MODEL TES-DE-VXX
VIBRATING WIRE DISPLACEMENT SENSOR
1. Introduction

The TRITECH model TES-DE-VXX linear displacement transducer incorporates a vibrating wire sensor. It converts mechanical displacement to an electrical frequency output. This frequency output can be read or logged by TRITECH model TES-DI-51V remote digital readout unit or TRITECH model TES-DAS-10 data acquisition system.

The model TES-DE-VXX vibrating wire displacement transducer is used in geotechnical and structural engineering applications where either it is difficult to take direct mechanical readings due to inaccessibility or online data needs to be logged at a remote location. Some uses are:

- to monitor rock mass or concrete displacement in single or multipoint borehole extensometers.
- to monitor soil displacement in soil extensometers.
- to monitor surface cracks in structures and rock mass (use TRITECH model TES-DJ-40V vibrating wire crack/joint meter).
- to monitor two or three axis displacement in joints of mass concrete (for uniaxial displacement use TRITECH model TES-DJ-50V vibrating wire joint meter).

Vibrating wire displacement sensors have an advantage over conventional transducers like LVDT as the former gives frequency, rather than a voltage, as output signal. The frequency signal can be transmitted over long distances without any change in value caused by variations in cable resistance which can arise from water penetration, temperature fluctuations, contact resistance or leakage to ground.

This factor, coupled with excellent zero stability and rugged design makes the model TES-DE-VXX displacement transducer preferable for long-term measurements in adverse environments.

1.1. Types manufactured

TRITECH manufactures vibrating wire displacement sensors in three configurations:

- TES-DE-VXX-WP: This is a water proof version and can withstand a water pressure upto 1 MPa equivalent to 100 m of water column. It finds applications in areas exposed to water pressure.
- TES-DE-VXX-RC: This has a cable coming out centrally from the back. It is for splash proof applications but will withstand a water pressure of 0.2 MPa. It is mostly used in applications like borehole extensometers and soil extensometers.
- TES-DE-VXX-SC: It has M6 threads centrally on both ends of the sensor and so has a cable coming out eccentrically from the back. The sensor is suitable for applications up to a water pressure up to 0.4 MPa. It is mostly used in crack meters and biaxial/ triaxial joint meters.

1.2. Conventions used in this manual

WARNING! Warning messages calls attention to a procedure or practice, that if not properly followed could possibly cause personal injury.

CAUTION: Caution messages calls attention to a procedure or practice, that if not properly followed may result in loss of data or damage to equipment.

NOTE: Note contains important information and is set off from regular text to draw the users’ attention.

1.3. How to use this manual

The users’ manual is intended to provide sufficient information for making optimum use of vibrating wire displacement sensors for different applications.

To make the manual more useful we invite valuable comments and suggestions regarding any additions
or enhancements. We also request to please let us know of any errors that are found while going through this manual.

**NOTE:** Installation personnel must have a background of good installation practices and knowledge of the fundamentals of geotechnics. Novices may find it very difficult to carry on the installation work. The intricacies involved in installation are such that even if a single essential but apparently minor requirement is ignored or overlooked, the most reliable of instruments will be rendered useless.

A lot of effort has gone in preparing this instruction manual. However the best of instruction manuals cannot provide for each and every condition in the field, which may affect performance of the instrument. Also, blindly following the instruction manual will not guarantee success. Sometimes, depending upon field conditions, the installation personnel will have to consciously depart from the written text and use their knowledge and common sense to find the solution to a particular problem.

**NOTE:** This sensor is normally used to monitor site conditions and will record any change, even though minor that may affect behaviour of the structure being monitored. Some of these factors amongst others, are, seasonal weather changes, temperature, rain, barometric pressure, earthquakes, nearby landslides, traffic, construction activity around site including blasting, tides near sea coasts, fill levels, excavation, sequence of construction and changes in personnel etc. These factors must always be observed and recorded as they help in correlating data later on and also may give an early warning of potential danger or problems.

The manual is divided into a number of sections, each section containing a specific type of information. The list given below tells you where to look for in this manual if you need some specific information. It is however recommended that you read the manual from the beginning to the end to get a thorough grasp of the subject. You will find a lot of unexpected information in the sections you feel you may skip.

*For description of vibrating wire displacement sensor manufactured by TRITECH:* See § 2 “Vibrating wire displacement sensor”.

*For test certificate:* See § 3 “Sample test certificate”.

*For installation:* See § 4 “Checking of sensor and installation”.

*For installation of crack/joint meter:* See § 4.5.1 “Checking of sensor and installation”.

*For temperature effect:* See § 5 “Thermistor - temperature resistance correlation”.

*For trouble shooting:* See § 6 “Trouble shooting”.

*For Warranty:* See § 7 “Warranty”.
2. Vibrating wire displacement sensor

2.1. Operating principle

Vibrating wire displacement sensor basically consists of a magnetic, high tensile strength stretched wire, one end of which is anchored and other end fixed to a shaft through a precision coil spring that deflects in some proportion to displacement. Any change in position of shaft, deflects the spring proportionally and this in turn affects tension in the stretched wire. Thus any change in displacement, directly affects tension in the wire and thus frequency of vibration.

The wire is plucked by a coil magnet. Proportionate to tension in wire, it resonates at a frequency ‘f’, which can be determined as follows:

\[ f = \left(\frac{\sigma g}{\rho}\right)^{1/2}/2l \text{ Hz} \]

where
- \(\sigma\) = tension of wire in kg/cm²
- \(g\) = 980 cm/sec²
- \(\rho\) = density of wire in kg/cm³
- \(l\) = length of wire in cm

The length of the wire in the displacement sensor is 5.5 cm. Consequently the formula can be reduced to:

\[ f = 32 \left(\frac{\sigma}{\rho}\right)^{1/2} \text{ Hz} \]

The resonant frequency, with which the wire vibrates, induces an alternating current in the coil magnet. The displacement is proportional to square of frequency and the readout unit is able to display this directly in engineering units.

2.2. General Description

The sensor body is of stainless steel construction. It has a shaft with M6 x 10 threads at the exposed end. For monitoring displacement in any application, the shaft slides inside the sensor body with respect to the latter. The shaft should never be rotated inside the sensor body as this will damage the transducer.

**CAUTION:** Never rotate shaft inside sensor body as this will damage the transducer. The shaft end is provided with an alignment pin that sits inside an alignment slot on sensor body. Always displace shaft axially while checking or installing sensor.

Each sensor is provided with a thermistor for monitoring temperature. Normally, no correction due to temperature induced frequency changes is required. However, if it is necessary to make these corrections, refer to data on zero shift due to temperature changes provided in test report (see § 3).

The displacement sensor is manufactured in various capacities. Dimensional details of the various types of vibrating wire displacement sensors manufactured are as follows:

2.2.1. TRITECH model TES-DE-VXX-WP

![Diagram of TRITECH model TES-DE-VXX-WP](image)

**Figure 2.1** – Water proof sensor to withstand a water pressure upto 100 m of water column with M6 threads on both sides for mounting
2.2.2. **TRITECH model TES-DE-VXX-RC**

![Diagram of TES-DE-VXX-RC model](image)

**Figure 2.2** – Sensor for splash proof applications with M6 x 10 threads on shaft. In applications like borehole extensometer, the sensor body is clamped on Φ 19

2.2.3. **TRITECH model TES-DE-VXX-SC**

![Diagram of TES-DE-VXX-SC model](image)

**Figure 2.3** – Water proof sensor to withstand a water pressure upto 40 m of water column with M6 threads on both sides for mounting

<table>
<thead>
<tr>
<th>Displacement mm</th>
<th>TES-DE-VXX-WP</th>
<th>TES-DE-VXX-RC</th>
<th>TES-DE-VXX-SC</th>
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<tbody>
<tr>
<td>15</td>
<td>X</td>
<td>X</td>
<td>207</td>
</tr>
<tr>
<td>25</td>
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<tr>
<td>150</td>
<td>590</td>
<td>552</td>
<td>X</td>
</tr>
</tbody>
</table>

A photograph on the next page shows the three sensors TES-DE-VXX-WP, TES-DE-VXX-RC and TES-DE-VXX-SC, respectively from top to bottom.

2.3. **Wiring**

The sensor is provided with an integral 1 m long φ 4 mm four core PVC sheathed cable with cores in red, black, green and white. Red and black cores are for frequency signal while green and white are for temperature monitoring through a thermistor. In case specially ordered, PU sheathed cable can be provided.
2.4. Taking readings with model TES-DI-51V vibrating wire indicator/logger

Model TES-DI-51V is a microprocessor based readout unit for use with TRITECH’s range of vibrating wire sensors. It can display measured frequency in terms of time period, frequency, frequency squared or value of measured parameter directly in proper engineering units.

TES-DI-51V indicator/logger can store calibration coefficients of up to 500 vibrating wire sensors so that value of measured parameter from these transducers can be shown directly in proper engineering units.

The indicator has an internal non-volatile memory with sufficient capacity to store about 4,500 readings from any of the 500 programmed transducers in any combination. 4,500 sets of readings can be stored either from any one transducer or 9 sets stored from all 500 transducers. Each reading is stamped with date and time of taking measurement.

Calibration coefficients are given in the individual ‘Test Certificate’ provided with each transducer. Refer to model TES-DI-51V instruction manual WI-6002.26 for entering the transducer calibration coefficients. The gage factor given in the test certificate and the zero reading in frequency $^2$ (digits) at the time of installation are used for setting up the transducer coefficients in the readout unit.

For polynomial linearity correction, displacement is calculated by following equation:

$$D(\text{mm}) = A(R1)^2 + B(R1) + C - K(T1-T0) - D0$$

where
- $D$ = displacement in mm
- $R1$ = current reading in digits during observation
- $A$, $B$, $C$ = polynomial constants
- $D0$ = initial sensor reading at time at installation in mm
- $K$ = thermal factor in mm/$^\circ$C
- $T0$ = initial temperature reading at time at installation in $^\circ$C
- $T1$ = current temperature reading in $^\circ$C

The polynomial constants are stored in model TES-DI-51V memory to give linearity corrected data of the parameter in engineering units. For more details refer to instruction manual WI-6002.26 of model TES-DI-51V.

For transducers with a built-in interchangeable thermistor, the model TES-DI-51V can also display and record the temperature of the transducer directly in degree Centigrade. Any TRITECH vibrating wire sensor with the exception of the temperature sensor has a thermistor incorporated in it for temperature measurement, unless not required specifically by the customer.

The stored readings can either be uploaded to a host computer using a serial interface or can be printed out on any text printer equipped with a RS-232C serial communications interface. The set-up information
(calibration coefficients) for all the channels can also be printed out for verification.

The readout indicator/logger is powered by an internal 6 V rechargeable sealed maintenance free battery. A fully charged new battery provides nearly 60 hours of operation on a single charge. A separate battery charger is provided with the TES-DI-51V indicator to charge the internal battery from 230 V AC mains.

The TES-DI-51V indicator is housed in a splash proof resin moulded enclosure with weatherproof connectors for making connections to the vibrating wire transducer and the battery charger.
# 3. Sample test certificate

## TRITECH INSTRUMENTS PTE LTD

2 Kaki Bukit Place Tritech Building #06-00 Singapore 418180
Tel: 68492567  Fax: 68482566  Email: instruments@tritech.com.sg

### TEST CERTIFICATE

<table>
<thead>
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<th>Customer</th>
<th>Date:</th>
<th>Temperature:</th>
<th>35°C</th>
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</thead>
<tbody>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instrument</td>
<td>Vibrating wire displacement sensor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model</td>
<td>TES-DE-V05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serial number</td>
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<td></td>
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<tr>
<td>Range</td>
<td>50 mm</td>
<td></td>
<td></td>
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</tbody>
</table>

### Input Observed value

<table>
<thead>
<tr>
<th>Displacement (mm)</th>
<th>Up1 (Digit)</th>
<th>Down (Digit)</th>
<th>Up2 (Digit)</th>
<th>Average (Digit)</th>
<th>End Point (mm)</th>
<th>Poly (mm)</th>
</tr>
</thead>
<tbody>
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<td>2353.8</td>
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<td>40.02</td>
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<td>8040.2</td>
<td>8039.0</td>
<td>8040</td>
<td>50.00</td>
<td>49.99</td>
</tr>
</tbody>
</table>

### Error (%FS) 0.20  0.03

- **Digit** $f \times 10^{-3}$
- **Linear gage factor (G)** 8.801E-03 mm/digit
- **Thermal factor (K)** -0.004 mm/deg C
- **Polynomial constants**
  - $A=1.1735E-08$
  - $B=8.6780E-03$
  - $C=-2.0532E+01$

Displacement "D" is calculated with the following equation:

- **Linear** $D(\text{mm}) = G(R1-R0) - K(T1-T0)$
- **Polynomial** $D(\text{mm}) = A(R1)^2 + B(R1) + C - K(T1-T0) - D0$
  - $R1$ = current reading & $R0$ is initial reading in digit.
  - $D0$ = Initial reading in mm

Zero reference (initial position) in the field must be established by recording the initial reading $R0$ (digit) along with temperature $T0$ (°C) just after installation.

### Note

Zero displacement reading given in above calibration chart is taken at around 3 mm from mechanical zero, i.e. slider fully in.

**Pin configuration / wiring code:**

- **Red & black:** Signal
- **Green & white:** thermistor

**Checked by**

**Tested by**
4. Checking of sensor and installation

4.1. Checking sensor before installation

The cable from the sensor is four wired 1 m long. Red and black cores are for frequency signal while green and white are for temperature monitoring through a thermistor.

Check the working of the sensor as follows:

- The coil resistance measured by the digital multimeter should lie between 130-180 Ohm. Determine resistance at the room temperature from thermistor temperature resistance chart in § 5. This resistance should be equal to that between the green and white wires. For example, in case the room temperature is 25°C, this resistance would be 3,000 Ohm.

- The resistance between any lead and the protective armour should be > 500 M Ohm.

- Connect the sensor to the TRITECH model TES-DI-51V portable readout unit and switch it on. The display will show something like:

  Freq: 2230.8 Hz

  where the actual figure will vary depending on the transducer connected to the indicator. This initial reading on the portable readout unit should be stable.

- A crude but a simple and very effective method of checking whether the displacement sensor is responding to changes in displacement is as follows:

  Shift the read-out unit display to the engineering unit mode. Using a scale, extend the displacement sensor by about 5 mm. The reading in the digital readout unit should change by around 5 mm. The change in reading ensures that the deformation produced by the displacement is transmitted to the vibrating wire sensing element.

CAUTION: The displacement sensor is a delicate and sensitive instrument. It should be handled with care. Twisting or applying too much force on the shaft with respect to the sensor body may result in a zero shift or even permanent damage. Always displace shaft axially while checking or installing sensor.

The shaft end is provided with an alignment pin that sits inside an alignment slot on sensor body. When not in use or while tightening sensor against a shaft mounting object, keep the pin engaged inside the slot to prevent any damage to the sensor by rotation of sensor against shaft body.

4.2. Lightning protection

Lightning during thunderstorms can induce short spikes of sufficiently high electrical energy in the wires connecting the vibrating wire sensor to the readout instrument that can damage the coils in the sensor assembly. Some measure of lightning protection for the vibrating wire sensor is recommended if the sensor is mounted in the field or in open areas and connected to the readout instrument through long wires. However, these protection schemes will not protect the sensor against direct or near direct lightning strikes. Lightning protection is generally not required if the connecting wire is very short, say only a few meters in length, or both the sensor and the vibrating wire indicator is used inside a shielded structure, e.g. a building.

The TES-DE-VXX vibrating wire strain gage is not available with any integral lightning protection component. If lightning protection is desired one of the following options may be used:

- Surge arrestors like Gas Discharge Tubes (GDT) or TransZorbs® (registered trademark of General Semiconductor Industries) may be fixed to the sensor cable as near to the sensor as possible and epoxy potted in place. The ground conductor would have to be connected to an earthing stake or the steel structure itself.
If the vibrating wire displacement sensor is mounted close to a junction box or a multiplexer, the surge arrestor component can be mounted in the junction box or the multiplexer box itself. TRITECH can provide junction boxes and multiplexers with lightning protection installed as an option (specify while ordering).

Lightning arrestor boards and enclosures are available from TRITECH, which can be installed at the exit point of the structure being monitored. Consult the factory for additional information on these or alternate lightning protection schemes.

4.3. General precautions in cable installation

Unless otherwise specified, each sensor is provided with 1 m cable attached. Cable may be extended without affecting sensor reading or its long term performance. Always ensure a waterproof joint of appropriate strength.

The procedure for laying of cables differs with individual installations. The cable should be routed in such a way so as to minimize the possibility of damage due to moving equipment, debris or other causes. In general:

- Protect cable from damage by angular and sharp particles of material in which it is embedded.
- In earth/rock embankments and backfill, cable must be protected from stretching due to differential compaction of embankment. Cable must also be protected from damage by compaction equipment.

The single most important factor leading to loss of worthwhile data from sensors is losing track of identification of cable ends. Proper identification and marking of the cables is generally taken most casually. Care should be taken to put an identification tag at the point where the cable comes out of the structure such that cable identity is not lost if the cable gets cut or damaged. Route the cable properly to the location where readings have to be taken, taking care that it is suitably protected. Gage and lead wires must be protected from mechanical damage and from water.

Take care to keep cables as far away as possible from sources of electrical interference such as power lines, welding equipment, motors, generators and transformers etc. To avoid picking up noise, cables should never be buried or run along with AC power lines as this will cause problems in obtaining stable data.

4.4. Initial reading

Always carefully record initial displacement reading along with temperature at time of installation to serve as a reference for determining subsequent deformation.

4.5. Installation

4.2.1 For using vibrating wire displacement sensor in borehole extensometer, refer to instruction manual doc. # WI 6002.79 model TES-DS-70V borehole extensometer system (bhe) with vibrating wire sensors.

4.2.2 For using vibrating wire displacement sensor in soil extensometer, refer to method statement MS 0407 TES-DS- 92 soil extensometer.

4.2.3 For using vibrating wire displacement sensor for monitoring of cracks or joint openings on the surface, refer to figures in § 4.5.1.
4.5.1. **TRITECH model TES-DJ-40V vibrating wire crack/joint meter**

Displacement sensor for Crack meter

![Diagram of TRITECH model TES-DJ-40V vibrating wire crack/joint meter](image)

**Figure 4.1** – Crack/joint meter mounting details

<table>
<thead>
<tr>
<th>Range mm</th>
<th>L mm</th>
<th>A mm (half open position)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>207</td>
<td>~ 255</td>
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<tr>
<td>25</td>
<td>222</td>
<td>~ 275</td>
</tr>
<tr>
<td>50</td>
<td>292</td>
<td>~ 357</td>
</tr>
</tbody>
</table>
5. Thermistor - temperature resistance correlation

Thermistor type: Dale 1C3001-B3

Temperature resistance equation

\[ T = \frac{1}{[A + B(LnR) + C(LnR)^3]} - 273.2 \, ^\circ C \]

where

- \( T \) = temperature in \(^\circ C\)
- \( LnR \) = Natural log of thermistor resistance
- \( A = 1.4051 \times 10^{-3} \)
- \( B = 2.369 \times 10^{-4} \)
- \( C = 1.019 \times 10^{-7} \) Ohm

<table>
<thead>
<tr>
<th>Ohm</th>
<th>Temp. (^\circ C)</th>
<th>Ohm</th>
<th>Temp. (^\circ C)</th>
<th>Ohm</th>
<th>Temp. (^\circ C)</th>
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5.1. Measurement of temperature

Thermistor for temperature measurement is incorporated in each displacement sensor. The thermistor gives a varying resistance output related to the temperature (see § 5). The thermistor is connected
between the green and white leads. The resistance can be measured with an Ohm meter. The cable resistance may be subtracted from the Ohm meter reading to get the correct thermistor resistance. However the effect is small and is usually ignored.

The TRITECH model TES-DI-51V read-out unit gives the temperature from the thermistor reading directly in engineering units.

5.2. Temperature correction

Each vibrating wire displacement sensor is relatively insensitive to temperature variations within certain limits and often the effect of temperature can be ignored. However in case a ‘displacement - temperature variation’ correlation is required, correction for the temperature effect on the sensor can be made by making use of the temperature zero shift factor (K) provided in the test certificate (see § 2.5) and substituting it in the following equation:

\[ d_{\text{correction}} = (\text{current temperature} - \text{initial temperature}) \times K \]

The temperature correction value is subtracted from the displacement reading from the TES-DI-51V read-out.
6. Trouble shooting

The displacement sensor is installed during construction of the structure. Once installed, the cell is usually inaccessible and remedial action is limited. Maintenance and trouble shooting is consequently confined to periodic checks of cable connection and functioning of the read-out unit. Refer to the following list of problems and possible solutions should problems arise. For any additional help, consult the factory.

6.1. Symptom: displacement sensor reading unstable

- Check the insulation resistance. The resistance between any lead and the protective armour should be > 500 M Ohm. If not, cut a meter or so from the end of cable and check again.
- Does the read-out work with another displacement sensor? If not, the read-out may have a low battery or be malfunctioning. Consult the manual of the readout unit for charging or trouble shooting instructions.
- Use another read-out unit to take the reading.
- Check if there is a source of electrical noise nearby. General sources of electrical noise are motors, generators, transformers, arc welders and antennas. If so the problem could be reduced by shielding from the electrical noise.

6.2. Symptom: displacement sensor fails to read

- The cable may be cut or crushed. Check the nominal resistance between the two gage leads using an Ohm meter. It should be within 130 - 180 Ohm. The correct value is given in the test certificate. Please add the cable resistance when checking. If the resistance reads infinite or a very high value, a cut in the cable is suspected. If the resistance reads very low (<100 Ohm), a short in the cable is likely.
- Does the read-out work with another displacement sensor? If not, the read-out may have a low battery or be malfunctioning. Consult the manual of the readout unit for charging or trouble shooting instructions.
- Use another read-out unit to take the reading.
7. Warranty

The Company warrants its products against defective workmanship or material for a period of 12 months from date of receipt or 13 months from date of dispatch from the factory, whichever is earlier. The warranty is however void in case the product shows evidence of being tampered with or shows evidence of damage due to excessive heat, moisture, corrosion, vibration or improper use, application, specifications or other operating conditions not in control of TRITECH. The warranty is limited to free repair/replacement of the product/parts with manufacturing defects only and does not cover products/parts worn out due to normal wear and tear or damaged due to mishandling or improper installation. This includes fuses and batteries.

If any of the products does not function or functions improperly, it should be returned freight prepaid to the factory for our evaluation. In case it is found defective, it will be replaced/repai red free of cost.

A range of technical/scientific instruments are manufactured by TRITECH, the improper use of which is potentially dangerous. Only qualified personnel should install or use the instruments. Installation personnel must have a background of good installation practices as intricacies involved in installation are such that even if a single essential but apparently minor requirement is ignored or overlooked, the most reliable of instruments will be rendered useless.

The warranty is limited to as stated herein. TRITECH is not responsible for any consequential damages experienced by the user. There are no other warranties, expressed or implied, including but not limited to the implied warranties of merchantability and of fitness for a particular purpose. TRITECH is not responsible for any direct, indirect, incidental, special or consequential damage or loss caused to other equipment or people that the purchaser may experience as a result of installation or use of the product. The buyer’s sole remedy for any breach of this agreement or any warranty by TRITECH shall not exceed the purchase price paid by the purchaser to TRITECH. Under no circumstances will TRITECH reimburse the claimant for loss incurred in removing and/or reinstalling equipment.

A lot of effort has been made and precaution for accuracy taken in preparing instruction manuals and software. However best of instruction manuals and software cannot provide for each and every condition in field that may affect performance of the product. TRITECH neither assumes responsibility for any omissions or errors that may appear nor assumes liability for any damage or loss that results from use of TRITECH products in accordance with the information contained in the manuals or software.

Products described in TRITECH’s catalogs are subject to modification and improvement as dictated by subsequent developments. TRITECH reserves the right to modify, change or improve products, to discontinue them or to add new ones without notice.
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