Howard Industries, Inc.
Substation Transformer Division

Catalog Section
34-10

Medium Power Substation Transformers

INTRODUCTION

Howard medium power substation transformers are designed and built according to the most exacting engineering standards to provide many years of outstanding performance and reliability in the most demanding utility, industrial, and commercial applications.

All designs incorporate the latest advances in materials, design techniques, and power transformer technology verified with 2D and 3D analysis software. Howard's Substation Division has staffed its operations with well-trained engineers, winders, assemblers, and testers, with many years of experience in the development, design, and manufacture of medium and large power transformers.

Howard's Substation Transformer Division also offers nationwide delivery and the option of complete job-site services, including unloading, inspection, assembly, fluid filling, and testing. Field supervision is available for customer-installed jobs.

PRODUCT SCOPE AND APPLICATIONS

Howard Industries currently manufactures fluid-filled medium power substation transformers with capacities through 60 MVA (ONAN) and primary voltage ratings through 230 kV at 900 kV BIL.
An extensive range of features and accessories are available, including de-energized tap changers, on-load tap changers, forced-air cooling systems, fluid preservations systems, and many other options to satisfy the special requirements of virtually any application.

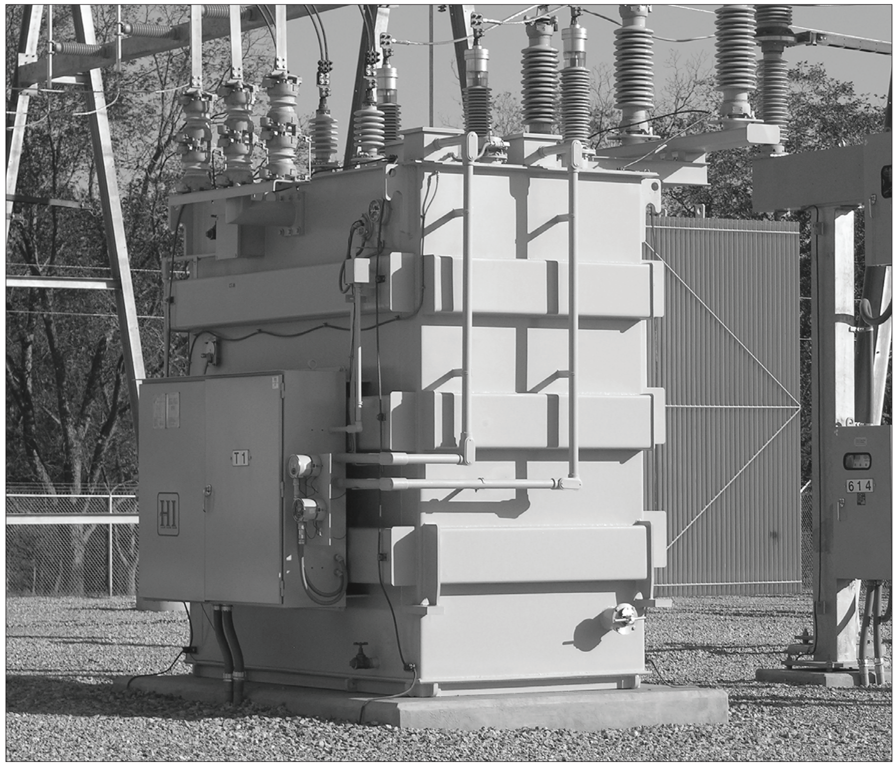

Figure 1: Medium power substation transformer with forced air cooling

Howard medium power substation transformers are suitable for a wide range of demanding applications, including utility substations, wind generation sites, chemical plants, oil and gas processing facilities, mining operations, paper mills, steel mills, water treatment plants, office and shopping centers, internet server facilities, and many other uses.

Figure 2: Howard Industries Substation Plant, Ellisville, MS

MANUFACTURING FACILITIES

Howard's new 355,000 square foot substation manufacturing facility (Figure 2) was custom designed and built specifically for the production of medium power transformers. Every aspect of the facility's design and construction was carefully considered to maximize its manufacturing capabilities and provide the flexibility needed to satisfy ever-changing customer requirements. The facility's air handling systems maintain a clean, positive-pressure environment throughout, with temperature and humidity controlled conditions maintained in the insulation staging and winding room. All floor surfaces are sealed to help control airborne contamination. Tank fabrication, insulation cutting, fluid storage and

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Laurel, MS 39440
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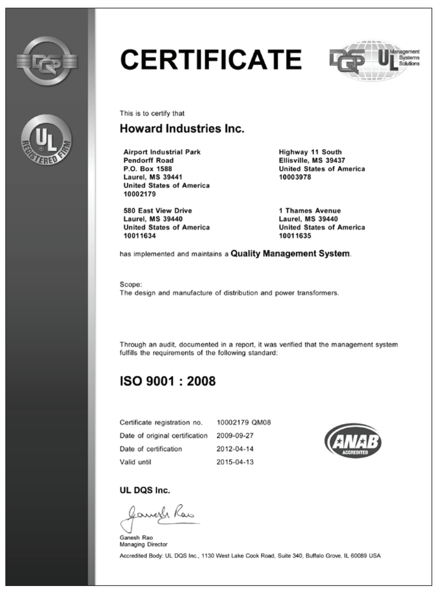
processing, and other potential sources of contamination are isolated from the main facility. Heavy-capacity, high-lift gantry cranes can travel the entire length of the manufacturing area and beyond to the covered truck and rail loading bay.

Production processes use the latest available technologies to enhance quality and efficiency. Computer-controlled coil sizing, vapor-phase coil drying, computer-controlled core lamination cutting (Georg) and state-of-the-art electrical test systems are just a few examples of leading-edge technologies that contribute to process precision and repeatability.

QUALITY

Howard employees understand the importance of quality, particularly as it relates to the critical nature of substation transformers. Emphasis on quality begins at design and follows throughout the manufacturing and delivery processes. Only the highest quality components and materials are used in Howard transformers. Attention to detail and thorough inspection and testing ensure that a high level of quality is maintained. Continuous process improvement is an integral part of our design and manufacturing goals.

The Substation Transformer Division's quality management system is designed to ensure that all of the company's products and services meet or exceed its customers' requirements and is certified as being compliant with ISO-9001:2008 (Figure 3). The ISO-9001 standard covers design, manufacturing, and servicing systems, and is the most stringent and comprehensive standard in the internationally recognized ISO-9000 series of quality standards. This certification is audited every six months with full re-certification occurring every three years.



CERTIFICATE

This is to certify that

Howard Industries Inc.

Airport Industrial Park
Pendorff Road
P.O. Box 1588
Laurel, MS 39441
United States of America
10002179

Highway 11 South
Ellisville, MS 39437
United States of America
10003978

580 East View Drive
Laurel, MS 39440
United States of America
10011634

1 Thames Avenue
Laurel, MS 39440
United States of America
10011635

has implemented and maintains a **Quality Management System**.

Scope:
The design and manufacture of distribution and power transformers.

Through an audit, documented in a report, it was verified that the management system fulfills the requirements of the following standard:

ISO 9001 : 2008

Certificate registration no.	10002179 QM08
Date of original certification	2009-09-27
Date of certification	2012-04-14
Valid until	2015-04-13

UL DQS Inc.

Ganesh Rao
Managing Director

Accredited Body: UL DQS Inc., 1130 West Lake Cook Road, Suite 340, Buffalo Grove, IL 60089 USA

Figure 3: ISO-9001 Certificate

DESIGN AND MANUFACTURING PROCESSES

TRANSFORMER DESIGN
Howard's design philosophy employs technology in ways that provide a cost-competitive transformer built with conservative design margins, a thorough verification of designs using the latest computer analysis tools, and automation of the design process to reduce cycle time and eliminate human error.

Our experienced mechanical designers employ the latest available computer-based design tools, such as parametric 3D computer-aided design systems (Figure 4) for both internal and external layouts. The Anderson 2D finite element analysis program, the Ansoft Maxwell 2D electrostatic and magnostatic field analysis program, 3D ALGORE mechanical analysis program, and others are used in the determination of electrical and mechanical design margins.

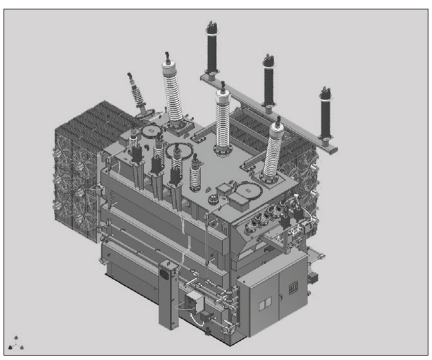


Figure 4: Image of 3D CAD model

The design verification process includes:

- Validation of transient voltage response
- Validation of short-circuit strength
- Analysis of eddy losses and hotspot calculations
- Validation of insulation design
- Verification of loading beyond nameplate capacity
- In-rush current analysis
- Over-voltage analysis

Howard substation transformers are designed with conservative mechanical and electrical margins to withstand the harsh environments encountered in today's power delivery systems. Exceptional short-circuit and impulse strengths are hallmarks of the Howard design. All transformer designs are optimized to satisfy our customers' total cost of ownership requirements.

General industry standards applicable to Howard substation transformer designs include IEEE C57.12.00 (Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers), IEEE C57.12.90 (Standard Test Code for Liquid-Immersed Distribution, Power and Regulating Transformers and Guide for Short Circuit Testing of Distribution and Power Transformers), IEEE C57.93 (Guide for Installation of Liquid-Immersed Power Transformers), IEEE C57.98 (Guide for Transformer Impulse Tests), and IEEE C57.100 (Standard Test Procedure for Thermal Evaluation of Oil Immersed Distribution Transformers).

MAGNETIC CIRCUIT
Howard medium power substation transformers employ core-type construction and are designed with an optimized cruciform configuration with step-lap joints to provide excellent mechanical strength and magnetic performance. Core designs use regular grain-oriented steels

Figure 5: Georg core cutter

which have been precision slit to width and stress-relieved by our supplier. Core laminations are precisely cut to length and mitered on a computer-controlled Georg cutting line (Figure 5).

Core laminations are carefully stacked on precision hydraulic lift tables to prevent misalignment when up-righting (Figure 6).

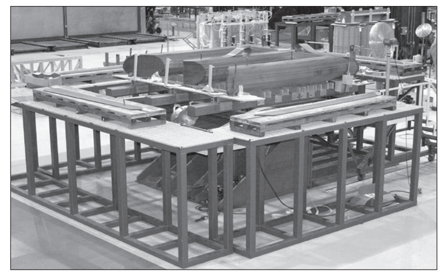


Figure 6: Core Stacking Table

Cores are securely banded and clamped with tie plates to ensure stability and minimize stress on the core. Core support blocks (Figure 7)

Figure 7: Core support blocks

and cooling ducts are used to provide uniform pressure across the lamination surface. The top and bottom core clamps are held together by steel lock plates configured to contain mechanical short-circuit forces and modified as necessary for leakage flux to limit excessive hot spots.

ELECTRICAL CIRCUIT

Windings are cylindrical construction, with concentric windings separated by axial oil ducts (Figure 8).

Figure 8: Coil winding

The type of winding used depends on the voltage rating. Low-voltage windings are helical type, medium-voltage windings are continuous disc type, and high-voltage windings are shielded disc. Conductor material is C11000 grade copper, tough pitch cast, with ASTM edge radius, and custom tempered per design requirements. The conductor is insulated with thermally upgraded crepe paper tape, wrapped in multiple layers. Rectangular conductor or continuously-transposed cable (CTC) is used according to design requirements.

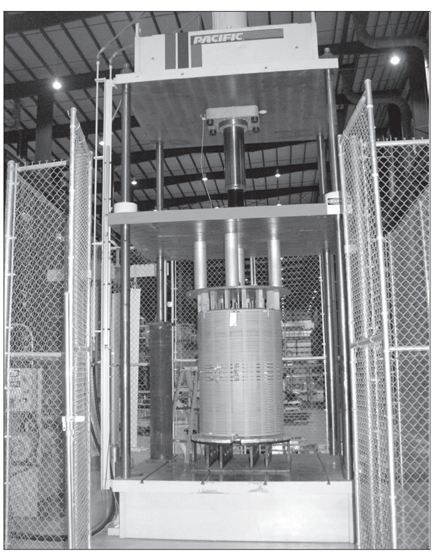


Figure 9: Coil sizing press

Finished coils are oven dried and accurately sized in a computer-controlled hydraulic press (Figure 9). Coil sizing establishes the coil's electrical length at a specified pressure. Sizing pressure is determined by design engineering, and is sufficient to contain axial short-circuit forces that would be generated during throughfault conditions.

ASSEMBLY

After the coil sizing process is completed, core and coils are assembled together in a heavy-duty clamping structure that produces a rugged, stable assembly, yet minimizes mechanical stress in the core (Figure 10).

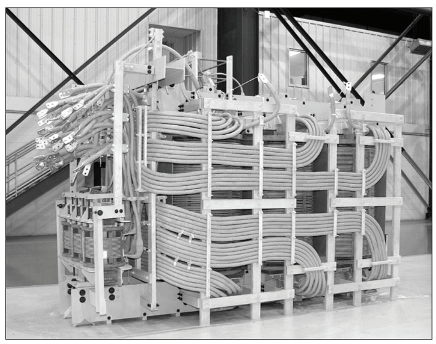


Figure 10: Core coil unit

High-density laminated pressure rings transmit uniform clamping pressure to each coil. The lead structure is designed to provide generous dielectric clearance and to resist the lead forces generated by system faults. Leads are secured using either pressboard or kiln-dried maple braces.

COIL DRYING

Core and coils are dried and oil impregnated in a Micafil automated vapor-phase system (Figure 11). Proper dryness is critical to maintain the integrity and life of the insulation system. The Micafil process automatically monitors and controls moisture extraction in an oxygen-free environment, producing an extremely dry insulation system. During the final phase of the Micafil process, the

Figure 11: Micafil vapor phase system

drying chamber is flooded with transformer oil to impregnate the insulation system fully.

FACTORY TESTING

In addition to numerous quality inspections throughout the manufacturing process, final tests are conducted on the completed transformer to ensure proper function of all systems. All tests are conducted in accordance with applicable industry standards. Test equipment is state-of-the-art and capable of extremely accurate and reliable test measurements, meeting all the industry loss measurement standards. (Figure 12). All test systems are calibrated regularly according to industry standards.

Figure 12: Electrical test station

Tests	Transformer Class			
	Class I (≤ 69 kV)		Class II (115-765 kV)	
	Standard	Optional	Standard	Optional
Winding resistance	●		●	
Winding insulation resistance (Megger)		●	●	
Core insulation resistance (Megger)		●	●	
Ratio	●		●	
Polarity and phase relation	●		●	
Insulation power factor		●	●	
Control (auxiliary) cooling losses				●
Single-phase excitation tests		●		●
No-load losses and excitation current	●		●	
Impedance voltage and load losses	●		●	
Zero-phase sequence impedance voltage		●		●
Temperature rise		●		●
Low frequency dielectric tests	●		●	
Low frequency dielectric tests on auxiliary devices, control, and current transformer circuits		●	●	
Lightning impulse	●		●	
Front of wave impulse		●		●
Switching impulse		●		●
Partial discharge		●	●	
Audible sound level		●		●
Operational tests (all devices)	●		●	
Dissolved gases in oil		●	●	
Leak test	●		●	

FEATURES AND ACCESSORIES

SUMMARY OF STANDARD FEATURES AND ACCESSORIES
Howard medium power substation transformers are supplied with the following standard features and accessories:

- Capacity range: Through 60 MVA (ONAN), with high-voltage ratings through 230 kV (900 kV BIL)
- Service location: Outdoor
- Core: Regular grain-oriented; mitered cruciform with step-lap construction
- Coils: Cylindrical construction; all copper windings, custom tempered per design requirements; circular windings with rectangular or continuously-transposed conductor; helical low-voltage windings; continuous disc medium-voltage windings; shielded disc high-voltage windings
- Conductor insulation: Thermally-upgraded crepe paper taping
- Cooling/insulating fluid: Type II mineral oil
- Fluid preservation system: Sealed tank
- Tank: All-welded construction; welded cover with manhole and non-skid finish; base construction suitable for jacking, skidding, and rolling
- Radiators: Detachable panel type with shut-off valves; mild steel
- Bushings: Oil-filled, cover-mounted, condenser type with power factor test points
- Dial-type fluid level gauge
- Dial-type fluid temperature gauge with maximum temperature drag hand
- Dial-type pressure/vacuum gauge
- Dial-type winding temperature gauge with maximum temperature drag hand (standard on forced-cooled transformers only)
- Automatic pressure relief device
- Rapid pressure rise relay (mounted on isolation valve)
- Fluid fill valve
- Fluid drain valve
- Diagrammatic nameplate, engraved stainless steel
- Tank grounding pads
- Filter press connections (top and bottom)
- Transformer lifting lugs
- Provision for cover-mounted posttype fall-protection device
- Paint finish: Exterior polyurethane enamel, ANSI 70 gray color; interior polyurethane enamel, white color

SUMMARY OF OPTIONAL FEATURES AND ACCESSORIES
Howard medium power transformers are available with many optional features and accessories to satisfy a customers' special needs for the operation, protection, monitoring, and maintenance of their equipment. The following list contains the most frequently requested options. Check with the factory for the availability of other optional features and accessories not listed below.

- Cooling/insulating fluid: Seedbased natural ester fluid
- Bushing-mounted current transformers
- Surge arresters and mounting brackets
- High-voltage and/or low-voltage terminal compartments
- Wye-delta or series multiple terminal connections
- Forced-air cooling with automatic control system or provisions for forced-air cooling
- Control cabinet
- Nitrogen gas fluid preservation system
- Dial-type winding temperature gauge (standard for forced-cooled transformers)
- Electronic temperature indicator
- Fiber-optic winding temperature indicator
- De-energized tap changer with pad-locking provisions
- On-load tap changer with microprocessor-based control
- Special exterior paint color
- Galvanized or stainless-steel radiators
- Cover-mounted fall-protection device

INSULATING/COOLING FLUID
Power transformers are filled with Type II mineral oil that is highly refined for excellent insulating properties and inhibited for long-term stability at elevated temperatures. Less-flammable ester-based fluids are available as an option in the main tank.

SELF-COOLED RATING
Power transformers rated for selfcooled operation (ONAN class) are designed to operate at rated load with natural cooling by ambient air flow outside the transformer and natural oil convection within the transformer tank. Heat is radiated from the transformer tank and from tank-mounted radiator panels.

FORCED-AIR COOLED RATINGS
A single-stage forced air cooling system may be supplied to increase the transformer load capacity (ONAF

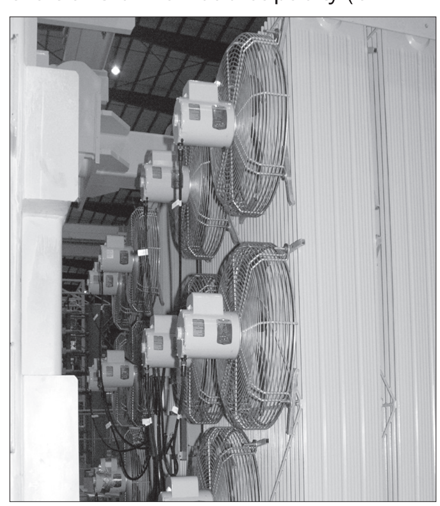


Figure 13: Cooling fans and panel radiator

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class) (Figure 13).
Sealed motor-driven fans are mounted on radiators to provide increased air flow. Fan operation may be manual or may be controlled automatically by temperature sensors mounted inside the transformer. Fans are connected to a weatherproof control box with weatherproof cable and a separable connector.

A second stage of forced-air cooling may be used (ONAF/ONAF class) to provide a further increase in load capacity beyond that provided by single-stage forced-air cooling. Stages one and two are operated automatically by heat sensors mounted inside the transformer tank and a control panel mounted inside the control cabinet.

FLUID PRESERVATION
A sealed-tank fluid preservation system is standard on all Howard medium power transformers. The interior of the tank is sealed from the ambient atmosphere, such that the gas-plus-oil volume remains constant throughout the range of normal operating temperatures. An automatic pressure relief device is provided to vent excessive pressure that might build up gradually during extreme overloads or fault conditions. A pressure/vacuum gauge is provided to measure internal pressure. Prior to shipping the gas space is pressurized with a dry air or nitrogen blanket.

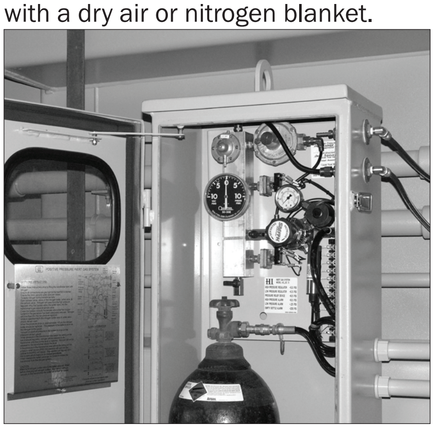

Figure 14: Nitrogen system

INERT GAS SYSTEM
An optional nitrogen inert-gas system provides a constant nitrogen atmosphere in the gas space of the transformer (Figure 14). The nitrogen blanket protects the transformer fluid from deterioration that could occur from exposure to moisture or oxygen. Main system components include a nitrogen cylinder, pressure regulators, valves, and gauges. The system also includes provisions for various pressure alarms. A lockable weatherproof enclosure protects the system.

BUSHINGS
Standard bushings are oil-filled condenser-type with porcelain housings (Figure 15).

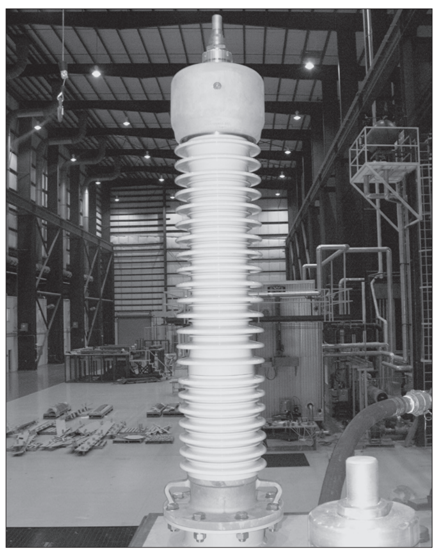

Figure 15: High voltage bushing

All bushings meet the requirements of the IEEE C57.19 series of standards.

CURRENT TRANSFORMERS
Current transformers (CTs) are bushing-mounted in the main tank interior (Figure 16). All CTs meet the requirements of the IEEE C57.13 series of standards.

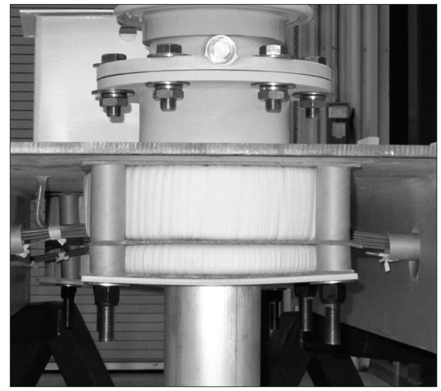

Figure 16: CTs mounted under cover

SURGE ARRESTERS
Surge arresters are porcelain or polymer housed, gapless metal-oxide-varister (MOV) type (Figure 17), externally mounted on heavy steel brackets. All arresters meet the requirements of IEEE C62.11.

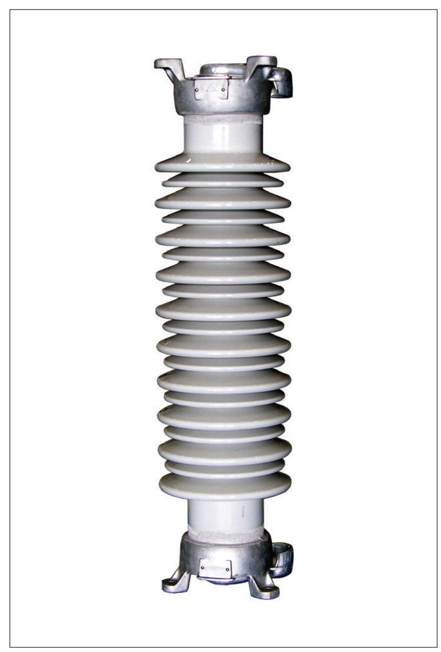

Figure 17: Lightning arrester

GAUGES
All gauges are dial-type and are located for convenient viewing at ground level (Figure 18).

Figure 18: Gauges

Fluid temperature and winding temperature gauges have resettable maximum temperature drag hands.

ELECTRONIC MONITORING
Various sophisticated electronic monitoring systems are available as options, including those that monitor oil temperature, winding temperature, pressure, moisture, gases, apparent charge, arrester surge count, and leakage current. Contact the factory for these and other monitoring systems that may be available.

CONTROL CABINET
The control cabinet provides a weatherproof enclosure for accessory items such as fan controls, OLTC controls, and terminal blocks for customer connections (Figure 19).

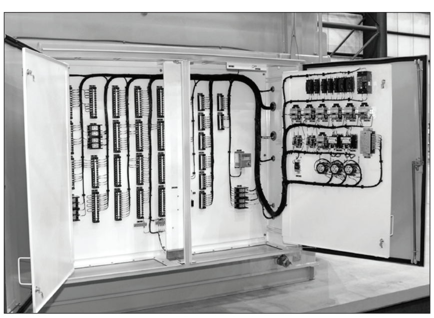

Figure 19: Control cabinet

The cabinet is mounted on the side of the transformer tank. Access to the cabinet is protected by a hinged door with three-point latch and padlock provisions. The cabinet interior is painted white to improve visibility and is equipped with a work light and accessory power outlet.

PRESSURE RELIEF DEVICE
A cover-mounted automatic pressure-relief device is provided to vent excessive pressure that might build up gradually during extreme over-loads or fault conditions (Figure 20).

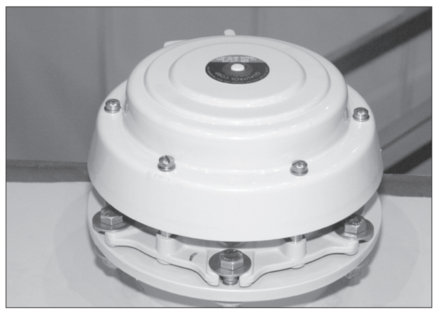

Figure 20: Pressure relief device

The standard device has a 6" throat and a cracking pressure of 10 psi. Devices with other pressure and flow characteristics are available with nonstandard operating characteristics. Options include alarm contacts, indicating flag, and discharge diverter.

DE-ENERGIZED TAP CHANGER
A de-energized tap changer can be provided to adjust the transformer voltage ratio to meet system requirements. An external operating handle is mounted on one end of the transformer near ground level (Figure 21).

Figure 21: DETC handle

The handle can be locked in any switch position and has provisions for a padlock.

ON-LOAD TAP CHANGER
A three-phase on-load tap changer (OLTC) provides automatic voltage regulation in an energized transformer while serving load (Figure 22).

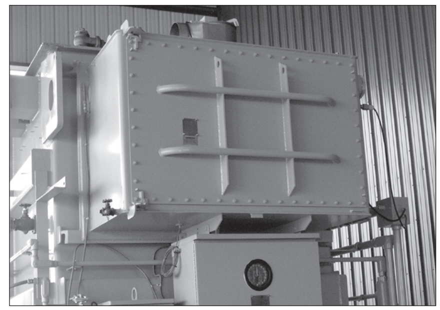

Figure 22: On-load tap changer

OLTC's typically operate over a range of thirty-two 5/8% voltage steps, sixteen above and sixteen below rated secondary voltage. The total tap range is typically 20% (10% above and 10% below rated secondary voltage). Standard OLTC's provided on Howard transformers use vacuum interrupter technology manufactured by Reinhausen or ABB.

The OLTC switch mechanism is sealed in an oil-filled enclosure welded to one end of the main transformer tank. A motor drive and switch position indicator are housed in a weatherproof cabinet mounted below the switch mechanism. A crank lever is provided to operate the tap changer manually.

OLTC control panels are housed in the control cabinet (Figure 23). A variety of microprocessor-based controls are available, including those manufactured by Beckwith, ICMI, and Reinhausen. In addition to the automatic regulation of secondary voltage, control systems can also be equipped to provide communication, data storage, and power quality analysis. All controls are provided with manual override capability.

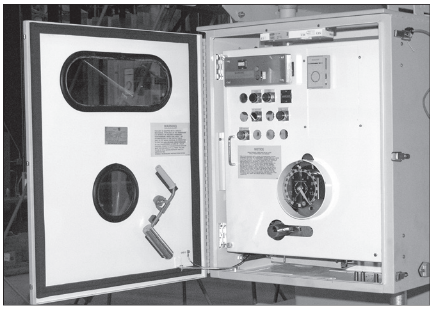

Figure 23: OLTC control

TANK

Howard transformer tanks are rectangular all-welded steel construction and are designed for strength, durability, and compact form. Tank corners are folded with welds made six inches from corners (no corner welds). Tanks are reinforced with external enclosed-box bracing to provide the necessary strength and rigidity.

Cover-mounted lifting lugs are provided for lifting the transformer cover. Additional lifting lugs are provided for safely lifting the completely assembled transformer. Copper or stainless-steel ground pads are located on tank sides near ground level. Transformer covers are constructed of a heavy steel plate that is internally braced and welded to the tank. Bolted and gasketed manhole covers are provided to allow convenient access to the main tank interior. Covers are supplied with provision for a post-type fall protection device. Other fall-protection provisions or systems are available as options.

The standard tank base is constructed of a heavy plate steel that is suitable for rolling or skidding in all directions. Jacking pads are provided on all four corners of the tank to allow for jacking of the completely assembled transformer.

Tank surfaces are sand blasted and coated with a rust inhibiting primer. After assembly and before shipping, completed transformers are leak tested, washed and then finished with a durable polyurethane topcoat. Tank interiors are painted white. Tank covers have a slip-resistant surface finish.

RADIATORS

Panel-type radiators provide additional cooling to supplement heat radiation from the transformer tank (Figure 13). The number and size of radiators is determined by the design. Radiators are typically detachable and are provided with individual shutoff valves. Standard radiators are made of cold-rolled mild steel that is primed and finished with a durable polyurethane top coat. Stainless steel and galvanized radiators are available as options.

OTHER FEATURES AND ACCESSORIES

Contact the factory for other features and accessories that are not discussed here but may beavailable as options.

DELIVERY AND INSTALLATION

Delivery is made by truck whenever possible or by rail when transformer size or weight makes truck delivery impractical. An impact recording device is provided on all rail shipments and can be provided on truck shipments upon customer request.

Figure 24: On-site installation

Impact recorders measure and store three-axis impact data, identifying any abnormally severe impacts that might have caused damage to the transformer during transportation.

Howard Industries offers a full complement of field installation services, including unloading, inspection, assembly, vacuum oil filling, and testing under the supervision of field service technicians (Figure 24). Field supervision is available for customer-installed jobs. Field inspection includes checks of bushings, gasket seals, tank pressure, tap changer operation, and controls. Tests include turns ratio, insulation resistance, power factor, internal moisture, and oil dielectric strength.

NOTES

Medium Power Substation Transformers

Catalog Section 34-10
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Laurel, Mississippi
Telephone: 601-425-3151
Fax: 601-649-8090
E-mail: mkt@howard.com
Web: howardtransformers.com