INSTITUT FÜR SOLARTECHNIK

SPF Institute for Solar Technology
Eastern Switzerland University of Applied Sciences (OST)
CH-8640 Rapperswil
www.spf.ch

SPF Test procedure No. 14

Compensators and connectors for solar thermal applications

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1 General

1.1 Introduction

The operational reliability and the service lifetime of a solar thermal system depend on the quality of all the components used. The connections between the collectors, as well as the connections of the collectors to the supply and return lines, have been identified as one of the potential weak points. Some of the connection systems that are used, are not capable of withstanding the mechanical and thermal loads caused by modern efficient collectors. After several years of operation leaks can then lead to system failure.

The following test procedure, which was specially developed for this purpose, can be used to detect problems with connection technologies in the laboratory within short time. The test procedure consists of three superimposed elements:

- Static load: Installation error/tolerance and misalignment (Figure 1).
- Dynamic load: Dynamic dilatation due to thermal expansion (Figure 2).
- Thermal load: Thermal shocks encountered in stagnation phases.

Different test classes as described later are defined and can be chosen for testing. Depending on the collector field layout, the collector size and the connection methods, the collector manufacturer and the installer should then choose appropriate connector systems.

1.2 Scope

This test method is applicable for all types of hydraulic compensators and connection systems in the solar thermal circuit, such as screwed connections, plug-in systems, compression fittings or other connection elements.

Rigid pipe connections, fittings and similar components are exposed only to the thermal loads.

2 Technical

2.1 Test conditions

The test cycles described below have been defined in such a way that the operating conditions (including stagnation) usually encountered in solar thermal installations are considered.

- Maximum operating pressure: 10 bar
- Heat transfer fluids: Technically inhibited glycol / water mixtures (ethylene or propylene glycol)
- The applied loads are separated into installation tolerances (static loads), and dynamic loads due to dilatations due to thermal expansion in operation.
- The requirements regarding temperature resistance correspond to the load in collector arrays with flat-plate collectors of state-of-the-art design (single glazing, solar-selective absorber coating).

Non-standard operating modes such as higher pressures, special heat transfer media, more frequent stagnation, etc. require appropriately adapted test cycles.

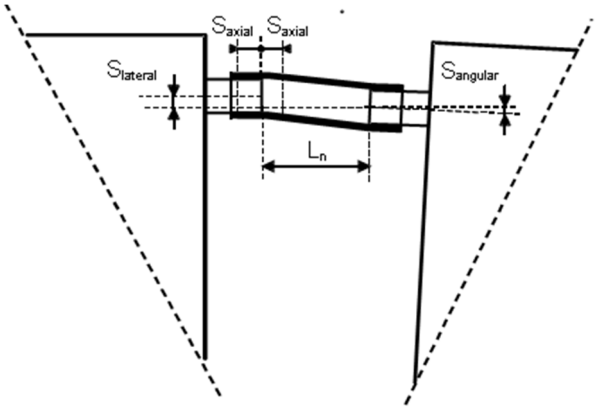

Figure 1: Definition of static load

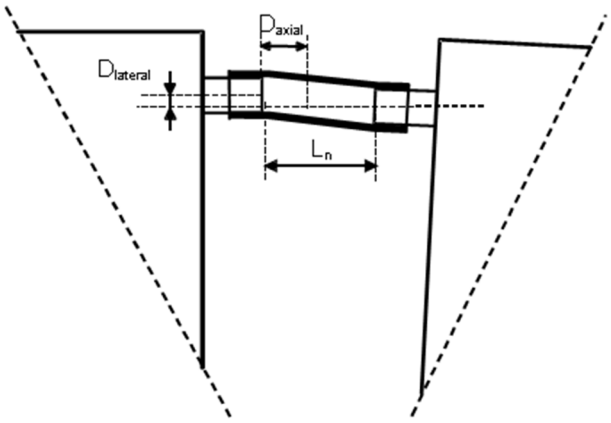

Figure 2: Definition of dynamic load

Nomenclature:

L_n : Nominal installation length

S_{axial} : Axial installation error (possible in both directions)

$S_{lateral}$: Lateral (radial) installation error

$S_{angular}$: Angular misalignment

D_{axial} : Axial dynamic load

$D_{lateral}$: Lateral (radial) dynamic load

3 Classification

The compensators and connecting parts are subjected to different loads. The following factors are important:

- Collector type (design of the connections)
- Collector design (absorber geometry, expansion)
- Layout of the field (thermal expansion, possible misalignments)
- Piping (elongation, installation problems
- Installation procedure (mounting errors)
- Selection of absorber material and connection lines (thermal expansion)
- Operating mode of the system (pressure, temperature)

The requirements for connectors and connecting parts can be assigned to the following classes accordingly. The range of classes has been designed to include the usual applications.

Any combination of static and dynamic load classes is possible.

For specific cases, the requirements can be defined on a customer-specific basis. These are both described and justified in the test results.

3.1 Static load classes

The defined static loads are essentially dependent on the mounting conditions or the mounting system. The installation tolerance can be reduced by an appropriately designed installation system. However, tolerances such as those defined in classes A to C (Table 1) are well within the scope of normal installation tolerances.

	S_{axial}	$S_{lateral}$	$S_{angular}$
Class A	< 5 mm	< 4 mm	< 1°
Class B	< 10 mm	< 5 mm	< 2°
Class C	< 20 mm	< 10 mm	< 5°

Table 1. Definition of static load classes

3.2 Dynamic load classes

The maximum dynamic load is expected when the system is in stagnation at a standstill. The maximum dilation is proportional to the temperature difference between the maximum temperature (stagnation) that can be reached and the minimum ambient temperature. Flat-plate collectors reach stagnation temperatures in the order of up to about 220°C. Considering the thermal expansion coefficient for copper ($\alpha \approx 17\ K^{-1}$) or aluminium ($\alpha \approx 23\ K^{-1}$) a dilatation of up to 4 mm per metre is possible, and this must be absorbed by the compensator (.

	D_{axial}	$D_{lateral}$
Class 1	< 8 mm	< 4 mm
Class 2	< 8 mm	< 8 mm
Class 3	< 20 mm	< 20 mm

Table 2. Definition of dynamic load classes

4 Test program

The test programme is intended to represent the loads imposed on connections and connecting parts over a period of at least 20 years. It is important to note that in addition to the mechanical loads, thermal loads on sealing materials (elastomer materials, etc.) must be considered. However, the thermal loads only refer to the heat transfer medium in liquid state! All effects due to steam or condensing heat transfer medium are not covered within the scope of this test. For the impact of evaporation and condensation on connectors (O-Rings and sealing) a specific test procedure is available as well (SPF-TP31).

4.1 Installation of the test sample

Mounting of the test specimen according to the mounting instructions while observing the minimum mounting length without considering the mounting tolerance.

The maximum mounting tolerance is applied according to the specified class division (A, B or C) in such a way that the maximum load results in combination with the dynamic load (see Figure 3).

4.2 Test program

During the entire service lifetime of the connection part, about 5000 cycles at normal operation and 500 cycles of stagnation can be expected in a solar thermal system. In the case of stagnation at the maximum temperature of the connecting piece, a "full stroke" is performed. This means that according to the selected class of dynamic load (1, 2 or 3), the dynamic load is applied in addition to the static load in such a way that the maximum total load results (see Figure 3). During the 5000 cycles of normal operation, half of the dynamic load (half stroke) is applied in the same way as the static load.

During the test, the sample is also exposed to high temperatures and thermal shocks. The "full stroke" cycle is started when the temperature of the test item has reached a temperature of 180°C. At maximum load (corresponding to the maximum expansion), the sample is then subjected to a thermal shock. The temperature is reduced from 180°C to below 80°C within 5 seconds. A complete full stroke (forward and backward movement) takes about 900 seconds During the half strokes, the cycles run at ambient temperature. A complete half-stroke takes approx. 15 seconds.

Rigid pipe connections, fittings and similar components are exposed to thermal loads only.

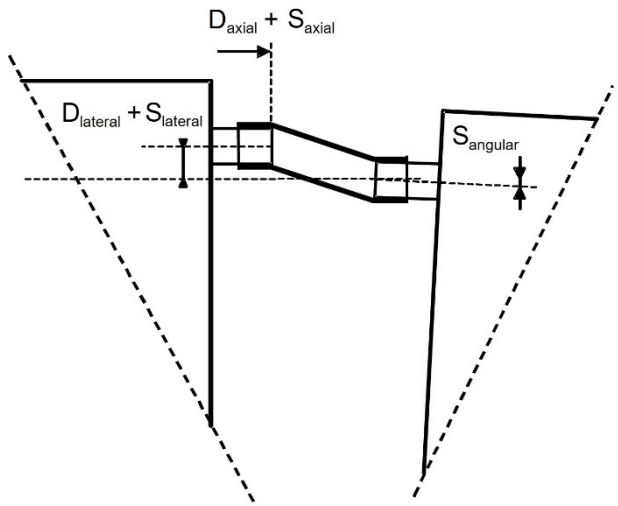

Figure 3: Maximum load is the sum of installation error and dynamic load

Parameter	**Value**
Nominal installation length	manufacturer specification
Installation error	Depending on the selected class (A, B, C) or according to the client's specification
Test pressure	10 (- 0.5 / + 0.5) bar or as specified by the manufacturer
Dynamic load	Depending on the class (1, 2, 3) or as specified by the client
Number of full strokes	500
Number of half strokes	5000
Test program	450 full strokes then 5000 half strokes then 50 full strokes

Duration	Full stroke approx. 900 seconds Half stroke approx. 20 seconds Total duration of the test approx. 7 days
Temperature load during full stroke	Full stroke 180 °C (+/- 5°C)
Thermal shock during max. load at full stroke	From 180°C to below 80°C for 5 seconds
Temperature load at half stroke	Ambient temperature

Table 3. Summary of parameters information on the test

4.3 Pass criteria

The test is considered passed if no leaks are found during the entire test.

5 Certificate

For successfully tested connectors a certificate is issued and published that contains the following information:

- Test number consisting of a J ("Joint") with a consecutive test number.
- Period of validity of the certificate: 5 years from date of issue.
- Description of the test specimen: materials, principle of sealing, dimensions, illustration.
- Indication of the nominal length.
- Selected test class for static and dynamic load.
- For test specimens that have only been subjected to thermal stress (such as fittings), it is mentioned that the dilatations must be absorbed by additional elements such as compensators, bows or hoses.
- In the case of user-specific test conditions, reference is made to this in the test report and the conditions are listed.

Rapperswil, 1. January 2023