



IEEE Guide for the Transportation of Transformers and Reactors Rated 10 000 kVA or Higher

STANDARDS

IEEE Power and Energy Society

Developed by the
Transformers Committee

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(Revision of IEEE Std C57.150-2012)



IEEE Guide for the Transportation of Transformers and Reactors Rated 10 000 kVA or Higher

Developed by the

Transformers Committee
of the
IEEE Power and Energy Society

Approved 21 September 2023

IEEE SA Standards Board

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Abstract: Information for reducing the risk of damage and delays during the transportation of transformers and reactors rated 10 000 kVA or higher is provided in this guide.

Keywords: IEEE C57.150™, reactors, shipping, transformers, transportation

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Introduction

This introduction is not part of IEEE Std C57.150–2023, IEEE Guide for the Transportation of Transformers and Reactors Rated 10 000 kVA or Higher.

This document is intended as a guide for the movement of power transformers and reactors via heavy-haul methods, with additional information on rigging of the equipment for loading and offloading procedures. It should be noted that the movement of a large piece of heavy equipment such as a power transformer or reactor is a demanding task that requires great care in planning and execution in order to safely and successfully move the equipment to its desired destination. Only persons or parties that are trained, skilled, and experienced with such work should plan this type of movement. Severe damage, injury, or worse can result if such moves are planned and/or executed by inexperienced or ill-equipped parties.

This document serves only as a guide for the end user to understand many of the considerations made and actions performed during the movement of power transformers and reactors via heavy haul and rigging activities. The use of this guide will provide the user with a better appreciation and understanding of the requirements and considerations for moving power transformers and reactors. Therefore, with this understanding, the user will be better able to verify the movement of transformers and reactors are properly planned and executed, thereby minimizing risks associated with potentially improper planning or execution of the work by other parties.

Continuous attention, communication, and cooperation should be maintained between all involved parties during the planning and execution of large power equipment moves in order to better ensure the success of the move.

This guide was prepared by the Power Transformers Subcommittee of the IEEE Power and Energy Society. The document is on a continuous revision cycle and is constantly being reviewed and updated. It was initially published in 2012 and was revised and republished in 2024. For information on select activities and to participate in upcoming projects, go to www.transformerscommittee.org.

Where applicable, editorial changes have been incorporated into this revision. Sentence structure and punctuation have been edited to improve clarity and conciseness. Also, editorial changes have been made to conform to the 2021 IEEE SA Standards Style Manual. Some changes have also been made to correct errors. When applicable, references to other standards have been updated. A summary of the noteworthy changes is listed in sequential order, as follows:

- a) Definitions: Added bill of lading, center of gravity, impact warning label, transloading, and IATA.
- b) Added new 3.2 Acronyms and abbreviations.
- c) Throughout the document, changed terms “insulating fluid” to “insulating liquid”, and “oil-filled” to “liquid-filled.” Also changed “LTC” to “OLTC.”
- d) Added additional text to 5.1. Added new subclauses 5.3 and 5.4.
- e) Revision to Clause 6.
- f) Replaced Incoterms 2010 with revised Incoterms 2020.
- g) Revised Figure 4 to make easier to read (no change of content).
- h) Added new Clause 10, with Figure 6 and Figure 7 (swim lanes concept).

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1. Overview

1.1 Scope

This guide provides recommendations and considerations for the transportation of transformers and reactors rated 10 000 kVA or higher. It provides information for minimizing the risk of damage and delays in the moving of transformers and reactors regarding their design, shipment preparation, transportation, heavy-[haul transport](#) ~~hauling~~, and arrival inspections.

1.2 Purpose

This guide is intended for the following purposes:-

- a) To provide a transportation methodology to [reduce](#) ~~help minimize~~ the risk of damage and delays during the movement of transformers and reactors. ~~, and~~
- b) To encourage the establishment of routine and accepted industry practices.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall equals is required to*).^{6,7}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should equals is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may equals is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can equals is able to*).

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

American Uniform Commercial Code (UCC).^{8 1-}

[ASTM D1933, Standard Specification for Nitrogen Gas as an Electrical Insulating Material.](#)⁹

⁶The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁷The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

^{8 1-} UCC documents are available from the Uniform Law Commission, The National Conference of Commissioners on Uniform State Laws (<http://www.uniformlaws.org/>)

⁹ ASTM documents are available from ASTM International (<https://www.astm.org/>)

[ASTM D3283, Standard Specification for Air as an Electrical Insulating Material.](#)

IEEE Std C57.12.10™, IEEE Standard Requirements for Liquid-Immersed Power Transformers. ^{10,11} ~~3, 4,~~

IEEE Std C57.93™, IEEE Guide for Installation and Maintenance of Oil-Immersed Power Transformers.

[IEEE Std C57.147™, IEEE Guide for Acceptance and Maintenance of Natural Ester Insulating Liquid in Transformers.](#)

IEEE Std C57.149™, Guide for Application and Interpretation of Frequency Response Analysis for Oil Immersed Transformers.

[IEEE Std C57.152™, Guide for Diagnostic Field Testing of Fluid-Filled Power Transformers, Regulators, and Reactors.](#)

IEEE Std 62™, Guide for Diagnostic Field Testing of Electric Power Apparatus—Part 1: Oil Filled Power Transformers, Regulators, and Reactors.-

IMO IA292E, Code of Safe Practice for Cargo Stowage and Securing. ¹² ~~5.~~

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¹³ [ICC documents can be obtained through ICC Publishing at: www.iccbooks.com](#)

² ~~ICC documents can be obtained through ICC Publishing, 38, Cours Albert 1^{er}, 75008 Paris, France, www.iccbooks.com~~

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.^{14 6-}

Association of American Railroads (AAR): A society that issues a manual providing guidance on tie downs and bracing for transporting dimensional loads by rail ~~[B5].~~⁷⁻

NOTE—See [B8].¹⁵

ballast: The means of maintaining the balance, stability, and height above the water level of a barge while the load weight is being redistributed due to loading, unloading, or movement of the load. Ballast is also extra mass added to one side of a rail car shipment to bring the center of gravity to the center of the rail car.-

barge crane: A heavy-lift crane installed on top of a large barge. This type of crane is useful for moving large loads, such as power transformers, from one type of vessel to another over water. Typical examples include unloading from an ocean-going vessel to a smaller vessel such as a barge.-

bill of lading: Detailed list of a shipment of goods in the form of a receipt given by the carrier.

counterweights: Large weights that can be added to balance the center of gravity of the total load more evenly if the center of gravity of the load is not in-line with the longitudinal and/or lateral center of gravity of the transport vehicle itself. Usually, this is referred to as ballast. Counterweights are used on cranes to keep them from overturning.-

^{14 6} IEEE Standards Dictionary Online ~~subscription~~ is available at: http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.ieee.org. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page. ~~html.~~

^{15 7} The numbers in brackets correspond to those of the bibliography in Annex A.

center of gravity: A point from which the weight of a body of system may be considered to act. The center of gravity is the center of mass and is not usually the centerline of the external tank.

cribbing: Temporary support materials, such as timbers or steel beams that are used to support a load at a particular elevation. *Syn:* **blocking**.

depressed-center rail car: A heavy-duty rail car that has a center deck that is lower than the heights of the decks above the wheels. This is used in order to reduce the deck height of the rail car as much as possible. [See Figure 1 for an example of a depressed-center rail car.](#)

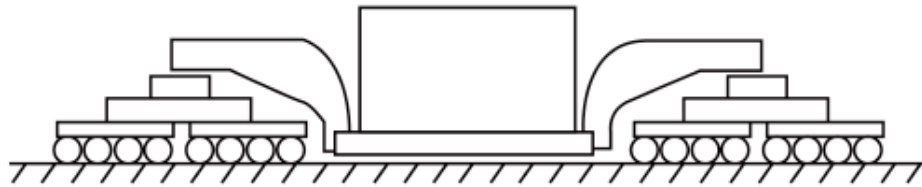


Figure 1—Example of a depressed-center rail car

dimensional load: A large piece of equipment loaded for shipment on a rail car or truck with over-dimension and/or over-weight classification.-

dissolved gas analysis (DGA): The measurement of gases dissolved in an insulating liquid.~~{B3}~~

[NOTE—See \[B5\].](#)

dolly trailer: An over-the-road transporter that consists of a series of beams that supports the load suspended from beams connected to multi-axle dollies at the front and back of the load. See Figure 2 for an example of a dolly trailer. *Syn:* **side beam trailer; side girder trailer**.

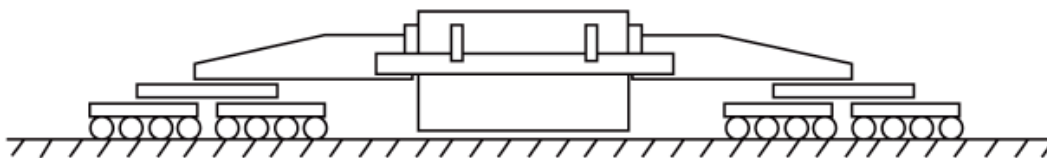


Figure 2—Example of a dolly, side beam, or side girder trailer and load

dunnage: Inexpensive or waste material used to protect and secure cargo during transportation. Dunnage also refers to material used to support loads and prop tools and materials up off of the ground such as jacks, pipes, and other supports.

footprint: The actual transformer base contact area with the supporting structure (deck, dock, or cribbing) including the locations relative to the x (major) axis and y (minor) axis.

frequency response analysis (FRA) test: A test that is performed on a transformer or reactor to help determine if any internal damage has been caused during transportation. This test is also used as an analysis tool to determine if damage has occurred from system short circuits. Test results before and after transport are compared.

gantry system: A system usually consisting of four hydraulic jacks, each pair of which is spanned by a lifting beam. A gantry system is generally used where the load is too heavy to be safely lifted using a mobile crane, or where a mobile crane cannot be used due to horizontal or vertical access restrictions.

heavy-haul transport: Transportation of dimensional loads (loads that exceed acceptable route limits for length, width, height, or weight) over roadway or land using specialized, heavy-duty multi-wheeled vehicles and associated rigging equipment.

hydraulic jack: A lifting means powered by hydraulic action. Hydraulic jacks may be used singly or with multiple jacks operated in parallel to lift the load.

idler cars: Empty rail cars in front and behind the rail car being used to carry a particular load, acting to add stability, to distribute the weight of the locomotive(s) and heavy rail cars more evenly over bridges or lighter track, to provide additional wheels for braking effort, for safety separation from the locomotive, and to better-protect the load as it is transported.

impact recorder: A device which records accelerations, g-force in the longitudinal (x axis), lateral (y axis), and vertical (Z -axis) directions. Impact recorders may have pre-set or user-settable threshold magnitude of impact registered, may measure magnitude of impact only, may measure magnitude and duration of the impact (energy) during the impact, and/or may be equipped with a global positioning system (GPS) location system. *Syn:* **shock recorder**.

impact warning labels: A device which can be used to monitor impacts occurring during transportation. In contrast to a traditional impact recorder, such a device provides a visual indication if an impact level exceeds a predefined level. A tube/cannula is used as indicator which changes the color in case such an excessive impact occurs. Such one-time-use devices are designed as stickers/labels, available for different impact levels. These can be adhered to the surface of the product to be monitored.

Incoterms®: Incoterms rules or International Commercial terms are a series of pre-defined commercial terms published by the International Chamber of Commerce (ICC) widely used in international commercial transactions.

International Air Transport Association (IATA): International trade organization concerned with aviation activities and influencing policy on critical aviation issues.

International Maritime Organization (IMO): United Nations agency concerned with safe, secure, and efficient shipping on clean oceans.

jack and slide procedure: A procedure using hydraulic jacks and cribbing materials to raise or lower a load onto a set of beams or rails on which the load is then pulled via the pulling facilities or pulled/pushed by hydraulic rams to slide or roll the load along the beams in order to locate the load in its final position. *Syn:* **jack and roll; jack and glide**.

jacking facilities: Reinforced portions of equipment tanks that are designated as points where the equipment can be lifted safely by hydraulic jacks (refer to IEEE Std C57.12.10). *Syn:* **jacking points; jacking pads**.

lifting lugs: Special connection points on equipment tanks that are designed to support the weight of the equipment (or other load) while being lifted from these points.

platform trailer: A multi-axle trailer with a flat load surface for transporting heavy loads.

prime mover: The driving equipment, such as a truck or tractor, which pulls or pushes a non-powered trailer.

pulling eyes: Special connection points that are designed to support the weight of the load while being pulled in a horizontal direction. *Syn:* **hauling eyes**.

rail siding: A portion of a rail line branching off the main line, where empty or loaded railcars can be placed to move the cargo from or to a different means of transport.

Railway Industrial Clearance Association (RICA): An association of members involved in providing rail clearance data for over-dimension and over-weight rail cargo loads.

rider/escort services: Monitoring services whereby an individual travels with or alongside the rail shipment in order to monitor movement from the point of origin to the final rail destination.

rigging: Equipment and materials such as lifting beams, slings, steel cables, shackles, etc. that are used for lifting and lowering.

Schnabel rail car: A special rail car designed to support a load from connection points on each end, making the load a structural part of the rail car. See Figure 3 for an example of a Schnabel rail car.

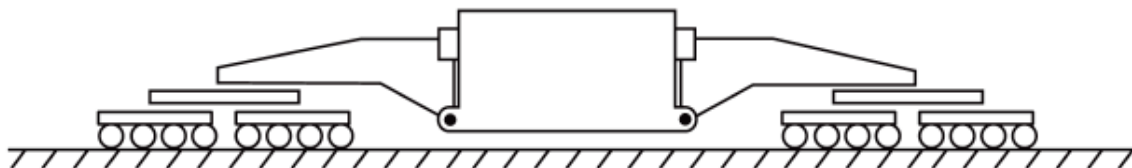


Figure 3—Example of a Schnabel rail car

self-propelled modular platform trailer (SPMT): Similar to a platform trailer, but the trailer has a built-in drive system to allow the trailer to move without a prime mover.

shallow draft barge: A barge that is designed to have a minimum depth below the water level, even when loaded.

shipping envelope drawing: A drawing or diagram which profiles the height, width, length, weights, and center of gravity of the transported equipment.

shipping mark: Notation stenciled onto the equipment main tank and accessory crates that identifies the destination of the equipment and parts, and provides identifying numbers in order to [help](#) ensure that the equipment is delivered to the proper destination.

Specialized Carriers and Rigging Association (SC&RA): An association involved in the heavy-haul transport industry.

sweep frequency response analysis (SFRA) testing: *See: frequency response analysis (FRA).*

transloading: A shipping term that refers to the transfer of goods from one mode of transportation to another en route to the ultimate destination.

3.2 Acronyms and abbreviations

CFR Cost and Freight

DDP Delivered Duty Paid

DETC De-energized Tap Changer

EXW Ex Works

FOB Free on Board

OLTC On-Load Tap Changer (also known as Load Tap Changer)

4. Request for quotation and specification

When a transformer or reactor is purchased with delivery included, the owner should include as much of the following information, when available, in the request for Quotation (RFQ) and related specifications.

- The owner should specify the types of transportation and possible shipping stresses that the equipment should be constructed to withstand. For example, the supplier may be able to deliver by truck, but the owner may want the option to ship by rail in the future, if needed.
- Site address and whether the site is a new or existing station.
- Availability of the foundation on delivery.
- Site conditions such as access to the foundation, offload point, and turning radius should be identified and the condition and capacity of roadways, bridges, and the owner's cranes taken into consideration. If the delivery point has complicated transportation conditions, consider requiring a site visit/inspection with the supplier prior to award. Seasonal, weekly, or daily restrictions should be identified.
- Coordination requirements of the delivery of parts and insulating liquid to the sites.
- Site contact information.
- Shipment preparation requirements, such as the installation of [small](#) FRA test [bushing](#) [\(also known as "sparkplug bushings"\)](#) for performance of pre- and post-shipment testing with the equipment in the shipping configuration, protection of installed accessories, provision of impact recorders, wrap or other protective covering to protect from transportation dirt or damage, and other transport quality or monitoring efforts.
- In transit tracking requirements, schedule, insurance coverage requirements, and special monitoring requirements during shipment.

- Any intended inspection points should be clearly identified. Multi-segment transport inspection/_hold points at each point of delivery should be considered rather than waiting for arrival at the final destination. However, it should also be kept in mind that the respective carriers/handlers may impose restrictions on access to the unit that could affect such intended inspections/tests.

The supplier is typically better able to manage shipment, delivery issues, and claims. Therefore, shipment is commonly specified for nearest rail site, destination, or pad. The supplier's proposal for transportation methods, routing, and restrictions should be reviewed by the owner for acceptance prior to actual shipment. Transportation terms and definitions can be found in ICC [732 560](#) or Incoterms® [2020 2010](#).

5. Design considerations for transport

5.1 New transformers and reactors

The design and shipping details of new transformers and reactors should be addressed during the design phase and prior to manufacture to address all aspects of transport from factory to final pad. The equipment should be designed to allow transportation, lifting, and moving by all modes and methods that the owner specifies. All anticipated modes of transportation should be analyzed.

All external components, such as valves, gauges, pipes, cabinets, or other devices should be protected from damage during all stages of transportation, lifting, and moving. This can be accomplished by locating the devices where they are not the highest or widest points on the unit in its shipping configuration, or with protective covers or shields. Restrictions in the angle of slings, use of spreader beams for lifting, etc. should be identified. The length, width, height, and location of devices on the transformer, such as control cabinets, can limit the choices in railcars or heavy trailers, as well as the available overland routes. The supplier should consider the available options when designing larger transformers or reactors or when shipping to sites with restricted access.

The transformer active part should be designed to withstand mechanical forces during transport and moving. The design of the active part and active part anchoring system should consider the shear, tensile and compressive forces on these dielectric materials and ensure that they should withstand the designed shipping force limits without damage.

Essential information such as dimensional profile, mass, center of gravity, location of jacking facilities, blocking areas, lift hooks, and hauling eyes should be documented on the transportation outline drawing provided by the equipment supplier. The adequacy of all lifting, jacking, and pulling facilities should be verified by the supplier by calculation or testing. The center of gravity for transporting the transformer, both empty and filled with insulating liquid ~~fluid~~, should clearly be marked on the drawings. If the owner requires the transformer to be moved fully or partially assembled, and/or fully or partially liquid-filled, this should be specified in the RFQ, and the supplier should ensure that no assembled components will interfere with, or be damaged by, rigging during lifting, jacking, or pulling operations.-

In the case where the supplier's responsibility ends at any point before final placement on the foundation or pad, the task of coordinating the technical and commercial details from the point of delivery and transfer of ownership to pad rests with the owner. In a like manner, this should be addressed during the design phase and prior to manufacture. Technical details such as choice of the transport vehicle, equipment design to suit the vehicle, transport routing, shipping profile limitations, weight limitations, lifting, jacking, hauling eyes, and special tie down requirements may become constraints for the supplier's design and should be incorporated into the original design, and clearly indicated on the manufacturer's drawings. Details such as weight limitations for jacking and lifting points should be denoted on the manufacturer's drawings. The transport segment from port to pad will require documentation in the form of dimensioned shipping drawings and loading instructions in order for the freight company to plan the logistics for the move and to secure necessary permits.

Equipment may also be required by individual specification to be fully assembled on a temporary foundation and then moved in the fully assembled state to the final location.

5.2 Existing transformers and reactors

In the case where the transformer or reactor owner wishes to relocate existing equipment, there are several details that need to be considered, including but not limited to the following:

- Rail clearances, routing, and rail cars used at the time of original shipment may no longer be valid or available.
- Equipment originally shipped by road transport and now requiring rail transport may not have been designed to sustain rail shipping forces. In this case, asking the original supplier's assistance would be prudent.
- Design changes and additions made by the owner may result in the equipment exceeding the original shipping profile and may require design solutions before the move can be made.
- If the equipment is to be moved without completely draining the insulating liquid or disassembling the unit to its original shipping configuration, the owner should determine whether or not the unit was designed to be moved in that condition or whether the unit can withstand the stresses of a move in that configuration. The owner should also ensure that any such move meets all applicable environmental requirements.

If the move is within the substation, and the plan is to move the fully assembled transformer or reactor, be aware that the stresses from impacts and accelerations may damage internal components such as connections to bushings and external components suspended from the transformer such as radiators, piping, conservators, and arresters. There is a risk that excessive mechanical stresses during the move will develop into new insulating liquid leaks in the equipment at tank weld joints, piping, and coolers. These may appear during or after the move.

Any such move should be planned with qualified and experienced heavy haulers using updated available documentation and equipment drawings. A good source of information is the documentation provided by the supplier at the time of the original shipment, including but not limited to nameplate, outline drawings, shipping drawings, and the instruction manual. Photos and installation records are also useful. The original drawings will normally show the components that were removed for shipment and list the shipping and assembled weights. The people responsible for the move should check to ascertain whether the equipment may have had temporary internal bracing designed to secure internal parts during shipping only. These types of temporary bracing should have been removed before energization and may no longer be available or in a suitable condition to be re-installed. If this is the case, the original supplier should be consulted on the need for the bracing with the proposed new shipping modes or to supply replacement braces or drawings for the braces. Check the drawings or instruction manual for this information and for how to store temporary shipping items for possible later use. If there is a lack of information or a concern about some aspects of the move, the original supplier should be consulted for assistance.

5.3 Internal Bracing

Core form and shell form transformer designs each have unique forces at work during normal operation. Each manufacturer may employ different techniques to support the internal assembly, but a manufacturer may decide that additional internal bracing is needed during transportation. In some designs this bracing will not interfere with the normal operation of the transformer and will remain in the transformer during normal operation. However, in some instances this bracing could interfere with the dielectric performance of the transformer during normal operation. It is recommended to avoid temporary internal bracing if possible. Temporary internal bracing is not preferred due to the risk of not removing internal bracing prior to final operation, or not properly installing all temporary bracing during future transportation preparation.

If a manufacturer uses temporary internal bracing that has to be removed before operating the transformer, the presence and locations of such bracing should be clearly indicated on the shipping drawings and instructions should be provided that describe the correct removal and potential future reinstallation of such bracing.

~~6. Transportation preparation~~

5.4 Main transformer or reactor tank

5.4.1 General

The owner and/or supplier may decide, according to the dimensions of the equipment, the form of transport, the installation site, etc., and whether to dismantle the conservator, radiators, and bushings from the transformer or reactor for shipment.

The equipment supplier should provide a transportation outline/dimension drawing or diagram showing the equipment footprint, the three axes for the center of gravity as shipped, and the height, length, and width centerlines of the equipment. In some cases, a redesign of the base of the equipment to decrease the amount of load spreading needed to stow the cargo on any particular transportation deck could be beneficial. Any increase in the length and the width combined with a reduction in the height of the equipment will help reduce the center of gravity. When this is not possible due to transportation profiles such as rail and tunnels, consideration should be given to providing a cradle/trestle/support that has been approved for all planned modes of transportation.

All accessories that are removed for shipping should be carefully packed to protect them from damage during shipping. Electronic components should be protected from rain or other ambient conditions. Pipes, radiators, and other parts that are normally liquid-filled should be sealed to maintain cleanliness and dryness inside. Accessories may or may not be shipped on the same vehicle as the equipment.

The transportation drawing should include, at a minimum, the following:

- Shipping dimensions.
- Shipping weight with clarification as to [liquid](#) ~~oil~~-filled or empty.
- Jacking facilities identified.
- Areas where blocking can be located

- Center of gravity for shipping (liquid ~~oil~~-filled or empty).
- A clear means of identifying the physical centerline of the equipment (for loading on the center of the transporter).
- Locations of lifting points along with any restrictions including sling angle, need for spreader(s), restriction on lifting the fully assembled unit, or lifting the unit with bushings installed, etc.
- Restrictions on tilt.
- Areas where slide/roll/glide systems can be installed in two axis.
- Attachment points for securing the transformer to each of the specific modes of transport to be used (ship, road, rail).
- Components that should be removed for movement or shipment.

5.4.2 How changes in ambient temperature affect transformer pressure

Typically, large transformers and reactors are shipped without insulating liquid and are normally filled with nitrogen or breathable dry air and should be shipped with a temporary regulated supply system attached to the transformer or reactor tank during transportation and storage. The reason for using a temporary regulated supply is because changes in ambient temperatures can impact the internal pressure of the transformers and reactors.

According to Amonton's law, if the volume of a gas is held constant, increasing the temperature of the gas increases its pressure. Equation (1) is valid when temperatures are in the Kelvin scale (T_K):

$$\begin{aligned} \text{Temperatures}_K &= \text{Temperatures}_C + 273.15 \\ \frac{P_1}{P_2} &= \frac{T_1}{T_2} \end{aligned} \tag{1}$$

(New)