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Manual

Ferrite Load

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1. Product Introduction

The concept of a AFT´s high-power ferrite load is based on the RF absorption of lossy solid-state ferrites. The ferrites are bonded to the broad walls of a waveguide by using a temperature-resistant adhesive. The waveguide walls are formed by brazed water cooling structures made of stainless steel.

This configuration has major benefits compared to conventional water loads:

- Broadband, temperature- and power-stable RF absorption.
- Stable input return loss performance (S_{11} > 30 dB) that significantly contributes to the isolation properties of the assembly of circulator and load.
- Excellent peak power capability due to solid-state nature of ferrites.
- Cooling water is clearly separated from the RF section by the brazed cooling structure, safely avoiding water to enter the waveguide section.
- RF absorption is independent of water quality.
- Robust design for high reliability and long life time.
- The device is basically free of maintenance and does not include wear parts.

Demineralized cooling water is used for removal of the dissipated energy.
The inlet water is significantly warmed up where the temperature rise is given by:

$$\Delta T = T_{out} - T_{in} = \frac{\mathbf{Powerloss}}{(\mathbf{Flow} * \mathbf{Cw})}$$

T_{out}:	Coolant outlet temperature
T_{in}:	Coolant inlet temperature
Powerloss:	RF powerloss
C_W:	Specific heat capacity of coolant e.g. 4.18kJ/(kg*K) for water

ΔT increases with increasing RF input power and can be controlled by the water flow rate. The flow rate of an AFT load is specified such, that:

1. the flow rate is sufficiently turbulent to allow effective cooling.
2. ΔT is limited to values of usually 10°C to 15°C.

Complementary electronic equipment such as AFT´s high-sensitivity arc detectors are strongly recommended to protect the device against permanent damage in case of unexpected arcing.

2. Preamble

Glossary of Terms

Customer

The customer is the organization, or entity that is using the product for its intended purpose and operation by its personnel.

User personnel

User personnel are those assigned by the customer for duties such as equipment, installation, operation, setting-up and maintenance including cleaning, troubleshooting and transportation.

Operational staff

Operational staff are personnel assigned by the customer for the operation of the system in which the product is installed.

Intended users of the manual

This manual addresses user personnel, who is in charge of the duties for installation, operation, maintenance and operational staff, which is responsible for the system operation.

The operating company has the obligation to:

- Supply and give access to this manual to user personnel and operational staff at any time.
- Train personnel concerning the use of AFT-products including safety notes.

This manual contains important information for customer about:

- Unpacking
- Installation
- Operation
- Maintenance

Intended operation

A precondition for the intended operation is the understanding of the manual and the recommended maintenance notes. Non-compliance can cause damages to the product as well as danger to personnel and equipment. Safety items should not be disabled, or modified, or used contrary to their intended operation.

The customer is responsible for operating the product in its intended manner!

The product is intended to be operated in an industrial, scientific research laboratory or production company and should not be used in a way which can cause damage to personnel or installations.
The customer assumes responsibility for use of the product outside its intended operation or in disregarding the instructions of the manufacturer. The manufacturer will assume no responsibility for misuse of the product.
The intended operation is obtained when the product is operated according to this manual, the technical specification and any additional supplied document. The use of the product requires special knowledge. The customer is responsible to ensure that only operational staff and well trained personnel with appropriate capabilities are using this product.

Warranty and liability disclaimer

The contractually agreed warranty expires immediately, if:

- the product or any of its components (incl. water fittings) is / are disassembled or changed,
- the device is operated not according to the intended operation,
- the device is intentionally or negligently damaged.

The warranty does not apply to natural wear and tear.

Warranty or liability claims concerning personal injuries or installation damages are forfeit if one or more of the following causes are involved:

- Improper mounting, setting up, use or maintenance of the product.
- Use of the product with non-operational, improper or defective protection and safety equipment.
- Disregard of the notes in this manual concerning transportation, mounting, setting up, use and maintenance of the product.
- Non-approved modifications of the intended installation of the product.
- Mechanical damage from foreign objects or force majeure.
- Non-intended operation of the product.

3. Safety Notes

General introduction

AFT is continuously improving the products to provide the highest safety standards and technical up to date state. To maintain this condition and to ensure safe operation, the user should read and comply with all notes and warnings.

Symbols and safety labels

Observation of the Safety Notes is necessary to avoid injuries to personnel and damage to equipment. Therefore, it is necessary to carefully read and observe all following safety notes, before setting up the product. The described symbols and labels are generally used by AFT but do not all necessarily apply to this specific product.

			
Observe important notes & instructions (a)	**Danger of electric shock (b)**	**Danger of RF radiation (c)**	**Danger of heat (d)**

Fig. 3.1: Safety symbols

			
Equipment ground conductor	**Grounding conductor**	**Ground**	**Components sensitive to electrostatic discharge**
(a)	(b)	(c)	(d)

Fig. 3.2: Electrical symbols

Table 3.1: Signal words

Signal Words	Meaning
Danger	Indicates a dangerous area with high-risk potential. Dangerous area can lead to death or serious injuries and severe damage to the product.
Warning	Indicates a dangerous area with medium risk potential. Dangerous area can lead to death or serious injuries and severe damage to the product.
Attention	Indicates a dangerous area with low risk potential. Dangerous area can lead to minor or to no injuries and damage to the product
Regard	Indicates a possibility for a misuse, which can cause damages to the product.
Note	Indicates circumstances, which have to be considered while using the product but does not cause damages.

Basic Safety Notes

Note

- Installation has to be done by qualified user personnel.
- The use of the product requires special knowledge and a high degree of concentration during use. Otherwise, a high degree of risk to personnel and installation exists. The customer should assign appropriate qualified personnel for the use of the product.
- Check prior to setting up of the product that all protective measures are installed in a proper way and are working. Use the product only if all safety and security measures are fully operational.
- Never remove a safety installation or other parts of the product while it is in use. Misuse can cause personnel injury and installation damage from heat, electrical shock or mechanical force.

4. Unpacking

Note

Receiving Inspection:

Please read and follow the instructions given in the paper “Instructions for Receiving Inspection” (AFT doc. no. P100211673) prior to unpacking of the device. The instruction paper can be found in the delivery note papers.

The scope of supply and the device serial number are documented in the accompanied delivery note papers.

AFT products are delivered in a wooden crate or a cardboard box**.** To unpack the product the following guidelines should be used:

- Never unpack a cold device due to the risk of condensation. The device should be warmed up to room temperature prior to unpacking.
- Unpack in clean and dry area only.
- Keep the original packaging including cover and caps for storage and future shipment.

In case of a wooden crate:

The wooden crate is not stackable if not otherwise noted..

- Ensure that the device is unpacked in an area where a crane is available.
- A series of marked srews attaches the cover to the box. Use a screwdriver to remove the screws.
- Lift the cover.
- Remove the sealing foil, packing material / foam and the desiccant bags. Dispose the desiccant bags, if applicable.
- In most cases the device in the crate is fixed against movement with additional crossbar(s). In this case remove the screws for the crossbar(s) on the side of the crate. Remove the crossbar(s).

For lifting the device out of the box observe the following points:

- Never lift the device at the RF flange.
- Lift a heavy device with a crane by using all provided crane eye bolts on top of the device, only.
- No personnel is allowed underneath or at side of a crane-lifted device!
- Ensure that the product is kept in balance during movement.
- Never drop the device.

In case of a cardboard box:

- Open the cardboard box carefully.
- Remove the sealing foil, packing material / foam and the desiccant bags, if applicable. Dispose the desiccant bags.
- Never lift the device at the RF flange. Use the main body close to the center of gravity to grab the device.
- Never drop the device.

To protect the device against damage, dust and particles the RF flanges and all interface connectors (e.g. water connector, viewport connector and the connectors for pressurization) are protected with covers and caps. Remove covers and caps in a clean area only for visual inspection or just before installation after the device has been moved to its final destination. Keep the original covers and caps for further transportation and storage.

Check the device for visual shipping or handling damage.

5. Installation

Before operating the device under high-power microwaves, the following installation procedure shall be followed.

Mounting:

- Move the device to its final mounting position.
- Mount the device onto its support structure by using the provided mounting holes/ threads as shown in the footprint drawing. Compact and light weight devices may come without mounting holes.
- The use of permanent magnets, magnetic steel or any other kind of magnetic material is not allowed within a distance of 10cm from the envelope of the device. Use not magnetic tools, only.

RF Connections:

- Remove RF connector cover or caps.
- Check waveguides or coaxial RF connectors for any damages before connecting.
- Align the waveguides or coaxial connection for a stress-free connection.
- Do not force the flanges or coaxial connectors when installing the load.
- Connect the waveguide flange or coaxial-connector properly to ensure good and low loss electrical contact and to avoid RF leakage. Never overtighten the screws on the flange.

Water Cooling:

Note

Flushed with antifreeze mixture

To avoid freezing of residual water in the cooling circuit during transport and storage the load is flushed with an antfreeze mixture (50% Glysofor N / 50% water), if not otherwise specified. The antifreeze mixture is drained carefully by using pressurized air and pumping. Small residuals of the mixture might remain in the cooling channels. In case the antifreeze mixture is not suitable for your water supply system using demineralized water, you should flush the load´s cooling system with demineralized or clean water for about 10 minutes, in order to remove all residuals.

- The ferrite load is equipped with an effective water cooling system in order to remove the power loss generated in the ferrites.
- The water inlet and outlet connectors are labeled explicitly. Please refer to the specified direction of water flow given by the labels “water in” and “water out”. Usually, the water inlet connector is located at a lower vertical position than the output. This arrangement better avoids air bubbles

remaining in the cooling channels. In case there is no distinction between water in and out, feel free to choose your own preference.

- Remove the protective cover or caps.
- Connect the water inlet and outlet pipes to the device. The connector type is given in the specification document.
- Do not use PTFE pipe tape or hemp pack for sealing additional water connections. Residues contaminate the coolant and may harm the effectiveness of cooling. Use pipe sealant e.g. Loctite 576.
- Ensure that water quality, inlet temperature, flow, and inlet pressure are controlled carefully within the specified values. Exceeding the specified values can lead to damage of the device.
- We recommend to not exceed a water flow rate by more than 30% above the specified minimum flow rate in order to avoid too high pressure drop. An excessively high water flow rate could damage the cooling circuits.
- Use demineralized water only, if not otherwise specified, in order to avoid deposits of calcium carbonate and mineral salts in the cooling channels.
- Air bubbles in the cooling channel have to be avoided.
- Turn on the cooling water and check for water leaks at all connector, tube and hose locations.
- For reason of protection, the device requires sensor technology with hard-wired RF interlocks for specified max. water outlet temperature, minimum water flow, and maximum water inlet pressure. See specification doc. for limits. The corresponding sensor and interlock equipment is not part of the load delivery and has to be provided by the customer.
- In case multiple loads are fed by one water supply, always connect the cooling circuits of the loads in parallel, not in series connection.

ARC Detector:

- In most cases AFT high-power devices are equipped with one or more arc detector viewport connector(s) of FSMA-type. The viewports allow the connection of an AFT arc detector system via low-loss fiber optical cables.
- The use of at least one arc viewport in connection with a proper arc detector system is recommended or even mandatory (see specification document) for a safe operation of the device. The viewport located at the end of the load shall be used primarily, as this arc detector covers the entire waveguide, usually. Not used arc viewports have to be covered by a lightproof protective cap (e.g. the caps AFT used during transport).
- See the corresponding arc detector manual for instructions on the installation and operation of the used arc detector system.
- The device itself is not protected against arcing that can occur as a consequence of moisture or contamination inside the waveguide or under abnormal operating conditions. However, the use of an arc detector can reduce the risk of permanent damage by arcing significantly.

6. Operation

6.1. Low-Power Test

Prior to any high-power operation we advise our customers to perform a low-power S-parameter test as described below. This is to verify that the device has not been affected by transport and handling. If the test data deviate from the factory results please refer to section 8 “Trouble Shooting and

Corrective Actions" or call AFT.

A low-power S-parameter test of the load is performed in the AFT factory prior to shipment. The test set-up usually consists of a calibrated network analyzer, coaxial RF test cables, and waveguide-to-coaxial transition (if applicable). Usually, the reference plane of calibration is set directly to the loads input port by using proper calibration standards in coaxial or waveguide technology. In case of a coaxial connector the calibration is done with N-connector calibration standards, only. For testing devices with larger size coaxial connector a well-matched coaxial transition is added to the load port while the reference plane remains at the N-connector.
The measurements are conducted at the optimum water inlet temperature and within the specified water temperature range. Water is supplied by a well-controlled thermostat. The ambient temperature is 22°C ± 3°C. The data are recorded in thermal equilibrium after about 1 hour dwell time.

Tab. 6.1: S-parameters in low-power test

Parameter	Description
$\|S_{11}\|$	Input Return Loss
arg(S11)	Phase of Input Reflection Coefficient

The low-power S-parameter test protocol with reference to the corresponding serial number is attached to this document.

6.2. High-Power Safety Issues

The ferrite load is a rugged, passive device and requires virtually no special care. However, specific start and safety issues must be addressed.

Microwave devices and systems working in high-power area may quickly build up extremely high electric field strength. If the disruptive strength of the air or the dielectric gas filled in the device exceeds, electrical breakdown in the form of arcing is possible. Typical reasons for arcing are:

- overheated surfaces by insufficient or missing water cooling,
- insufficient or missing gas pressurization or impure gas,
- humidity, e.g. by condensation or water leaks,
- contamination by dust, dirt or small particles.

In this case, part of the microwave energy is reflected and the arc travels back to the source. If the arc burns long enough, its energy reaches such high values that ferrites, waveguide and microwave source might be subject to considerable damage and might even be completely destroyed. The use of an arc detector can reduce the risk of permanent, costly damage by arcing significantly. AFT´s high-sensitivity arc detector systems detect light and provide an interlock output signal within a very short response time of a few microseconds. The interlock signal must be hard wired to the RF source in such a way that the RF source can be shut down within about 10µs.

To stabilize the operation and to protect the device against damage, the following general instructions must be followed before applying high-power:

- Check for clean and dry device.
- Check for properly connected RF Flanges to avoid RF leakage.
- It is recommended to cool the device with a water temperature well above ambient temperature; thus to prevent condensation. Condensation promotes arcing and corrosion.

- The device should be warmed up with cooling water until a thermal steady state is reached. This settling time is usually ½ hour. Never switch on high-power immediately after starting the water supply.
- Check if specified water flow is applied (if applicable).
- Check if specified gas pressurization is applied (if applicable).
- Check for properly installed and operational arc detector system.
- Check for properly installed RF interlocks.
- Strictly limit the RF input power to the max. peak and average values specified for the device.

Regard

Monitoring and RF interlocking is mandatory for:

- max. water outlet temp., min. water flow & max. water inlet pressure (see specification doc. for allowed limits)
- ARC detector output signal

Attention

Hot Surface

The surface of the high-power load may heat up to temperatures above 50°C. There is a risk of getting burnt when touching the water connectors / pipes and waveguide surfaces.

Warning

RF Connections

Inadequately connected or bad RF flanges and connectors may lead to significant radiation of RF energy under high-power operation and thus may irradiate personal.

Warning

Arcing

If any arcing occurs switch off RF immediately (best done with an arc-detector). Do not proceed with high-power operation to avoid or limit damage to the device. Please contact AFT microwave.

7. Maintenance and Storage

7.1. Maintenance

The passive device is basically free of maintenance and wear parts.

During maintenance periods of your system or after long non-operational periods, we recommend checking the device for moisture, contamination or corrosion. In case of abnormalities or problems please contact AFT.

7.2. Storage

The following instructions shall be followed for a safe transport and storage of the device after uninstallation.

- Drain the water cooling system completely, and blow out the pipes with compressed air. This is essential to prevent freezing of residual water during cold storage. That could lead to damage to the device.
- Clean the device and remove any moisture, in particular in the interior, if required.
- Repack the device by making use of the original AFT packaging, including protective covers, connector caps and box / container. The device must be properly protected from outside humidity.
- The storage shall take place in a clean and dry environment. See product specification or data sheet for storage conditions.

Special care should be taken after long non-operational periods and storage to prevent cold water (below ambient) to enter the device. Contamination, moisture and condensed water have to be removed carefully from the waveguide interior by drying before restart of operation.

Regard

Storage

Inappropriate preparation for storage and improper storage conditions can lead to long-term damage to the device.

8. Trouble Shooting and Corrective Actions

Tab. 8.1: Trouble shooting of potential problems

Problem	Corrective Action
Low-power measurement data differs from factory results	Check for: • visual damage of the device after shipment • calibration of the applied test equipment • coolant inlet temperature • ambient temperature
The device does not operate satisfactory under nominal high power	Check for: • visual damages at the device • calibration of applied test equipment (e.g. directional couplers) • coolant inlet temperature and water flow • ambient temperature • particles or dirt inside the waveguide • moisture or condensation inside the waveguide
Arcing occurs	Do not proceed with high-power operation. Contact AFT microwave.
Dust or particle inside waveguide	• contact AFT microwave for information on cleaning procedure, if applicable

We do not recommend any customer repair action on site. Please contact AFT in case of problems. A problem report or measurements data, sent by email, may be helpful for analyzing and troubleshooting.

9. Help and Service Request

For open questions on the use of the product or the understanding of the Manual or for trouble shooting assistance or service please contact our sales department.

Contact address:

AFT microwave GmbH
Donaustrasse 18
71522 Backnang

Phone: +49 7191 9659 0
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E-mail: sales@aft-microwave.com
Website: www.aft-microwave.com

Procedure Return Shipment

1 First of all send a non-conformity or problem report.

2 Please contact AFT customer service center for RMA prior to any return shipment.

Note: Return shipments without RMA will not be accepted by AFT.

3 Packing:

Follow the instructions in section 7.2 to condition the device for packing and transport. For warranty reasons always use the original AFT packaging with box / container. For details about “Packaging / repackaging of AFT High-Power products in wooden crates” see AFT document P100278833, available on request.

4 Please include a final non-conformity or problem report in hardcopy form.

10. Appendix

- Specification or Data Sheet
- Footprint Drawing
- Low-Power RF Test Report (S-Parameter viewgraphs)
- Factory Acceptance Test Protocol (if agreed)
- Technical Notes (if applicable)

Revision History:

Revision	Date	Description
1.0	26.09.2016	initial
1.1	29.11.2016	Chap. 5 Arc detector completed
1.2	13.03.2017	Introduction formula for temperature rise added
1.21	11.04.2017	Typos corrected
1.22	17.07.2017	Chap. 4 Unpacking corrected
1.23	13.12.2017	High Power Operation and Trouble shooting modified (Arcing)
1.24	26.02.2018	Chap. 4 Unpacking corrected
1.3	19.02.2020	Safety Notes and warranty information completed
1.4	07.04.2020	Layout changed
1.5	25.06.2020	Labels updated
1.6	22.03.2021	Contact information updated
1.7	04.03.2022	Formal change
1.8	02.02.2023	Note antifreeze mixture added