



***TECHNICAL DESCRIPTION***  
***TVM/38-E DI.8286***

**TEC-DESC-TVM38E**

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## 0. INTRODUCTION

The present document describes the technical aspect of the product TVM/38-E DI.8286.

## 1. GENERAL DESCRIPTION

Voltage transformer TVM/38-E is designed for rolling stock top roof installation.

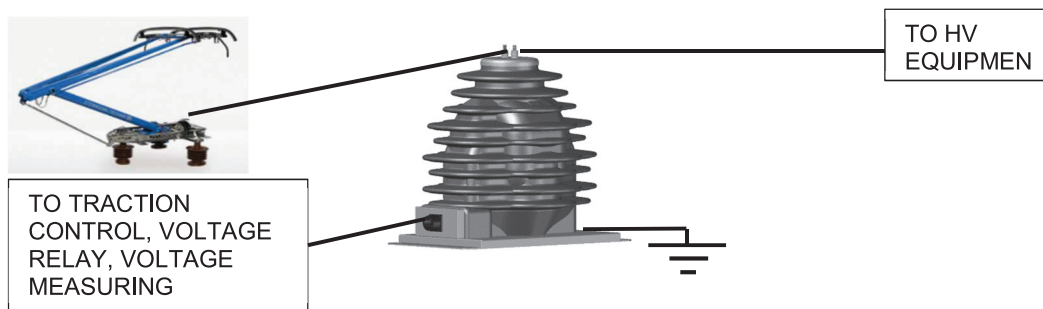
The purpose of TVM/38-E are:

- Measuring: the secondary output can be connected to a device for measuring the primary voltage at the pantograph.
- Protection: the secondary output can be connected to a voltage protection relay.

The secondary output can be connected to many devices in parallel. The only care is that the total power of all equipment must be within 100% and 25% of the voltage transformer burden.

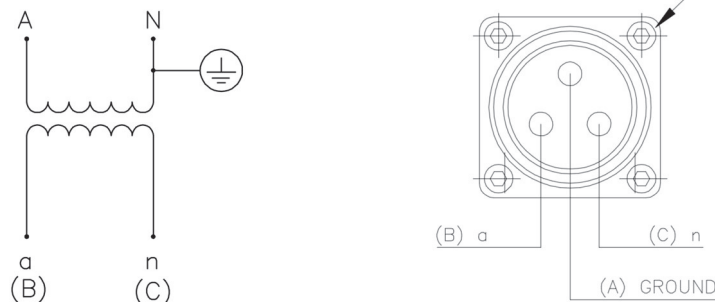
### 1.1 General layout

The general layout is as below:



### 1.2 Schematic diagram

The schematic diagram of TVM/38-E DI.8286 is:



Where:

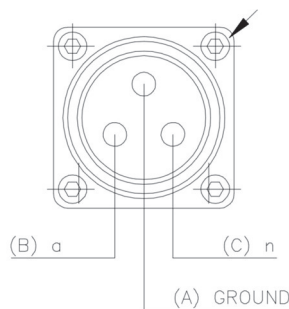
- "A" is the high voltage connection on the top
- "N" is the earth connection on the base plate
- "a" and "n" are the secondary output connection.

When wiring instrument transformer circuits, it is necessary to maintain the correct polarity relationship between the line and the devices connected to the secondary output. For this reason, the relative instantaneous polarity of each winding of a transformer is indicated by a marker. The primary terminals are "A" and "N" (capital letter). The secondary terminals are "a", "n" (lowercase). The marker "A" always indicates the same instantaneous polarity as "a".

### 1.3 Secondary connector

The secondary output is with a Glenair connector MIL-DTL-5015 standard reverse bayonet type. The code of the connector is FR ITS 41 02 R 22-9 S B0 F7. The connector code has the following meaning:

- FR: fire resistant and EN45545-2 compliant. (-25°C to +175°C)
- ITS: reverse bayonet coupling
- 41: crimp contact type (no soldering)
- 02: front panel mount
- R: for harsh environment
- 22-9: size of the connector and pin arrangement. Tested by Glenair at 3,5kVrms 50Hz. Operating voltage 1250Vrms. Minimum insulating resistance tested by Glenair: 5GΩ.
- S: socket or female contact gender
- B0: without contact pins
- F7: Aluminium/Black Zi-Ni surface treatment RoHS compliant.



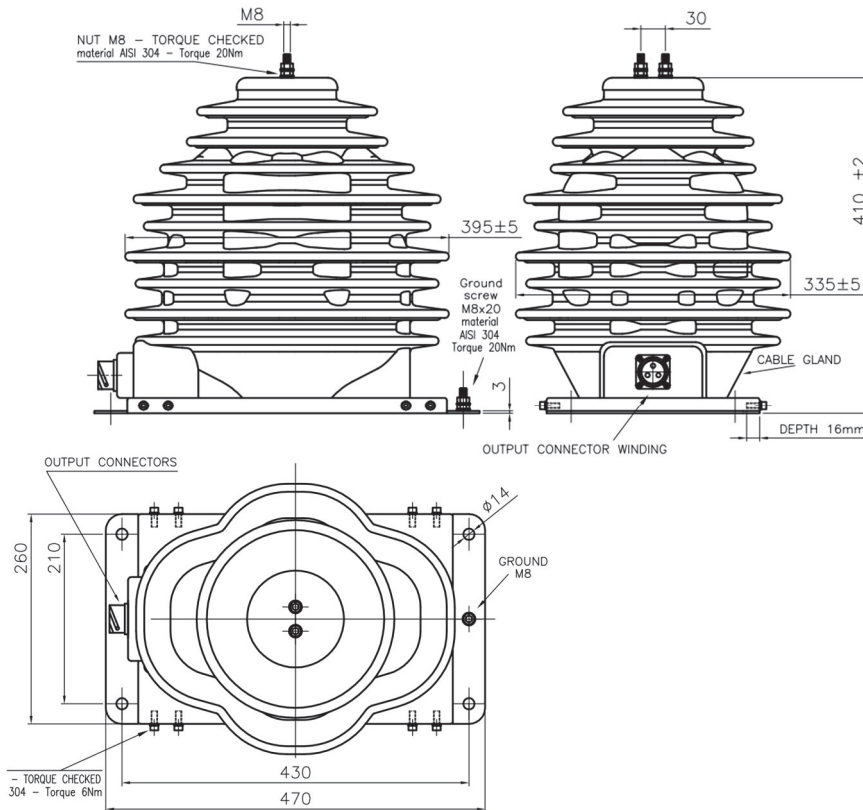
Contact pin code for the connector is 10-40560-G117:

- 10-40560 is contact pin female size 12 tested by Glenair at 41A@20°C or 23A@80°C for continuous service
- G117: gold plated for best durable contact in harsh environment

## 1.4 Dimension

The dimension of TVM/38-E are:

- Height: 410 ±2mm plus connection bolts
- Baseplate: 260 x 470mm



## 1.5 Installation

Use the four hole of the base plate: please see the relevant drawing.

Inter-axis are: 210mm and 430mm

TVM/38-E voltage transformer may be mounted in vertical position only (with terminal of primary winding facing the top). Other mounting positions are not allowed.

## 1.6 Weight

The weight of the TVM/38-E is about 53kg.

## 1.7 Materials

All materials are EN45545-2 compliant, in particular all external material are:

- Stainless steel AISI 304
- Silicone

Materials are chosen to last in harsh environment without problem or defect with minimum maintenance.

Stainless steel AISI 304 is very good material for outdoor installation.

Silicone has the following high performances points:

- It guarantees high performances also with high humidity or heavy rains since it is totally water repellent

- the creepage distance does not change also in case of impact with stones, hail or other pieces of hard materials.
- under sun, it does not have degradation because of UV rays.
- It does not scratch wires or other parts inside the transformer especially in case of quick thermal changes.

## 1.8 Safety

For safety issue the earth connection on the base plate must be connected first.

The "n" pin (C) of the secondary output must be connected to earth.

The voltage transformer must work with secondary circuit opened or loaded maximum with the rated burden indicated on the rating plate

Always consider an instrument transformer as a part of the circuit to which it is connected, and do not touch the leads and terminals or other parts of the transformer unless they are known to be adequately grounded.

Always ground the metallic cases, frames, bases, etc., of instrument transformers. The secondaries should be grounded close to the transformers. However, there should only be one grounded point in this circuit to prevent accidental paralleling with system grounding wires.

Check with care if both terminals of the same secondary winding are grounded by accident. Grounding both terminals of secondary winding can result in damage of voltage transformer over a short period of time. Any claims for resulting transformer damages will be void.

Do not short circuit the secondary terminal of a voltage transformer while the transformer is energized. Voltage transformers with secondary terminals short-circuited may be hazardous to personnel or may damage the transformer itself or equipment connected in the secondary circuit. Any claims for resulting transformer damages will be void.

Identify the product, check the rating plate and terminal markings on the voltage transformer and properly connect the voltage transformer. Check that all data indicated in the rating plate (rated primary and secondary voltage, rated frequency, rated burden, accuracy class) have been respected.

Check that connections were properly performed:

- Secondary terminals are connected to the rated load or they are not connected (open).
- All secondary windings are correctly earthed

## 2. REQUIREMENTS

### 2.1 Reference standards

TVM/38-E is designed according to the following standards:

IEC 61869-3:2011	Instrument transformers - Part 3: Additional requirements for inductive voltage transformers
IEC 61869-1:2007	Instrument transformers - Part 1: General requirements
IEC 60044-2	Instrument transformers - Part 2: Additional requirements for inductive voltage transformers expired and substitute by IEC 61869-3
EN 45545-2:2015	Railway applications - Fire protection on railway vehicles - Part 2: Requirements for fire behavior of materials and components
EN 50124:2017	Railway applications – Insulation coordination
EN 50163:2006	Railway applications. Supply voltages of traction systems
EN 50388:2012	Railway Applications. Power supply and rolling stock. Technical criteria for the coordination between power supply (substation) and rolling stock to achieve interoperability
EN50153:2014	Railway applications – Rolling stocks – Protective provisions relating to electrical hazards

## 2.2 Customer Requirements

II TVM/38-E is designed according to the following requirements:

MML27_CbC_ERTS_20181120-1-For STE Transformers	Customer technical specification ERTS

## 2.3 Electrical requirement

- Rated primary voltage 25kVrms 50Hz
- Rated secondary output 100Vrms 50Hz
- Rated power frequency voltage: 70kV
- Rated lightning impulse withstand voltage: 170kV
- Ratio : 25000/100V
- Accuracy class 0.5 (As per ERTS clause 8.5.1 and 8.6.1)
- Protection accuracy class 3P (As per ERTS clause 8.5.1 and 8.6.1)
- Rated burden 25VA
- Rated frequency 50Hz
- Frequency variation 48 to 52Hz
- Voltage factor 1,5/30s
- Insulation 36/70/170 kV
- Minimum instantaneous voltage 17,5kV
- Minimum voltage 19kV
- Maximum voltage 27,5kV
- Occasional maximum voltage 31kV

## 2.4 Environment requirement

- outdoor installation
- high pollution
- Operating temperature -25°C a +70°C
- pollution degree level PD4 (as defined by EN 50124)
- overvoltage level OV4 (as defined by EN 50124)
- On board rolling stock installation
- On board rolling stock installation near pantograph without overvoltage protection system: overvoltage category OV4 (as defined by EN 50124)
- IP67

## 2.5 Safety requirements

- Explosion proof
- EN 45545-2 compliant
- Minimum design life 35 years
- Working under 3kVdc for 2 minutes without damages.

### 3. TECHNICAL DESCRIPTION AND DESIGN

#### 3.1 Electro-magnetic design

Magnetic core and windings are designed according to requirements using STE VT software design tool.

Basic data are:

- Ratio 25000/100V
- Burden 25VA  $\cos\phi=0,8$  (according to IEC 61869-3)
- Accuracy class 0,5 for measuring
- Protection class 3P

Design verification:

- The winding is designed to respect accuracy class 0,5 between 17,5 and 31kV according to requirements of voltage variation and between 25VA (100% burden) and 6,25VA(25%burden). Limits are according IEC 61869-3.

This point is tested on every TVM/38-E before shipping as routine test (see attachment [3]).

Voltage	17,5kV	17,5kV	25kV	25kV	31kV	31kV
Burden	25VA $\cos\phi=0,8$	6,25VA $\cos\phi=0,8$	25VA $\cos\phi=0,8$	6,25VA $\cos\phi=0,8$	25VA $\cos\phi=0,8$	6,25VA $\cos\phi=0,8$
Ratio Accuracy limit	$\pm 0,5\%$	$\pm 0,5\%$	$\pm 0,5\%$	$\pm 0,5\%$	$\pm 0,5\%$	$\pm 0,5\%$
Phase Accuracy limit	$\pm 20'$	$\pm 20'$	$\pm 20'$	$\pm 20'$	$\pm 20'$	$\pm 20'$

- The winding is designed to respect accuracy class 3P between 1,25kV and 31kV according to IEC 61869-3 and between 25VA (100% burden) and 6,25VA(25%burden). Limits are according IEC 61869-3.

This point is tested on every TVM/38-E before shipping as routine test (see attachment [3]).

Voltage	1,25kV	1,25kV	25kV	25kV	37,5kV	37,5kV
Burden	25VA $\cos\phi=0,8$	6,25VA $\cos\phi=0,8$	25VA $\cos\phi=0,8$	6,25VA $\cos\phi=0,8$	25VA $\cos\phi=0,8$	6,25VA $\cos\phi=0,8$
Ratio Accuracy limit	$\pm 3\%$	$\pm 3\%$	$\pm 3\%$	$\pm 3\%$	$\pm 3\%$	$\pm 3\%$
Phase Accuracy limit	$\pm 120'$	$\pm 120'$	$\pm 120'$	$\pm 120'$	$\pm 120'$	$\pm 120'$

- Verification that there is no core saturation at the maximum overvoltage of 38.750V ( $U_{max3}$  according to EN 50163). The design of TVM/38-E is always with very low induction.

This point is type tested going up at 38,75kV and checking the accuracy when the voltage goes back to 25kV. See type test attachment [4].

- Sizing of copper wires of primary and secondary winding for the continuous thermal current at 31kV and for the current at 1,5 Vn (37,5kV) for 30 seconds. Current density is below 2 A/mm<sup>2</sup>.

This point is type tested with temperature rise test (see attachment [5]). The total consumption power is about 50W considering Joule power in the copper and power loss in the magnetic core. Considering the thermal condition, the final temperature rise is about 10°C. Therefore, if the air temperature is 20°C the voltage transformer will be at 30°C. The design and type test is according IEC 60044-2:2002 and IEC 61869-3:2011. Also at the maximum environment temperature of 70°C the VT would work at about 80°C.

- Verification of copper size for withstanding short circuit current for 1 second. Current density is below 160 A/mm<sup>2</sup>.

This point is type tested with secondary output short-circuited and primary input energized at 25kV according to IEC 61869-3. (see attachment [6]).



### 3.2 Design for environment requirements

The insulation class is B for maximum operating temperature 130°C according to IEC 61869-1. Considering the maximum air temperature of +70°C, the maximum temperature variation is 60°C. Current density is below 2 A/mm<sup>2</sup>, so the maximum temperature variation at 31kV continuously is about 10°C. Therefore, the maximum temperature variation is within the limits according to IEC 61869-1 and IEC 61869-3.

The degree protection is IP67:

- The Glenair connector is IP68
- All other electrical equipment are casted under vacuum in silicone with no possibility of water penetration.

IP67 is type tested in two times:

- IPx7 for the water
- IP6x for the dust

In both cases, the TVM/38-E passed the tests.

### 3.3 Insulation coordination design according to EN50124

Standard EN 50163 define the following voltages for the overhead line

Lowest non-permanent voltage (max 2 minutes)	Lowest permanent voltage	Nominal voltage	Highest permanent voltage	Highest non-permanent voltage (max 5 minutes)	Highest long term overvoltage (max 20ms)
<b>Umin2</b>	<b>Umin1</b>	<b>Un</b>	<b>Umax1</b>	<b>Umax2</b>	<b>Umax3</b>
17.500V	19.000V	25.000V	27.500V	29.000V	38.750V

Therefore

$$U_{nm} = U_{max1} = 27,5kV$$

Unm is the nominal insulation voltage

The requirements are for overvoltage category OV4:

Unm =27,5kV For rolling stock	OV4	<b>Uni = 170kV</b> Rated lightning impulse voltage (1,2/50µs)
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Therefore the minimum clearance is defined by EN 50124 as:

Uni = 170kV	PD4 Pollution degree	<b>310mm</b> Minimum clearance
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Creepage distance is deefined as

Materiale classe II	PD4	30mm/kV To be calculated considering Unm	<b>825mm</b> Minimum creepage distance
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Insulation coordination is :

clearance	370mm > 310mm
creepage	900mm > 825mm

Therefore, the TVM/38-E insulation coordination is compliant to EN 50124.

The insulation is type tested as wet test at 70kV for 60 seconds under rain (see attachment [7]).

Moreover, the insulation is type tested with impulse voltage of 170kV 1,2/50µs with 15 positive impulses and 15 negative impulses (see attachment [8]).

The insulation is routine tested on every piece at 70kV for 60 seconds (see attachment [3]).

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### 3.4 Secondary terminals insulation

Secondary terminals are designed and tested to be insulated at 3kVrms according to IEC61869-3 and IEC 60044-2. The insulation is routine tested on every piece at 3kV for 60 seconds (see attachment [3]).

The secondary terminal is a reverse bayonet connector according to MIL standard. The connector is tested and certified by the manufacturer Glenair at 3,5kVrms.

### 3.5 Short circuit withstand and fault protection

The design and type test is according standard IEC 60044-2:2002 and IEC 61869-3:2011 (see attachment [6]).

The calculated short circuit current at the secondary is about 69Arms (duration 1 second)

The primary and secondary winding wires are sized to resist to this current for 1 second without problem.

### 3.6 Fire and smoke EN 45545-2

All materials used are according EN 45545-2 standard. All data and analysis are included in the attached document [1] EN45545\_assessment report\_TVM38E\_rev1.

### 3.7 Explosion proof

TVM/38-E is designed as explosion proof. Explosion proof is according to IEC 61869-3 as special test "internal arc fault test". Since VM/38-E is fully casted in silicone without resins during the arc silicone works as a fuse limiting the explosion and containing all hard materials. If some parts of silicone are thrown away by the explosion they are soft and they cannot cause any damage.

Type test was performed in Siemens laboratory according to IEC 61869-3 and to IEC 60099-4:2014. The test is performed according to voltage transformer standards and surge arrester standard because surge arrester standard are more strict in the evaluation of results (see attachment [11]).

Moreover, TVM/38-E is designed for anti-ferroresonance execution:

- Very low magnetic induction
- Temperature rise test at 27,5kV at 16,67Hz (which corresponds to temperature rise test at 82,5kV at 50Hz). The temperature rise is about 14°C.

At 50 Hz the ferroresonance is a well known phenomena which bring voltage transformers to work in saturation so the current is very high and the temperature increase very much. When the temperature is too high the internal insulation is lost and the voltage transformer is damaged. In the worst case the voltage transformer can explode.

TVM/38-E is designed so as to never have ferroresonance damages.

Type test was performed at 27,5kV at 16,67Hz with very low temperature rise (see attachment [9]).

Another point on explosion are scratches on the wires which bring to loss of insulation, so internal short-circuit and damages and, in some cases, explosion. Resin as insulator is hard and can scratch wires during operation and during fast temperature change because of different coefficient of thermal expansion of materials.

TVM/38-E is silicone insulated which does not scratch any material: this decrease a lot risks of damages and explosion during operation.

### 3.8 MTBF and design life

MTBF calculation is reported in the attached document [2].

MTBF value is 322958h, which corresponds to about 37years operation between failures.

Therefore, the design life is at least 35 years.

### 3.9 Working at 3kVdc

For multi-voltage train there are equipment for 3kVdc and equipment for 25kVac. The voltage transformer is between the pantograph and the main circuit breaker. If for some reason the voltage transformer TVM/38-E is under the 3kV, the voltage protection of the train will lower the pantographs, but for a while the voltage transformer will work under 3kVdc.

TVM/38-E is type tested to work at 3kVdc for 2 minutes (see attachment [10]). Of course the output is 0V, but TVM/38-E can withstand 3kV for 2 minutes without any damage. The test is conducted as temperature rise test. After 2 minutes the TVM/38-E has a temperature increase of about 40°C.

### 3.10 Monkey Bites

Our silicone is characterized by a hardness >50 Shore, which is superior compared to the commonly used silicone for insulators, bushings, transformers...

Up to now, with several hundreds of our TVM/38-E circulating in India and several thousands in the world, we have never faced any issue concerning monkey bites on our silicone.

The silicone supplier informed us that also in all other applications for which he's selling the same silicone to other customers, he never received any feedback concerning animal bites.

## 4. ATTACHMENTS

ITEM	Description	File name
[1]	Fire smoke EN 45545-2 assessment	01_EN45545_assessment report_TVM38E_rev1.pdf
[2]	MTBF and FMECA assessment	02_MTBF-FMECA-TVM38E-DI8286_R0.pdf
[3]	Routine test plan	03_RTP-TVM38E-DI8286_r0.pdf
[4]	Type test at 38,7kV Umax3	04_18007_Overvoltage type test.pdf
[5]	Temperature rise type test	05_TVM38-E_8442_20130704_TEMPERATURE RISE TYPE TEST.pdf
[6]	Short circuit type test	06_TVM38-E_13-0514-04_20130719_SHORT TIME CURRENT TYPE TEST.pdf
[7]	Wet test 70kV x 60s	07_TVM 38-E_13-0514-05_20170719_WET TEST.pdf
[8]	Impulse voltage test 170kV 1,2/50µs	08_TVM38-E_9546_20140618_LIGHTNING TYPE TEST.pdf
[9]	Temperature rise type test for anti-ferroresonance : 27,5kV 16,67Hz	09_TVM-38-E-RP10564_FERRORESONANCE.pdf
[10]	Temperature rise test at 3kVdc	10_17572_TVM38-E_3000Vdc_TypeTest.pdf
[11]	Explosion test	11_TVM38-E_RP LS 17-188A_20171012_INTERNAL ARC TEST COMP 40 kA.pdf