

Reactors



TRENCH

Reactors

Introduction

With 40 years of successful field experience, Trench is the recognized world leader in the design and manufacture of air core, dry type, power reactors for all utility and industrial applications. The unique, custom design approach, along with fully integrated engineering and manufacturing facilities in both North America and Europe have enabled Trench to become the technical leader for high voltage inductors worldwide.

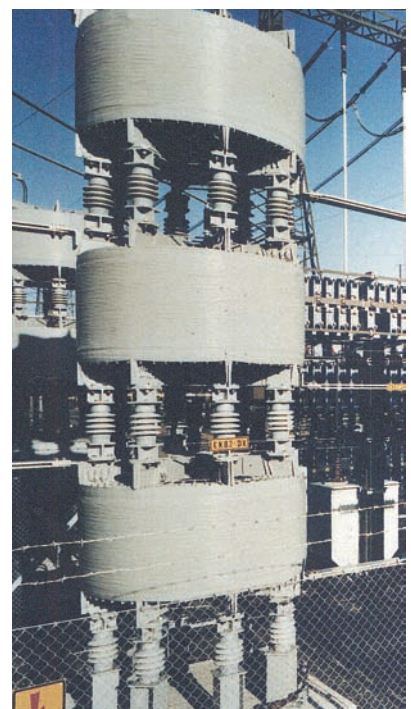
A deep commitment to the power industry, along with extensive investment in engineering, manufacturing and test capability give Trench customers the utmost in high quality, reliable products which are individually designed for each application. Trench reactor applications have grown from small, distribution class, current limiting reactors to complex EHV applied reactors surpassing 300 MVA per coil. Trench Management systems is certified to ISO 9001, ISO 14001 and OHSAS18001. Trench's highly developed research and development program constantly addresses new technologies and their potential application in reactor products. Trench welcomes challenges for new applications for power reactors.

This brochure outlines the features, capabilities and applications of Trench reactors. Although air-core, dry type reactors

represent the majority of reactor production volume, Trench also produces a highly successful line of iron core/iron shielded and oil type reactors for specific application (eg. Resonance Grounding/Petersen Coils). These reactors are also described in detail in other sections of the Trench product catalogue.

Design Features of Air-Core Dry Type Reactors

- Epoxy impregnated, fibreglass encapsulated construction
- Aluminum construction throughout with all current carrying connections welded
- Highest mechanical and short circuit strength
- Essentially zero radial voltage stress, with uniformly graded axial voltage distribution between terminals
- Low noise levels are maintained throughout the life of the reactor
- Weatherproof construction, with minimum maintenance requirements
- Design service life in excess of 30 years
- Designs available in compliance with ANSI/IEEE, IEC and other major standards.



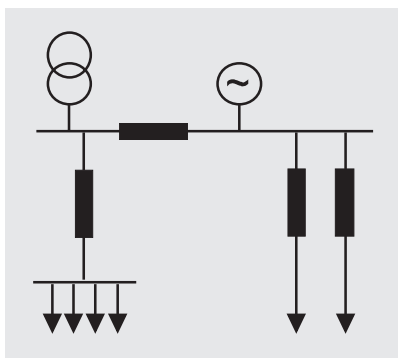
*Fig. 1
Three-phase stacked
current limiting reactor*

Reactor Applications

Trench reactors are utilized on transmission and distribution systems. Although it is not possible to list all reactor applications, some of the most common are described below.

Series Reactors

Reactors connected in series with the line or feeder. Typical uses are fault current reduction, load balancing in parallel circuits, limiting inrush currents of capacitor banks, etc.



*Fig. 2
Schematic diagram*

Current Limiting Reactors, reduce the short circuit current to levels within the rating of the equipment on the load side of the reactor.

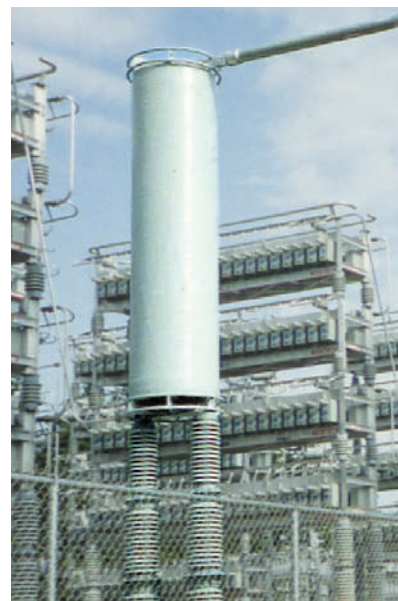
Applications of current limiting reactors range from the simple distribution feeder reactor to large bus-tie and load balancing reactors on systems rated up to 765 kV/ 2100 kV BIL.

Capacitor Reactors are designed to be installed in series with a shunt connected capacitor bank to limit inrush currents due to switching, to limit outrush currents due to close in faults and to control the resonant frequency of the system due to the addition of the capacitor banks. Reactors can be installed on system voltages through 765 kV/2100 kV BIL.

When specifying capacitor reactors, the requested continuous current rating should account for harmonic current content, tolerance on capacitors and allowable system overvoltage.



*Fig. 3
Single phase series reactors*



*Fig. 4
Current limiting reactor*

Buffer Reactors for Electric Arc Furnaces (EAF).

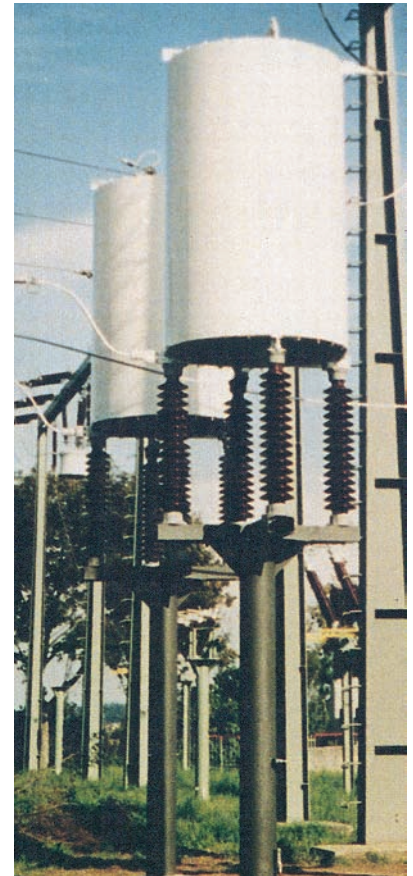
The most effective use of EAFs is achieved by operating the furnace at low electrode current and long arc length. This requires the use of a series reactor in the supply system of the arc furnace transformer for stabilizing the arc.

Duplex Reactors are current limiting reactors which consist of two half coils, wound in opposition. These reactors provide a desirable low reactance under normal conditions and a high reactance under fault conditions.

Load Flow Control Reactors are series connected on transmission lines up to 800 kV. The reactors change the line impedance characteristic such that load flow can be controlled, thus ensuring maximum power transfer over adjacent transmission lines.



*Fig. 5
Buffer reactor
for E.A.F.*



*Fig. 6
Load flow control reactors*

Filter Reactors

Filter Reactors are used in conjunction with capacitor banks to form series tuned harmonic filter circuits, or in conjunction with capacitor banks and resistors to form broad-band harmonic filter circuits.

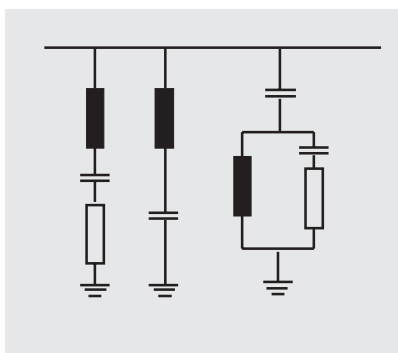


Fig. 7
Schematic diagram

When specifying filter reactors, the magnitudes of fundamental and harmonic frequency current should be indicated. If inductance adjustment for fine tuning is required, the required tapping range and tolerances must be specified.

Many filter applications require a Q-factor which is very much lower than the natural Q of the reactor. This is often achieved by connecting a resistor in the circuit. An economical alternative is the addition of a de Q'ing ring structure on a reactor. This can reduce the Q-factor of the reactor at tuning frequency up to as much as one tenth without the necessity of installing additional damping resistors. (see Fig. 9 below)

These rings, mounted on the reactor are simply coupled to the magnetic



Fig. 8
Filter reactors

The Capacitor/Filter Protection Relay CPR 04 is a microprocessor based protection relay specially designed for optimized protection of shunt banks and harmonic filter circuits.



Fig. 10
Capacitor/filter protection relay



Fig. 9
Filter reactors with
de Q'ing rings

Static VAR Compensators are used on transmission systems to improve the overall reliability, correct for voltage fluctuations and power factor as well as increasing the transmission capability and reducing losses.

Shunt Reactors

Shunt Reactors are used to compensate for capacitive VARs generated by lightly loaded transmission lines or underground cables. They are normally connected to the transformer tertiary winding but can also be directly connected on systems up to 115 kV.

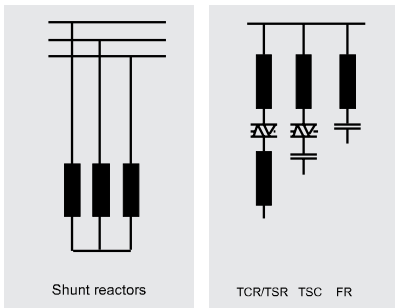


Fig. 11
Schematic diagram

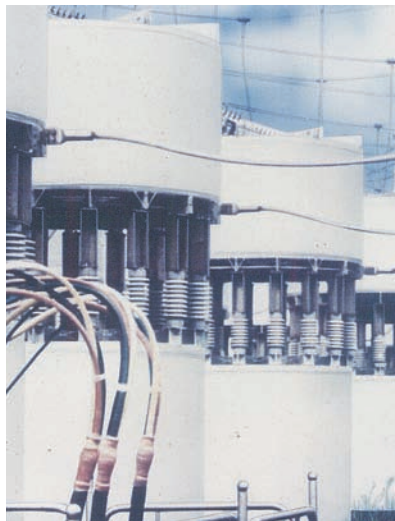


Fig. 12
Tertiary connected shunt reactors

Thyristor Controlled Shunt Reactors are extensively used in static VAR systems, where reactive VARs are adjusted by thyristor circuits. Static VAR compensator reactor applications normally include:

- Thyristor controlled shunt reactors (TCR). The compensating power is changed by controlling the current through the reactor by means of the thyristor valves.
- Thyristor switched reactors (TSR)
- Thyristor switched capacitor reactors (TSC)
- Filter reactors (FR)

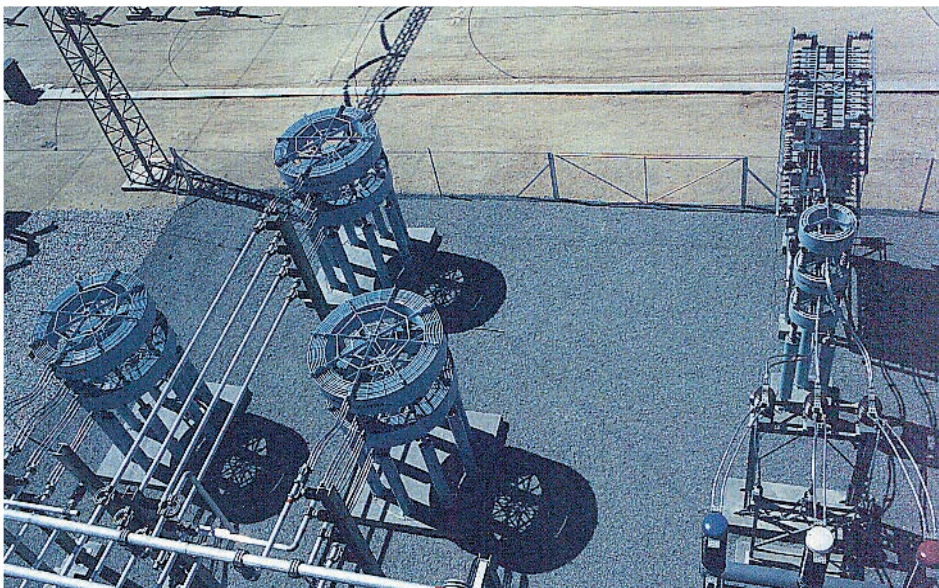


Fig. 13
Thyristor controlled shunt reactors and filter reactors in a Static VAR Compensator

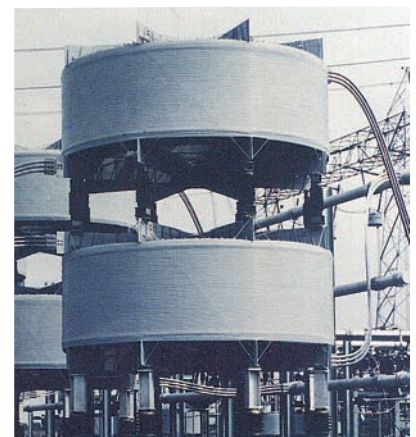


Fig. 14
Thyristor controlled reactor

HVDC-Reactors

HVDC lines are used for long distance bulk power transmission

as well as back-to-back inter-connections between different transmission networks. HVDC Reactors normally include

Smoothing Reactors, AC and DC Harmonic Filter Reactors as well as AC and DC PLC Noise Filter Reactors.

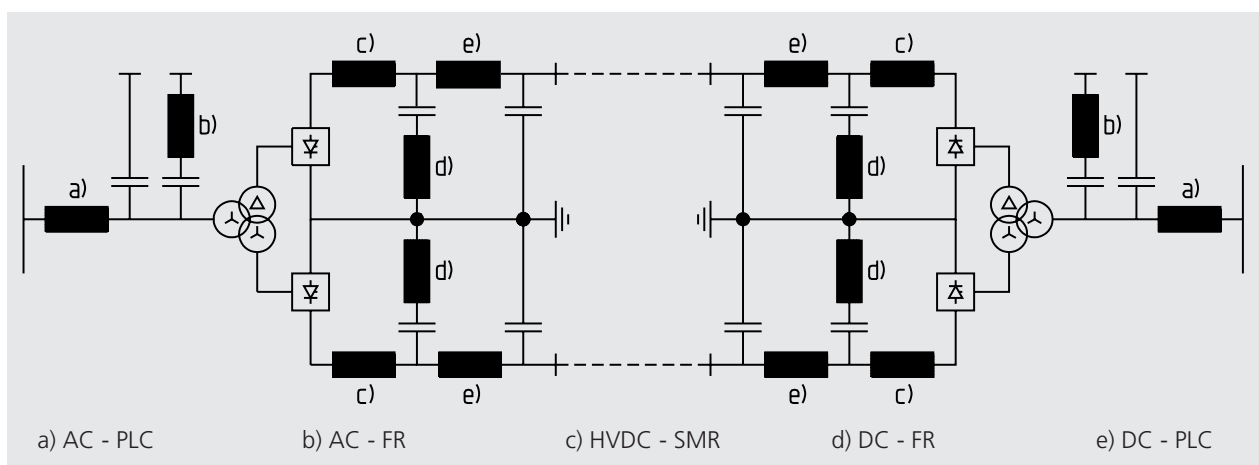


Fig. 15
Schematic diagram



Fig. 16
AC-Filters



Fig. 17
HVDC-Smoothing reactor

Smoothing Reactors

Smoothing reactors are used to reduce the magnitude of the ripple current in a DC system. They are used in power electronics applications such as variable speed drives and UPS systems. They are also required on HVDC transmission lines for system voltages up to 500 kV.

Several design and construction techniques are offered by Trench.

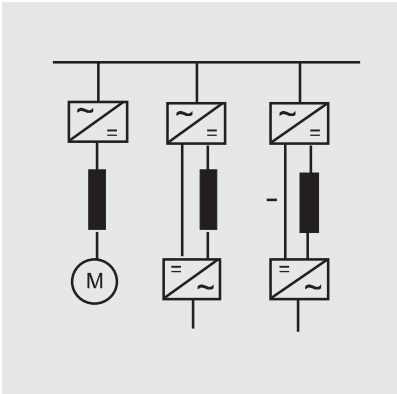


Fig. 18
Schematic diagram

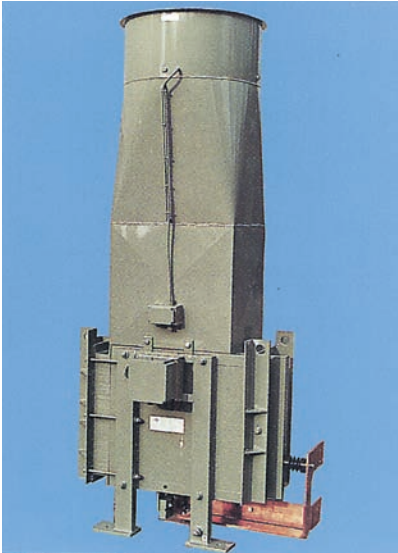


Fig. 19
Iron core,
forced air cooled reactor

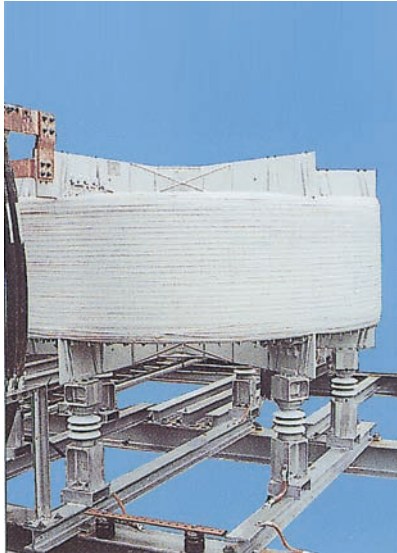


Fig. 20
Air core,
encapsulated winding design

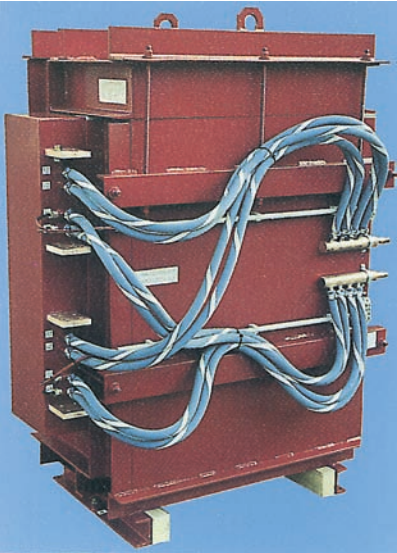


Fig. 21
Iron core,
water cooled reactor

Test Lab Reactors

Test Lab Reactors are installed in high voltage and high power test laboratories. Some typical applications include current limiting, synthetic testing of circuit breakers, inductive energy storage, artificial lines, etc.

Fig. 22
Schematic diagram

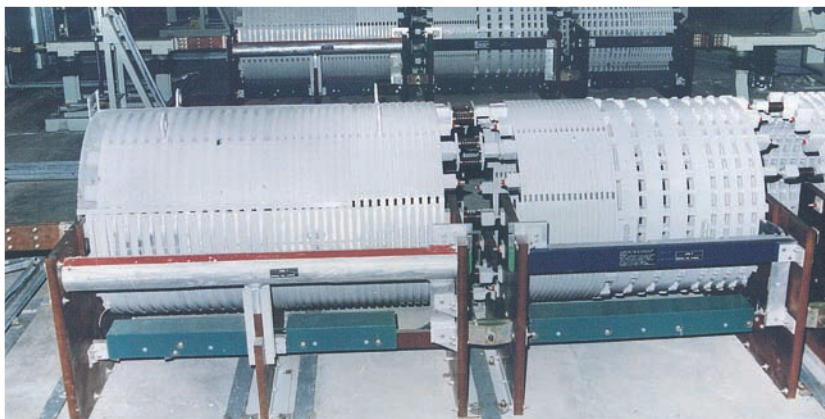
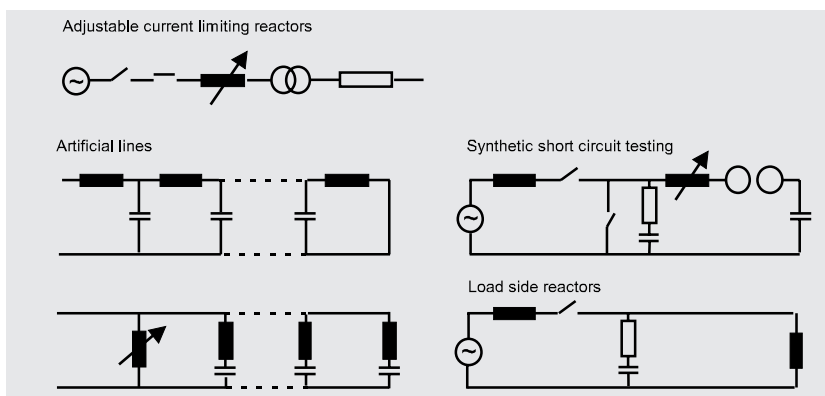
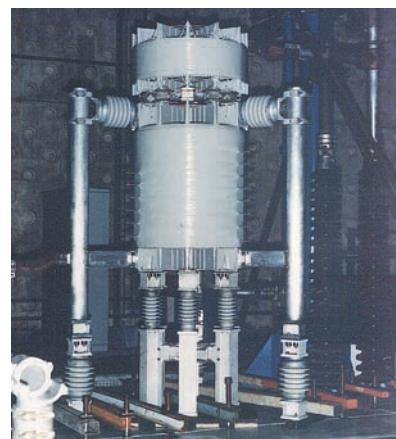


Fig. 24
Adjustable
current limiting reactor

Fig. 23
Reactor bank for the
voltage circuit for synthetic testing
of circuit breakers;
32 kA peak to peak,
0,318 mH to 353,6 mH,
up to 1600 kV BIL

Fig. 25
Short circuit
test reactor



Neutral Grounding Reactors

Neutral Grounding Reactors limit the line to ground fault current to specified levels. Specification should also include unbalanced condition continuous current and duration.

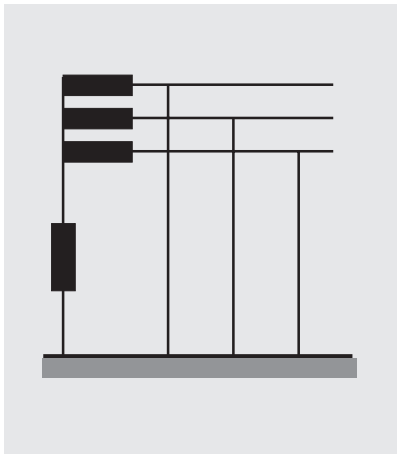


Fig. 26
Schematic diagram

Arc Suppression Coils

Single-phase neutral grounding (earthing) reactors (arc suppression coils) are intended to compensate for the capacitive line-to-ground current during a single phase ground-fault.

The arc suppression coil (ASC) represents the central element of the Trench earth fault protection system.

Since the electric system is subject to changes, the inductance of the ASC used for neutral earthing must be variable.



Fig. 27
Arc suppression coil 110 kV

The earth fault detection system developed by Trench utilizes the plunger core coil (moveable core design). Based on extensive experience in design, construction and application of ASCs, Trench products can meet the most stringent requirements for earth fault compensating techniques.



Fig. 28
Standard arc suppression coil

Construction

A Trench air core dry type reactor consists of a number of parallel connected, individually insulated, aluminum (copper on request) conductors. These conductors can be small wire or proprietary cables custom designed and manufactured.

The size and type of conductor used in each reactor is dependant on the reactor specification. The various styles and sizes of conductors available ensure optimum performance at the most economical cost. The windings are mechanically reinforced with epoxy resin impregnated fibreglass, which after a carefully defined oven cure cycle produces an encapsulated coil. A network of horizontal and vertical fibreglass ties coupled with the encapsulation minimizes vibration in the reactor and achieves the highest available mechanical strength.

The windings are terminated at each end to a set of aluminum bars called a spider. This construction results in a very rigid unit capable of withstanding the stresses developed under the most severe short circuit conditions.

Exceptionally high levels of terminal pull, tensile strength, wind loading and seismic withstand can be accommodated with the reactor. See Fig. 29 for details on construction.

This unique design can be installed in all types of climates and environments and still offer optimum performance.

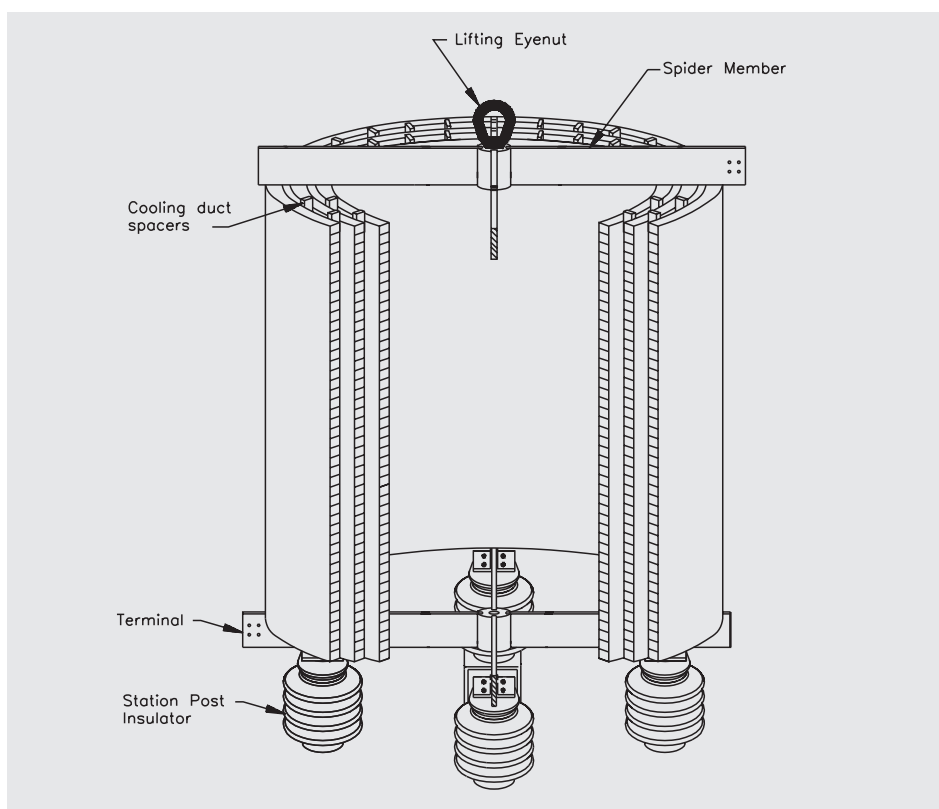


Fig. 29
Typical Trench air core dry type reactor construction

Trench air core dry type reactors are installed in polluted and corrosive areas supplying trouble free operation. In addition to the standard fixed reactance type of coil, units can be supplied with taps for variable inductance. A number of methods are available to vary inductance for fine tuning or to provide a range of larger inductance steps.

Trench utilizes various other designs for reactors (eg. iron core, water cooled, etc.) which are described in other sections of this catalogue.

Terminals/ Magnetic Clearance

Terminals

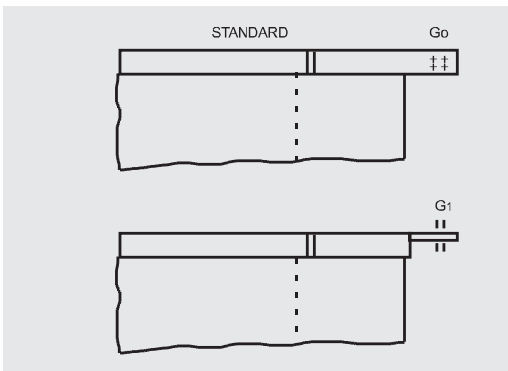


Fig. 30
Terminal orientation

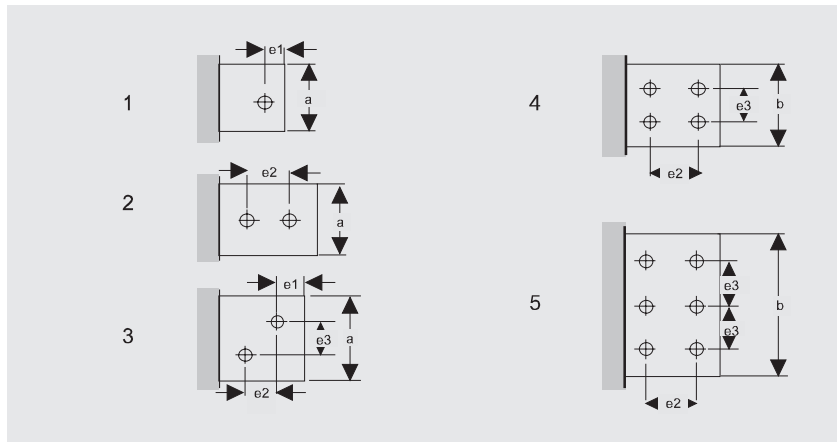


Fig. 31
Terminal details

Magnetic Clearance

Minimum clearances to metallic parts, and between coils, must be maintained as indicated by Figs. 32 and 33. The values shown are only guidelines. Each specific reactor design will specify magnetic clearance requirements.

It is the customer's responsibility to consider these minimum clearances, especially if steel reinforcing in concrete foundations or floors, or structural steel is involved in the building or station design. It is important, even outside these minimum magnetic clearances, to avoid closed electrical loops with metallic parts.

If required, non-magnetic extension brackets can be supplied by Trench to maintain the necessary magnetic clearance below the reactor. Trench can provide additional details on space requirements and recommended reinforcing steel (rebar) design, if requested.

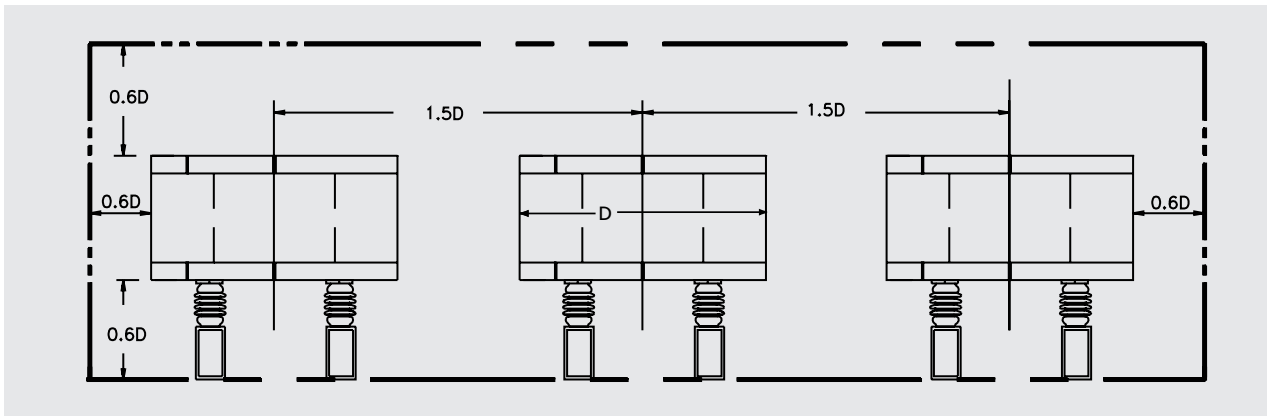


Fig. 32
Minimum magnetic clearance to other reactors and metallic parts
not forming closed loops (approximate values only)

Installation

Generally, air core, dry type reactors can be installed in either side by side or vertically stacked configurations and are often added to existing substations or locations where space limitations exist. With its highly developed computer design expertise, Trench can design reactors with optimized dimensions, to suit limited space requirements. The multi-spider construction allows flexibility in terminal location, which minimizes connection problems (see Fig. 35).

Number of spider arms to be obtained from the actual quotation design.

Installation assembly is minimal and typically requires only that brackets and insulators be bolted to the main coil. Installation instructions are provided with each reactor order.

Trench takes into consideration all aspects of the reactor installation. These include requirements of ventilation, reactor supports, connections and busbar arrangements.

Trench can also provide detailed information regarding:

- magnetic field distribution analysis for mounting pads and foundations, grounding grids, fences and adjacent structures
- Force calculations on adjacent coil installations, bus and cable connections

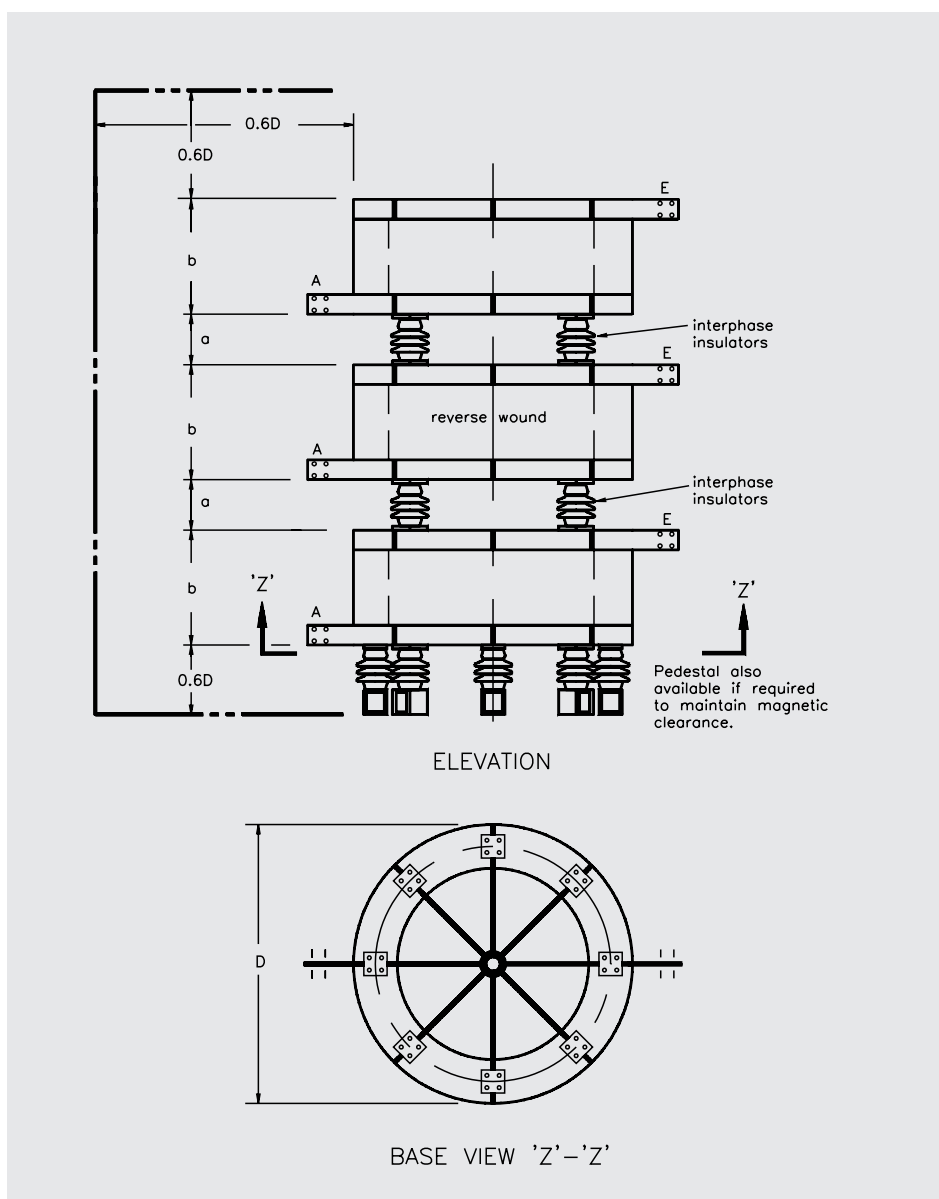


Fig. 33
Three-phase
stacked arrangement

- Seismic analysis on entire reactor assemblies, including support insulators and mounting pedestals, when furnished.

Testing/ Losses



*Fig. 34
High voltage test laboratory*

Testing

At Trench each reactor manufactured is subjected to a rigorous test and inspection program. In addition to the routine testing required by ANSI/IEEE or IEC a number of in-process tests are performed on each unit during production to ensure maximum in-service reliability. Each reactor is supplied with a certified test report with the results from all tests performed.

In addition to routine testing we have the capability in our High Voltage and Power labs to perform most of the design tests described in the applicable standards. Design tests can be performed at an additional cost or test reports on similar units can be supplied upon request.

The materials used in the manufacture of the reactor are also subject to a strict test program. Cooling duct spacers and the fibreglass epoxy resin composite encapsulation are subject to routine mechanical strength and tracking resistance testing. Accelerated thermal and multifactor aging studies are carried out which help to verify performance of the reactor components over their full service life.

This testing coupled with our Quality Assurance program enables us to ensure the continuous performance of our reactors throughout the design service life.

Losses

The custom design approach used by Trench allows optimum use of materials to control reactor losses. If a loss evaluation is not indicated in the specification, the reactor will be designed to meet the applicable standards at a most economical initial cost.

All customers are aware of the advantages in minimizing system losses and are applying loss evaluation techniques for reactor purchases. In the cases where loss evaluations are included in the reactor specifications, Trench optimizes the initial cost of the reactor plus the cost of operating losses, to ensure the most economical balance. Generally, a loss optimized reactor will operate at a lower temperature rise and will thus extend the reactor overload capability.

Trench's ability to design and manufacture low loss reactors allow many electric power utilities to economically justify the replacement of older, inefficient reactor installations. The low loss reactors can usually be installed on existing mounting pads.

Losses can also be influenced for other purposes. In some applications it is important to control the Q factor (X/R ratio) of the reactor. This may be important at the fundamental frequency or at specific harmonic frequencies where additional losses are advantageous, for example capacitor switching reactors and certain filter applications.

Enclosures and Pedestals



*Fig. 35
Filter reactor with sound shield*



*Fig. 36
Filter reactor with top-hat
and pedestal*

Trench designs and manufactures enclosures and support pedestals specifically for air core, dry type reactors.

Enclosures, depending on the requirement, are made of steel or fibreglass and can be designed for indoor or outdoor installations. Trench enclosure design minimizes circulating current loops and optimizes the size by defining ventilation area and acceptable temperature rise. Enclosures have been qualified as complete assemblies by short circuit testing of the enclosed reactor.

Trench can supply support pedestals to elevate reactor live parts to a height commensurate with personnel safety standards. Pedestals also provide proper magnetic clearance below the reactor.

Various pedestal designs are available and include fibreglass, braced aluminum and non-magnetic steel designs.

Trench can recommend the most practical pedestal for each reactor application. Additional information on enclosures and pedestals is available on request.

Sound shields can be provided to reduce the reactor noise level for special applications (HVDC).

Data required with order

- Reactor application
- Indoor or outdoor installation
- System voltage, impulse insulation level (BIL)
- Rated and maximum continuous current (fundamental and harmonics)
- Short circuit current level and duration
- Rated inductance/impedance
- Mounting arrangement (side by side or vertical stack)
- Detailed accessory requirements (connectors, buswork, etc.)
- Location of installation and site conditions
- Ambient temperature range

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