ENGINEERING
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Functional Safety

Product Reliability Data (MTTF) for
H1P045-280

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Revision history

Table of revisions

Date	Changed	Rev
June 2023	Added H1P 045-68 frames	0301
April 2021	Changed document number from '70086000' to 'AB159286485026' and added H1 280 information	0204
May 2015	Added CCO information	CB
April 2014	Danfoss layout	CA
May 2013	Revise Functions - EC1035798	B
August 2012	First edition - EC1014364	A

Contents

Reliability Data (MTTF/MTTFd)

General

The Mean Time to Failure (MTTF) and Mean Time to dangerous Failure (MTTFd) data included in this document was compiled by Danfoss engineering and experts with the technical expertise to determine the MTTF/MTTFd data for the product based on the standards set in place by the industry.

The purpose of this document is to assist in the transfer of MTTF and MTTFd data for the product from Danfoss to the appropriate party in a way which will result in a clear understanding of the product reliability information. MTTF and MTTFd information is provided to assist in calculating the overall MTTF/MTTFd of a complete or partially complete piece of machinery. MTTFd information may be required for functions where a failure can lead to a dangerous situation. The different methods used to calculate MTTFd values for specific functions are shown in *Standards and Assumptions* on page 7.

Disclaimer

Danfoss cannot be held responsible for the suitability of these calculated MTTF/MTTFd values for use in the calculation of the overall machinery MTTF/MTTFd values.

The MTTF/MTTFd values for the H1 pump transmissions are based on a specific machine use, specific functions, operating environment, and/or duty cycle as stated by the standards set in place by the industry and/or Danfoss. This communication along with any attached Danfoss drawings, sketches, or data is transmitted in confidence. No information stated in this document or any attachments or supplements may be reproduced or disclosed in whole or in part without written permission of Danfoss. Further, neither these documents nor any attachments are a warranty of any sort by Danfoss or a guarantee of machine suitability for its intended purpose. It remains the responsibility of the machine manufacturer to ensure overall machine functionality and overall machine safety.

Danfoss Component

H1 Pumps

The H1 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. H1 pumps are compact and high power density where all units utilize an integral electro-hydraulic servo piston assembly that controls the rate (speed) and direction of the hydraulic flow. H1 pumps are specifically compatible with the Danfoss family of PLUS+1 microcontrollers for easy Plug-and-Perform installation.

H1 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 H1 axial piston variable displacement pumps are of cradle 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*.

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 H1 pump 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 8.

Results

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

Results of $MTTF_d$ on pump level

ID	Pump Configuration	$MTTF_d$ [years]
1	EDC Pump	150
2	NFPE, AC, FNR, FDC Pumps	150
3	CCO Function*	150

* No failures have occurred

Danfoss Component

Mission Time

Definition

- Mission time represents the maximum period of time for which a subsystem (or system) can be used
- After this time it must be replaced
- The safety system designer must consider the mission time of the components to determine the mission time of each safety function

The mission time of the above mentioned component is 20 years unless otherwise explicitly stated.

Standards and Assumptions

Standards

The calculations are performed with reference to the Danfoss Global Standard GS-0078. The standard GS-0078 defines the following options for how to determine the MTTF/$MTTF_d$ value for a specific component or product.

Criteria

The process and algorithm depends on multiple factors, including:

- 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

Calculation options:

- The methods outlined in ISO 13849-1 2006 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 PDLP
- Danfoss design practices and procedures for hardware and software design
- Defects data from Danfoss CQAR 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

$MTTF_d$ Individual Pump Functions

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

$MTTF_d$ for H1 Pumps

ID	Function	Specification/performance	Input	Output	$MTTF_d$ [years]
F1	Provide controlled output flow	See TI manual for specification/ performance of function	Current to control	System flow A/B	150
F2	Provide hydraulic braking power	See TI manual for specification/ performance of function	Increased flow	Seal increase pressure	150
F3	No unintended movement of machine without input signal	See TI manual for specification/ performance of function	No input	No system flow A/B	150
F4	CCO function (decelerating the vehicle to 0 m/s)	See TI manual for specification/ performance of function	When de-energizing C3	No system flow A/B	150
F5	Safe Start	See TI manual for specification/ performance of function and boundries shown in Safe Start chapter	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 boundries shown in Safe/Correct direction of rotation chapter	Force or current on selected port	Flow out of selected port	N/A*

* 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.

Detailed boundaries to prevent this failure mode:

- Controls: EDC, NFPE, FDC (Input current is either constant or changes according to the defined ramps).
- Control: FNR (Input current/voltage are either switched on or off)
- Controls: 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.
- Controls: AC-1, AC-2:

  o Provide demanded displacement signal. Stroking times are controlled by selected ramp time parameters.

  o All AC parameters are set correctly as found with the prototype machine
- With negative load (e.g. downhill condition), the engine / prime mover needs to have sufficient braking torque

Component Information and Calculations

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 PL-Valve	
	Sticky control spool/solenoid	
Broken connection servo system to swash plate	Swash plate	Flow of the unit cannot be controlled
	Servo 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	

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.

Detailed boundaries to prevent this failure mode:

- 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: CCO part of NFPE, EDC or MDC (Input current/voltage is switched off, additionally apply neutral signal to NFPE, EDC or MDC)
- Control: FDC (Apply ramped current up or down to neutral current as specified in technical information)
- Controls: AC-1, AC-2:

  o Provide requested displacement signal for neutral and / or deselect current high pressure port

  o All AC parameters are set correctly as found with the prototype machine
- 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	Cylinder roller 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)	

Component Information and Calculations

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. Detailed boundaries to prevent this failure mode:

- Controls: EDC, NFPE, FNR (Input current for pump is zero)
- Control: FDC (Apply neutral current as specified in technical information)
- Controls: AC-1, AC-2 (No displacement requested)
- 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

Loss of F3 Function Description

Failure	Failed Part	Description
Breakage in feedback system (only EDC)	Feedback link spring	Loss of hydraulic neutral position, free movement of control spool
	Feedback link	
	Excenter	
	Feedback link	
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 both servo cylinders. 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. Detailed boundaries to prevent this failure mode:

- Controls: EDC, NFPE (Input current is ramped from below threshold)
- Control: FNR (Input current/voltage is switched on from neutral)
- Control: FDC (Apply neutral current as specified in technical information)
- Controls: AC-1, AC-2
  - Select requested mode (1, 2, 3, or 4)
  - Provide requested displacement signal
  - All AC parameters are set correctly as found with the prototype machine
- 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

Component Information and Calculations

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 PL-Valve	
	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	

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. Detailed boundaries to prevent this failure mode:

- Controls: EDC, NFPE (Input current is provided to the correct connector / solenoid)
- Control: FDC (Apply ramped current up or down as specified in technical information)
- Control: FNR (Input current / voltage is provided to the correct connector / solenoid)
- Controls: 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.
- Controls: AC-1, AC-2
  - Provide correct direction signal (FNR)
  - AC output current is provided to the correct connector/solenoid
  - All AC parameters are set correctly as found with the prototype machine
- With negative load (e.g. downhill condition), the engine/prime mover needs to have sufficient braking torque

References

List of References

These 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; ISO13839-1:2006, ISO13849-2:2003
- **BC152886483968** H1 Axial Piston Pumps, Single and Tandem Basic Information
- *H1 pumps product page*

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