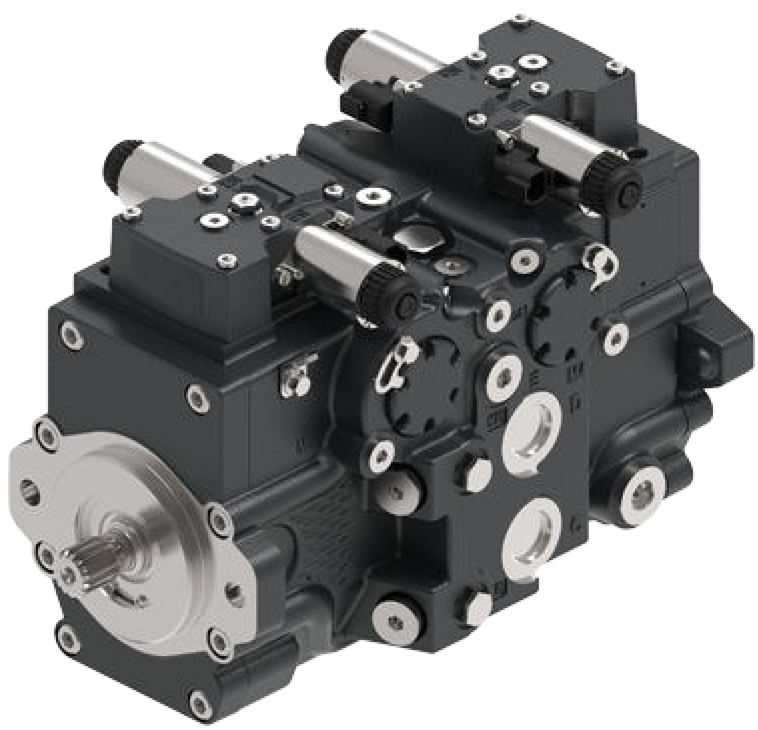
ENGINEERING
TOMORROW

Functional Safety

Product Reliability Data (MTTF)
MP1T 028/032 Tandem Pumps



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Revision history

Table of revisions

Date	Changed	Rev
August 2025	First edition	0101

Contents

Overview

Reliability Data (MTTF)

Transfer of Mean Time to Failure (MTTF) data for the given product from Danfoss to the appropriate party.

This Mean Time to Failure (MTTF) data has been compiled by the Business Area engineering team responsible. These are professionals at Danfoss, who have the authority and technical knowledge to calculate the MTTF Data for this product based on the standards set in place by both the industry and/or Danfoss.

The purpose of this document is to assist in the transfer of MTTF data for the given product from Danfoss to the appropriate party in a way which will result in a clear understanding and documentation on how we derived it.

This MTTF data is provided to assist in calculating the overall MTTF of a complete or partially complete piece of machinery. Danfoss cannot be held responsible for the suitability of these calculated MTTF values for use in the calculation of the overall machinery MTTF values.

The MTTF values are based on a specific machine use, operating environment, and/or duty cycle as stated by the standards set in place by both the industry and/or Danfoss.

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Danfoss Component

MP1 Pump Overview

The MP1 family of closed circuit variable displacement axial piston pumps is designed for use with all existing Danfoss hydraulic motors for the control and transfer of hydraulic power. MP1 pumps are compact and high in power density where all units utilize an integral hydraulic or electro-hydraulic servo piston assembly that controls the rate (speed) and direction of the hydraulic flow. MP1 pumps are specifically compatible with the Danfoss family of PLUS+1® microcontrollers for easy Plug-and-Perform installation.

MP1 pumps can be used together in combination with other Danfoss pumps and motors in the overall hydraulic system. Danfoss hydrostatic products are designed with many different displacement, pressure and load-life capabilities. Go to the Danfoss Power Solutions website or applicable product catalog to choose the components that are right for your complete closed circuit hydraulic system.

Intended Use

The MP1 axial piston variable displacement pumps are of trunnion style swash plate design and are intended for closed circuit applications. The flow rate is proportional to the pump input speed and displacement. The latter is infinitely adjustable between zero and maximum displacement. Flow direction is reversed by tilting the swash plate to the opposite side of the neutral (zero displacement) position.

Details regarding intended use, such as application examples and operating conditions, are available in Technical Information documents on our Danfoss Power Solutions web site:

https://www.danfoss.com/en/products/dps/hydraulic-pumps/mobile-pumps/mobile-piston-pumps/closed-circuit-piston-pumps/

For any intended use other than the above, contact your local Danfoss representative for advice.

Introduction

This technical report states the $MTTF_d$ for a MP1 tandem configuration. The pump configuration is discriminated between a pump with feedback system and without a feedback system. The calculation of the $MTTF_d$ values of each function is described in the chapter *Component Information and Calculations* on page 7.

Results

The following table shows the MTTFd values of pump configurations and special functions.

Results of $MTTF_d$ on pump level

ID	Pump Configuration	$MTTF_d$ [years]
1	EDC Control	≥150
2	NFPE, MDC, FNR Pumps	≥150
3	NFPH	Reference ISO 13849-1:2015 Table C.1*

* For further information, please see *Applying MTTFd and Safety Principles for NFPH Control Systems* on page 11

Standards and Assumptions

MTTF Global Standard Calculations

The calculations are performed with reference to the Danfoss Global Standard 504H0078. The standard 504H0078 defines the following options for how to determine the MTTF/$MTTF_d$ value for a specific component or product.

The process/algorithm selected will depend on:

- Whether the component is purchased or manufactured
- The availability of Danfoss field usage history
- The availability of industry standard field usage history (primarily for electronic components)
- Similarity of design to existing products
- Knowledge of the design process

Some calculation options are listed below:

- The methods outlined in ISO 13849-1 Annexes C and D
- Comparison to similar products already in production
- Industry MTTF databases for widely available components (i.e. electronics)
  - MIL-HDBK-217
  - Siemens SN29500
  - Manufacturer's Information
- MTBF data from Verification testing in PDP
- Danfoss design practices and procedures for hardware and software design
- Defects data from Danfoss CAR (Customer Action Report) database and/or customer data
- Information on sold products originates from Danfoss SAP
- Information on application profiles originates from Danfoss technical support knowledge

Component Information and Calculations

MTTFd for Individual Pump Function

The following table lists the MTTFd for each individual pump function. Please consult your Danfoss representative for further understanding of functions and the MTTFd values.

$MTTF_d$ for MP1 Pumps

ID	Function	Specification/performance	Input	Output	MTTFd [years][1]
F1	Safe controllability (pump at demanded displacement)	See TI manual for specification/ performance of function	Current to control	System flow A/B	150
F2	Safe stop (pump to neutral)	See TI manual for specification/ performance of function	Increased flow	Seal increase pressure	150
F3	Prevent unexpected movement	See TI manual for specification/ performance of function	No input	No system flow A/B	150
F4	CCO function	See TI manual for specification/ performance of function	When de-energizing CCO solenoid	No system flow A/B	150
F5	Safe start	See TI manual for specification/ performance of function and boundaries shown in Safe Start section.	Current C1/C2	No system flow A/B	150
F6	Safe/correct direction of rotation/ movement (hydraulic motor/cylinder)	See TI manual for specification/ performance of function and boundaries shown in Safe/ Correct direction of rotation section.	Force or current on selected port	Flow out of selected port	N/A[2]

[1] Does not apply to NFPH controls. For applications using an NFPH control, please refer to *Applying MTTFd and Safety Principles for NFPH Control Systems* on page 11

[2] Customer is responsible for correct port selection due to input signal

F1: Safe Controllability (Pump at Demanded Displacement)

An input signal on the control solenoids C1 and C2 will lead to a proportional system flow A/B of the hydraulic pump. The following table describes the failures and failed parts that can lead to a failure of the function.

Appropriate boundaries for fulfilling the safety function:
- Controls EDC, NFPE: Input current is either constant or changes according to the defined ramps.
- Control FNR: Input current/voltage are either switched on or off.
- Control MDC: Provide controlled and limited rotation of MDC input shaft, torque within specified torque limits. Pump displacement is directly proportional to the MDC input shaft rotation.
- With negative load (e.g. downhill condition), the engine / prime mover needs to have sufficient braking torque

Loss of F1 Function Description

Failure	Failed Part	Description
Not returning to neutral	Swash plate bearing	Pump does not move to neutral
	Sticky servo piston	
	Sticky control spool/solenoid	
Broken connection servo system to swash plate	Swash plate	Flow of the unit cannot be controlled
	Servo piston assembly	

Component Information and Calculations

Loss of F1 Function Description (continued)

Failure	Failed Part	Description
High servo pressure differential due to leakage	Servo cylinder assembly	Pump does not move to neutral
	Tycon glide ring	
	Housing crack at servo bores	
	Control gasket	
	Loss of solenoid	

F2: Safe Stop (Pump to Neutral)

Hydraulic pressure up to the high pressure relief valve setting is sealed by the pump. The following table describes the failures and failed parts that can lead to a failure of the function.

Appropriate boundaries for fulfilling the safety function:

- Controls EDC, NFPE: Input current is ramped down below application dependent threshold.
- Control FNR: Input current/voltage switched off.
- Controls MDC: Provide controlled and limited rotation of MDC input shaft towards neutral. Pump displacement is directly proportional to the MDC input shaft rotation.
- Controls EDC, NFPE or MDC: Input current/voltage is switched off, additionally apply neutral signal to EDC.
- Provide proper timing between park or holding brake engagement and displacement command according to the application needs.
- Engine / prime mover has sufficient braking torque.

Loss of F2 Function Description

Failure	Failed Parts	Description
Block Lift	Shaft bearing	These failures decrease the block lift speed. It means the block lift will occur at lower speeds than maximum allowed speed.
	Snap ring	
	Valve plate	
	Retaining spring	
System pressure not sealed	Sticky check/high pressure valve	The high pressure loop is bypassed so no flow is backed up to create braking pressure.
	Cylinder block	
	Valve plate	
	End cap (high pressure core)	

F3: Prevent Unexpected Movement

Without an input to the control, the pump must not create a system flow A/B. The following table describes the failures and failed parts that can lead to a failure of the function.

Appropriate boundaries for fulfilling the safety function:

- Controls EDC, NFPE and FNR: Input current for pump is zero.
- Controls MDC: No force on MDC lever.
- Machine is stand still (zero vehicle speed)
- No differential pressure (machine is e.g. standing on incline); Park brake recommended.
- Pump speed zero to max speed.

Component Information and Calculations

Loss of F3 Function Description

Failure	Failed Part	Description
Breakage in feedback system (only EDC)	Feedback link	Loss of hydraulic neutral position, free movement of control spool
	Servo spring	
	Excenter	
High servo pressure differential	Loss of solenoid	High servo pressure difference due to leakage of one servo cylinder to a lower pressure level
	Control gasket	

F4: CCO Function

When the CCO solenoid is de-energized, the pressure supply to the control is blocked and the pump returns to a safe state where no output flow of the pump is being created.

Loss of F4 Function Description

Failure	Failed part	Description
No short circuit of servo pressures after de-energizing of CCO solenoid	Sticky solenoid	No short circuit between servo cylinders and case. No spring force that swashes the pump back to neutral.
	Sticky spool	

F5: Safe Start

For the pump, this failure is equal to F1: Safe Controllability. The boundaries for the customer are different. An input signal on the control solenoids C1 and C2 will lead to a proportional system flow A/B of the hydraulic pump. The following table describes the failures and failed parts that can lead to a failure of the function.

Appropriate boundaries for fulfilling the safety function:
- Controls EDC, NFPE: Input current is ramped from below threshold.
- Control FNR: Input current/voltage is switched on from neutral.
- Controls MDC: Provide controlled and limited rotation of MDC input shaft, torque within specified torque limits.
- Provide proper timing between park or holding brake release and displacement command according to the application needs.

Loss of F5 Function Description

Failure	Failed part	Description
Not returning to neutral	Swash plate bearing	Pump does not move to neutral
	Sticky servo piston	
	Sticky control spool/solenoid	
Broken connection servo system to swash plate	Swash plate	Flow of the unit cannot be controlled
	Swash piston assembly	
High servo pressure differential due to leakage	Servo cylinder assembly	Pump does not move to neutral
	Tycon glide ring	
	Housing crack at servo bores	
	Control gasket	
	Loss of solenoid	

Component Information and Calculations

F6: Safe/Correct Direction of Rotation/Movement (Hydraulic Motor/Cylinder)

This failure can only be influenced by the customer. An example is the wrong wiring of control solenoids, so the vehicle would drive in the opposite direction as expected. Or wrong outputs that are depending in the software on the controller.

Appropriate boundaries for fulfilling the safety function:

- Controls EDC, NFPE: Input current is provided to the correct connector / solenoid.
- Control FNR: Input current / voltage is provided to the correct connector / solenoid.
- Control MDC: Provide controlled and limited rotation of MDC input shaft in the correct direction, torque within specified torque limits. Pump displacement is directly proportional to the MDC input shaft rotation
- With negative load (e.g. downhill condition), the engine/prime mover needs to have sufficient braking torque.

Applying MTTFd and Safety Principles for NFPH Control Systems

ISO 13849-1:2015 Annex C lists several validation tools which may be applied for use on NFPH (Non-Feedback Proportional Hydraulic) closed circuit pump control systems.

Table C.1: Basic Safety Principles

The system integrator should ensure compliance to table C.1 Basic Safety Principles for any relevant hydraulic system. Danfoss hydrostatic components are designed and specified to be included in hydraulic systems that comply with table C.1 Basic Safety Principles. Relevant hydraulic systems should remain within scope of “Intended use” as described in this document, and system operating conditions should remain inside component specifications as published by Danfoss.

Table C.2: Well-tried Safety Principles

Danfoss hydrostatic components are designed and validated using well-tried safety principles as listed in table C.2.

Well-tried Components

Danfoss hydrostatic components may be considered well-tried, when applied in accordance with “Intended use” as described in this document, and when operating conditions remain inside of component specifications. Application of Danfoss hydrostatic components for purposes other than “intended use” may fall outside of scope of well-tried components.

Practical Application of MTTFd for a Well-Tried NFPH System

An MTTFd value of ≥150 years would typically be associated with a Danfoss NFPH control as according to the above basic and well-tried safety principles. Similarly, an appropriate non-Danfoss hydraulic pilot control device could also have an associated MTTFd of ≥ 150 years.

When these components are used in series and a system MTTFd is calculated, the effective MTTFd would be ≥ 75 years. To achieve a more desirable and realistic system MTTFd, the machine designer could consider the NFPH and hydraulic pilot control device to be one in the same system and based off the above basic and well-tried design practices as outlined in ISO 13849-1:2015 Table C.1, could assign a total system MTTFd of ≥ 150 years for this combination of components.

References

MTTF List of References

The following documents provide design theory and detailed calculations for building hydraulically powered machines:

ISO 13849-1,2	Safety of machinery – Safety-related parts of control systems; ISO13839-1:2015, ISO13849-2:2014
504H0078	MTTF calculations for Danfoss products
CAR (Customer Action Report)	Danfoss global tool based process for managing defects on Danfoss products

MP1 Weblink:

https://www.danfoss.com/en/products/dps/hydraulic-pumps/mobile-pumps/mobile-piston-pumps/closed-circuit-piston-pumps/

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