  - Washing, e.g. heavy vehicles
- Manual on dehumidification technique
- Manual on how to set up maintenance schedules according to Vård FM
- Manual on containers and loose load carrier

The system also comprises these documents:

- Materiel maintenance schedule for daily controls - "MVSCHD"
- Materiel maintenance schedule for special controls - "MVSCHS"
- Materiel maintenance schedule for main inspection - "MVSCHG"
- Materiel maintenance schedule for storage - "MVSCHF"

- Lubrication schedule -"SMSCH"
- Anticorrosive treatment schedule - "ROSKSCH"
- Washing schedule - "SPSCH"
- Instruction Book - "IBOK", for chapter on maintenance
- Book of Repairs - "RBOK", for chapter on maintenance
- Control book - "KBOK"

3.1 Daily Inspection

Carrying out daily inspections ensures that the equipment is ready for use. The daily inspections are carried out by the user.

Daily inspections are the following:

- Inspections before use
- Inspections when in use (during pauses)
- Inspections after use
- Storage - dehumidification
- Inspections when refueling
- Special inspections during wintertime.

The inspections are carried out by the user, without any special order from a superior.

Defects that cannot be rectified immediately must be reported in a "failure report", a deviation report, which then is submitted to the closest manager.

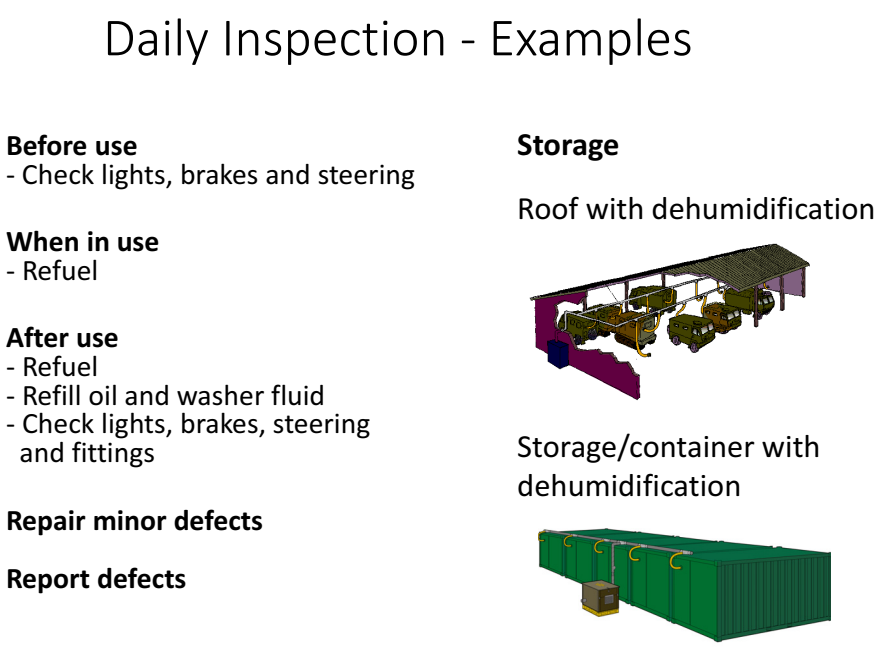


Figure 1. Examples of daily inspections.

There are two alternatives for dehumidifying materiel. In most cases, only one alternative shall be part of a storage scheme:

- Alternative 1 - Connect to a dehumidifier if stored from one night up to one month.

- Alternative 2 - If not in use for more than a month, keep the materiel in a dehumidified storage.

Daily Inspection – Storage

The user must carry out the following inspections before storing the materiel:

Storage
Period of time: One night to one month.
For inspection measures, see Materiel Maintenance Schedule – Daily Inspection

Short-term storage
Period of time: Storage for up to one year.
Materiel is stored as ordered by the responsible Technical Officer.
For inspection measures, see Materiel Maintenance Schedule – Daily Inspection, or Materiel Maintenance Schedule for Short-term Storage

Figure 2. Daily Inspection - Storage.

3.2 Special inspection

Special inspection shall ensure that the materiel is usable. For some materiel, inspection can be carried out on a monthly basis, while other materiel is inspected every third or sixth month. If materiel is used very little during a three-month period, the technical officer can decide that inspection is carried out after six months, which is the next highest maintenance interval. Some materiel always has to be inspected at the regular interval of three months, for example if required by civil law or safety and security regulations. This is decided by the responsible design managers.

Special inspection can also be carried out as needed, e.g. based on mileage, hours of operation, or shots fired. The inspection can be carried out by the user based on to specific orders or specifically scheduled time. Specifically scheduled time can be divided into several occasions within a certain period of time.

Special inspection can also be ordered e.g. before a break during an exercise, transport or after heavy usage.

Defects that cannot be rectified immediately must be reported in a "failure report", a deviation report, which then is submitted to the closest manager.

All inspections must be documented on a maintenance card, which is part of a separate Control Book, see Figure 21. Control Book.

The maintenance card "Calendar" shows which type of inspection has been carried out during a certain month, at which mileage, operation time, or number of shots fired for heavy weapons. For examples, see below.

Schedule – Special Inspection

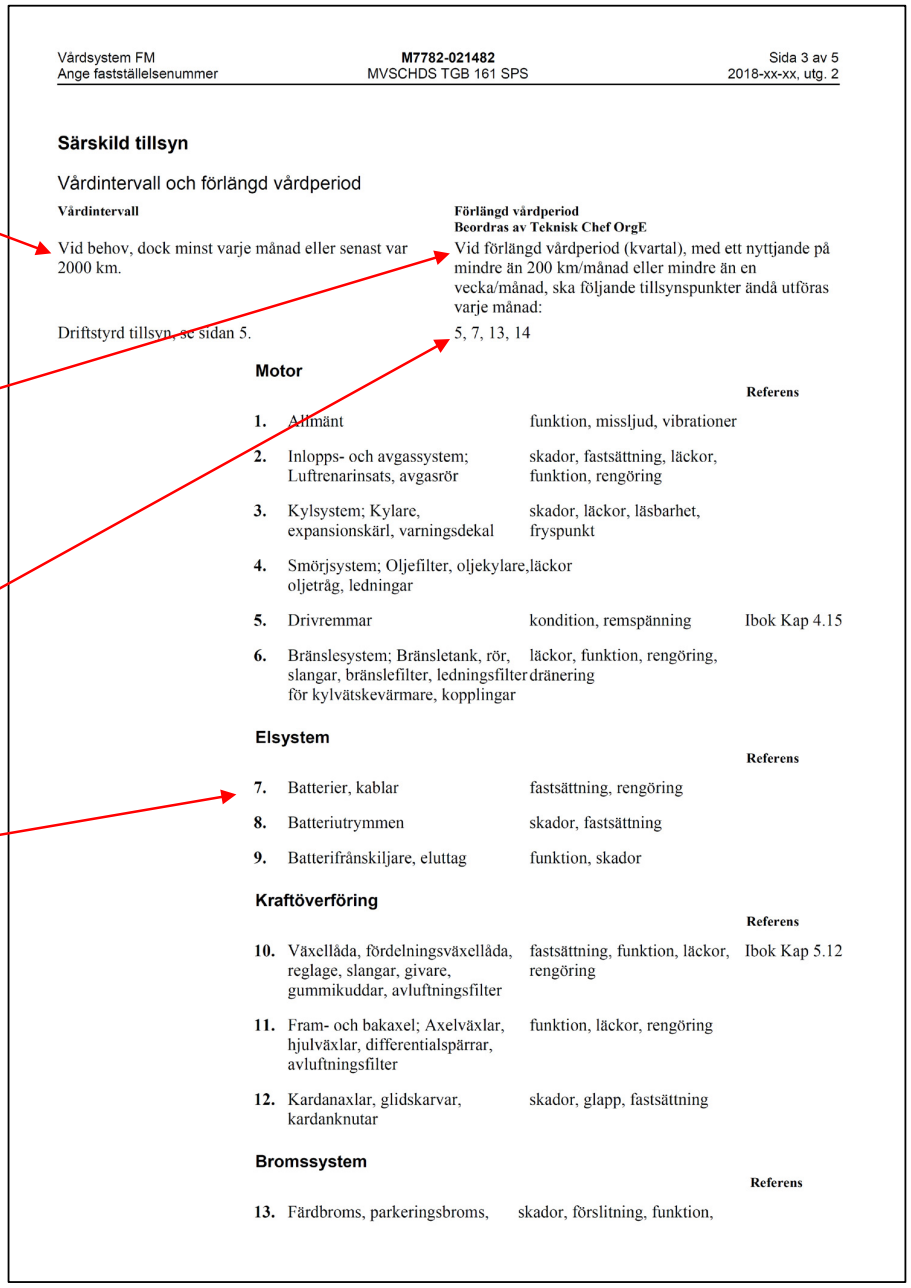
Calendar-based inspection

Interval – months or mileage.

Extended maintenance period for low usage of materiel.

Some inspections must be carried out according to the 3-month-interval, in spite of an extended maintenance period.

Inspection points.



Särskild tillsyn

Vårdintervall och förlängd vårdperiod

Vårdintervall	**Förlängd vårdperiod** **Beordras av Teknisk Chef OrgE**
Vid behov, dock minst varje månad eller senast var 2000 km.	Vid förlängd vårdperiod (kvartal), med ett nyttjande på mindre än 200 km/månad eller mindre än en vecka/månad, ska följande tillsynspunkter ändå utföras varje månad:
Driftstyrd tillsyn, se sidan 5.	5, 7, 13, 14

Motor

			Referens
1.	Allmänt	funktion, missljud, vibrationer	
2.	Inlopps- och avgassystem; Luftrenarinsats, avgasrör	skador, fastsättning, läckor, funktion, rengöring	
3.	Kylsystem; Kylare, expansionskärl, varningsdekal	skador, läckor, läsbarhet, fryspunkt	
4.	Smörjsystem; Oljefilter, oljekylare, oljetråg, ledningar	läckor	
5.	Drivremmar	kondition, remspänning	Ibok Kap 4.15
6.	Bränslesystem; Bränsletank, rör, slangar, bränslefilter, ledningsfilter för kylvätskevärmare, kopplingar	läckor, funktion, rengöring, dränering	

Elsystem

			Referens
7.	Batterier, kablar	fastsättning, rengöring	
8.	Batteriutrymmen	skador, fastsättning	
9.	Batterifrånskiljare, eluttag	funktion, skador	

Kraftöverföring

			Referens
10.	Växellåda, fördelningsväxellåda, reglage, slangar, givare, gummikuddar, avluftningsfilter	fastsättning, funktion, läckor, rengöring	Ibok Kap 5.12
11.	Fram- och bakaxel; Axelväxlar, hjulväxlar, differentialspärrar, avluftningsfilter	funktion, läckor, rengöring	
12.	Kardanaxlar, glidskarvar, kardanknutar	skador, glapp, fastsättning	

Bromssystem

			Referens
13.	Färdbroms, parkeringsbroms,	skador, förslitning, funktion,	

Figure 3. Special Inspection - Schedule.

Maintenance Card – Calendar View

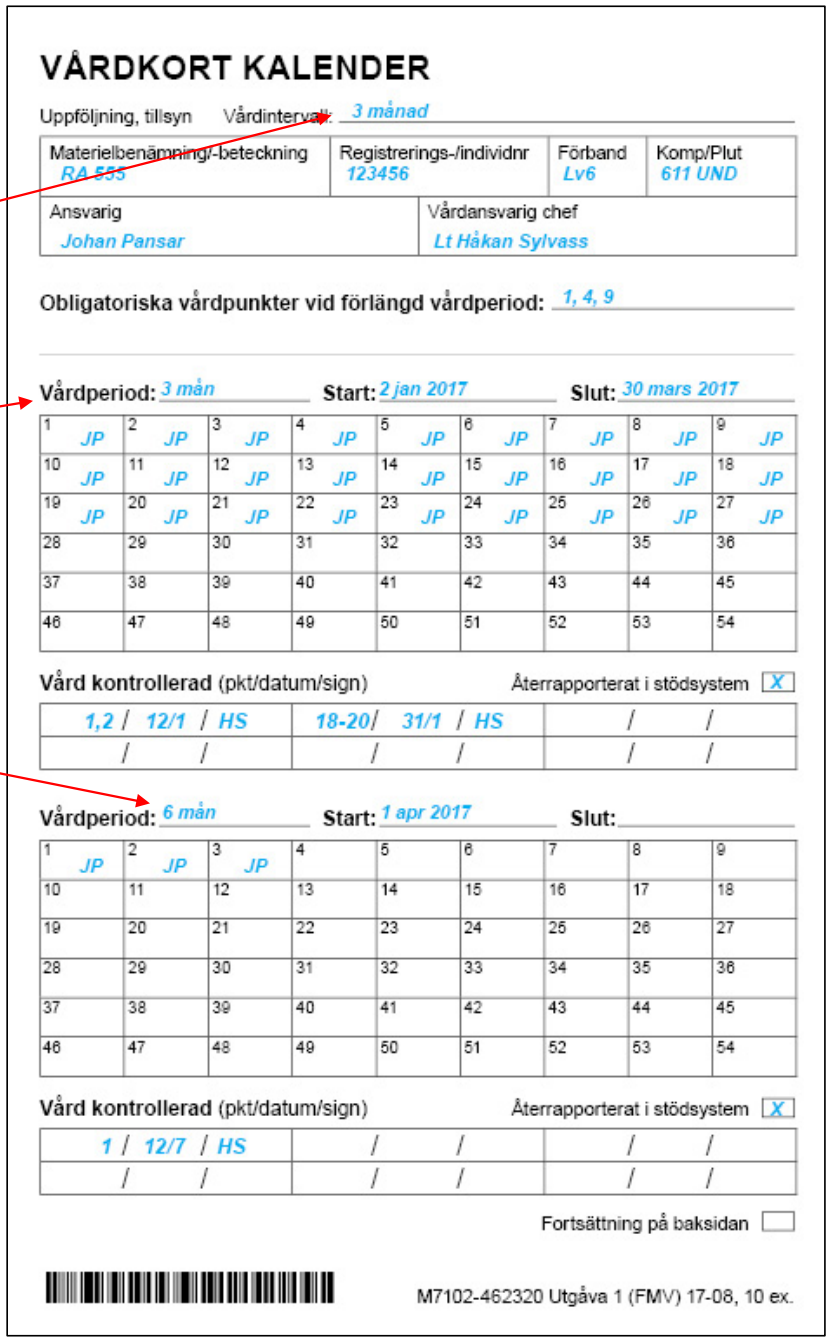
Calendar-based maintenance

Example 1 - Radio

This radio has a maintenance interval of 3 months.

First, the radio is inspected after 3-months.

The following maintenance period is extended to 6 months, due to low usage of the radio.



VÅRDKORT KALENDER

Uppföljning, tillsyn Vårdintervall: 3 månad

Materielbenämning/-beteckning	Registrerings-/individnr	Förband	Komp/Plut
RA 555	123456	Lv6	611 UND

Ansvarig	Vårdansvarig chef
Johan Pansar	Lt Håkan Sylvass

Obligatoriska vårdpunkter vid förlängd vårdperiod: 1, 4, 9

Vårdperiod: 3 mån Start: 2 jan 2017 Slut: 30 mars 2017

1 JP	2 JP	3 JP	4 JP	5 JP	6 JP	7 JP	8 JP	9 JP
10 JP	11 JP	12 JP	13 JP	14 JP	15 JP	16 JP	17 JP	18 JP
19 JP	20 JP	21 JP	22 JP	23 JP	24 JP	25 JP	26 JP	27 JP
28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45
46	47	48	49	50	51	52	53	54

Vård kontrollerad (pkt/datum/sign) Återrapporterat i stödsystem X

1,2 / 12/1 / HS	18-20/ 31/1 / HS	/ /
/ /	/ /	/ /

Vårdperiod: 6 mån Start: 1 apr 2017 Slut:

1 JP	2 JP	3 JP	4	5	6	7	8	9
10	11	12	13	14	15	16	17	18
19	20	21	22	23	24	25	26	27
28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45
46	47	48	49	50	51	52	53	54

Vård kontrollerad (pkt/datum/sign) Återrapporterat i stödsystem X

1 / 12/7 / HS	/ /	/ /
/ /	/ /	/ /

Fortsättning på baksidan

M7102-462320 Utgåva 1 (FMV) 17-08, 10 ex.

Figure 4. Maintenance Card - Calendar View.

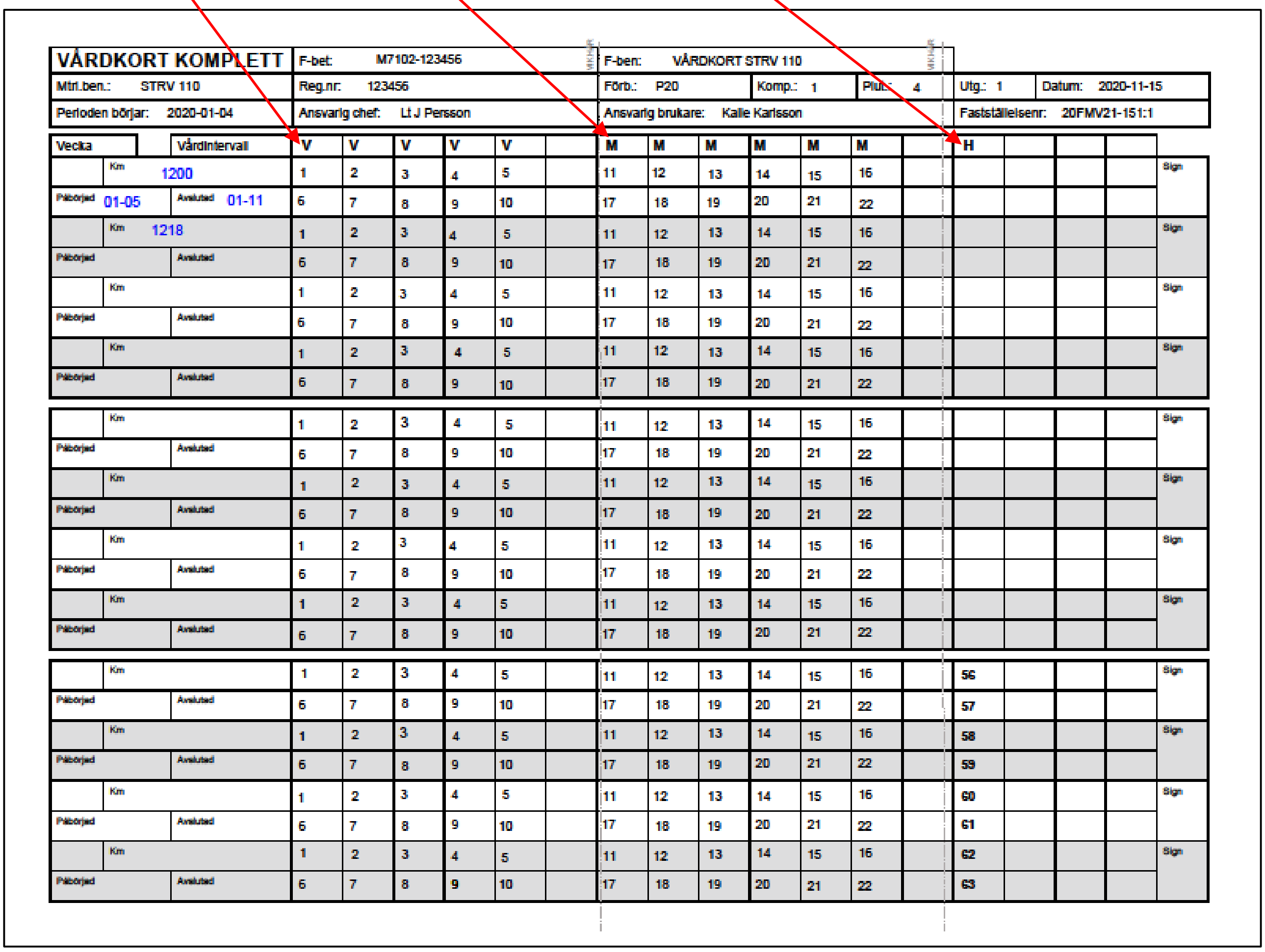
Maintenance Card – Calendar View

Calendar-based maintenance

Example 2 – Combat Vehicle

Materiel with more than 54 inspection points.

Inspection points according to the schedule,
every week, every month and every 6th month.



VÅRDKORT KOMPLETT	F-bet: M7102-123456	F-ben: VÅRDKORT STRV 110				
Mtrl.ben.: STRV 110	Reg.nr: 123456	Förb.: P20	Komp.: 1	Plut.: 4	Utg.: 1	Datum: 2020-11-15
Perioden börjar: 2020-01-04	Ansvarig chef: Lt J Persson	Ansvarig brukare: Kalle Karlsson			Fastställelsenr: 20FMV21-151:1	

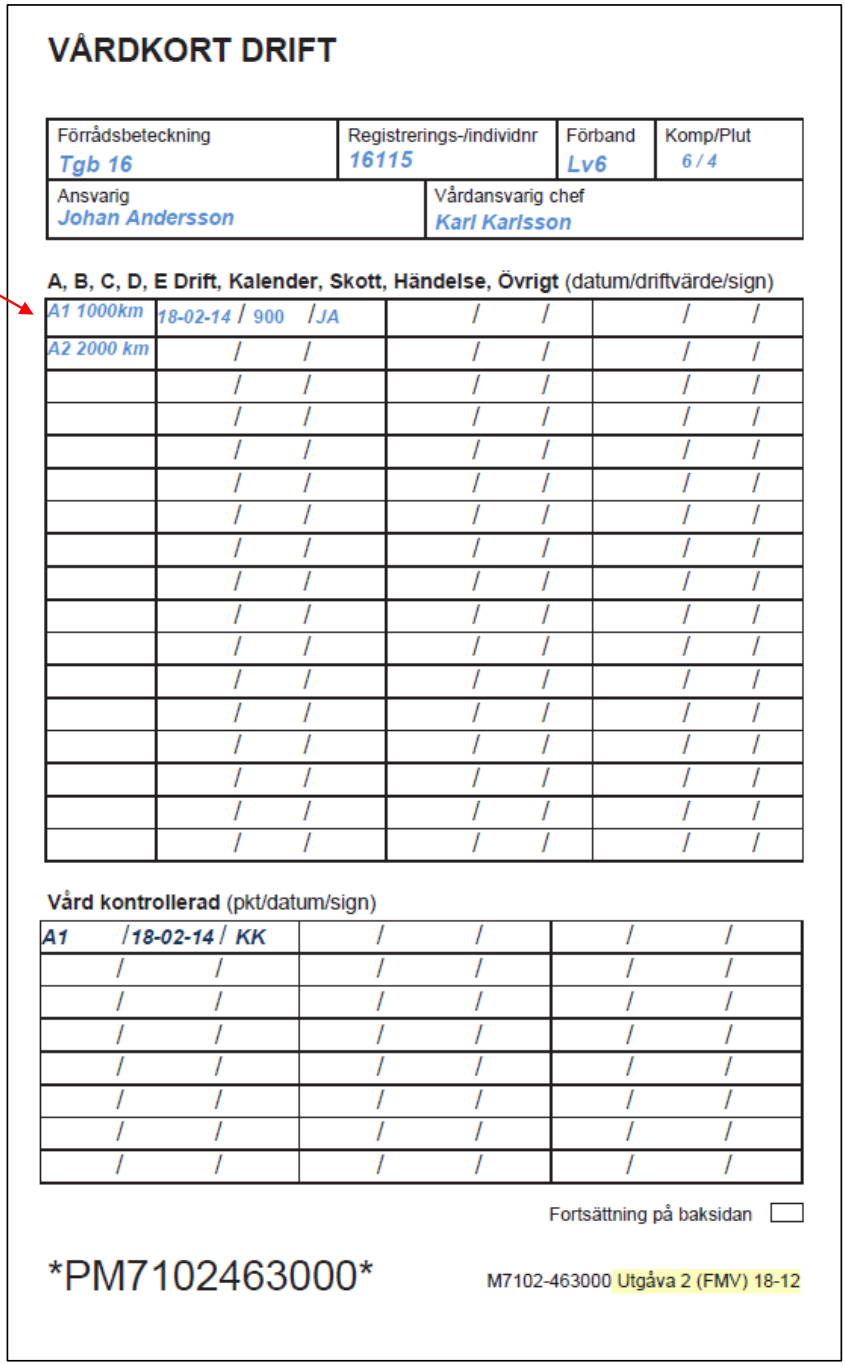
Vecka	Vårdintervall	V	V	V	V	V		M	M	M	M	M	M		H				
Km 1200		1	2	3	4	5		11	12	13	14	15	16						Sign
Påbörjad 01-05	Avslutad 01-11	6	7	8	9	10		17	18	19	20	21	22						
Km 1218		1	2	3	4	5		11	12	13	14	15	16						Sign
Påbörjad	Avslutad	6	7	8	9	10		17	18	19	20	21	22						
Km		1	2	3	4	5		11	12	13	14	15	16						Sign
Påbörjad	Avslutad	6	7	8	9	10		17	18	19	20	21	22						
Km		1	2	3	4	5		11	12	13	14	15	16						Sign
Påbörjad	Avslutad	6	7	8	9	10		17	18	19	20	21	22						
Km		1	2	3	4	5		11	12	13	14	15	16						Sign
Påbörjad	Avslutad	6	7	8	9	10		17	18	19	20	21	22						
Km		1	2	3	4	5		11	12	13	14	15	16						Sign
Påbörjad	Avslutad	6	7	8	9	10		17	18	19	20	21	22						
Km		1	2	3	4	5		11	12	13	14	15	16						Sign
Påbörjad	Avslutad	6	7	8	9	10		17	18	19	20	21	22						
Km		1	2	3	4	5		11	12	13	14	15	16						Sign
Påbörjad	Avslutad	6	7	8	9	10		17	18	19	20	21	22						
Km		1	2	3	4	5		11	12	13	14	15	16		56				Sign
Påbörjad	Avslutad	6	7	8	9	10		17	18	19	20	21	22		57				
Km		1	2	3	4	5		11	12	13	14	15	16		58				Sign
Påbörjad	Avslutad	6	7	8	9	10		17	18	19	20	21	22		59				
Km		1	2	3	4	5		11	12	13	14	15	16		60				Sign
Påbörjad	Avslutad	6	7	8	9	10		17	18	19	20	21	22		61				
Km		1	2	3	4	5		11	12	13	14	15	16		62				Sign
Påbörjad	Avslutad	6	7	8	9	10		17	18	19	20	21	22		63				

Figure 5. Maintenance Card - Calendar-based maintenance.

Maintenance Card

Materiel in Operation

The user keeps record of the operation time and mileage.



VÅRDKORT DRIFT

Förrådsbeteckning	Registrerings-/individnr	Förband	Komp/Plut
Tgb 16	16115	Lv6	6 / 4
Ansvarig: Johan Andersson		Vårdansvarig chef: Karl Karlsson	

A, B, C, D, E Drift, Kalender, Skott, Händelse, Övrigt (datum/driftvärde/sign)

A1 1000km	18-02-14 / 900 /JA	/ /	/ /
A2 2000 km	/ /	/ /	/ /
	/ /	/ /	/ /
	/ /	/ /	/ /
	/ /	/ /	/ /
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Vård kontrollerad (pkt/datum/sign)

A1 /18-02-14 / KK	/ /	/ /	/ /
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M7102-463000 Utgåva 2 (FMV) 18-12

Figure 6. Maintenance Card - Materiel in Operation.

3.3 Main inspection

The main inspection is carried out to establish the condition and functionality of materiel and to determine the basis for any repairs.

Main inspection includes:

- Statutory rules for testing vehicles, cranes and containers for vehicles, as well as electricity safety.
- Status checks to obtain documentation for assessment.
- Preventive maintenance such as lubrication and oil changes according to the instruction manual of the materiel.

The main inspection is usually carried out once in a year. Some materiel may have several intervals, such as every other year or every fourth year.

Main inspection is carried out before long-term storage in mobilization stores, together with other arrangements prior to long-term storage.

The main inspection must be documented on the "surveillance-card" in the control book as well as in "LIFT", the digitalized follow-up system.

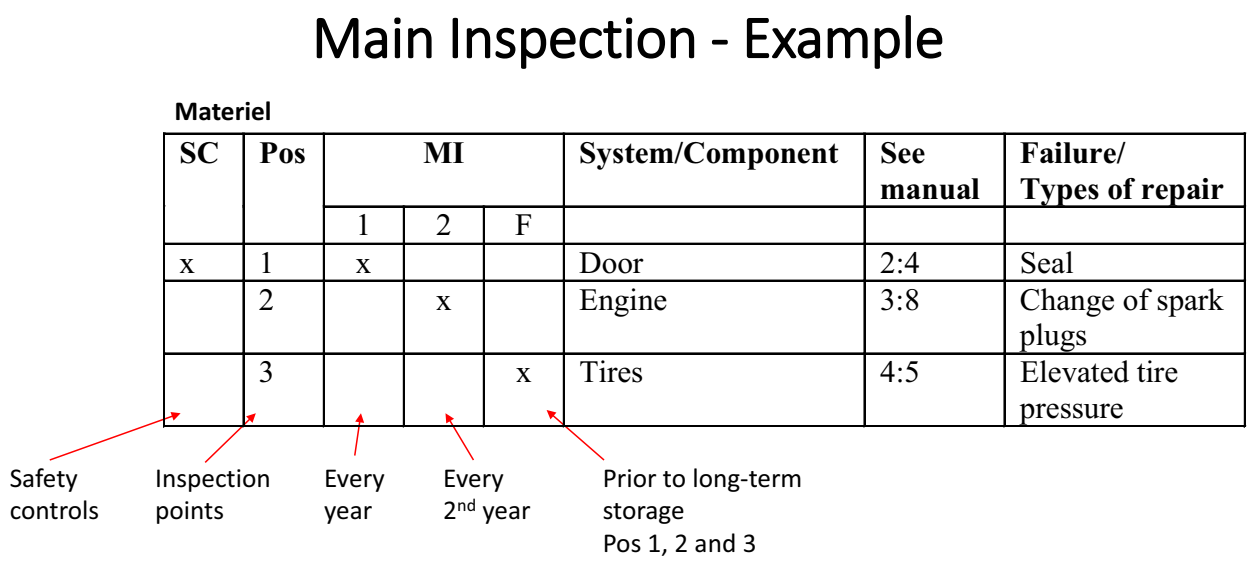

Figure 7. Example of Main Inspection.

3.4 Inspection prior to long-term storage in mobilization stores

Inspection must be carried out prior to, during and after long-term storage, so that the materiel can be used directly in case of mobilization. Preferably, all materiel shall be stored dehumidified. That way, longer inspection intervals are possible, with a lower need of maintenance.

- Arrangements prior to storage:
  - Main inspection and necessary repairs
  - Thorough cleaning
  - Lubrication
  - Oil change
  - Dehumidification

- Arrangements during storage:
  - Special inspection
  - Oil and fuel change
- Arrangements prior to usage
  - In peacetime - statutory controls and special inspection
  - In mobilization - special inspection

Storage maintenance includes, but is not limited to, the following:

Each maintenance schedule starts with a so-called standard table. The table has eight columns as shown in Figure 8.

Type of materiel	**Handling and Transport**	**Maintenance documentation**	**Packaging**	**Storing method**	**Maintenance interval**	**Maintenance personnel**	**Maintenance place**
Vehicle	Careful handling	Control book	N/A	Dehumidified	4 years	Specialized Technician	Storage

Figure 8. Standard maintenance schedule for a vehicle.

Most of the materiel is kept in dehumidified storage which extends maintenance intervals and reduces the amount of required maintenance work.

See the table below for examples of maintenance intervals for different types of materiel in long-term storage.

Materiel	**Interval - Year**
Radio transmitter	8
Radio link	4
Radar station	4
Optical	12
Optronics	4
Electricity board	8
Medical app/instrument	8
Combat vehicle	4
Self-propelled howitzer	4
All terrain carrier	4
Missile	4
Ammunition	4

3.5 Short-term storage

Materiel is considered to be in use if it will be taken out of storage during a 12-month-period. Storage for up to 12 months is called short-term storage. Preventive inspections are necessary even if the materiel is kept stored for a short period of time, such as one night. The scope of inspection varies depending on the length of the storage period.

Prior to making a decision about long-term storage, it therefore has to be established when the materiel will be used next time. If the materiel is to be used within the coming 12 months, only inspections and measures for short-term-storage shall be carried out. This saves work effort as well as time and money.

On materiel containing fuel which is kept in storage for more than 3 months, the tank must be drained of condensate and then filled up with fuel to avoid condensation as well as evaporation of fuel.

In principle, all materiel kept dehumidified during long-term storage shall also be kept dehumidified during short-term storage.

3.6 Lubrication schedule

The lubrication schedule describes which units of the materiel must be lubricated, at which interval and what type of lubricant must be used. The graphical overview in the lubrication schedule shows the lubrication points and where to change the oil. The same overview shows which lubrication and oil change has to be carried out as part of the Daily inspection, Special inspection and Main inspection.

3.7 Anticorrosion protection schedule

The anticorrosion protection schedule describes which parts of the materiel need anticorrosion treatment as well as which agent and equipment must be used. The anticorrosion protection schedule consists of simplified images of the materiel with references to the anticorrosion treatment points and instructions on how anticorrosion treatment must be carried out.

3.8 Washing schedule

The washing schedule describes which parts of the materiel need to be washed, and how washing is carried out without damaging the materiel during the process. There is also information about which agent and equipment must be used for washing. The washing schedule consists of simplified images of the materiel with references to washing points and instructions on how washing must be carried out.

4 Dehumidification and storage

In principle, all materiel of the Swedish Armed Forces is stored either in dehumidified storage or is kept dry by directly connecting dehumidifiers to the materiel. Thus accessibility of the materiel is kept high at reduced maintenance costs.

The Swedish Armed Forces have with very good experience used dehumidification systems for over 60 years, both, for long- and short-term storage. In long-term storage, materiel can be kept for long intervals between 1 year and up to 16 years. Short-term storage of up to 1 year is used for materiel that is part of training and operation during different periods of a training year.

4.1 Relative Humidity (RH)

When temperature changes quickly, corrosion processes start and can cause damage to the material and affect its functionality.

See below for a description of various environmental parameters' effect on the materiel and how dehumidification techniques are used to prevent corrosion.

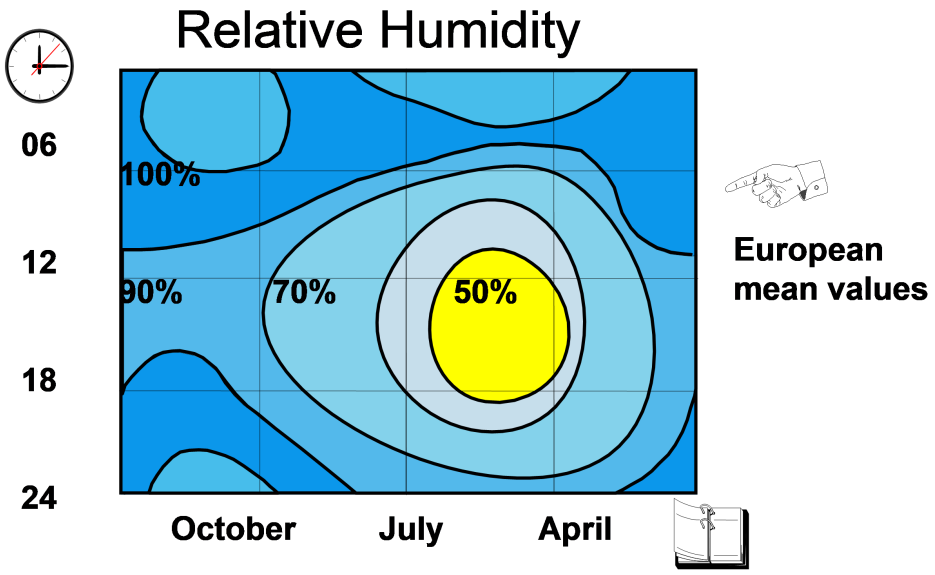

Figure 9. Relative Humidity varies with temperature.

Figure 9 shows that Relative Humidity (RH) varies with temperature:

- RH is only below 50 % for a few hours in the middle of the day, during May and June.
- RH is usually above 80 % during day and night. These values are almost the same throughout Europe, while they may be higher in both, Africa and Asia.
- As the temperature varies between day and night, condensation is formed, which increases the risk of corrosion and oxidation.
- The temperature variation is higher in warmer countries, which makes it even more important to dehumidify the equipment when the Swedish military participates in international missions, e.g. Kosovo, Liberia, Mali and Afghanistan.

During missions in Afghanistan, materiel can be exposed to wearing conditions. In the wintertime there can be -15-20 °C at night and around 20 °C during the day. In the summertime there can be 15-20 °C at night and around 40 °C during the day, which means that even then condensation can be formed, as mentioned above. See figure 10 on Meteorological data in Afghanistan.

Meteoroligical data in Afghanistan

Temp-diff mean value during 24 h gives condensation on the materiel

High RH in the air after midnight and in the morning

	KABUL				KANDAHAR			
Month	Temperature °C		Relative Humidity %		Temperature °C		Relative humidity %	
	Lowest	Highest	Kl. 05	Kl. 16	Lägsta	Högsta	Kl. 05	Kl. 16
January	-21	14	80	70	-10	21	83	51
February	-21	23	79	62	-6	27	75	38
March	-14	25	76	44	-6	31	74	31
April	-3	28	69	35	1	36	64	28
May	1	35	51	32	4	42	57	28
June	6	37	52	24	9	44	52	23
July	11	38	51	22	12	42	57	28
August	8	40	54	25	11	43	53	23
September	2	36	58	18	4	31	56	21
October	-5	32	59	22	-1	32	65	23
November	-15	25	67	31	-9	32	76	29
December	-15	19	76	53	-9	25	81	43

Figure 10. Meteorological data in Afghanistan.

Note: The red values indicate that the Relative Humidity is above 50 % during the nights and mornings, which results in an increased risk of damage due to corrosion during these times of the day.

4.2 Corrosion on steel and electronic materiel

Corrosion starts at about 50% relative humidity (RH) on steel and at slightly higher values on other types of metal. See Figure 11 for Relative Humidity vs increasing weight. The weight of materiel increases due to corrosion.

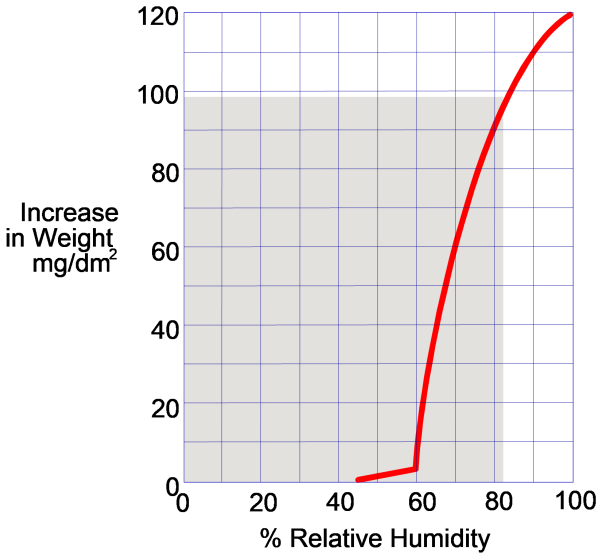

Figure 11. Relative Humidity vs increase in weight.

High Relative Humidity is a major problem for electronic materiel. The electronic resistance values for the insulation of electronic materiel gets affected by humidity, which then causes disturbances. See figure 12 Relative Humidity's impact on electronic materiel.

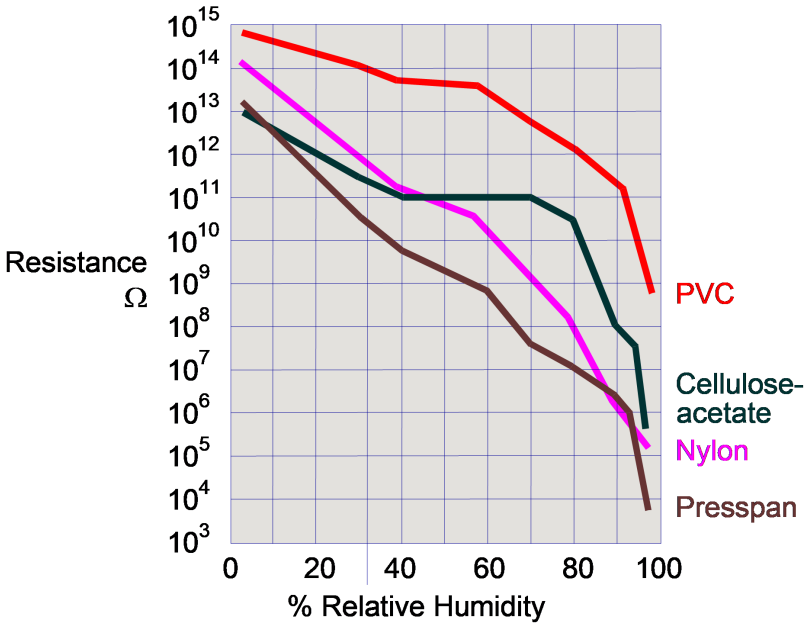

Figure 12. Relative Humidity´s impact on electronic materiel.

4.3 Mold

Even though mold is not necessarily a problem for the materiel, it is a problem for the personnel since mold can lead to lung disease. It is difficult and expensive to remove mold from materiel. Mold starts growing at a Relative Humidity (RH) of 70 %.

The conditions for how well mold grows are a combination of RH and temperature. See the example in Figure 13, where the condition is RH of 80% at a temperature of 20 °C, which results in mold growing 1 mm per day.

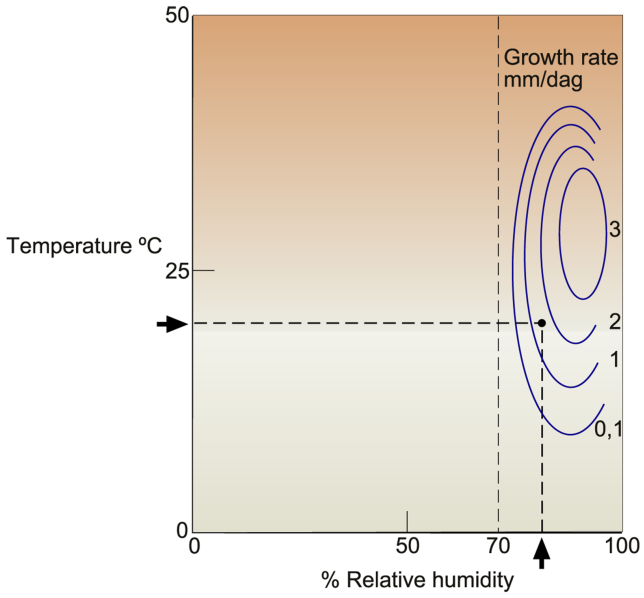

Figure 13. Conditions for mold are bassed on RH and temperature.

4.4 Hygroscopic materials

Some materiel are very hygroscopic, which means that they contain different amounts of water, which increases the risk of mold and corrosion. See figure 14.

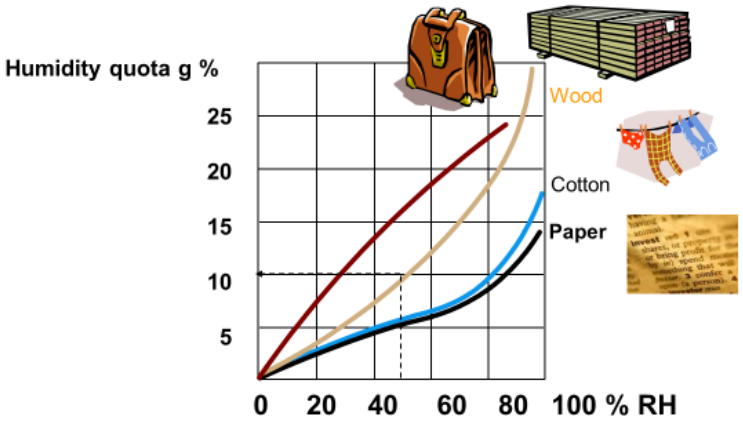

Figure 14. Relative Humidity´s impact on different hygroscopic materials.

4.5 Ozone and ultraviolet radiation

Ultraviolet radiation leads to oxidation processes, which are a problem particularly for electronics.

Air contains ozone, providing protection against ultraviolet radiation. Electricity plants and other electric machines also produce ozone.

Ozone damages rubber, plastics and textiles. Previously, cracks on rubber materials and tires were referred to as dry cracks, but nowadays we know that these cracks occur due to exposure to ozone.

The dehumidifying absorption systems used by the Swedish Armed Forces reduce the exposition of materiel to ozone.

4.6 Dehumidification technology

Technically advanced materiel must be dehumidified in storage, platoon

storage, caissons and containers. Dehumidified air is led directly into the materiel via fixed connections.

Dehumidification technology is used for:

- Materiel in long-term storage
- Materiel in use and in short-term storage
- Materiel in transport to mission abroad.

4.6.1 Dynamic dehumidification

To protect personnel and various technical materiel against the environmental factors mentioned above, dynamic dehumidifiers are used to reduce the moisture in and around the materiel. With this dehumidification method, the proportion of ozone in the air will decrease, thus reducing the risk of damage. See examples of how dynamic dehumidification is applied later in this document. Figures 16, 17, 18, 19 and 20 show different types of dynamic dehumidification.

4.6.2 Static dehumidification

During long transport to mission areas, it is often difficult to get access to electricity needed for the dynamic dehumidifiers. Therefore, during transport, static dehumidification is used.

In a box with electronic materiel, or in a container with sensitive materiel, a number of cloths is placed. The cloths contain so-called vapor phase corrosion inhibitors. These emit a harmless gas which prevents ion migration, thus avoiding formation of corrosion. The cloths together with bags containing a moisture-absorbing material, which reduces the Relative Humidity (RH), prevents mold from growing in or on the materiel. Figure 15 shows an example of static dehumidification.

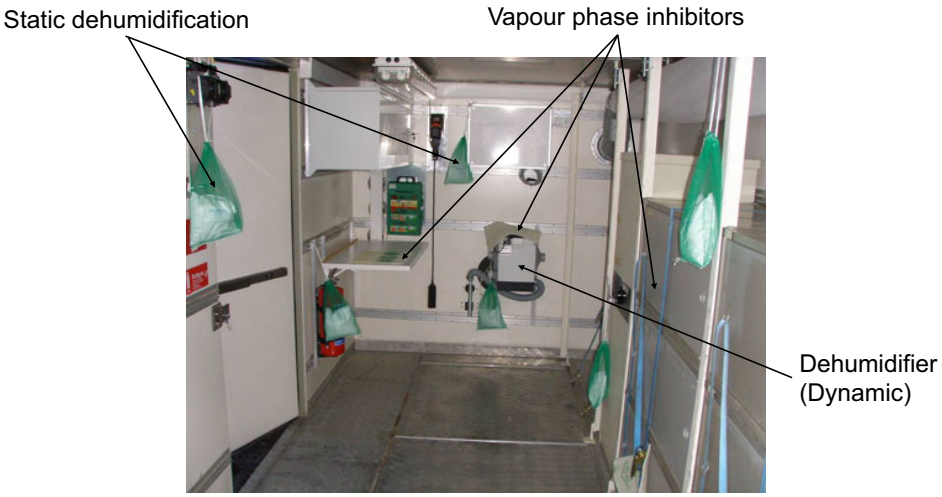

Figure 15. Static dehumidification in a container.

Figure 16. Containers connected to a dynamic dehumidifier via tubes.

Figure 17. A dynamic dehumidifier on the top of a container provides four containers with dry air.

Figure 18. A roof for storage of vehicles, heavy weapons, radar stations and similar. Underneath the roof, there are tubes connected to a dynamic dehumidifier. Via the tubes, dry air is distributed directly into the materiel.

4.6.3 Total dehumidification

Figure 19 shows the Swedish Armed Forces Central storage of 48 000 m² and a height of 18 m. The entire building is completely dehumidified.

Figure 19. The Swedish Armed Forces Central storage.

Spare parts, tools and smaller materiel are kept in completely dehumidified storage.

Heavy materiel such us tanks and containers are also kept in completely dehumidified storage, using dehumidification directed at each individual materiel. Each tank and container is supplied individually with dry air. See Figure 20.

Figure 20. Storage with individually directed dehumidification.

5 Documentation

There is a so-called Control Book for more complex materiel. In the Control Book, users of the materiel and technicians keep record of inspections and maintenance measures that have been carried out.

Figure 21. Control Book.

The Control Book comprises:

- Failure report - Incl. failures which have to be rectified at a later point.
- Maintenance card - Record of which inspections have been carried out.
- Maintenance schedule - Schedule for inspections.
- Lubrication schedule - Schedule for lubrication.
- Follow-up-list - e.g. on shots fired, hours of use, kilometers driven.
- Surveillance card - Records of inspection for complex materiel.
- Repair journal - Records of major repair work.
- Registration certificate.
- Inspection protocols.
- Table of max. loading weights for different types of vehicles.
- Record card for short-term storage.

6 Results from storage tests

The Swedish Armed Forces Materiel Administration, short FMV, has carried out comprehensive tests with materiel kept in mobilization storage. The objective of the tests was to establish how materiel is affected during long-term storage. The test results allow FMV to demand and recommend the defense industry which materials should be used to develop materiel. The overall objective is to maintain high availability of materiel at low costs. FMV conducted these tests in cooperation with a number of different Swedish industries.

6.1 Tests carried out on materiel in mobilization storage

During a time-span of eight years, every minute environmental measurements were taken for the following parameters:

- Relative humidity
- Sulphur oxide
- Hydrogen sulphide
- Nitrogen dioxide
- Ozone
- Solar intensity
- Air pollution and dust particles
- Wind direction

The materiel was stored in the following environments:

- Outdoors
- On open shelves in a non-dehumidified storage
- In a dehumidified storage in the non -dehumidified storage
- The storage above with filtered air
- Objectively dehumidified equipment

Materiel examined:

- Tanks and off-road trucks
- Radio transmitters
- Spare parts
- Gaskets made of rubber and plastic
- Textiles
- Medical equipment

For these materials, follow-up examinations were carried out:

- Sheet of steel, untreated and galvanized
- Sheet of aluminium, untreated
- Sheet of silver, untreated
- Sheet of copper, untreated
- Rubber, 14 different qualities
- Plastic, 7 different qualities

6.1.1 Vehicle fuel, various oils and coolant

The tests showed that unleaded petrol is of an acceptable quality even after four years. Prior to the tests, the assumption was that the unleaded petrol could not cope with long-term storage in vehicles. The tests also show that unleaded petrol containing potassium ages marginally faster than petrol without potassium. Both potassium additives and the plastic bottles they are stored in do cope with four years of storage without deterioration in quality.

The tests have given important evidence. The water content was significantly lower in the petrol of the vehicles stored in dehumidified stores. In dehumidified storage, the water content does not increase and petrol therefore does not age. This reduces the risk of corrosion in the fuel system. For long-term storage it is vital to use absolutely clean petrol, without any pollution.

The following time periods apply to storage:

- Diesel fuel oil 50 - can be stored for 8 years without any problems
- Motor oil - still meets the requirements after 8 years
- Transmission oil A - still meets the requirements after 8 years
- Pressure oil - still meets the requirements after 8 years
- Brake fluid - does not meet the requirements after 8 years
- Coolant, glucose and water - still meets the requirements after 8 years

6.1.2 Rubber

The tests show that it is very important to choose a suitable rubber quality when manufacturing materiel for the Armed Forces. Using low-cost rubber quality in production can result in high repair costs and low availability of materiel. It must be taken into account how materiel copes with the surrounding environment.

The majority of the different rubber qualities tested were negatively affected when stored outdoors or non-dehumidified. Rubber in e.g. tires suffered from severe damage such as cracks or increased hardness when stored outdoors or non-dehumidified. In dehumidified environments no damage occurred. Therefore, it is recommended that dynamically dehumidified air shall be used for all materiel. In dehumidified storage there is no risk of the materiel getting too dry or dried out. Tests confirming that were carried out at RH as low as 15%. The test results show that a dehumidified storage environment of 50% is preferable for all rubber qualities.

6.1.3 Plastic

A number of different types of plastic have been tested. Without dehumidification, damage occurred in all types of plastic. In a dehumidified storage environment only polypropylene showed a decrease in quality.

6.1.4 Fire hose

A fire hose stored on an open shelf in a storage room, deteriorated slightly in comparison to a fire hose kept in a dry-air-box. However, all measurements were still within the acceptable range of differences. A used fire hose kept in dark, closed storage showed better values than a new fire hose still in its packaging.

6.1.5 Fire engines and rock drills

Fire engines and rock drills show no changes after the test storage-period, regardless of whether they were kept in dry air or not.

6.1.6 Circuit boards and contact materials

No significant changes due to different storage conditions have been observed on circuit boards. After eight years of storage the components are not or only slightly changed.

6.1.7 Capacitors

Metal-encapsulated capacitors deteriorated to a certain degree when kept outdoors. Despite the deterioration, tests showed no alarming interruptions when the materiel was put in use. However, vibration and corrosion in outdoor environments can cause some mechanical changes and affect the functionality of materiel.

6.1.8 Gaskets

Nitrile rubber is the most common rubber material for gaskets. The tests showed that nitrile rubber can get severely damaged by ozone content in the environment. The rubber quality that shows best results and least damage is fluorine rubber. The damage is very limited in the dehumidified storage.

6.1.9 Medical equipment

The materiel has to be stored in bags of polyethylene, in dehumidified storage with a relative humidity of about 50 %. Medical equipment contains a lot of electronics and must be stored dehumidified to prevent gas particles from causing damage. This applies to all medical materiel, regardless of whether it is kept in storage or is part of the equipment to be used during e.g. a mission.

Cracks on rubber material occured. Natural rubber and styrene rubber are very sensitive to ozone. These materiels should therefore be replaced by ethylene propylene and chloroprene, which have better ozone resistance.

6.1.10 Vehicle parts

The spare parts tested were mainly brake parts for vehicles on wheels. All components tested were in reasonably good condition after the test period. When examining corrosion, though, there were noticeable differences between parts kept in dehumidified and non-dehumidified storage.

6.2 Tests with dehumidification of materiel in use

The tests were carried out on three military units, a tank unit, a staff unit and an air defense unit. All units operate highly complex and technological materiel. The materiel is usually placed outdoors, such as radar stations, communication vehicles and tanks.

Half of the tested materiel was kept connected to dehumidification systems, stored with dehumidification directed at each individual materiel or stored in dehumidified spaces such as storage rooms or containers, so-called closed dehumidification. The other half of the materiel was kept without dehumidification and used to compare with the dehumidified materiel.

The test showed that dehumidified storage reduces maintenance time, number of spare parts needed as well as costs.

6.2.1 Vehicles

The following vehicles kept in dehumidified storage for eight years were part of the test:

- Tanks
  - While being kept in storage, the tanks were checked according to their inspection scheme at intervals of two and four years during the test period. All vehicles started without any problems after 8 eight years. After starting them up, the vehicles were driven and exposed to heavy usage for 4 hours and then tested again. Only a lamp and a fuse needed to be replaced, and a small cooling water leakage had to be fixed.
- Off-road truck with and without radio equipment
- All terrain carrier
  - All vehicles complied with the MVIF-requirements after 8 years of storage. During the test period, the trickle charge was turned off, something that needs to be considered in case of only having a 2-year-interval for inspection.
- New off-road trucks
  - Only minor remarks after 8 years of storage. The new trucks showed the same degree of corrosion as trucks already in use. The rate of corrosion is probably lower compared to the trucks already in use, since the latter are affected by calcium chloride on the roads, outdoor storage and humidity inside the vehicles.
- Tracked vehicle

Somewhat alarming was that the fuel contained a higher level of resin after the test period of 8 years. This is due to the fact that the fuel affected the plastic material of the fuel tank. Normally this is not a problem since the fuel is changed often when the vehicle is in use. After only 4 years these values were not at such a high level and would not have affected functionality in any way.

6.2.2 Electronic parts

During 1995 to 1999, FMV tested modern materiel containing electronic parts, such as radio transmitters, predictors and computers. No failures occured during these four years, with the electronic equipment e.g. computers. The computers did not lose the data stored on them, which was very important.