UNIFIN

Cardinal Pumps and Exchangers

PEAK MEASURE Manufacturers’ Representative

Transformer Maintenance / Monitoring Seminar

Wilsonville Training Center

August 12th & 13th, 2014
UNIFIN
Cardinal Pumps and Exchangers

TRANSFORMER COOLING SYSTEMS
PUMPS and COOLERS
Replacement & Maintenance

Greg Stem
Engineering Services Manager
Cardinal Pumps & Exchangers
Presentation Outline:

• Transformer Oil Pump Basics
• Bearing Designs / Failure Modes
• Pump Maintenance, Monitoring & Troubleshooting
• Pump Accessories

• Cooler / Radiator Basics
• Transformer Coolers – Design & Maintenance
Company Overview...

Where Does Unifin Fit Today

Now Owned by **Wabtec** Corporation

- $1.5 Billion Annual Revenue
- 3 Major Business Units
- 5,000+ Employees
- 50+ Mfg, Service and Sales Facilities Worldwide

**Young Touchstone**

- Heat Exchanger and Cooling Systems Manufacturer
- 500+ Employees

Unifin Purchased by **Wabtec** October 1, 2009
Who is UNIFIN . . .

Owned by Wabtec Corporation (Since October 1, 2009)

Unifin International
- Founded in 1920’s in London, Ontario (Blast Coils)
- Began Manufacturing Heat Exchangers in the 1930’s (Power & Industrial)
- Purchased Cardinal Pumps in 1990
- Purchased by Koch Industries in 1991
- Purchased Flakt CoilTech (NA) in 2004 for Plate Fin Cooler Technology
- Launched Dengfeng (China) – Unifin Joint Venture in 2005
- Purchased GE Harley Pump & GE Generator Cooler Businesses in 2007
- Purchased by Wabtec in 2009
- 2 Manufacturing Facilities (NA); 1 in China
- 150+ Employees (Primarily North America)
- ~$50M Annual Sales
Unifin Manufacturing Facilities . . .

Canada
- Transformer Cooler Manufacturing
- Some Generator Cooler Manufacturing

USA
- Transformer Pump Manufacturing
- Generator Cooler Manufacturing

China
- Transformer Cooler Manufacturing

Locations:
- London, Ontario
- Salem, OH
- Chesapeake, VA
- Daye City, China
What Does UNIFIN Do? . . .

- Transformer Coolers (air cooled, water cooled)
- Transformer Oil Pumps & components
- Generator Coolers (Air or Hydrogen /water)
  - Includes bearing lube oil and seal oil coolers
- TEWAC Motor Coolers (similar to air gen cooler)

Unifin is not just a “heat exchanger company” . . . Unifin is a Power Industry Focused, electric power equipment cooling company . . . focused, end user dedicated, responsive, highest quality!
Unifin . . . Power Plant & Transmission Substation focus
Extensive knowledge of Generator and Power Transformer applications . . .

Cooling Solutions

Coal-Fired Power Plant

Transformer Cooling System

Generator/Lube Oil Cooling System
Transformer Oil Pumps
And
Related Products
Cardinal Pumps and Exchangers

Cardinal / Harley Pump Business

Products Offerings:

- Transformer Oil Pumps
  - Remanufactured pumps (Customer’s pump or core stock direct replacement)
  - New pumps (Identical to original or replacement design)
- Transformer Pump Isolation Valves
- Flow Gages
- Electrical Power Cords
- TecSonics™ Bearing Wear Detection / Monitoring System
- Piping Adapter Pieces
Transformer Cooling System
Coolers and Radiators

- Shell / Tube Water Coolers
- Forced Air Coolers
- Natural Convection Radiators
Coolers / Pumps
Radiators / Pumps
Transformer Cooling System Variables:

- Type of Transformer
- Cooling Requirements / Rating (FOFA; ONAN, etc.)
- Coolers or Radiators
- Quantity of Cooler / Radiator Banks and Pumps
- Pump Mounting - Bottom or Top of Cooler
- Thermal Calculation Requirements (GPM / Pressure Drop)
- Piping / Mounting Configurations
- Flange Sizes
- Flow Gages / Valves / Alarms
- Electrical - Voltage & Phase
Why Are Pumps Used on Transformers?

**Efficient Cooling:**

- Extends transformer life at a given load
- Maintains load effectively
- Manages variable loads economically
- Maximizes transformer contribution
TRANSFORMER OIL PUMP
Bearings are lubricated, and the motor is cooled by the transformer oil. The motor operates at 7 to 10 degrees F above the oil temperature.
MODEL 370 CONNECTOR

Used on:
- McGraw Pumps
- Reman. Pumps with Terminal Board Connector Conversions

MODEL 377 CONNECTOR

Used on:
- GE Pumps
BENDIX CONNECTOR

Used on most Westinghouse / ABB pump applications
MODEL 378 CONNECTOR

Terminal Board / Box

Used mostly with OEM applications – not Remanufactured Pumps
MODEL 379 CONNECTOR
Model 379 CONNECTOR

- THERMAL OVERLOADS:
  - Texas Instrument Brand Name
  - Tie to the coil head of the motor, in 3 locations
  - Manual resetting – Not an Auto Thermal Device
    - Must be reset at the control panel
  - Thermal overloads, NORMALLY CLOSED SWITCH, measure the winding temperature – Open at 120Deg. C (+/-5 Deg. C), and can be reset at 98Deg. C (+/-11Deg. C)
Sight Glass

Vent and Drain Plugs
Sight Glass, and plastic shipping plug

Brass Vent plug
Pump Bearing Options:

A. Sleeve
   - Cardinal Standard Sleeve (OEM’s Only)
   - HARLEY™ Sleeve (HBC)
   - TecSonics™ Bearing Wear Monitoring System

B. Ball
Pump Sleeve Bearings
BEARING LUBRICATION
Harley™ Sleeve Bearing
Transformer Oil Pumps . . .

Bearing Types . . .

Cardinal Standard Sleeve Bearing – (Available to OEM’s only)

Harley™ by Cardinal (HBC) Sleeve Bearing

Harley™ by Cardinal (HBC) Sleeve Bearing with TecSonics™ Wear Detection System
TecSonics™
Bearing Wear Monitoring System
TecSonics™ Bearing System

- Sleeve Bearing Condition Assessment
- External Readings With Equipment Operating or Static
- Actual Material Measurement
- Enables True Condition Based Maintenance
- Patented Design
Transducer
PIEZOELECTRIC CRYSTAL
A HIGH FREQUENCY SOUND WAVE IS EMITTED WHEN THE CRYSTAL IS EXCITED
A HIGH FREQUENCY SOUND WAVE IS EMMITED WHEN THE CRYSTAL IS EXCITED.
ELECTRONICS MEASURE THE TIME FROM SIGNAL EMISSION TO ECHO RECEPTION

MEASURED DISTANCE
<table>
<thead>
<tr>
<th>STYLE/CATALOG NO.</th>
<th>MODEL NO./SIZE</th>
<th>SERIAL NO.</th>
<th>BASE LINE READINGS</th>
<th>CASING END</th>
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<tr>
<td>HBC-6X6-TEC.</td>
<td>31343-6X6</td>
<td>7543-1</td>
<td>156.6</td>
<td>156.3</td>
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<td>173.1</td>
<td>176.7</td>
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<td>VOLTS</td>
<td>PH.</td>
<td>AMPS</td>
<td>460</td>
<td>3</td>
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<tr>
<td>H.P.</td>
<td>R.P.M.</td>
<td>CY.</td>
<td>5.5</td>
<td>1750</td>
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<tr>
<td>BEARING WEAR MONITORING SYSTEM</td>
<td>US PAT. NO. 4649749</td>
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<td>2008</td>
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<td>Pump Type</td>
<td>Station</td>
<td>Trans/Ctr#</td>
<td>Serial#</td>
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Notes:

If you have any questions, please contact us at the phone numbers listed above.
Centrifugal Pump Hydraulic Design

Theory & Operation
Pump Performance & Terminology

Total Head – The height to which liquid can be raised by a pump, expressed in feet
Capacity – The volume of liquid pumped, usually expressed in gallons per minute
Velocity Head – $V^2/2g$
System Head / System Curve – comprised of (3) components:
  - Static Head – constant at all flows
  - Pressure Head – constant at all flows
  - Friction Head – flow dependent – increases as flow increases
    - Head loss thru pipe, valves, fittings and other obstructions in the system $h_L = K \frac{V^2}{2g}$ (Cooling system pressure drop)
Impeller / Casing Interaction
Pump’s Head - Capacity (Performance) Curve
Variations in pump speed or impeller speed or impeller diameter (Affinity Laws)
  - Flow varies proportional to speed or diameter ratio
  - Head varies as the square to speed or diameter ratio

Pump Curve vs. System Curve
Cardinal Dev. Corp
Salem, Ohio

Model: 31348  Size: 6x6
L=1750-290 = S-60
Trans Oil: S.S. 0.65
2/14/84
Case: E1107  Imp: 1197  B:1105
6'96x145"  M.D.

GPM
0  100  200  300  400  500  600  700  800  900  1000

Head: 40

MTR: 32

Wells @ 240V
Pump Curve

System Curve

Model: 1348  Size: 6x6
6-1750-200-3-60
Trans Oil S.G. 0.88
2/9/66
Case: E1107  Imp. O-1197  B-ilms
6-71x95  14-D.

950 vs 900
Pumps...

- Pump and Cooler Packages are Designed and optimized to Work Together
- Single point responsibility

**PERFORMANCE GUARANTEED!**
Cooler and Pump Curve Matched...
Types of Centrifugal Pumps

A. Centrifugal Flow
   - Performance
   - Impellers
   - Applications

B. Axial Flow
   - Performance
   - Impellers
   - Applications
IMPELLER TYPES

MIXED FLOW
GE Style Impeller

AXIAL FLOW
Model 54525 Style Impeller

CENTIFUGAL FLOW (Radial)
Model 31343 Style Impeller

2X2’s
3X3’s
4X4’s
These curves derived from tests using Transformer Oil. Specific gravity = 0.86.
These curves derived from tests using Transformer Oil Specific gravity = 0.88
Centrifugal impellers, and mixed flow impellers can be trimmed to obtain different flow rates.

Axial impellers provide only 1 performance, and the only change comes from motor speed.
Impeller Trims
Transformer Pumps
Centrifugal / Mixed Flow

Cardinal 6X6
Model 31343

ASEA VMO

GE Transil

McGraw 5X5

Allis Chalmers 3X3

GE Barrel Pump

WH XP56
Transformer Pumps
Axial Flow

- GE ½ HP 6X6
- Cardinal 6X6 Model 54525
- Renzmann Grunewald 12X12
- Allis-Chalmers 4X4 Inline
- McGraw 8X8
### Transformer Pump Manufacturers

- General Electric
- Westinghouse
- McGraw
- Allis-Chalmers
- Ingersoll-Rand
- Cardinal
- Moloney
- Sealmaster

- Peerless
- Sigmund Pulsometer
- Renzmann - Grunewald
- Asea
- Oerlikon
- Scai
- Toshiba
- Harley (Harley by Cardinal)

**Pump brands that can be either remanufactured or directly replaced with new pumps**
Transformer Oil Pump Types

- Centrifugals
- Axflo's
- Inline
- Bolted
- Welded
- Turkey Roaster
- GE Transils

- Barrel
- Box
- Half Barrel
- Deming
- Flush Mount
- Low Flow
- Standard Flow
- Reverse Flow
Westinghouse / ABB
Pumps
Westinghouse 6X6 / Cardinal 31343 / HBC 6X6
5.5 HP / 1750 RPM

- Standard Flow (800 GPM)
- Low Flow Impeller (650 GPM)
- 2 HP 1150 RPM (450 GPM)
Westinghouse Turkey Roasters
Turkey Roaster Pump / WH 4X6 I-R Pump / HBC 31343 4X6
Westinghouse XP-56 Pumps
WH XP-56  31356-6X6
(New Motor Replacement)
General Electric Pumps
GE Transil Pump / Cardinal / HBC 6X6 MB5
GE Barrel Pump -
Cardinal / HBC 6X6 MD5
GE Flush Mount Barrel Pump
Cardinal / HBC 6X6 MC5
GE ½ HP Axial Flow Pump – Cardinal 54521 / HBC 6X6 AxFlo

GE – RADIATOR BANKS

2 VANE PROPELLER
(5 THRU 25 DEGREE)

No TecSonics™ Available
McGraw Edison Pumps
McGraw 5X5

• 5 HP
• 2 HP

McGraw 8X8

• Standard Flow or Reverse Flow
• 4 HP (1150 RPM) or 1-3/4 HP (880 RPM)
• Grooved or Ungrooved Flanges
Allis-Chalmers Pumps
Allis-Chalmers Pumps

A-C 3X3 (Centrifugal Pump)

Mobile Transformer

A-C 4X4 (Inline Pump)
Asea / ABB
Pumps
ABS Pump

VMO Series

Used on VVAH series

• Ball bearing design

Cardinal / HBC 31342VMO-4x4
Transformer Pump
Design Flaws / Failure Mechanisms

Bearing System Failures
• Sleeve & Ball Bearings

Leaks and Sealing
• Gaskets & O-Rings

Electrical Problems
• Motor Windings & Connectors
Bearing Problems
Design Flaws

Bearing System Failures

- Loss of Bronze
- Scoring of Shaft Journal
- Ball Bearing Wear (Degradation)
- Misalignment of Shaft System
BEARING FAILURES ARE CAUSED BY...

OIL FILM BEING PREVENTED FROM FORMING

• IMPROPER ASSEMBLY OF PARTS
• BEARING MISALIGNMENT
• PIPE STRAIN
• POORLY MACHINED PARTS – SURFACE FINISH
Sleeve Bearings

Ground Thrust Collar & Shaft

Harley by Cardinal Sleeve Bearing

Cardinal Bearing – Pre 1985

Harley by Cardinal vs. Standard Cardinal Bearing

WH Cleanflow Pump - Torlon Bearings

Ingersoll-Rand Sleeve Bearings
WH Cleanflow – Torlon Bearings
Old Cardinal Sleeve Bearing Design
(Pre 1985)
GE Rotor / Sleeve Bearing
Ingersoll-Rand Pump
Ingersoll-Rand Sleeve Bearings
Ingersoll-Rand Impeller
Ball Bearings
Ball Bearings – Fragmented Bearing Race and Cage
Ball Bearings – Balls Missing
Ball Bearings - Metallic Dust
GE Transil Pump – with Ball Bearings Destroyed
Transformer Pump Bearing Designs

- Bronze Sleeve Bearings w/ Hardened Steel Thrust Collars
  - All Harley by Cardinal Pumps
  - Most Older Westinghouse Pumps (Ingersoll-Rand & Cardinal)
  - Most Older McGraw Pumps (Cardinal)
  - Some GE Designs
  - Very Small Percentage of Foreign Manufactured Pumps

- Ball Bearings
  - Most GE Designs
  - All Allis-Chalmer Designs
  - All Pennsylvania / Moloney / Sealmaster Designs
  - All ABB Designs
  - Most Foreign Manufactured Pumps
Sealing & Leak Problems
Design Flaws

Leaks and Sealing

- Electrical Connector
- Main Flange
- Gasket Area
- Between Flanges Integral to Pump
- Plugs
- Cracks
ELECTRICAL PROBLEMS
Design Flaws

Motor Problems

- Overheating from lack of oil circulation
- Breakdown of insulation
- Phase to phase shorts
- Turn to turn shorts
- Poor insulation (Class A or B)
Design Flaws

Connectors & Terminal Boards

- Defective power cord or connector
- Terminal board cracks / leaks
## Maintenance Strategies

<table>
<thead>
<tr>
<th>Traditional Solutions</th>
<th>Solution Shortfalls</th>
</tr>
</thead>
<tbody>
<tr>
<td>• “Run Until Broke”</td>
<td>• Unplanned Outages, Scheduling Problems, Reliability Issues, Unstable Costs</td>
</tr>
<tr>
<td>• Preventative Maintenance</td>
<td>• Symptom Fixes, Limited Life Extension, OEM Dependent, Large Maintenance Dept., Snapshot of Equipment Health</td>
</tr>
<tr>
<td>• Predictive Maintenance</td>
<td>• High IT Infrastructure, Dependent on Quality of Expert Interpretation</td>
</tr>
</tbody>
</table>
Troubleshooting

• Visual Inspection
• Sound
• Vibration Signature
• Thermal Scan
• Flow Gage (Visual & Alarm)
• Amp Readings
PUMP OPERATING PROBLEMS

- EROSION OF BEARING SYSTEM AND IMPELLER
- DEGRADATION OF DIELECTRIC PROPERTIES
- REDUCTION IN PUMP FLOW
- FAILURE OF MOTOR WINDINGS
- POTENTIAL FOR ARCING
- LEAKING ELECTRICAL CONNECTORS & SEALS
PROPER MAINTENANCE FOR...

- RELIABILITY
- PROTECTING INVESTMENT
- EXTENDING USEFUL LIFE OF TRANSFORMER
Transformer Oil Pumps – Tech Study Report

Customized Report:

- Details pumps in service and spares
- Makes knowledgeable maintenance recommendations
- Explains typical modes of failure
- Prioritizes maintenance decisions

To: [Recipient]

Subject: Transformer Oil Pump Tech Study

Reference: Transformer Oil Pump Tech Study

This is an outline of what we have found over the last 20-plus years of inspecting and remanufacturing transformer oil pumps. All of the pumps listed here have a 100% failure rate with the definition of failure being metal-to-metal contact on the bearing surface causing wear. The severity of the failure varies however relative to the length of time in service and other circumstances. Therefore, the priority codes group similar “modes of failure” rather than probability of failure. We have noticed however that pumps with ball-bearings tend to fail in groups, that is if one pump on a transformer that has multiple pumps fails, the remaining pumps have high probability of failure in the near future. Sleeve bearing type pumps are also closely related. I have included design life and recommended service life estimations for the priority coded pumps as well. Currently, we do not have a recommended method for long term (greater than three months) storage of spares that will ensure guaranteed results. Pumps should be stored oil-filled in a climate-controlled environment and the oil should be changed annually to help reduce the possibility of rust accumulating on internal components.

Thank you for the opportunity to participate with this committee.

Priority One:

These pumps are the Cardinal 900 Series (7630000H80x) with the “clean-flow” torlon plastic bearing manufactured by Westinghouse. Our experience with these pumps shows a high incidence of bearing failure as shown. Over a period of time, the torlon (shown in the left half of the bearings pictured here), wears to a point that it breaks away and washes through the oil system. That in itself is okay, because the torlon is non-conductive. Unfortunately, when the plastic is gone, you immediately have metal-to-metal contact in the pump’s bearing system, and with the amount of end-play that is created instantly, we often see impeller contact inside the casing. In a very short period of time, a considerable amount of metal is introduced to the transformer’s oil reducing its dielectric properties. Design life of this pump is ten years. All pumps of this type that have been in service for ten years or more are highly suspect for failure and should be considered for first available maintenance.
## Transformer Oil Pumps – Tech Study Form

<table>
<thead>
<tr>
<th>Station</th>
<th>Transformer Serial or Equipment Number</th>
<th>Pump Manufacturer (L.R. Cardinals, GE)</th>
<th>Pump Serial Numbers</th>
<th>Qty</th>
<th>Pump Style No. or Catalog No.</th>
<th>Pump Model Number</th>
<th>Voltage</th>
<th>Phase</th>
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</tbody>
</table>

**Transformer Designation**

**Pump Manufacturer**

**Pump s/n**

**Qty.**

**Pump Style**

**Pump Model**

**Electrical Data**
Pump Accessories

- Power Cords
- Valves
- Flow Gages
- Spool Pieces
Replacement Power Cords

For Transformer Pumps and Fans
Withstands harsh substation environment, ultraviolet rays, oil, and water.

Bendix Style Power Cord

Qualitrol Style Power Cord
Power Cord / Pump Connector
Model 351 Connector

THE 351 CONNECTOR IS USED FOR FIELD REPAIR ON LEAKING MODEL: 370 AND 377 CONNECTORS
Power Cord Test
Pump Isolation Valves
Valves
V601A

6" GE VALVE, 4 HOLE

AVAILABLE IN SINGLE AND DOUBLE GROOVE
6” ANSI BOLT-ON VALVE

FOR NEW INSTALLATIONS AND RETROFIT OF OLD WESTINGHOUSE WELDED FLAPPER VALVES

SINGLE AND DOUBLE GROOVE AVAILABLE
Pump Flow Gages
Pump Flow Gages

WH Style

GE Style
Interconnecting Piping – Spool Pieces

GE Box Pump

Replaced with HBC 6X6 MB-5 and Spool Pieces
Pump Operation:

A. Convective Flow (Thermal Siphoning)
B. Running in Reverse Rotation
C. Pumping of Various Dielectric Fluids
D. Voltage Variations
E. Single Phase Pumps
Pump Operation:

A. Convective Flow (Thermal Siphoning)
B. Running in Reverse Rotation
C. Pumping of Various Dielectric Fluids
D. Voltage Variations
E. Single Phase Pumps
Single Phase Pump – Start / Run Capacitor

2GU21
50μF ± 5% CBB65A-1
440VAC (VCA) 50/60Hz
Protected 10,000 AFC
MPP2506440J
2605W
UL®
E236128
C22.2 No.190
Made in China
Hecho en China
Pump Mounting / Piping Best Practices:

A. Top or Bottom Mount
B. Mounting & Alignment
C. Bends / Direction Changes
D. Hydraulic Noises / Vortexing / Bubbles
E. NPSH / Cavitation
F. Flange Gasketing
Pump Mounting / Piping Best Practices:

A. Top or Bottom Mount
B. Mounting & Alignment
C. Bends / Direction Changes
D. Hydraulic Noises / Vortexing / Bubbles
E. NPSH / Cavitation
F. Flange Gasketing
TRANSFORMER OIL PUMP
BEST PRACTICE GUIDE

ENGINEERING/SELECTION

1. PIPING PRACTICES
   a. Minimize the number of restrictions on the suction piping, ie: elbows, valves, flow gauges, etc.
   b. Allow a minimum length of three pipe diameters between the pump suction and the restrictions outlined in (a) above.
   c. Never use piping on the suction side of the pump that is smaller than the nominal pump suction size.
   d. When pipe size reduction is required on horizontal runs, use an eccentric reducer with the eccentric side down to avoid air pockets.
   e. When selecting a pump, the oil flow rate needs to be known to meet the thermal requirements, and ensure the flow rate can be obtained against the total system pressure losses.

2. MOUNTING/ALIGNMENT
   a. Pumps can be mounted either at the top or bottom of the transformer (figure 1 & 2). It is preferred to mount the pumps below the cooler or radiator so that they are accessible for maintenance and inspection.
   b. As a general rule of thumb, if pumps are mounted on the top of the cooler, a minimum of 2 feet of oil above the suction connection is required as submergence to prevent vacuuming or air entrainment.
   c. Pumps mounted below the cooler or radiator must ensure a positive NPSHA (Net Positive Suction Head Available) at the pump section.
      \[\text{NPSHA} = H_l - \left( H_p + H_f + H_s \right)\]
      \[H_l = \text{absolute pressure (in feet) on the surface of the oil (Amerianl Pumps, System Pressures)}\]
      \[H_p = \text{read (in feet) corresponding to the vapor pressure of the liquid at pump, being pumped (inft ofgauge for transformer oil)}\]
      \[H_f = \text{static head (in feet) at the top of the level above the impeller centerline)}\]
      \[H_s = \text{ suction line losses (in feet) - i.e., entrance losses and friction losses through pipes, valves, cooler, radiator, fittings, etc.}\]
   d. Piping flanges must be parallel and square to the pump flanges (Figure 3).
   e. Pump dimension "A" must be equal to piping dimension "B" (Figure 3).
   f. Pump dimension "C" must be equal to piping dimension "D" (Figure 3).

3. GROOVE/GASKET DETAILS
   a. Do not use gasket rings that are larger than the gasket groove.
   b. The gasket ring should be designed to have a 25% to 30% compression ratio to the groove depth (Figure 4).
c. The gasket ring should be designed to fill 80% to 85% of the groove volume (Figure 5).

The thickness of the gasket ring should never be greater than the gasket ring cross section width.

When selecting a groove on the pump flange face (optional), ensure that the gasket surface will mate 100% with the face of the piping flange. This is extremely important with slip-on style flanges.

4. VENT PLUGS
   a. Vent plugs are available for pumps when required for a TIF MOUNT non-vacuum fill, an optional feature (Figure 6).
   b. Pipe plugs are installed at the factory, and vent plugs will be shipped loose for installation in the field.

TYPICAL INSTALLATION

1. Check the pump on receipt for shipping damage, along with optional items such as power cables and vent plugs.
2. Handle the pump with care when removing it from the shipping container. Use proper lifting practices; devices to protect personnel and product.
3. On a clean surface, remove the cover plates from the pump flanges. WARNING: The pump may be under positive pressure, (kips) nitrogen purge. Bleed off the pressure through the purge valve on the cover plates prior to removing any of the cover plates.
4. Turn the impeller by hand several times to ensure it moves freely, and no significant interference noise is detected.
5. Check the gasket design to ensure it meets the requirements outlined in Section 3, Gasket Design Details.
6. Review the piping configuration to ensure it meets the requirements outlined in Sections 1, Piping Friction and Section 2, Mounting/Alignment.
7. Check line voltage, phase, and frequency against the pump nameplate to ensure compatibility.
8. Install the gaskets onto the flanges. It is recommended that a white petroleum jelly be used to hold and lubricate the gasket during installation.
9. During handling of the pump, ensure no contaminants enter the pump opening.
10. Mount the pump into the desired location, using proper lifting techniques and devices. Ensure that the pump is not forced into the location due to flange misalignment as outlined in Section 3, Mounting/Alignment.
11. Secure the pump with flange bolts and washers, ensuring not to over torque. Typical bolt torque values are listed below in Figure 7.

<table>
<thead>
<tr>
<th>Bolt Diameter</th>
<th>Torque Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>⅜&quot;, 1NC</td>
<td>113 FT-LBS (MAXIMUM)</td>
</tr>
<tr>
<td>⅜&quot;, 11NC</td>
<td>118 FT-LBS (MAXIMUM)</td>
</tr>
<tr>
<td>⅜&quot;, 10NC</td>
<td>256 FT-LBS (MAXIMUM)</td>
</tr>
<tr>
<td>⅜&quot;, 8NC</td>
<td>621 FT-LBS (MAXIMUM)</td>
</tr>
</tbody>
</table>

12. Fill the system as per the transformer manufacturer's recommended procedure.
13. Connect the power cable to the pump.
   a. Three phase motors are phased out at the factory. Connect L1 to A, L2 to B, and L3 to C. Quick disconnect style connectors ground through the piping to the transformer ground.
   b. Single phase pumps are supplied with an externally mounted capacitor(s). Single phase pumps have wiring diagrams included with the pump, showing the capacitor and power connections.
14. Briefly energize the pump, and check the shaft rotation through the sight glass. Compare the actual rotation to the rotation nameplate.
15. Check all wiring connections are secure, and apply all needed covers.
16. Start the pump, and monitor the pump's operation for 2 to 3 minutes for severe noise, leaks, or vibration.
17. The pump is ready for normal system operation.

Cardinal Pumps & Exchangers
A Midtec company

Cardinal Pumps & Exchangers, Inc.
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WebSite: www.cardinalpumps.com

Revised: 11/11/09 (logo change) TAS
Revised: 2/11/10 (updated #2) TAS
Pump Mounting / Piping Best Practices:

A. Top or Bottom Mount
B. Mounting & Alignment
C. Bends / Direction Changes
D. Hydraulic Noises / Vortexing / Bubbles
E. NPSH / Cavitation
F. Flange Gasketing
NPSH / CAVITATION

NPSHA = \( H_a - H_{vpa} + H_{st} - H_{fs} \)

where:

\( H_a = \) Absolute pressure (in feet) on the surface of the oil (Atmospheric + System Pressure)

\( H_{vpa} = \) Head (in feet) corresponding to the vapor pressure of the liquid at temp. being pumped (Negligible for transformer oil)

\( H_{st} = \) Static height (in feet) of the top oil level above the impeller centerline

\( H_{fs} = \) Suction line losses (in feet) – i.e., entrance losses and friction losses through pipe, valves, cooler, radiator, fittings, etc.
UNIFIN
Cardinal Pumps and Exchangers

Pump Mounting / Piping Best Practices:

A. Top or Bottom Mount
B. Mounting & Alignment
C. Bends / Direction Changes
D. Hydraulic Noises / Vortexing / Bubbles
E. NPSH / Cavitation
F. Flange Gasketing (Design and Materials)
3. GROOVE/GASKET DETAILS

a. Do not use gasket rings that are larger than the
   groove.

b. The gasket ring should be designed to have a 25% to
   30% compression ratio to the groove depth
   (Figure 4).

c. The gasket ring should be designed to fill 80% to
   85% of the groove volume (Figure 5).

d. The thickness of the gasket ring should never be
   greater than the gasket ring cross section width.

e. When selecting a groove on the pump flange face
   (optional), ensure that the gasket surface will
   mate 100% with the face of the piping flange.
   This is extremely important with slip-on style
   flanges.

4. VENT PLUGS

a. Vent plugs are available for pumps when required
   for a 10" 301. NP non-vacuum fill, as an
   optional feature (Figure 6).
Cardinal Pumps and Exchangers

For Replacement Pumps, need . . .

- Pump Make & Model Number
- All Nameplate Data
- Pictures (if Possible)
- Options (Valves, Flow gages, TecSonics, etc.)
Questions on Pumps ?
Transformer Cooling Basics

• As transformers increase in size, the heat generated due to losses that needs to be dissipated to protect the transformer’s insulation from aging and deterioration increases exponentially.
Transformer Cooling Systems

- F/A with Pumps
- Flexibility – Can operate as O/A, F/A or FOA (Triple Rated)
- Can run into space restrictions with large transformers
Transformer
• Oil circulates naturally through temperature differences
• No Pumps /No Fans
• Limited cooling rate
• Similar to OA except add fans to improve air side cooling
• Can be Dual Rated by turning on fans in banks
• Greater cooling rate than OA, but still limitations
- Forced air with pumps
- Flexibility - Can operate as ONAN, ONAF or OFAF (Triple Rated)
- Greater level of cooling, but still limitations (space)
Radiator Cooling
Radiator Applications

• Account for 80-85% of transformer cooling worldwide
• Applications start at approx 250 KVA, can go thru 500MVA or higher
• Provide self-cooled (ONAN) rating (triple rating capability)
• Fans and Pumps not required in all applications
• Large Footprint
• Problems with leaks and rust
• More inlets/outlets to tank (risk)
• Commodity type Item (low price and profit)
• Currently **not** in Unifin portfolio – Unifin only applies coolers
### Advantages and Disadvantages of Radiators

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Self-cooled capability</td>
<td>• Large Foot Print</td>
</tr>
<tr>
<td>• No fan or pump motors</td>
<td>• Rusting</td>
</tr>
<tr>
<td>• Lower maintenance cost</td>
<td>• Many openings to tank</td>
</tr>
<tr>
<td>• Aux Power not req’d</td>
<td>• Many valves</td>
</tr>
</tbody>
</table>

OFAF (FOA) Coolers
OFAF Coolers

- Most Effective Cooling for Large Transformers, especially GSUs
- Designed for a Forced Oil Rating only
  - ie. Pump must be on
- Same level of cooling in approximately 1/6 the space of radiators with fans
- No added foundation work needed
- Fewer inlets & outlets on tank wall (ie. fewer leak sources)
OFAF & ODAF Coolers

• Consist of:
  • Heat Exchanger core (extruded tube or plate fin)
  • Fan Cabinet
    • Fans & motors integrally mounted in cabinet, prewired to terminal box
  • Directly connected to an oil pump
  • Flow rates from 140 to 800 GPM
  • Fan motors are integral HP (≥ 1.0 HP) and 3 phase
  • Requires fans and pump operating to be efficient
  • Significantly more efficient than radiators
  • Smaller footprint than radiators, reduced inlets/outlets on tank wall
Directed Vs Non-Directed Flow
Advantages and Disadvantages of OFAF Coolers

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Footprint</td>
<td>No self-cooled rating</td>
</tr>
<tr>
<td>Less Tank Wall Space</td>
<td>Aux Power Required</td>
</tr>
<tr>
<td>Lower Oil Gradients</td>
<td>Motor Maintenance</td>
</tr>
<tr>
<td>Lower Top Oil Temps</td>
<td>Fans and Pumps must operate</td>
</tr>
<tr>
<td>Lower Hot Spots</td>
<td></td>
</tr>
<tr>
<td>Possible Lower Cost</td>
<td></td>
</tr>
</tbody>
</table>
Shell and Tube Coolers
(bearing lube oil, seal oil applications)
Shell and Tube Coolers

- **Most efficient** cooler available
- **Water-to-oil** heat exchanger
- Water in the tubes
- Oil in the shell.
- Used in bearing lube oil and seal oil generator applications
- Some are applied to transformers - mostly on arc furnace and rectifier transformers (industrial)
- Some transformer hydro applications (utility)
- Natural or forced oil flow (usually forced with pumps)
- Open discharge on water side
- Vertical or Horizontal mounting
Shell-and-Tube Coolers

The Tubes
OFWF or OFWN Coolers

**Advantages:**
- High Efficiency
- Small Footprint

**Disadvantages:**
- Water Supply
- Fouling of water tubes
- Potential Oil / Water Mix
Transformer Cooler Products
What Does UNIFIN Do? . . .

We only do this. . . . Nothing else . . . Complete focus . . .

Transformer Coolers (Air, Water etc)

Generator Coolers (Air to Water, Hydrogen etc)

- TEWAC Motor Coolers
- Transformer Oil Pumps

Unifin is NOT a General “Heat Exchanger Company” . . .

Unifin is an “Electric Power Equipment Cooling Company” . . .

Power Industry focused, end user dedicated, responsive, highest quality!
Unifin Coolers . . . 2 core (fin & tube) technologies

Integral Finned Tubing

Plate-Fin Tubing
Integral Finned Tubing

- Extruded Thick-walled Aluminum Tube (Mono-Aluminum)
- Bi-metal Tubing -
  (Inner tube of Copper-Nickel; Stainless Steel or Titanium)
- Integrally Extruded Turbulator
Internally Extruded Turbulator
Heat Exchanger Cores

Extruded Tube
Unifin Coolers . . . 2 core (fin & tube) technologies

Plate-Fin Tubing

- Aluminum or Copper Fins
- Copper; Copper-Nickel or Stainless Steel Tubes
Plate Fin Cooler Core

Courtesy of Coiltech
Plate Fin Cooler Construction
Plate fin cooler Construction
Transformer Cooler Product Line . . .

3 Product Applications . . .

- Large Power Transformer Coolers
- Mobile substation/transformer Coolers
- Auxiliary (Portable) Transformer Coolers (Heatsink)
Transformer Cooler Major Features . . .

- Hinged fan cabinets – standard for ease of maintenance & cleaning
- Stainless steel connection hardware – standard
- 1 to 6 fan cooler designs
Transformer Cooler Major Features . . .

- Two core technologies with multiple fin/tube material options

- Multiple Finish Option
  - Galvanized cabinets (standard)
  - Epoxy coated (core, side casings)
  - Solder coated (core)
  - Stainless steel (headers)

- Updraft Louver Option
Mobile Substation Coolers

- Uses Unifin ForZair cooler.
- Use integral/extruded fin design for mechanical robustness.
- Site visit to take measurements for physical fit, thermal performance.
- Restores cooler performance & condition
- Might require piping adaptations by customer if rearranged.
Heatsink® Auxiliary Transformer Coolers

- Used for overheating transformers
- 4 fan design, 230V w/460V option
- One 5.5 HP pump
- Flow rate = 40 - 45 GPM
- Connected by 1.5” oil hose
- Self-contained controls
- Dissipates 100+ KW
- Trailer or Skid Mounted
Heatsink ®

Applications

- Overloaded Transformers
- Enclosed locations
- High Ambients
- Short term relief of top oil alarms

Designed to emulate the natural oil flow in units w/o pumps
Heatsink--Unusual Applications

Parallel units on large GSU’s
Transformer Coolers - Replacements & Uprates . . .
Transformer Coolers - Replacements & Uprates . . .

- Physically designed to replace existing cooler dimensions

- Thermally designed to restore original cooling system rating, or uprate in same physical space (flange-to-flange)

- Cooler & Pump package matched for Maximum Performance

- Extensive experience, database in replacing diverse brands of coolers on diverse brands of transformers.

- Work with transformer OEM’s and consultants to help determine resulting transformer nameplate uprate.

- For existing Unifin coolers, we can provide a fan cabinet replacement to get hinged panel feature.
Transformer Coolers - Replacements & Uprates...

What we need from you to help (our “wish list”):

- Transformer nameplate info
- Existing cooler & pump nameplate info (write & take picture)
- Existing fan motor nameplate info
- Take pictures from different angles of existing coolers
- CTR of transformer – temp run (if available)
- Outline drawing of transformer & coolers (if available)
- Describe environment (coastal? high altitude?, etc)
- Describe any physical limitations (firewalls, deluge system, etc)
Cooler Maintenance !!!!

• Maintenance neglect
• Sprayed with plant water for years
• No air flow thru coolers
• Transformer derated & life shortened
Operations’ Maintenance Checklist . . .

- Inspect general surface condition:
  - Fan cabinets, guards
  - Headers, tubesheets
  - Side casings
  - Connections

- Inspect core (fins & tubes) condition
  - Oil leaks (tubesheet, tubes)
  - Fin condition
  - Fouling (corrosion, dirt, debris)

- Inspect fan assemblies
  - Blade condition
  - Motors – winding insulation resistance (megger)

- Inspect mounting/supports
- Inspect pumps, valves
Why coolers lose Efficiency . . .

- **Fouling:**
  - Corrosion (salt air or caustic environment)
  - Cottonwood, weeds, etc.
  - Coal dust, dirt
  - Mineral deposits (deluge system)
  - Bugs (mayflies, etc)

- **Loss of thermal contact (fin-tube)**
- **Fin deformation/damage**
- **Cooler fan problems**
- **Recirculation of air or restriction of air circulation**
- **Pump problems**
- **Leaks**
Some Platefin Cooler Designs:

Problems:

- Fouled with Mayflies and mineral deposits
- Plates (fins) sagging
  - lost contact interface with tubes
  - great reduction in air flow
- Some mild leaking

- Uncleanable except with acid bath
  (not recommended)
- Transformer life reduced
Leak at tubesheet
Fin Damage
Evidence of leaking (oil on pumps & ground)
Incorrect support by Transformer OEM (resulted in leaking)
Transformer Coolers - Replacements & Uprates . . .

What we need from you to help (our “wish list”):

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Unifin Cooler Customers - Transformer OEMs . . .

- GE & GE Prolec
- ABB
- Siemens
- Hyosung (HICO)
- SMIT
- Tamini
- TBEA
- Pauwels
- Toshiba
- PTTI
- Areva
- Baoding
- EFACEC
- Delta Star
- Hyundai (HHI)
- JST
- VA Tech
- Mitsubishi (MHI)
Unifin Manufactures all Types of Generator Coolers . . .

- Air / Water
- Hydrogen
- Exciter
- Bearing Lube

- Fossil Fuel
- Hydro Electric
- Combustion Turbine
- Nuclear
Generator Cooler Major Features . . .

Removable Cover Plate Coolers

Unique Leak Detector Configuration
Unifin Int’l. / Cardinal Pumps and Exchangers

Contacts . . .

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QUESTIONS ?